IMPROVING COAL-FIRED PLANT PERFORMANCE THROUGH INTEGRATED PREDICTIVE AND CONDITION BASED MONITORING TOOLS

(Award No. DE-FE00031547)

2019 Annual Project Review Meeting for Crosscutting Research

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Presentation Overview

- **Project Information**
  - Project Team
  - Project Goal and Objectives
- **Background**
  - Microbeam's Fireside Performance Indices
  - Microbeam's Combustion System Performance Indices (CSPI) Program
- **Accomplishments**
  - CoalTracker Algorithm Development and Testing
  - Combustion System Performance Indices Algorithm Development and Testing
- **Opportunities for Plant Improvement and Cost Savings**
- **Next Steps**

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Project Team

- Technical Team:
  - Microbeam Technologies Inc.
  - University of North Dakota
    - Institute of Energy Studies (IES)
  - Rochester Institute of Technology
    - Department of Software Engineering
- Funding Support:
  - U.S. Department of Energy, National Energy Technology Laboratory
  - Otter Tail Power's Coyote Station
  - North American Coal Company
  - Great River Energy
- Project Support:
  - Energy Technologies Inc.

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R·I·T

OTTER TAIL POWER COMPANY

NORTH AMERICAN COAL CORPORATION

Energy Technologies Inc.

GREAT RIVER ENERGY®

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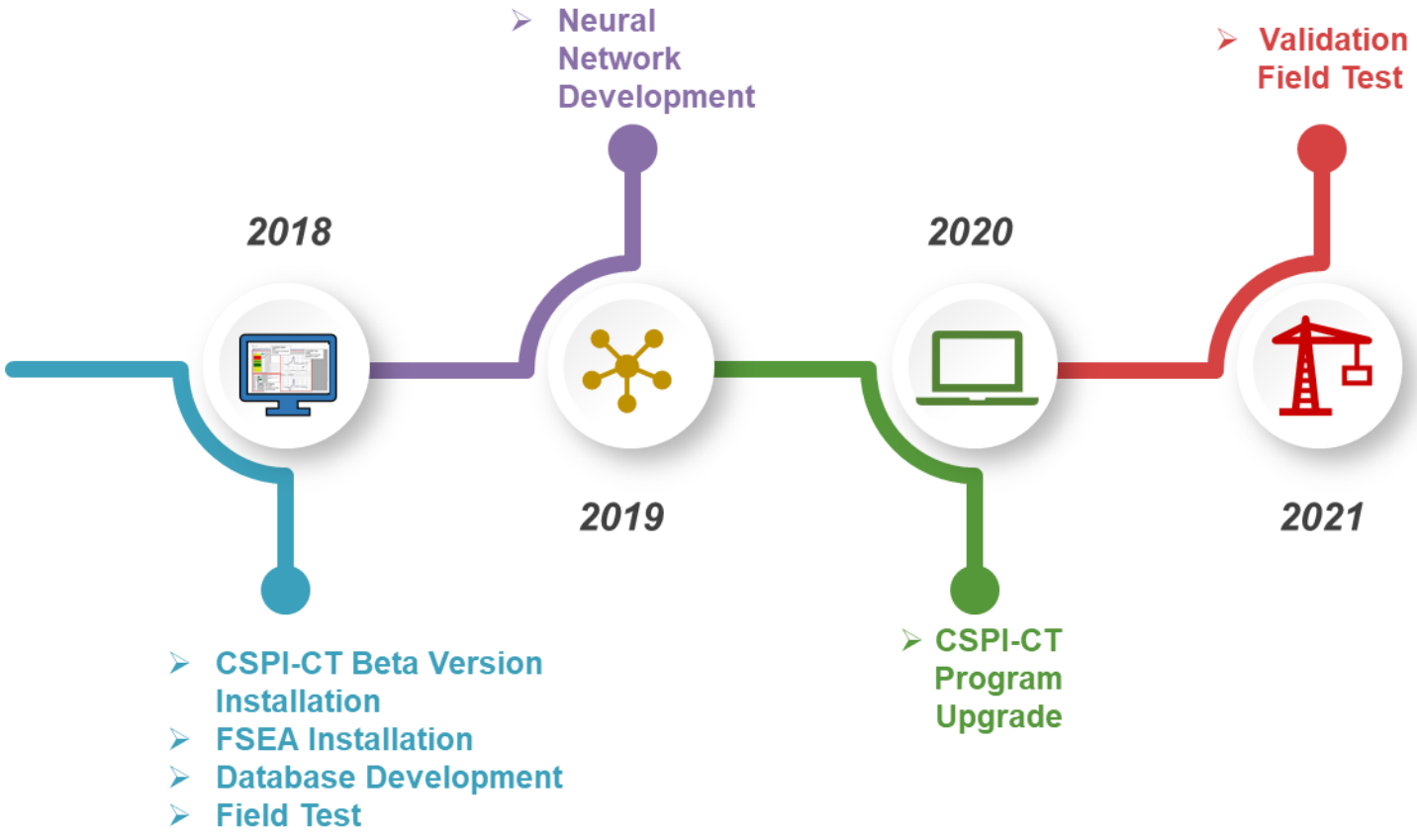
Project Information

