Extended Low Load Boiler Operation to Improve Performance and Economics of an Existing Coal Fired Power Plant (DOE/NETL Cooperative Agreement No. DE-FE0031546)

Project Kickoff Meeting

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February 12, 2018

Imagination at work

Extended Low Load Boiler Operation

This material is based upon work supported by the Department of Energy under Award Number DE-FE0031546.

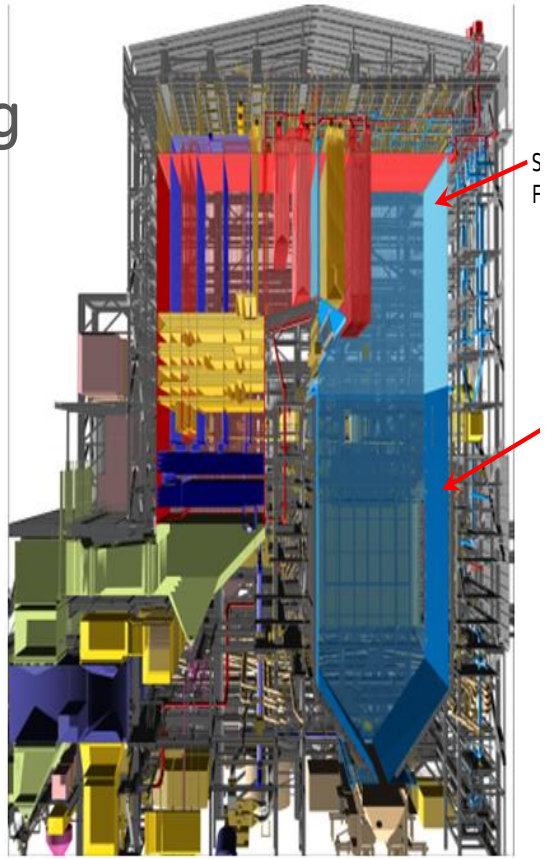
Extended Low Load Boiler Operation Agenda

- Technical Background
- Statement of Objectives
- Project Team / Project Structure
- Technical Approach
- Project Deliverables / Budget / Status
- Project Schedule
- Technical Risks

Extended Low Load Boiler Operation Technical Background

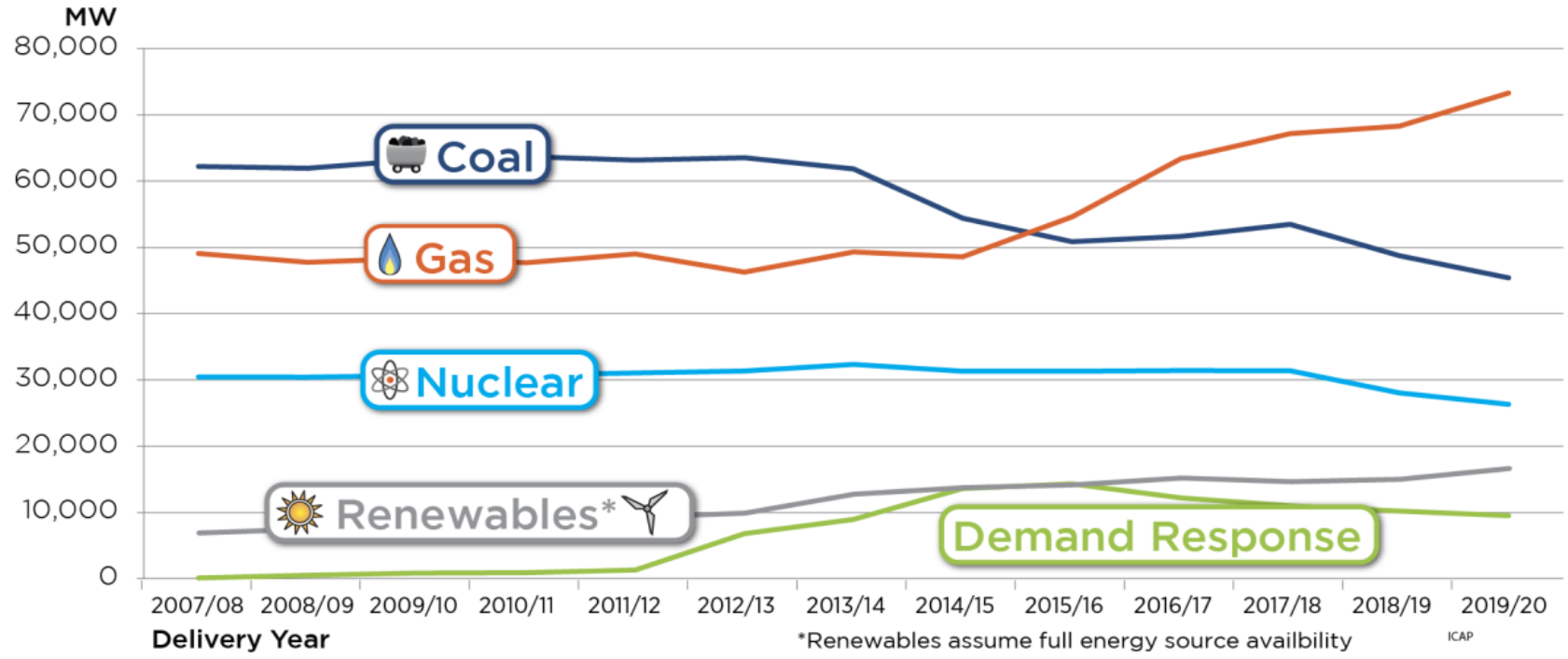
- Increasing load from renewables, low natural gas price, and a flat load demand has caused many base load coal plants to become cycling plants.

