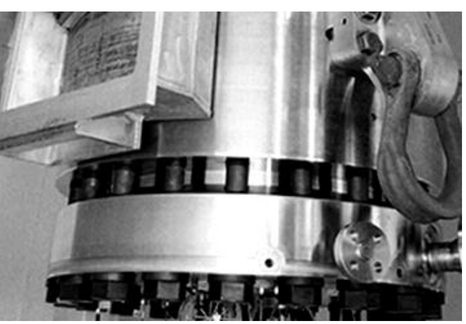
Equipment Anomaly Detection Using an Auto-Encoder Neural Network



"IT'S TOUGH TO MAKE PREDICTIONS – ESPECIALLY ABOUT THE FUTURE."

-- Yogi Berra or Neils Bohr, depending whether you prefer physics or baseball

… what we want is a machine that can learn from experience.

-- Alan Turing, 1947

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The Challenge

- Aging equipment and workforce
  - Average age of nuclear plant in the US is 37 years old
  - Nine Mile Point started producing power 12/14/69
- Reduced workforce
- Competition and environmental regulations
- Need for increased efficiency and reliability

A study by Boeing found that 85% of all equipment failed at random no matter how much preventive maintenance measures were applied to equipment.*

ARC Advisory Group reports 82% of failures cannot be avoided with traditional equipment monitoring.*

*https://www.processingmagazine.com/maintenance-safety/article/15587836/why-times-up-on-preventive-maintenance

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Equipment Anomaly Detection

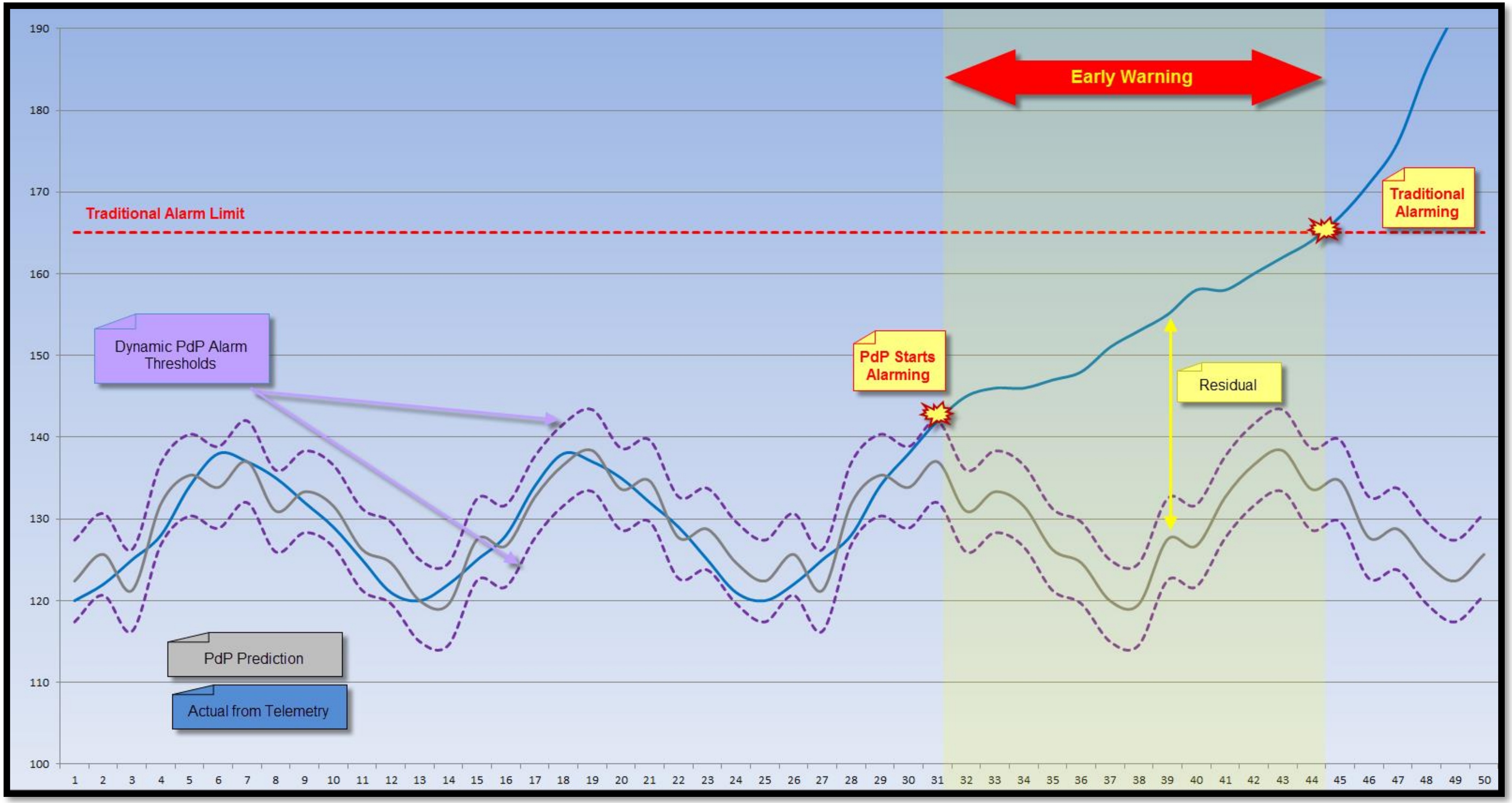
"The identification of rare items, events or observations which raise suspicions by differing significantly from the majority of the data."

-- Wikipedia

Equipment anomaly detection uses existing data signals available through plant data historians, or other monitoring systems for early detection of abnormal operating conditions.

Equipment failures represent the potential for plant deratings or shutdowns and a significant cost for field maintenance.

Anomaly Detection vs Traditional Alarming



Our History

Pattern-Recognition Software
For Plant
Surveillance

1988

United States Patent [19]
Mott

[11] **Patent Number:** **4,937,763**
[45] **Date of Patent:** **Jun. 26, 1990**

[54] **METHOD OF SYSTEM STATE ANALYSIS**

[75] Inventor: **Jack E. Mott**, Idaho Falls, Id.