Goal

Demonstrate at a full-scale coal-fired power plant the ability to improve boiler performance and reliability through the integrated use of condition based monitoring (CBM) and predictions of the impacts of coal quality on boiler operations.

Project Period

January 1, 2018 – December 31, 2021 (4 Years)



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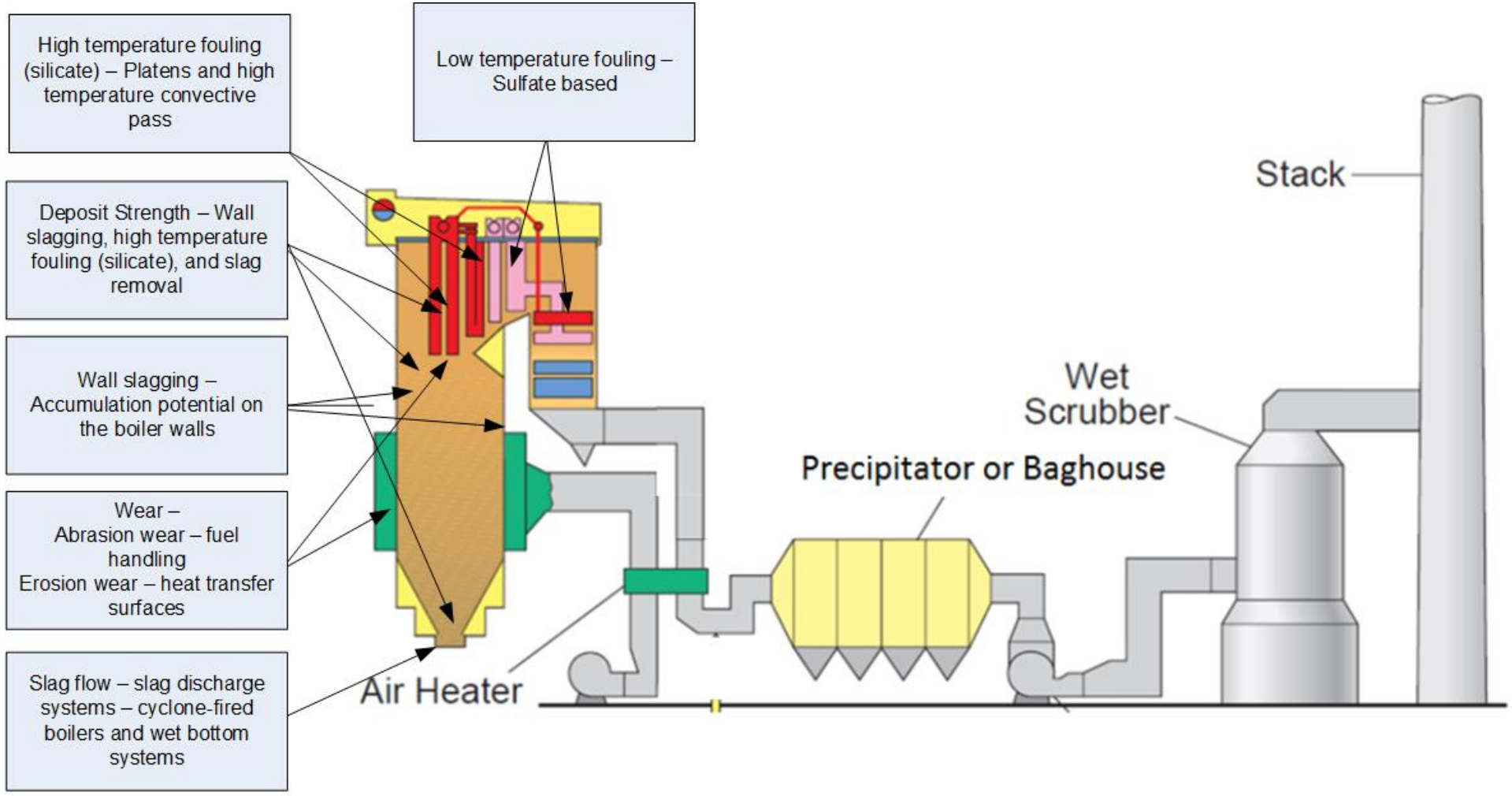
Project Background