- Dispatching of fossil-fueled power plants has changed to require increased flexibly.
  - More unit starts
  - Higher ramp rates
  - Increased layup status
  - Lower minimum loads



Extended Low Load Boiler Operation Technical Background

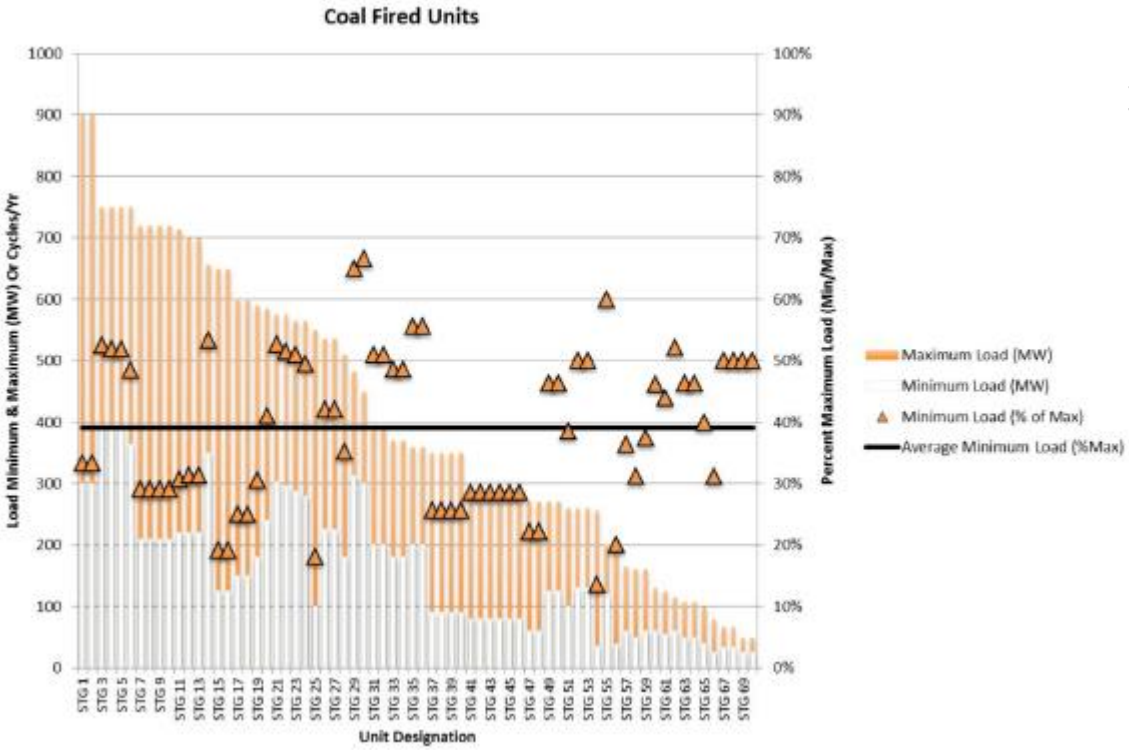
Power generation trend/forecast (2007 – 2020)



Reference:
http://www.pjm.com/~/media/library/reports-notices/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx

Extended Low Load Boiler Operation Technical Background

- 57% of units surveyed have been able to lower load below 35%
- Average minimum load reported was 40% for coal units (33% for all fossil)
- Minimum load appears to have no correlation with unit size
- Constraint on low load was often environmental or boiler design



Ten (10) challenge areas identified

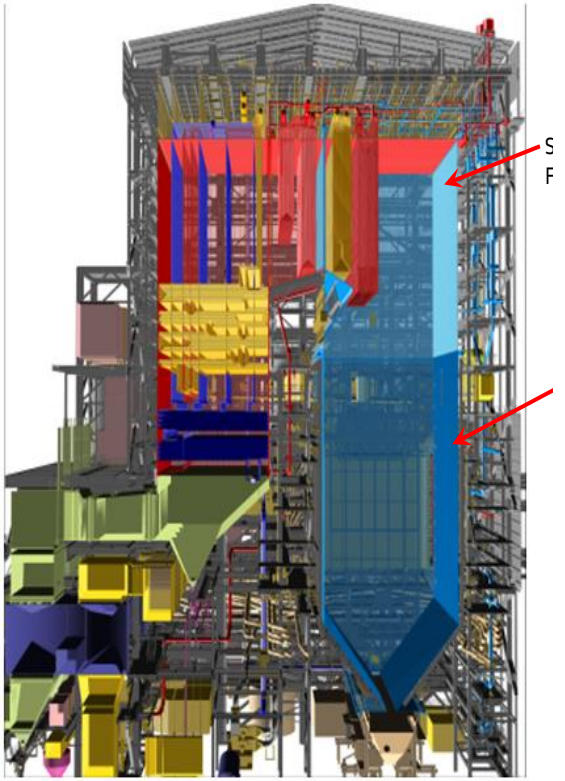
1. Steam Pressure and Temperature
2. Level Measurement and Control
3. Flow Control
4. Feedwater Chemistry
5. Boiler Water Chemistry
6. Chemistry Sampling
7. Combustion Control
8. Plant Controller & Instrumentation
9. Air Emissions
10. Component Condition Monitoring

Reference: Impact of Minimum Load Operation on Steam Turbines, EPRI 2013 Technical Report (3002001263)

Extended Low Load Boiler Operation Technical Background

- Definition - Low Load :

The minimum output level achievable without requiring support fuel and without compromising safety, reliability, or equipment.