[73] Assignee: **E I International, Inc.**, Idaho Falls, Id.

[21] Appl. No.: **240,262**

[22] Filed: **Sep. 6, 1988**

[51] **Int. Cl.**^{5} **G08B 17/00**
[52] **U.S. Cl.** **364/550**; 364/551.01; 364/148

[58] **Field of Search** 364/550, 551.01, 552, 364/150, 571.02, 571.05; 364/492, 496, 148

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,63
4,70

Primary Examiner—Parshotam S. Lall
Assistant Examiner—Michael Zanelli
Attorney, Agent, or Firm—Hopkins, French, Crockett, Springer & Hoopes

[57] **ABSTRACT**

A process for monitoring a system by comparing learned observations acquired when the system is running in an acceptable state with current observations acquired at periodic intervals thereafter to determine if the process is currently running in an acceptable state. The process enables an operator to determine whether or not a system parameter measurement indicated as outside preset prediction limits is in fact an invalid signal resulting from faulty instrumentation. The process also enables an operator to identify signals which are

1990

Instrumentation Surveillance at TMI 1 Using Pattern Recognition Techniques

1993

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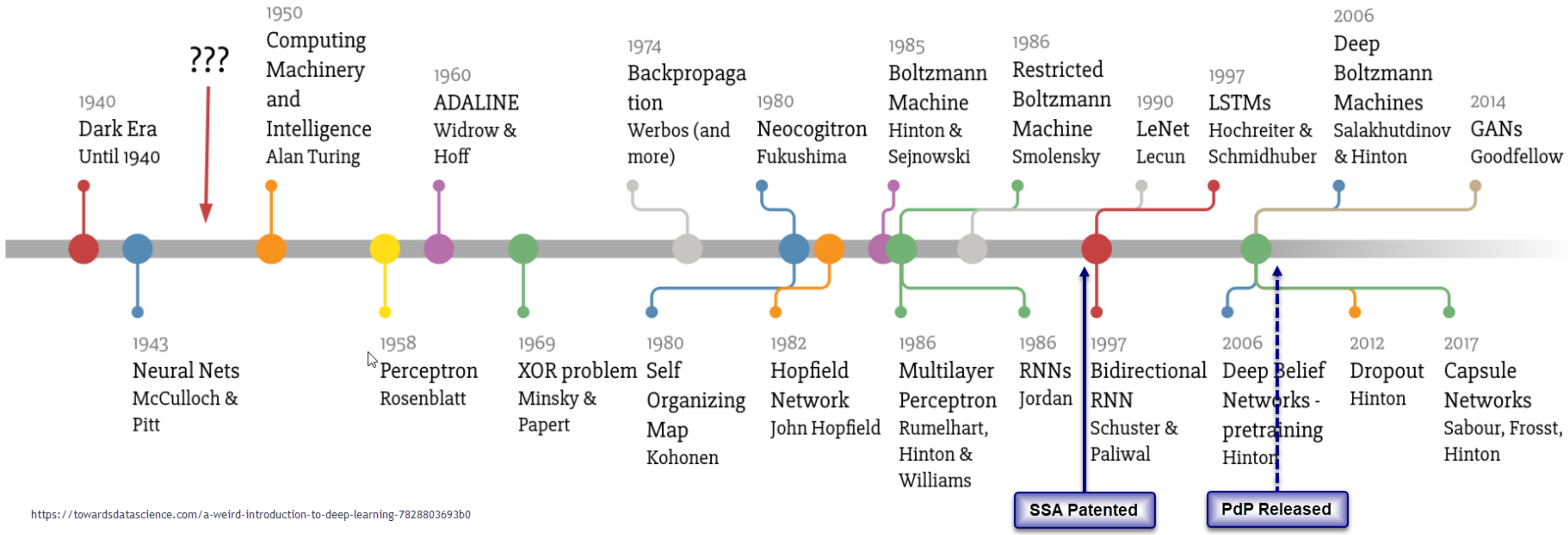
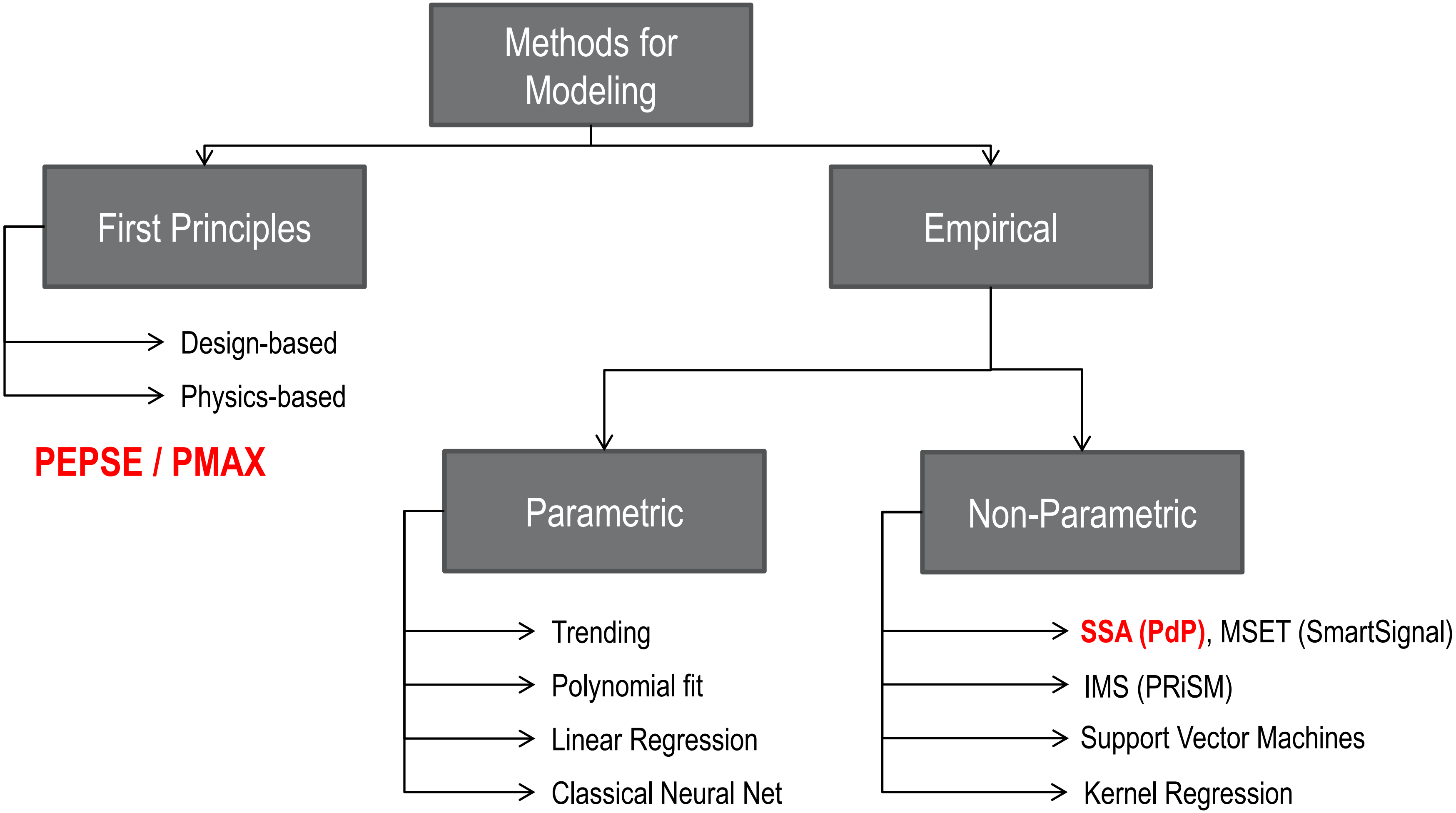
Waiting for Processing Power to Catch Up