Microbeam's Fireside Performance Indices



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Accomplishments

- **CoalTracker Algorithm Development and Testing**
  - Analyzer installation (Coal properties)
  - Database development (Coal properties)
  - Coal Tracking applications
- **Combustion System Performance Indices Algorithm Development and Testing**
  - Access to plant operating/conditions monitoring (Plant operation and performance)
  - Beta version of Combustion System Performance Indices (CSPI) installed at plant
  - Database development (Powerplant Parameters)
  - Neural network training (Plant performance)

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CoalTracker Algorithms Development and Testing

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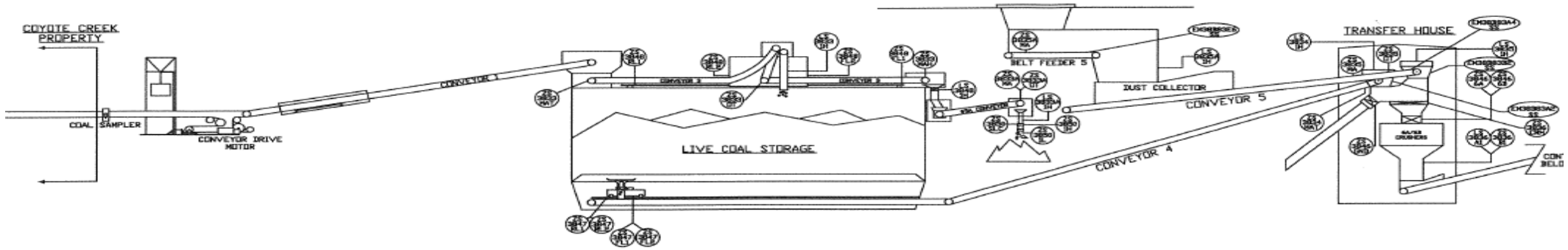
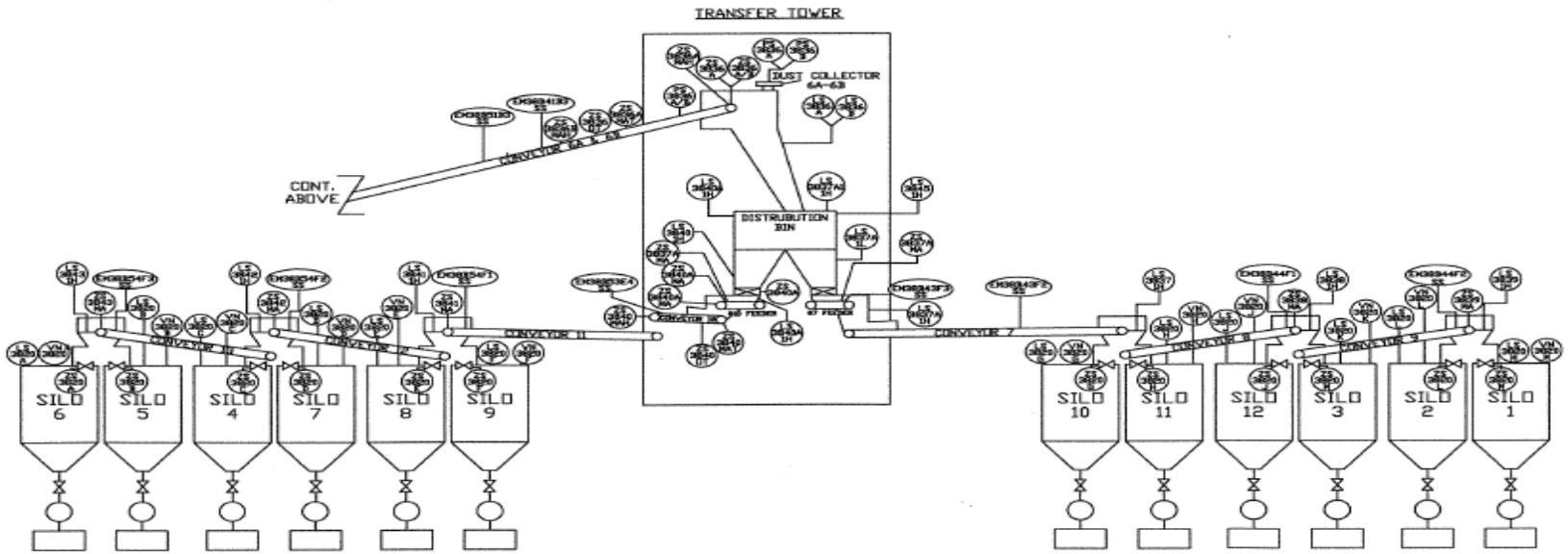
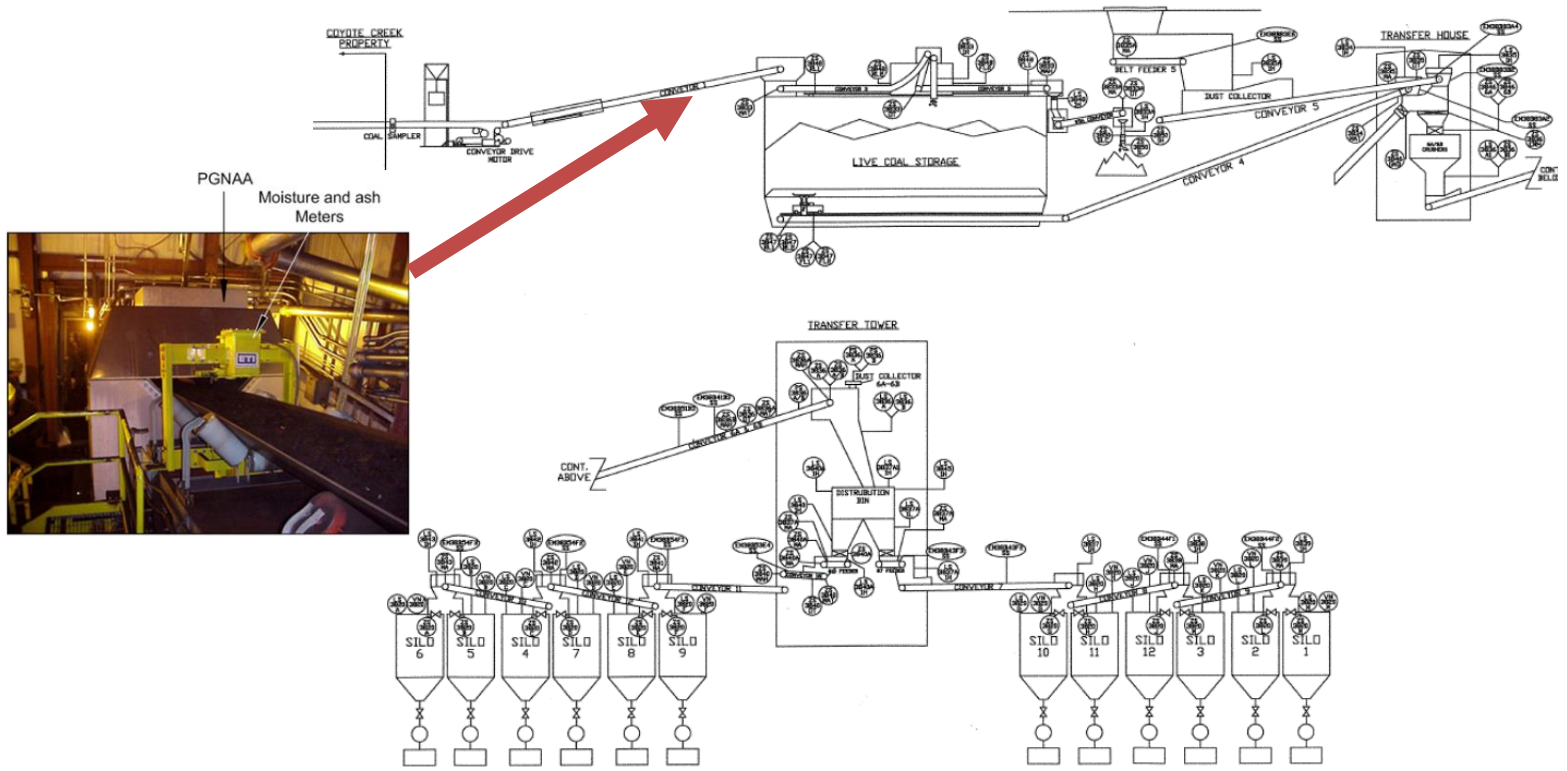
Coal Handling System

Coal from the mine → Belt 1 → Live Storage → Transfer Tower → Belt 7/10 → Silos → Cyclones/ Boiler





Full Stream Elemental Analyzer (FSEA) Installation July 2018



Before Installation – Coal analysis results from one composite sample representing 7000 – 12000 tons of coal available **after 3 days of firing**.

FSEA Impact – Coal properties are reported **every minute** for every 90-120 tons of as-delivered fuel **before firing**.
Flexibility of coal blending and storage.