Focus Areas:

Pulverizer, Main Burner Zone, steam and gas temperature control

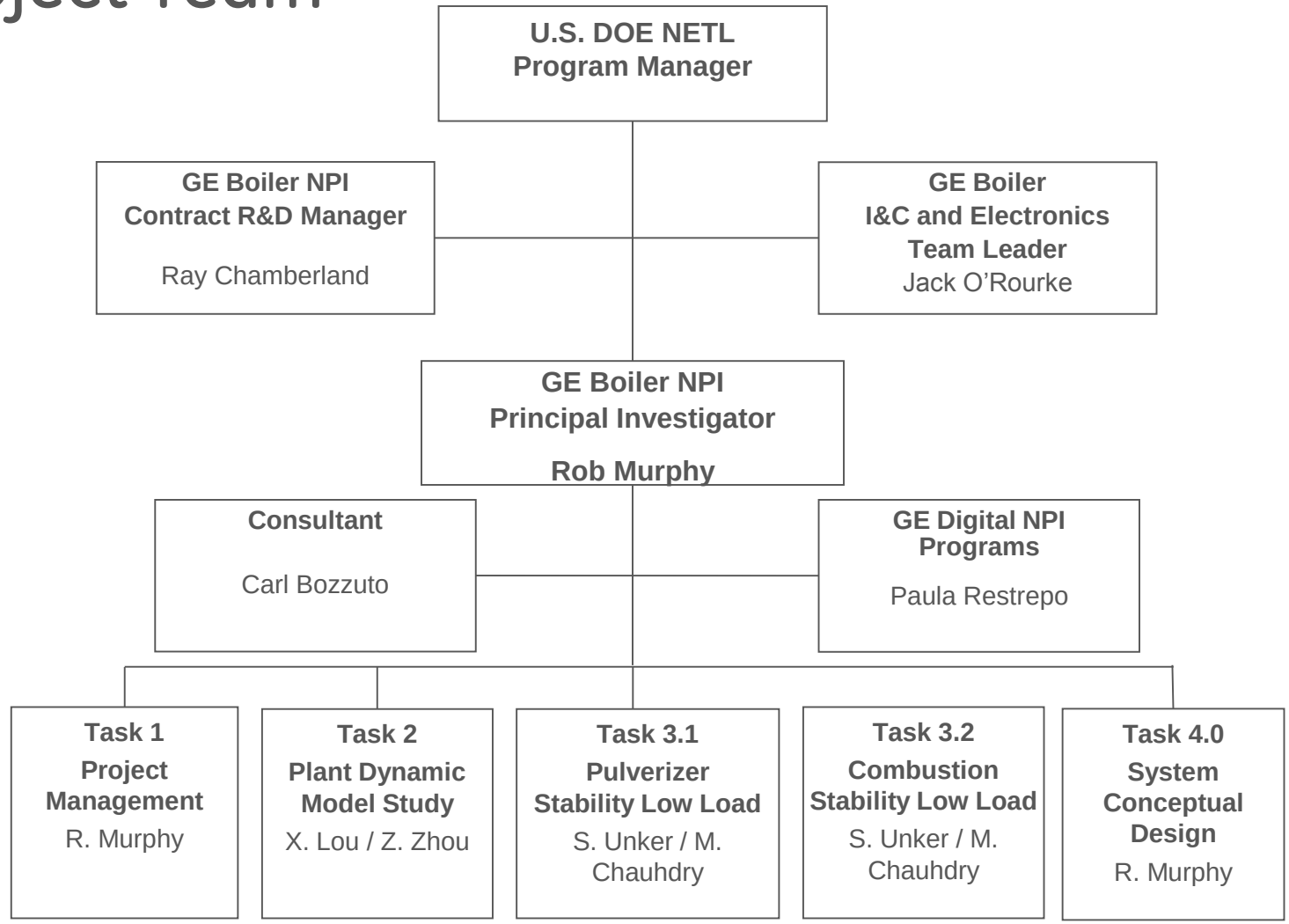
Constraints:

Minimal capital cost solutions

Extended Low Load Boiler Operation Statement of Objectives

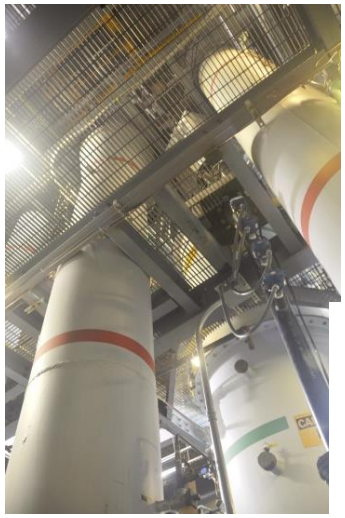
- Identify control methods for steam and gas temperature regulation at low load
- Investigate Sensors and Analytics for monitoring pulverizer operation at lower loads to maintain/optimize coal distribution, mill outlet temperature, and fineness.
- Investigate flame monitoring techniques that quantify local and global flame stability. Classify burner to burner fuel-air balance to compensate with fuel or air distribution biases.

Extended Low Load Boiler Operation Project Team

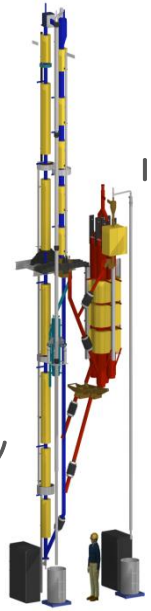


GE Clean Energy Center Overview

Provide GE Power Businesses with world class pilot and bench scale test facilities for testing and validating boiler technologies