https://towardsdatascience.com/a-weird-introduction-to-deep-learning-7828803693b0

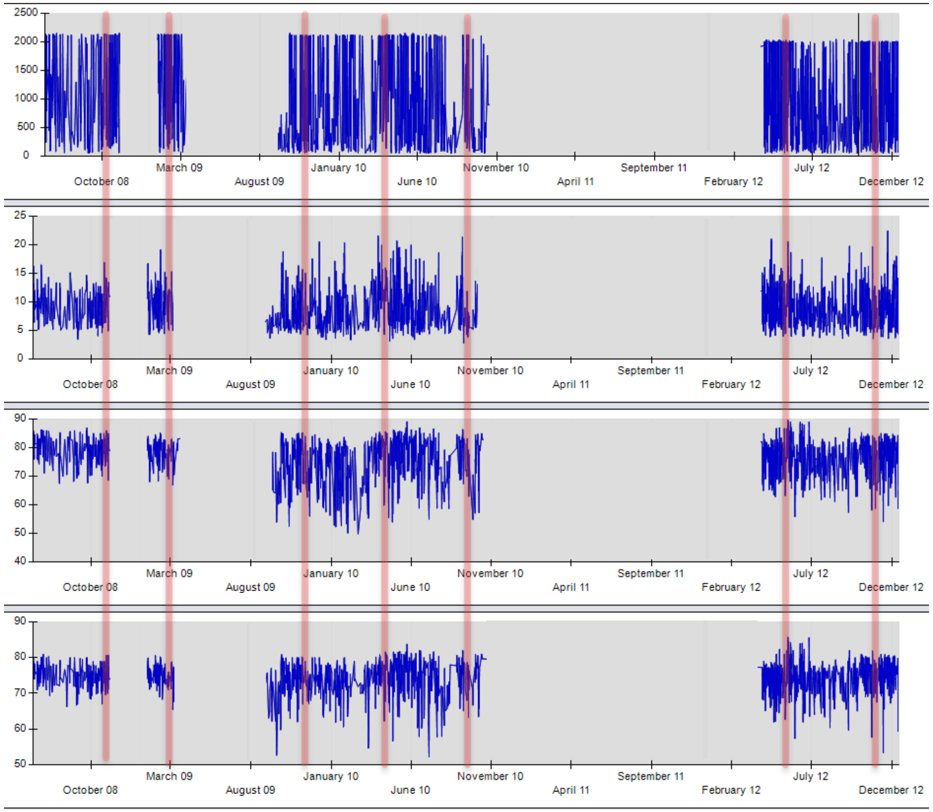
PdP's underlying algorithm required maturing of computing architecture to provide the speed to make training and real time processing commercially viable. Also required migration of analog to digital and associated historians

Predictive Analytic Methods



PdP (Similarity Based Model)

Current Value	Reference File (Normal Data)	Predicted Value
1800		1810
12		11.8
82		82.1
75		75.3



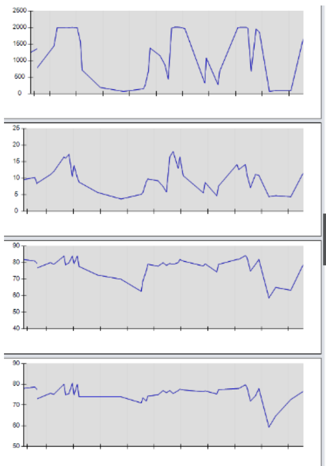
One Snapshot at a time

Find the most similar snapshots in the normal data regardless of time of year, time of day, previous operating conditions

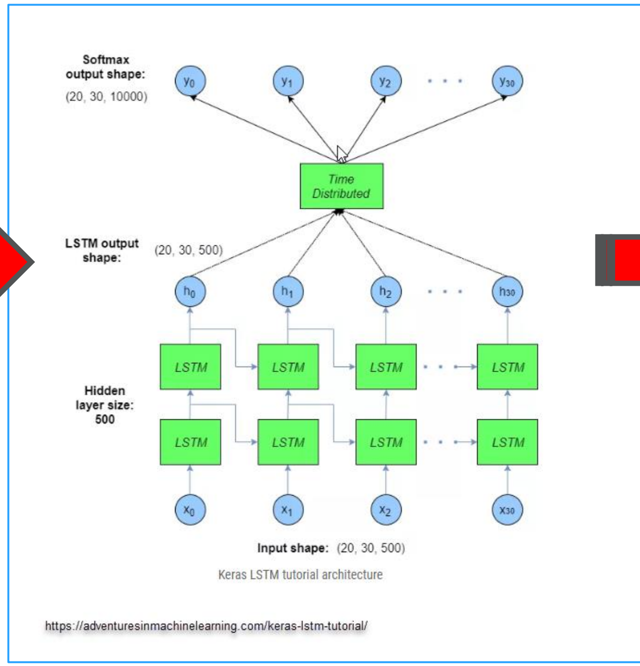
Weight Average most similar data to predict