Coal Properties from FSEA – Ash, Moisture, Heating Value, S, C, and inorganic constituents based on prompt gamma neutron activation, microwave, and dual gamma attenuation.

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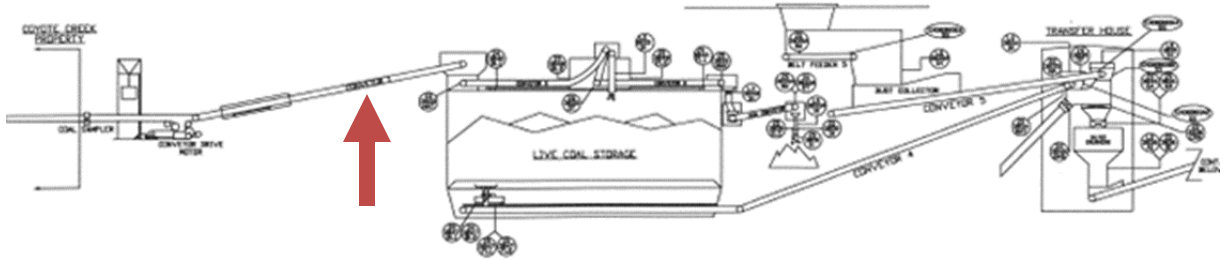
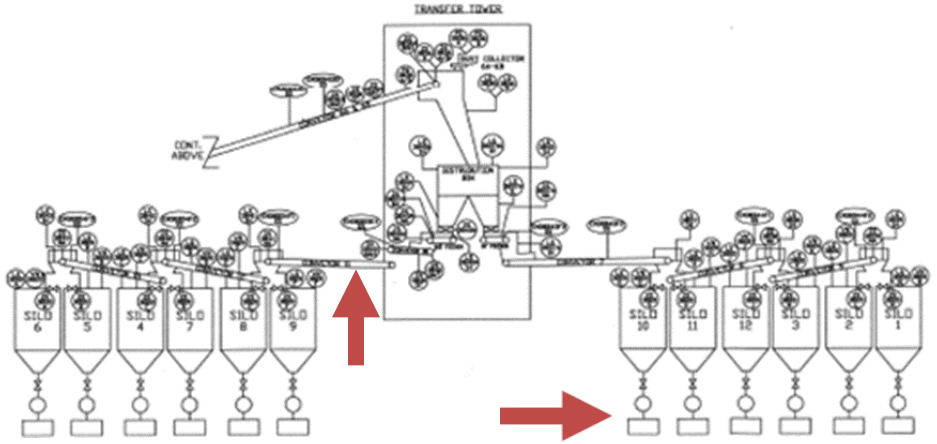
Field Testing

Coal from the mine → Belt 1 /FSEA → Live Storage → Transfer Tower → Belt 7/10 → Silos → Cyclones/ Boiler

- Collect and analyze coal samples
  - Continued characterization of FSEA performance
  - Obtain detailed data for CoalTracker
- Track power plant performance during the field test
- Use CSPI-CT beta version to predict plant performance
- Validate plant performance with real-time data





Total Number of Coal Samples Collected during the field test -> 149

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Combustion System Performance Indices (CSPI) Program