3 MWth Multi-Use Test Facility



100 kWth Pilot Facility CLC, CFB, transport, & BFB reactor system

Industrial Scale Burner Test Facility

- Balanced draft, front wall fired
- 15MWt, 50MMBtu/hr

Clean Energy Center – Bloomfield, CT

Drop Tube Furnace

HP Style Bowl Mill at the Pulverizer Development Facility

Extended Low Load Boiler Operation Project Structure

Phase I – 4 Tasks

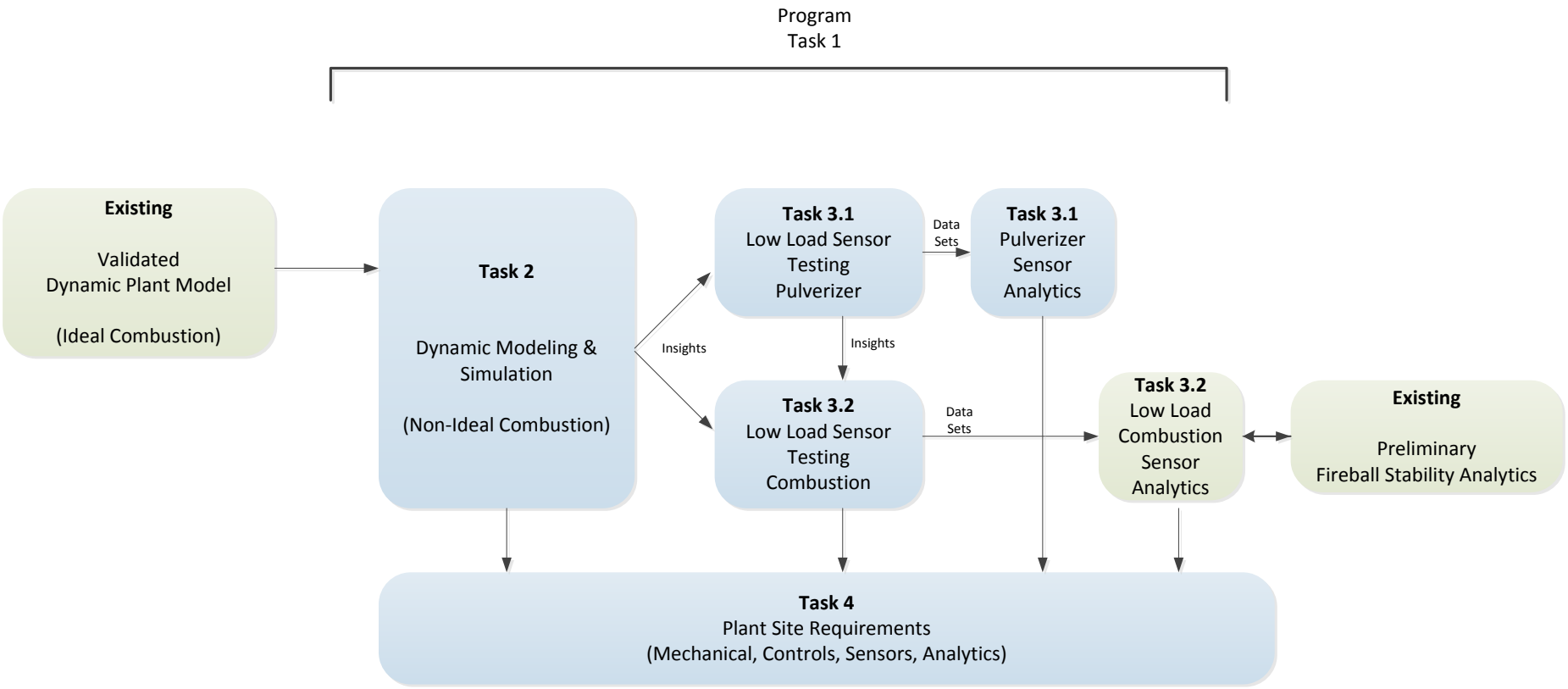
Task 1: Project Management, Planning, and Reporting

Task 2: Plant Low Load Dynamic Model Based Investigation

Task 3: Development of Extended Low Load Operation System

Task 4: Conceptual Design of Utility Boiler Extended Low Load System

Extended Low Load Boiler Operation Project Structure



Extended Low Load Boiler Operation Technical Approach

Task 1.0 Project Management and Planning

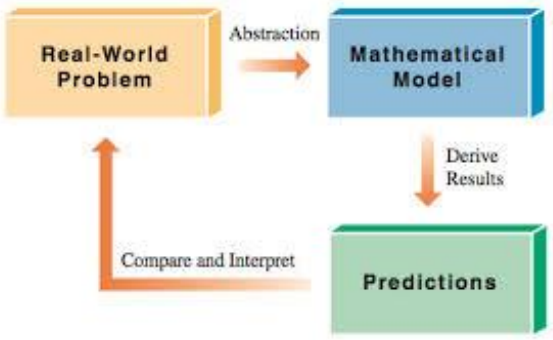
GE Power will manage and direct the project in accordance with a Project Management Plan to meet all technical, schedule, and budget objectives and requirements.

- Quarterly reporting
- Poster session at annual project review (due February 28, 2018)
- Project closeout presentation (March 2019)

Extended Low Load Boiler Operation Technical Approach

Task 2 Plant Low Load Dynamic Model Based Investigation

- To develop a typical dynamic model for boilers to support low load operation analysis
  - To integrate the models for simulating low load operations for pulverizers
  - To integrate the models for simulating low load operations for flue gas temperature controls for SCR operations
- To evaluate overall low load capability, fast load ramping controls, safe operations in case of abnormal situations
- To evaluate the feasibility and benefits of new sensing and controls schemes for low loads



$$\frac{\partial}{\partial t}(\varepsilon\rho_g)+\frac{\partial}{\partial z}(\varepsilon\rho_g v_g)=0$$

$$\frac{\partial}{\partial t}(\varepsilon\rho_g v_g)+\frac{\partial}{\partial z}(\varepsilon\rho_g v_g^2)+\varepsilon\frac{\partial P}{\partial z}+\varepsilon\rho_g g+\frac{\varepsilon\rho_g v_g^2 f_{gF}}{r}+(1-\varepsilon)\rho_s F_D\left(v_g-v_s\right)=0$$