LSTM Neural Net plus time series outlier detection

Last X Snapshots Including Current



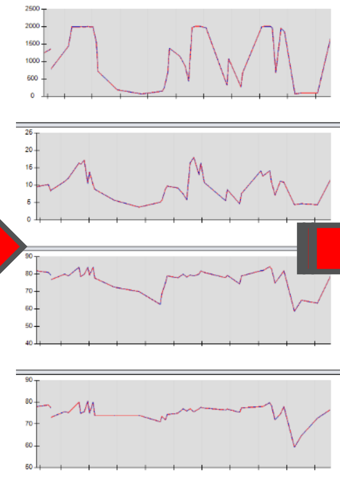
Neural Net Trained to Use X Previous Snapshots



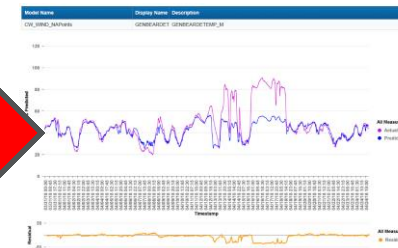
Keras LSTM tutorial architecture

https://adventuresinmachinelearning.com/keras-lstm-tutorial/

Predictions for All Snapshots



Times Series Outlier Detection



Data for window of operating time

Neural Net Trained on normal windows of contiguous time series data representing normal operation including transients like ramping, start up and shutdown

Predictions reflect behavior leading up to current time

The Technical Challenge

- Requires marriage of equipment/process SMEs and technical SMEs (data scientist)
- Requires a high technical competency to implement and maintain
- Requires processing power beyond computing horsepower
- Data…

The Data Challenge

- Lack of volume
- Lack of good data for training
- Normal vs. Failure
- Seasonality
- Start-ups and shut-downs
- Changing environmental conditions

Innovation as a Service

INNOVATION COOPERATIVE

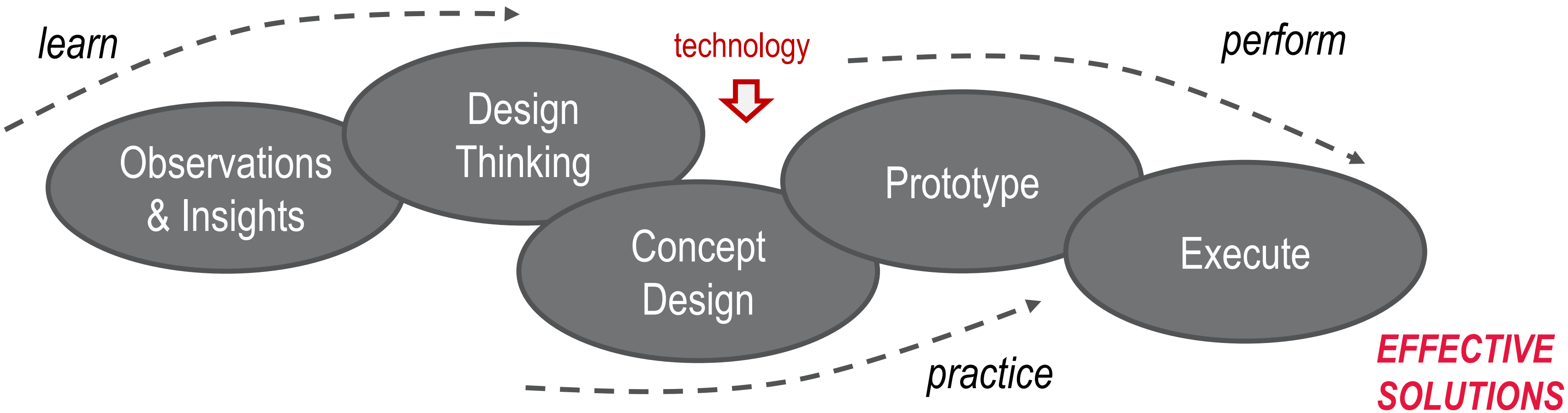
LEAN CONSULTING ENGAGEMENT

Customer discovery, outcomes

Identification of improvement opportunities

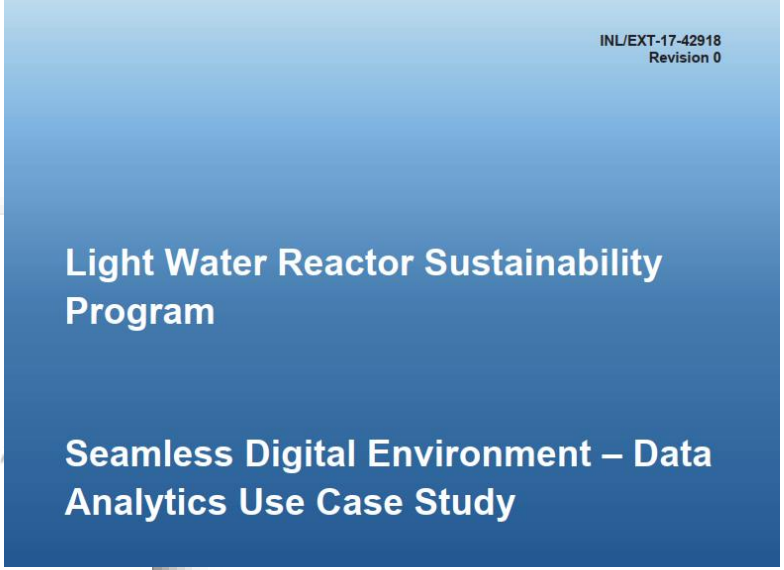
Collaborate focused on problem solving & solutions