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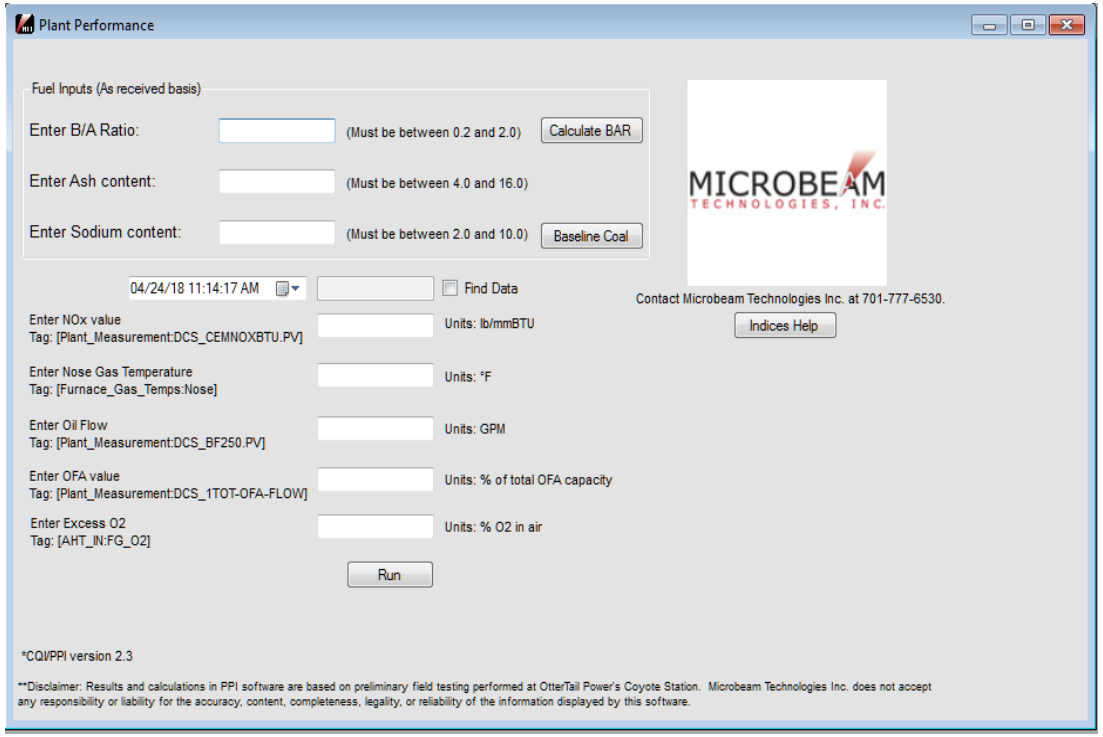
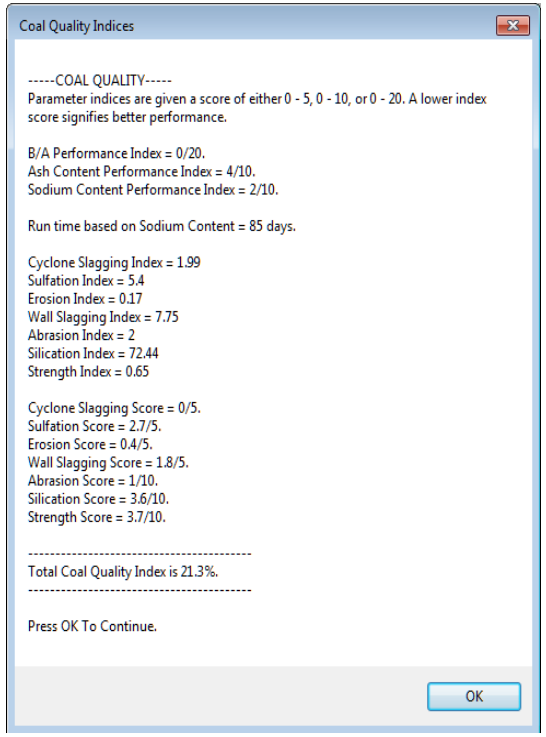
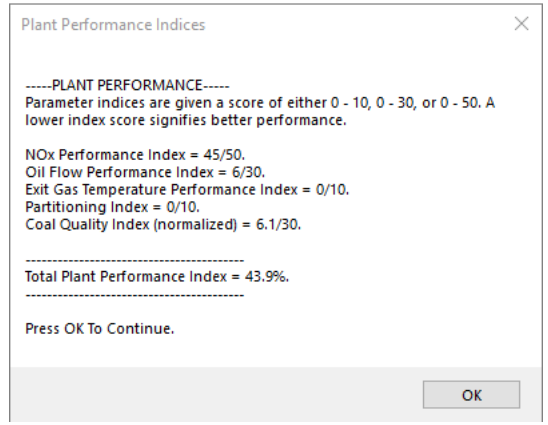
Milestone : CSPI-CT Program's Beta Version On-Site Installation

- CSPI-CT program's beta version was installed at Coyote station on April 25, 2018.