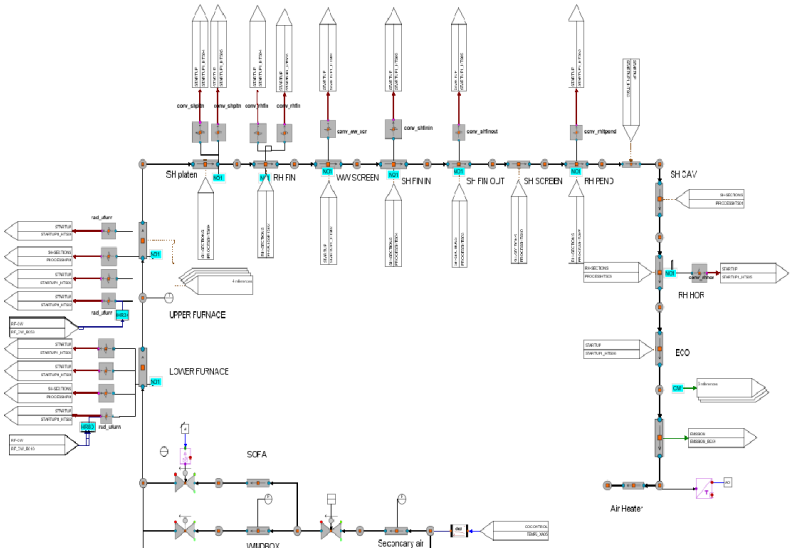
$$\frac{\partial}{\partial t}\left[\varepsilon\rho_g\left(h-\frac{P}{\rho_g}+\frac{v_g^2}{2g}\right)\right]+\frac{\partial}{\partial z}(\varepsilon\rho_g \mathbf{v}_g\left(h+\frac{v_g^2}{2g}\right))+\frac{\partial}{\partial z}\left(k_g\frac{\partial T_g}{\partial z}\right)$$

$$-\frac{6}{d_p}(1-\varepsilon)h_{sg}\left(T_s-T_g\right)+\frac{2h_{wall}\left(T_g-T_{amb}\right)}{r}+S_{rg}=0$$

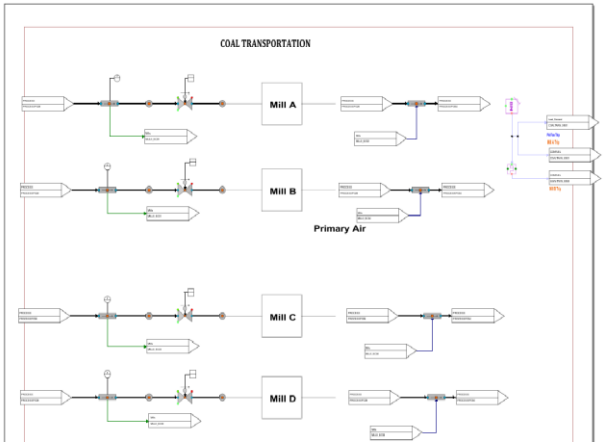
Extended Low Load Boiler Operation Technical Approach

Task 2 Plant Low Load Dynamic Model Based Investigation

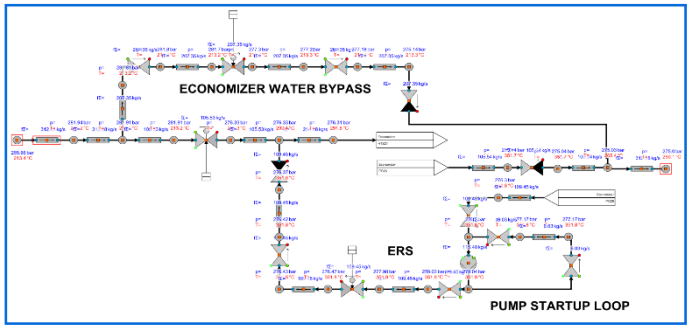
Dynamic Models for Boiler Island



1000MWe PC Boiler Model



Coal Transport Model with Mills



Flue Gas Temperature Controls for Lower Load SCR Operation

Extended Low Load Boiler Operation Technical Approach (Flame Stability)

Task 3: Development of Extended Low Load Operation System

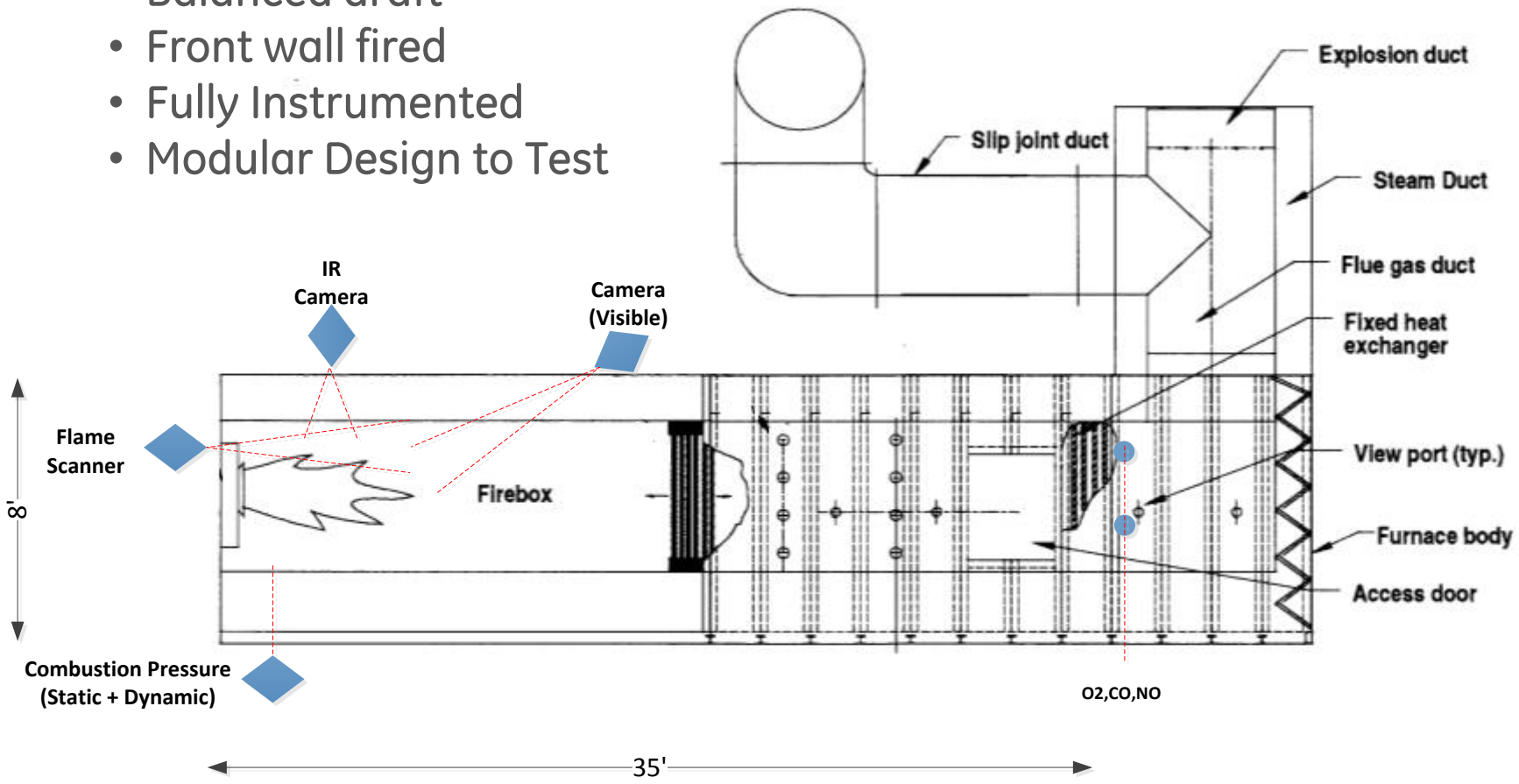
- Added sensors for Low load burner testing
  - High turndown flame scanner
  - Visible light furnace camera
  - Flame temperature probes
  - IR furnace camera
  - Static / Dynamic combustion pressure
  - Near furnace O2, CO, NO sensor grid
- Targeted Analytics
  - Burner flame stability (local and global)
  - Fuel/Air balance classification
  - Flame emissions