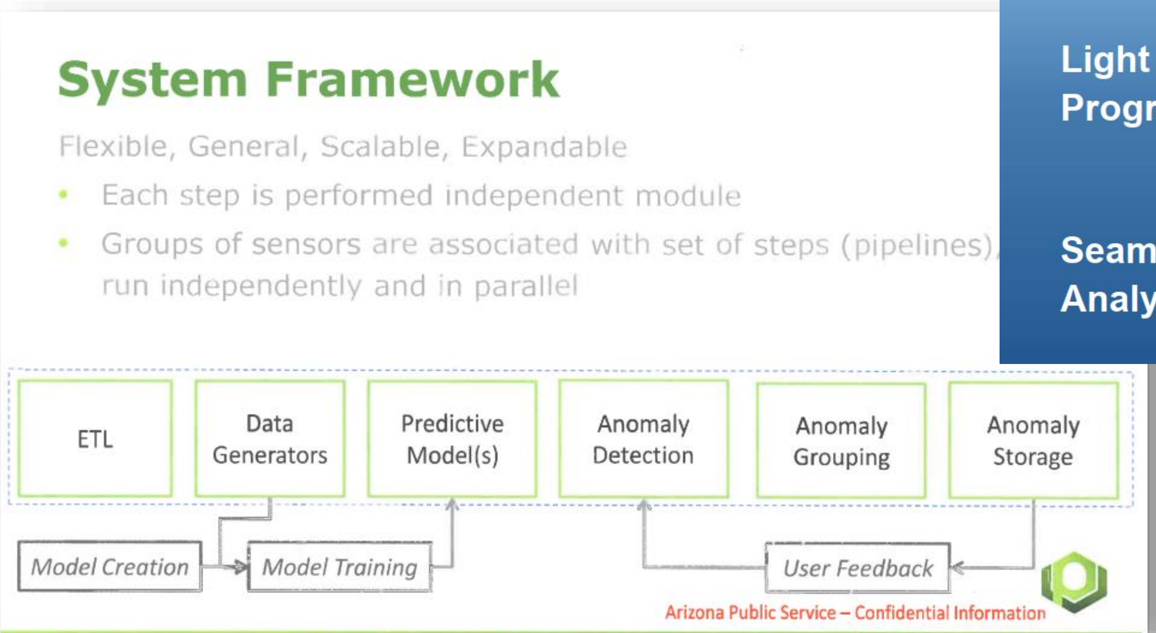
STRUCTURED PROCESS



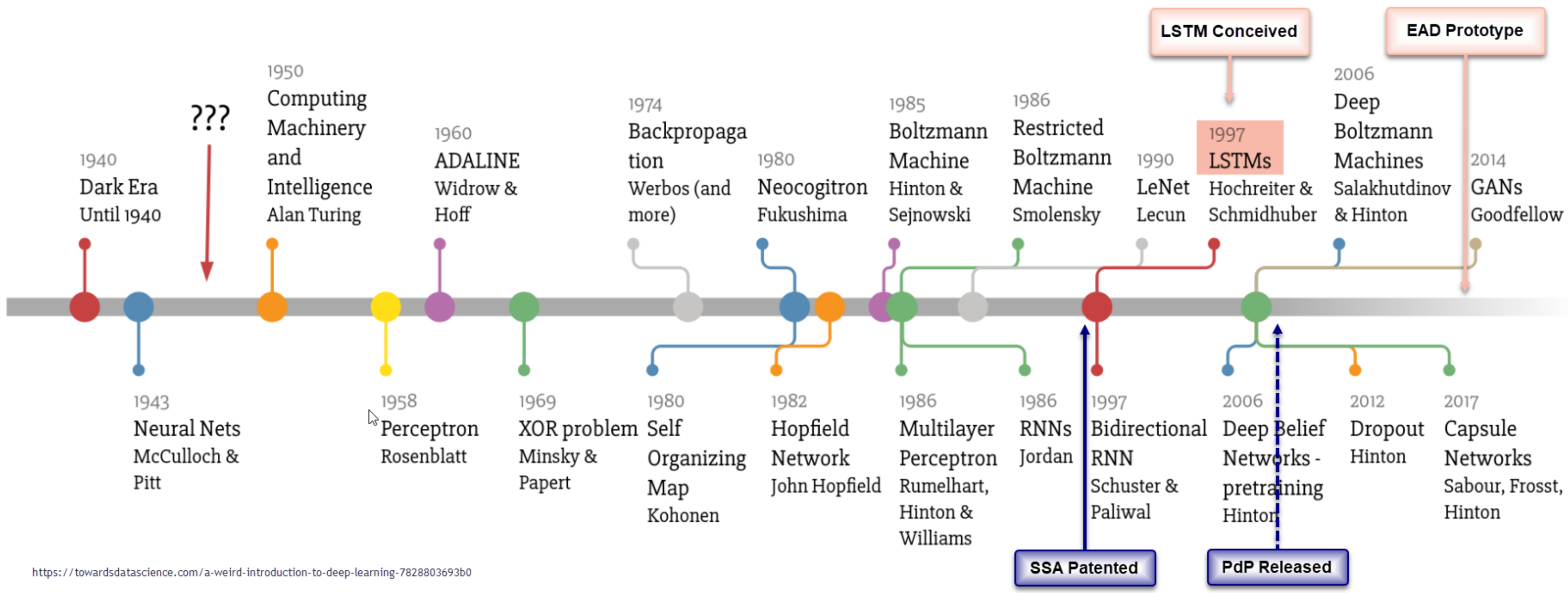
APS Equipment Anomaly Detection (EAD)

- Uses open-source packages
- Built as a platform rather than a solution
- Team has full access to plant data
- Semi-supervised Learning
- Efficient use of SMEs