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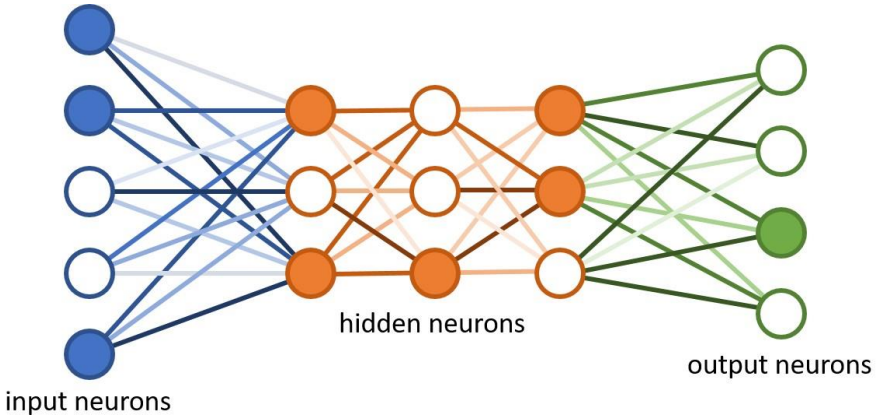
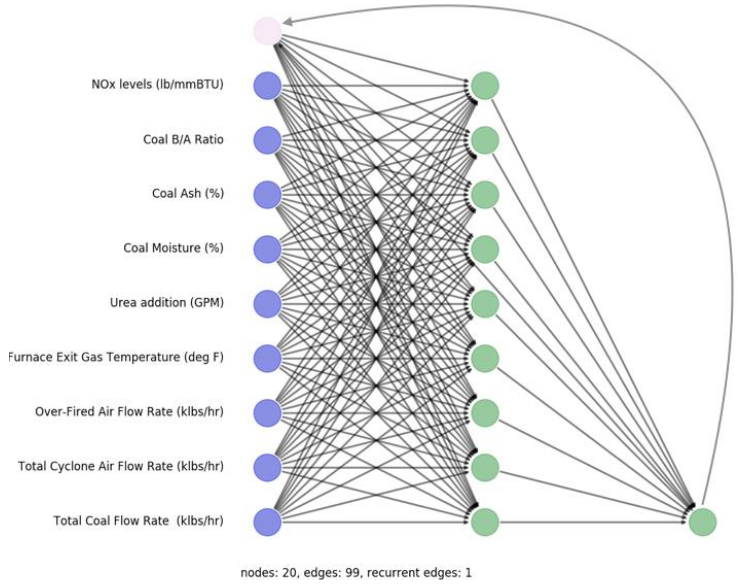
Augmenting CSPI Program

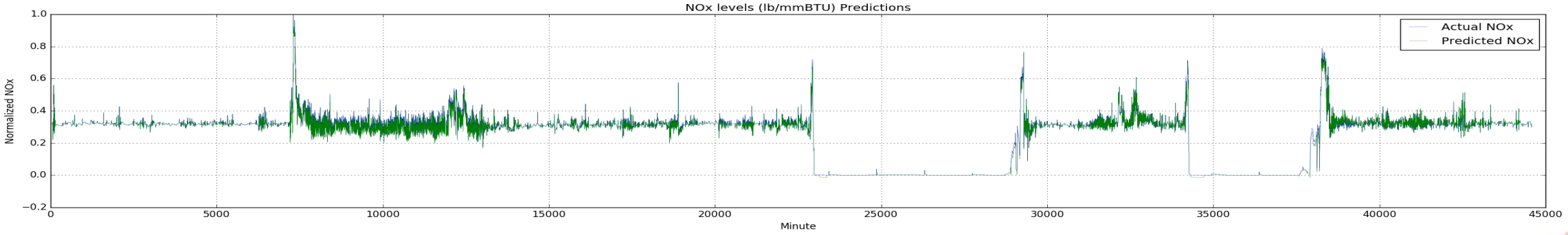
Neural Networks

Why Neural Networks?

- Because they are generic methods which can represent any function.
- They can be trained to be powerful predictors for time series data.