Industrial Scale Burner Facility (ISBF)

Extended Low Load Boiler Operation Technical Approach (Flame Stability)

15 MWth Industrial Scale Burner Facility (ISBF)

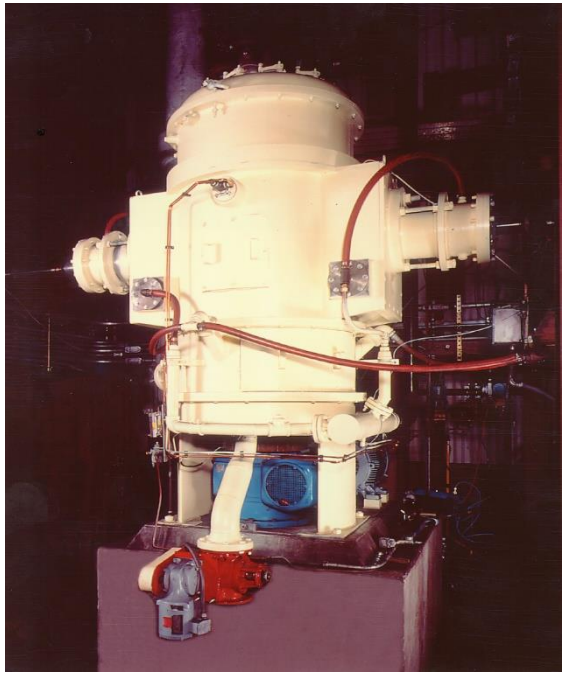
- Balanced draft
- Front wall fired
- Fully Instrumented
- Modular Design to Test



Extended Low Load Boiler Operation Technical Approach (Pulverizer Turndown)

Task 3: Development of Extended Low Load Operation System

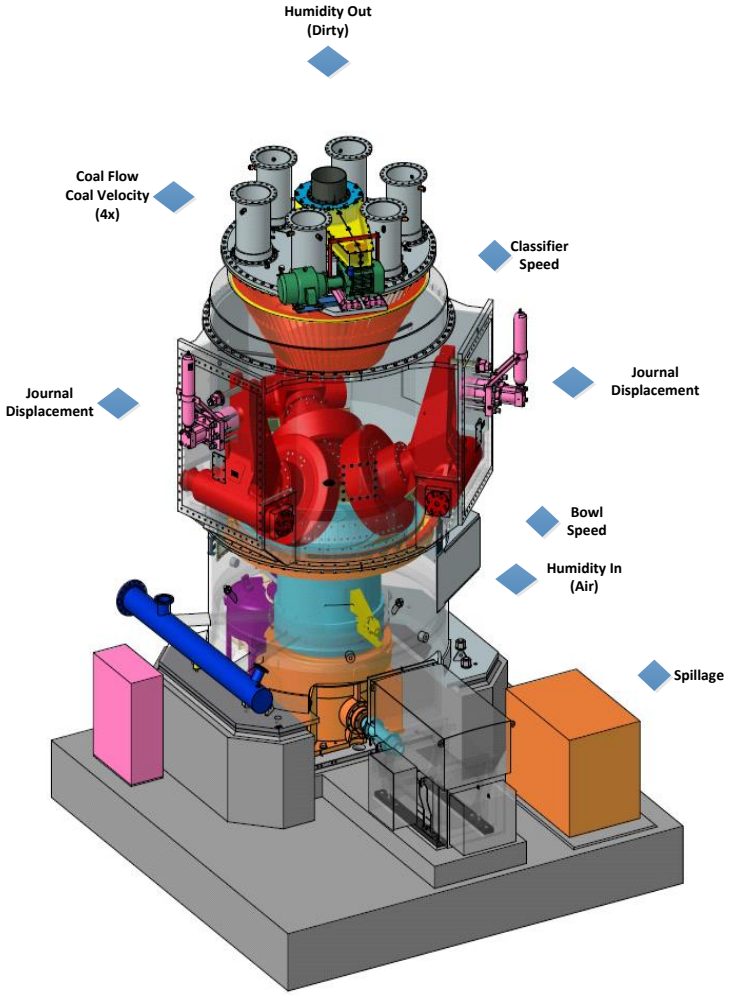
- Added sensors for Pulverizer testing
  - Vibration
  - Journal displacement
  - Humidity (In/Out)
  - Coal Distribution (4 pipes)
  - Spillage
  - Motor Torque (Bowl/Classifier)
  - Bowl Speed (control)
  - Additions Pressure measurements
- Targeted Analytics
  - Vibration (Smooth-Rough, Rumble)
  - Coal Velocity/Flow
  - Correlations (Humidity, Air-Fuel slip)
  - Distribution versus feed rate, classifier speed, bowl speed, etc.