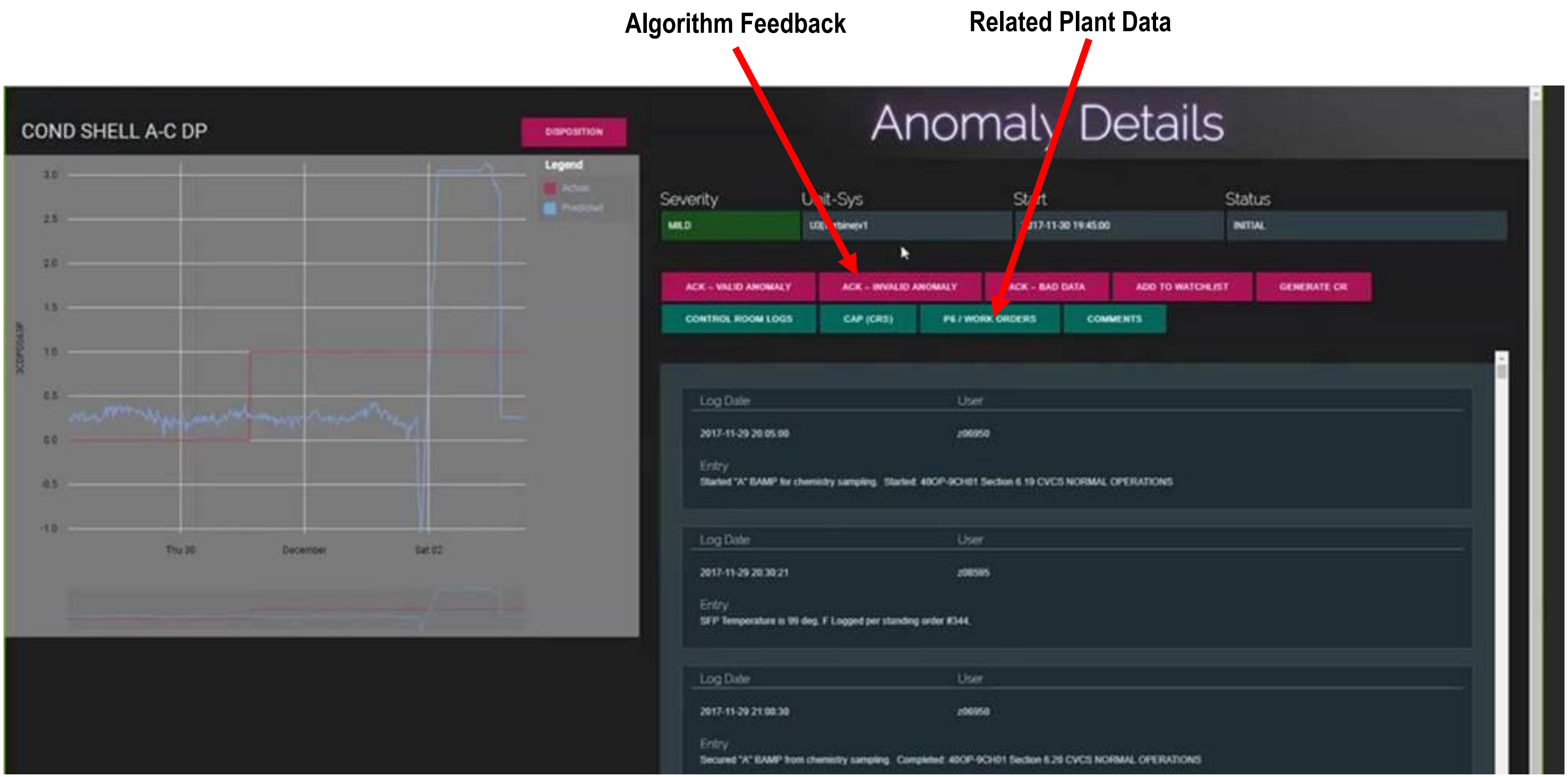


Waiting for Processing Power to Catch Up



EAD's underlying neural net algorithms also required maturing of computing architecture to provide the speed to make training and real time processing commercially viable.

APS Equipment Anomaly Detection User Interface



Graphical display of anomaly data, plus real-time connection to plant systems for control room logs, condition reports and work orders