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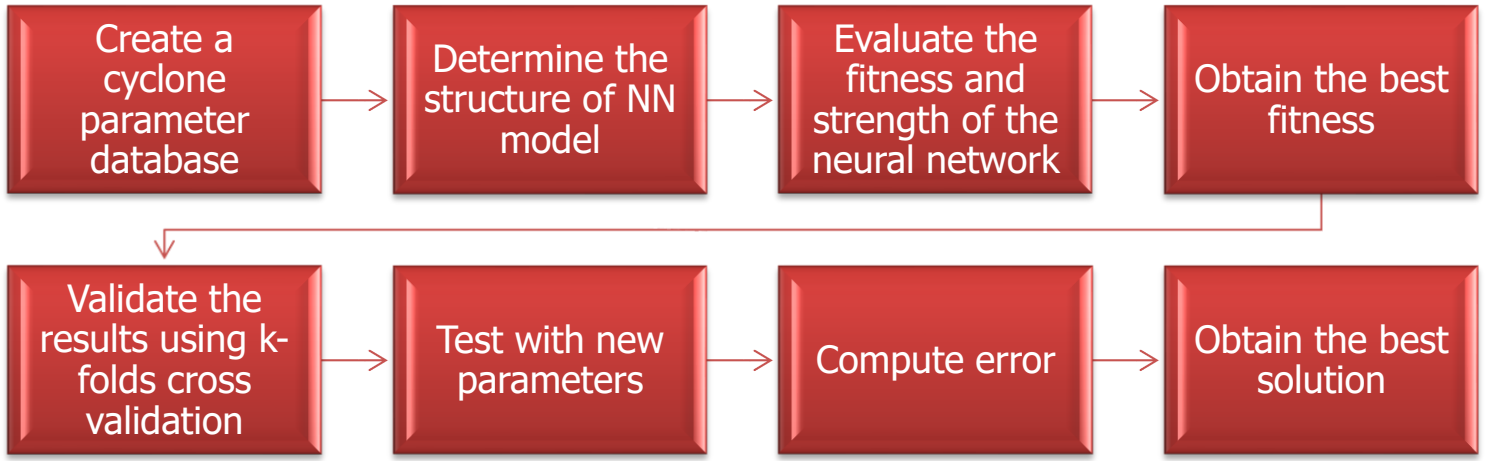
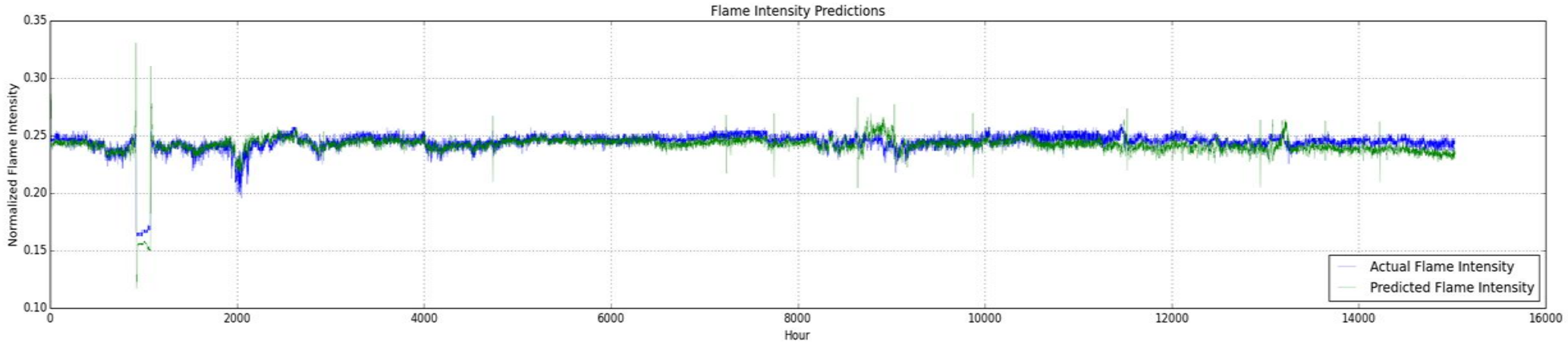
Evolutionary Algorithms Developed under this Project

- **Evolutionary eXploration of Augmenting LSTM Topologies (EXALT)**
  - Progressively evolves larger recurrent neural networks (RNNs) to perform time series data prediction.
  - Can select which input parameters have the best predictive ability and eliminate confuser parameters.
  - Can be executed in parallel over a large number of cores on high performance computing clusters.
  - Evolved RNNs exported to binary files for use within Microbeam's software.
- **Evolutionary eXploration of Augmenting Memory Models (EXAMM)**
  - Based on EXALT, except with a library of memory cells. Nodes can be LSTM, GRU, MGU, or Delta-RNNs.
  - Can be executed in parallel.
  - Mutations have further refinements from EXALT.

Neural Networks for Cyclone Database

- Input parameters –
  - 6 months of operating data
  - 12 operational parameters
  - 12 independent cyclones
- Predicted parameters – flame intensity and oil flow
- K fold cross validation with 2 files per fold and 10 repeats per fold – 1320 runs – 14,200 CPU hours





Opportunities for Plant Improvement and Cost Savings

- Installation of FSEA
  - Decreased cost of analysis
  - Opportunity to blend coal
  - Opportunity to optimize plant operating conditions to match coal properties
- Improved heat rate – coal property impacts
- Decrease oil firing through optimizing fuel properties
- Decrease fireside ash deposition- reduce number of scheduled and forced outages (maintenance costs)

Next Steps

- **CoalTracker Algorithm Development and Testing**
  - CCSEM mineral analysis on field test samples
  - Improve CoalTracker predictions based on field test and slagging event data
- **Combustion System Performance Indices Algorithm Development and Testing**
  - Conduct neural network analysis on waterwall, superheater and economizer database
  - Improve indices predictions based on field test data
  - Augment indices with neural network derived relationships
  - Installation and testing of a neural network based CSPI-CT
- **Operator and Plant Personnel Training**

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Questions?

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