Extended Low Load Boiler Operation Technical Approach (Pulverizer Turndown)

Pulverizer Development Facility (PDF)

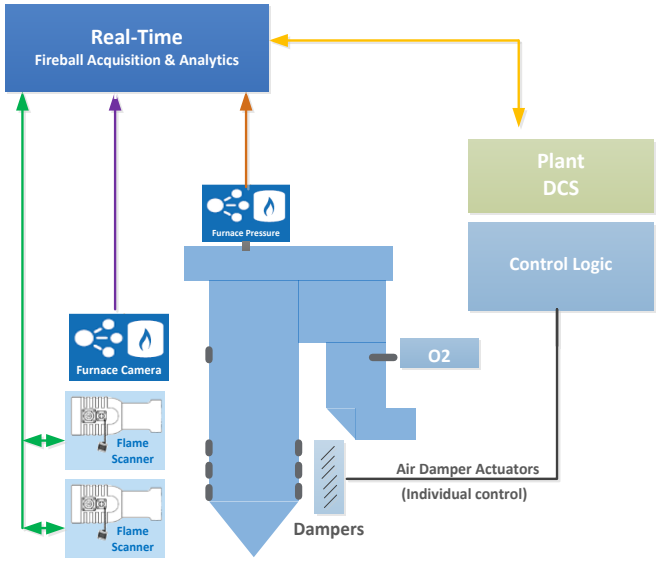
- 323 HP Pulverizer
- Nominal capacity – 8,000 lbs/hr
- Fully Instrumented
- Modular Design to Test



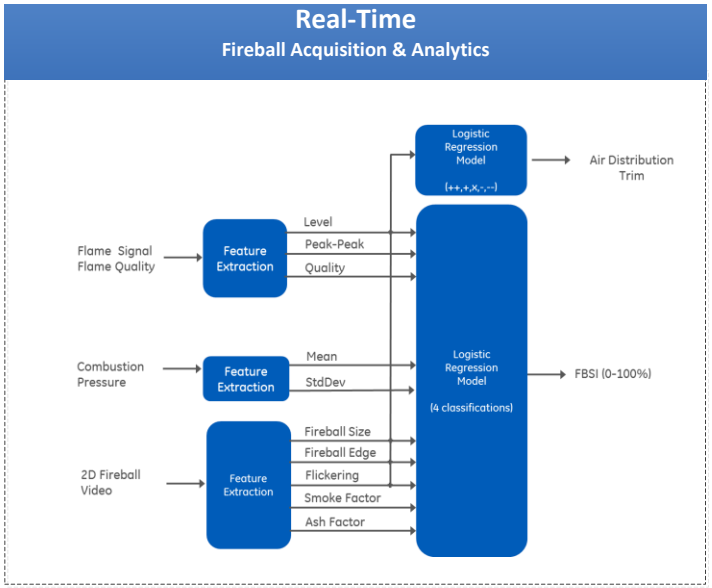
Extended Low Load Boiler Operation Data Analytics - Example

Task 3: Development of Extended Low Load Operation System

- Classify fireball quality/stability using,
  - Flame scanners
  - Combustion pressure
  - Furnace camera video



System Configuration



Analytics Framework

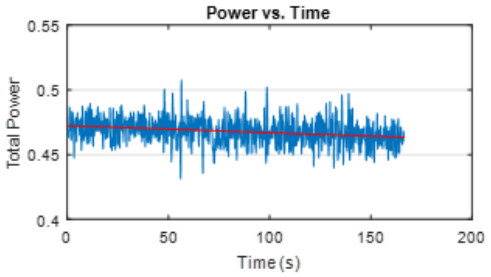
Extended Low Load Boiler Operation Data Analytics - Example

Task 3: Development of Extended Low Load Operation System

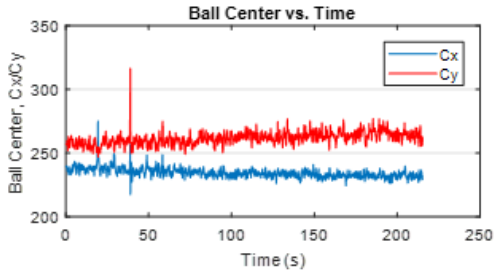
Low Load

Lower Load

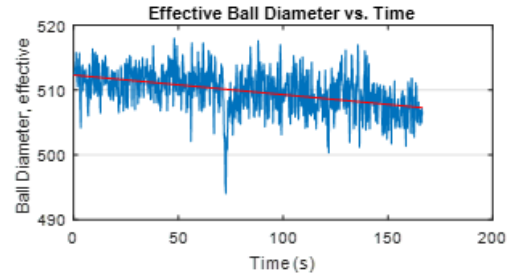
Time



Total Power



Center Location



Diameter

Decreasing Load

Extended Low Load Boiler Operation Technical Approach

Task 4.0 Conceptual Design of Utility Boiler Extended Low Load System

This task completes the conceptual engineering design of new sensors and algorithms that would be needed for demonstration of the extended low load operating system on a selected utility boiler under a later project. If necessary, individual air damper drives/controls or alternate burner tips may also be specified to support extended lower load operation.