The APS EAD Toolkit

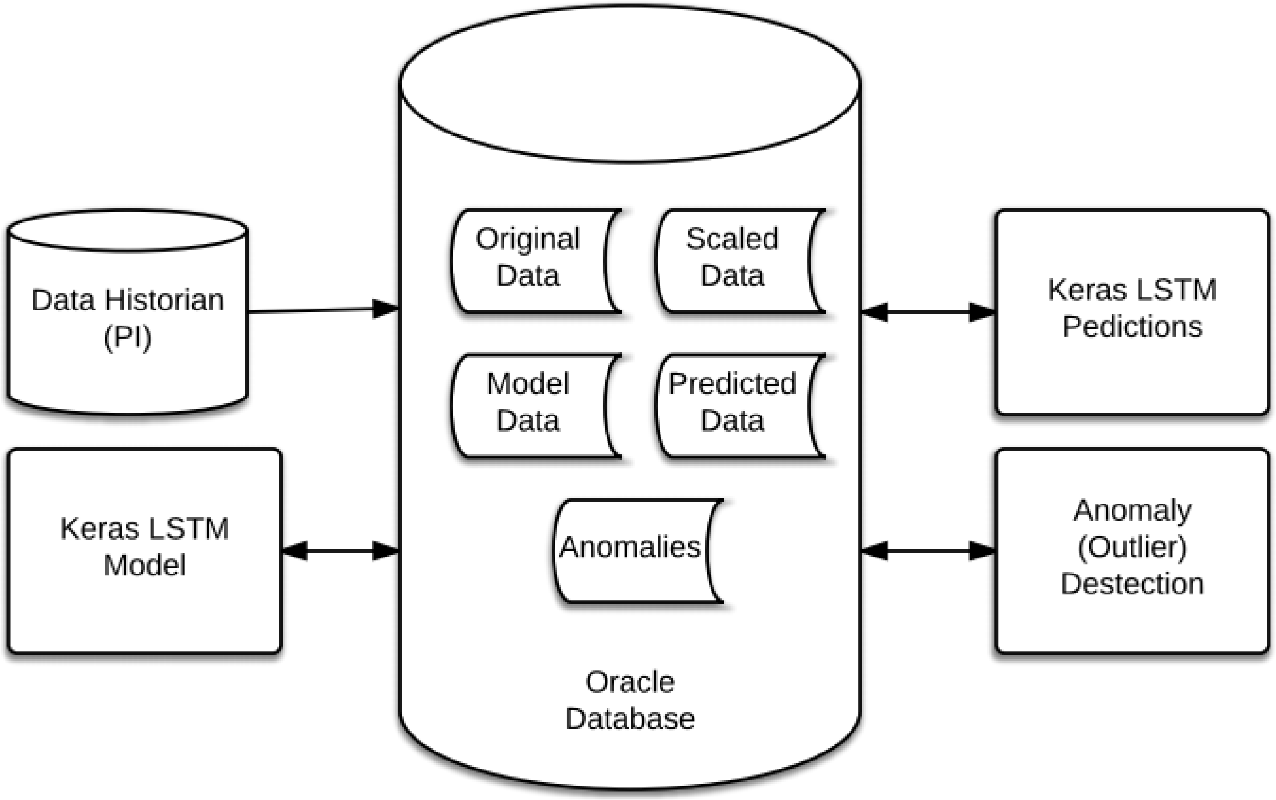
Open Source

- R Programming
- Keras LSTM Autoencoder
- TSOutliers outlier detection

Commercial Products

- Oracle Database
- Domino Labs Containers
- NextAxiom Hyperservices
- PI Data Historian