Extended Low Load Boiler Operation Deliverables

- Task 1: Progress Reports, issued quarterly
- Task 1: Poster at NETL annual project review
- Task 2: Webcast with NETL Project Manager
  Summary of Dynamic Modeling Simulation
- Task 1: Final technical report
- Task 1: Webcast with NETL Project Manager
  Project closeout meeting

Extended Low Load Boiler Operation Budget Period 1

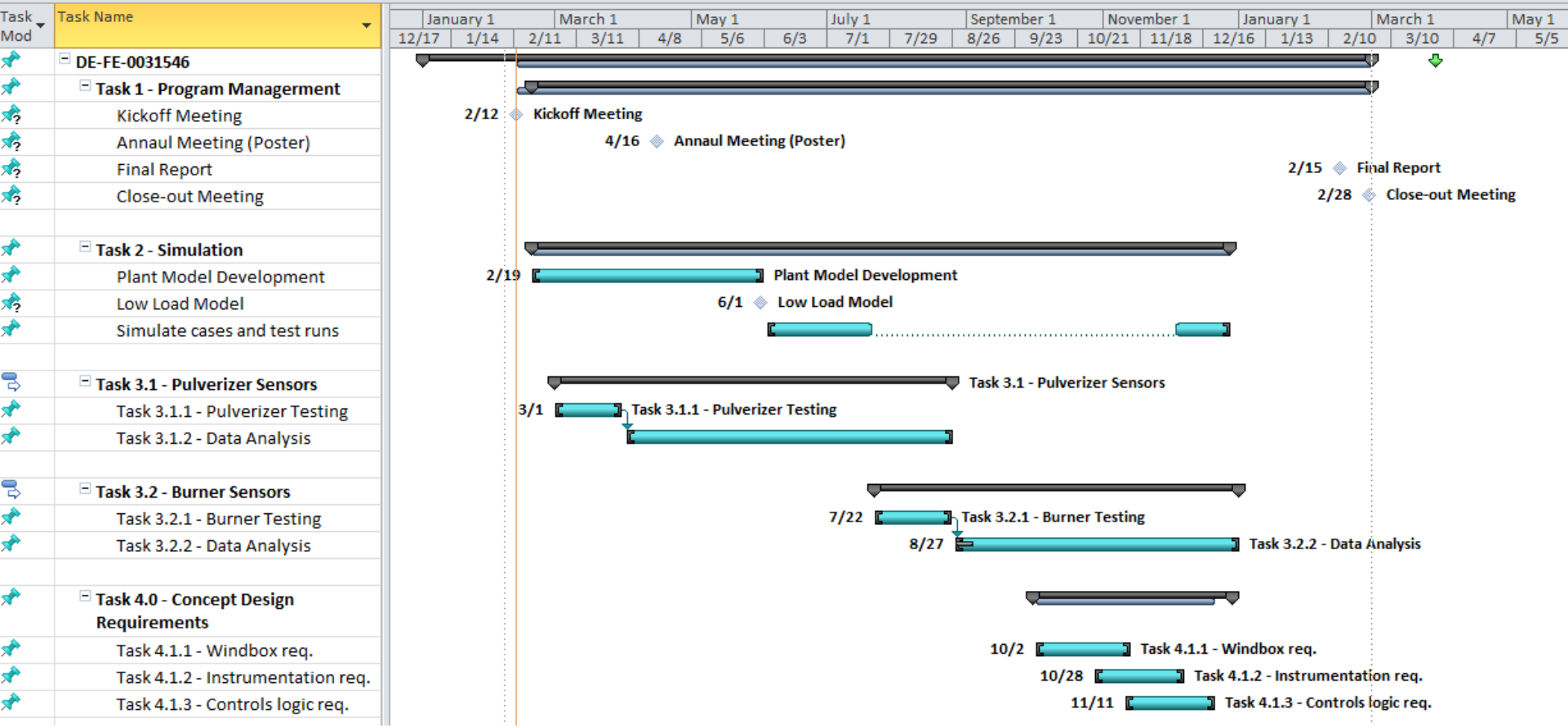
Phase I Budget

		Labor ($)	ODE ($)	Total ($)
TASK 1	Program Management	103,494	3,768	107,262
TASK 2	Dynamic Modelling	210,988	-	210,988
TASK 3	System Development	375,217	321,732	696,949
TASK 4	Conceptual Design	43,844	5,538	49,382
	Total	733,543	331,037	1,064,580
	DOE/NETL (80%)			851,664
	GE (20%)			212,916

Extended Low Load Boiler Operation
Current Project Status

- Proposal selected October 19, 2017
- Awarded December 27, 2017
- Pulverizer test facility sensor integration, Dec – Feb 2018
- Kick-off meeting with the DOE PM, February 12, 2018
- Developing test matrix and internal project specifications for use by GE technical teams - in progress since Jan 2018

Extended Low Load Boiler Operation Phase I Project Schedule



Extended Low Load Boiler Operation Technical Execution Risk Management

Risk	Risk Level	Cost Range	Mitigation Actions
Sensor Technology	Low	Low	1. Apply extensive experience and research for successful identification and availability of required sensors 2. Develop "Soft Sensors" to infer missing measurement
Analytics	Medium	Medium	1. GE has highly experienced engineers with analytic skills to research and apply the most suitable algorithms for data analysis. 2. Add sensors to improve analytics
Difficulty establishing non-ideal combustion portion of dynamic plant model	Low	Medium	1. Combine models from different modeling tools.
Burner testing at Low-Low load	Low	Medium	1. Plan for frequent cold starts.
Unexpected test results	Medium	Medium	1. GE simulation model (Task 2) will be used to predict limitations other than flame stability (such as outlet steam temperature etc.)