The APS EAD Architecture

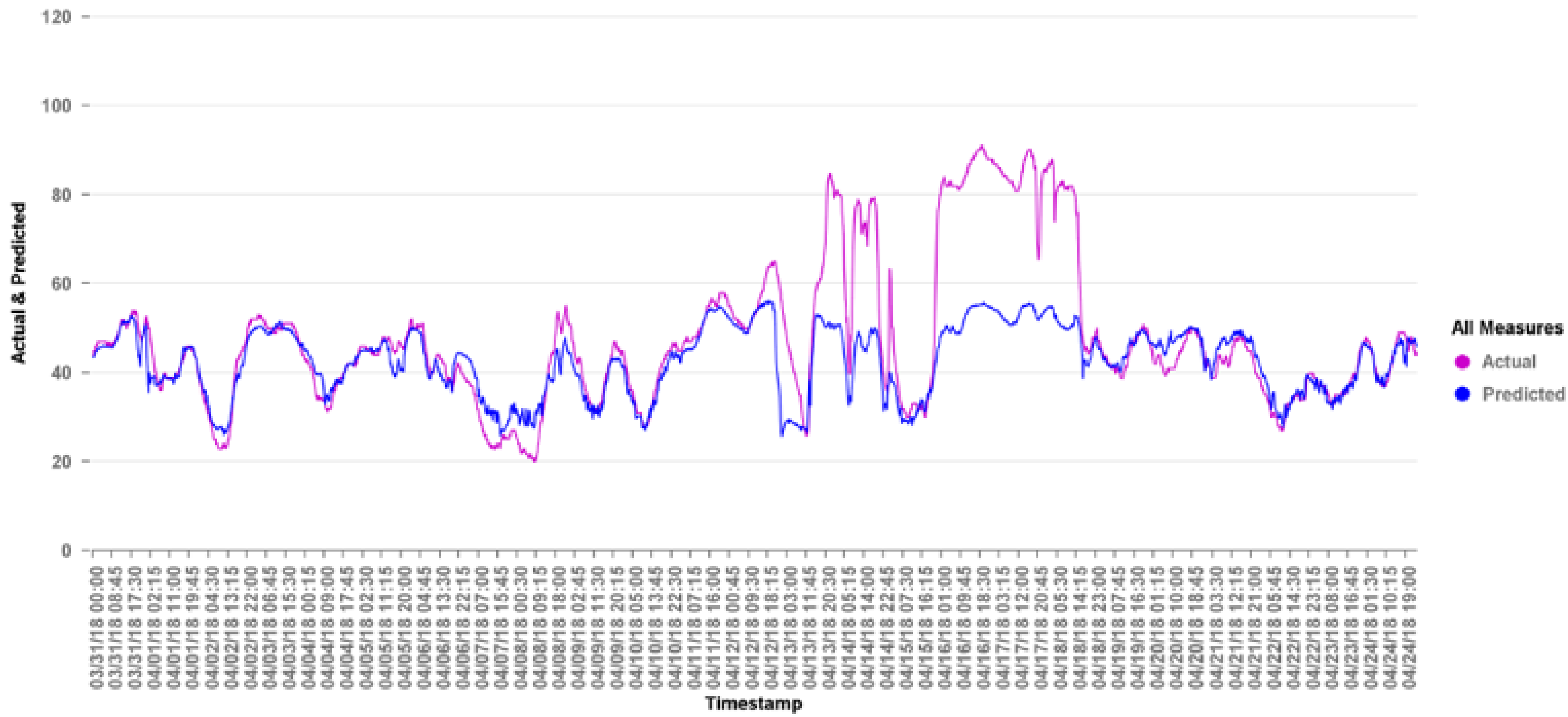


40,000 sensors
30 models
2-hour training
15-minute updates

3 servers
8 cores
32GB RAM/server
No GPU

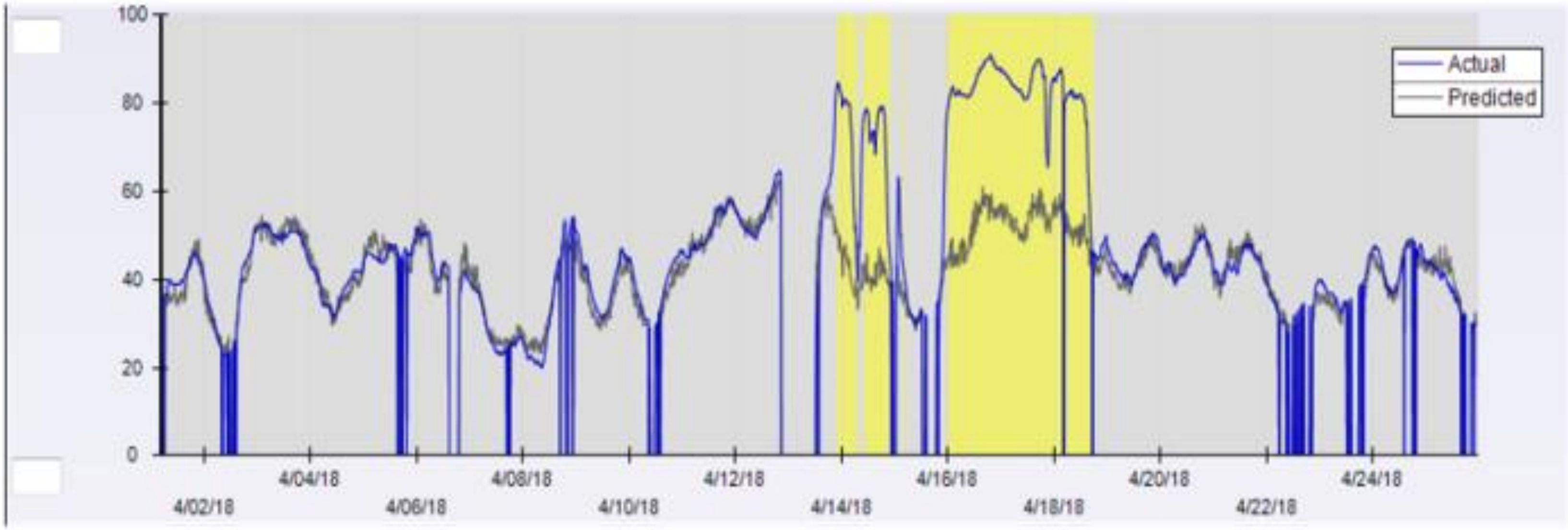
The Autoencoder Analysis

Model Name	Display Name	Description
CW_WIND_NAPoints	GENBEARDET	GENBEARDETEMP_M



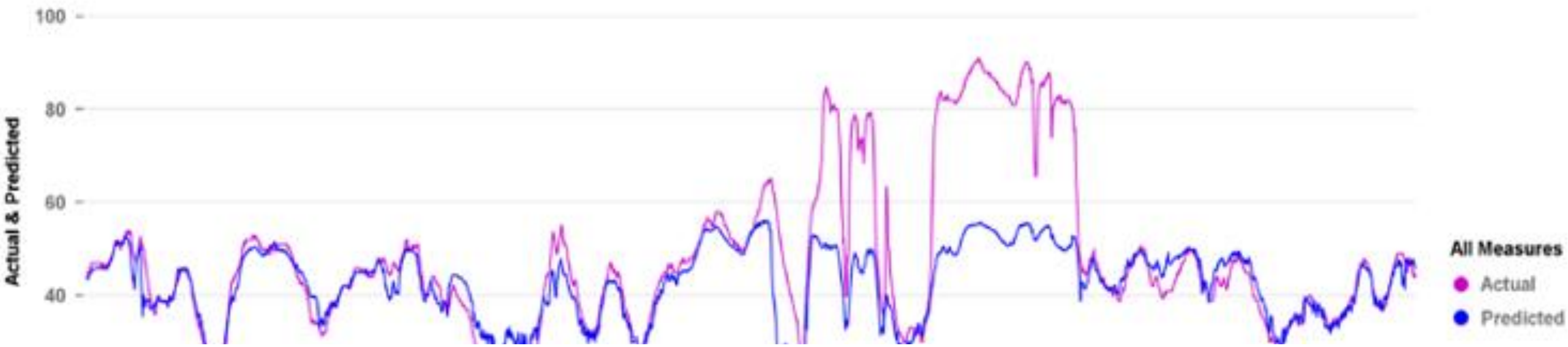
Autoencoder Analysis

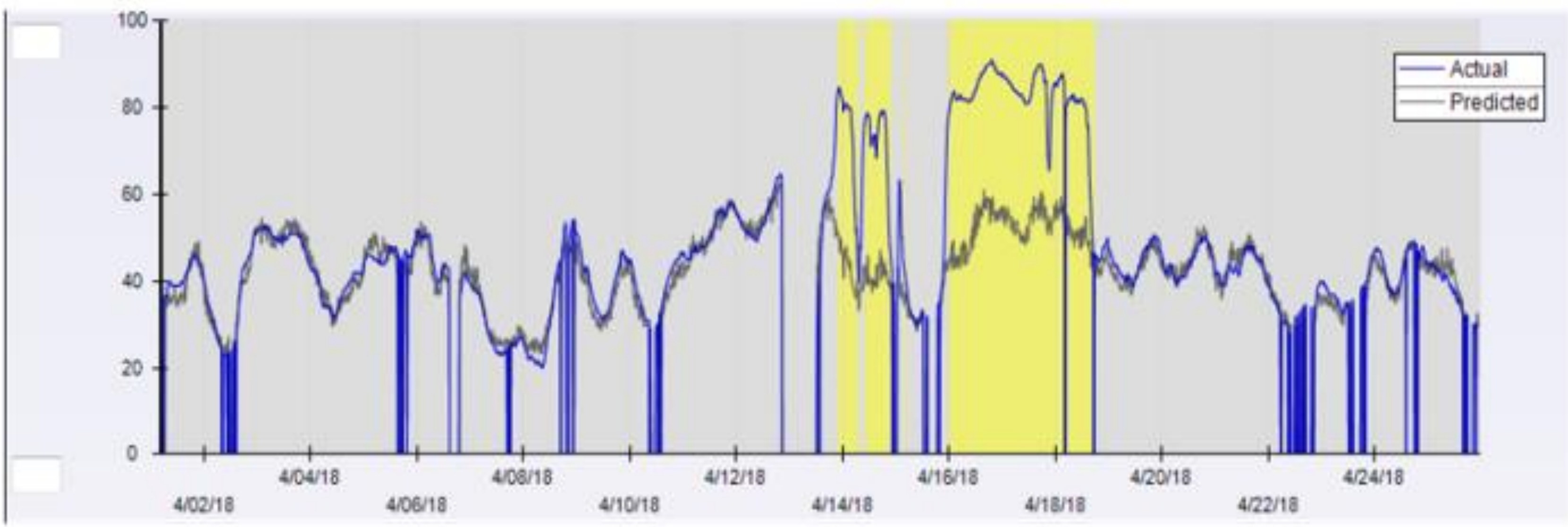
The System State Analysis



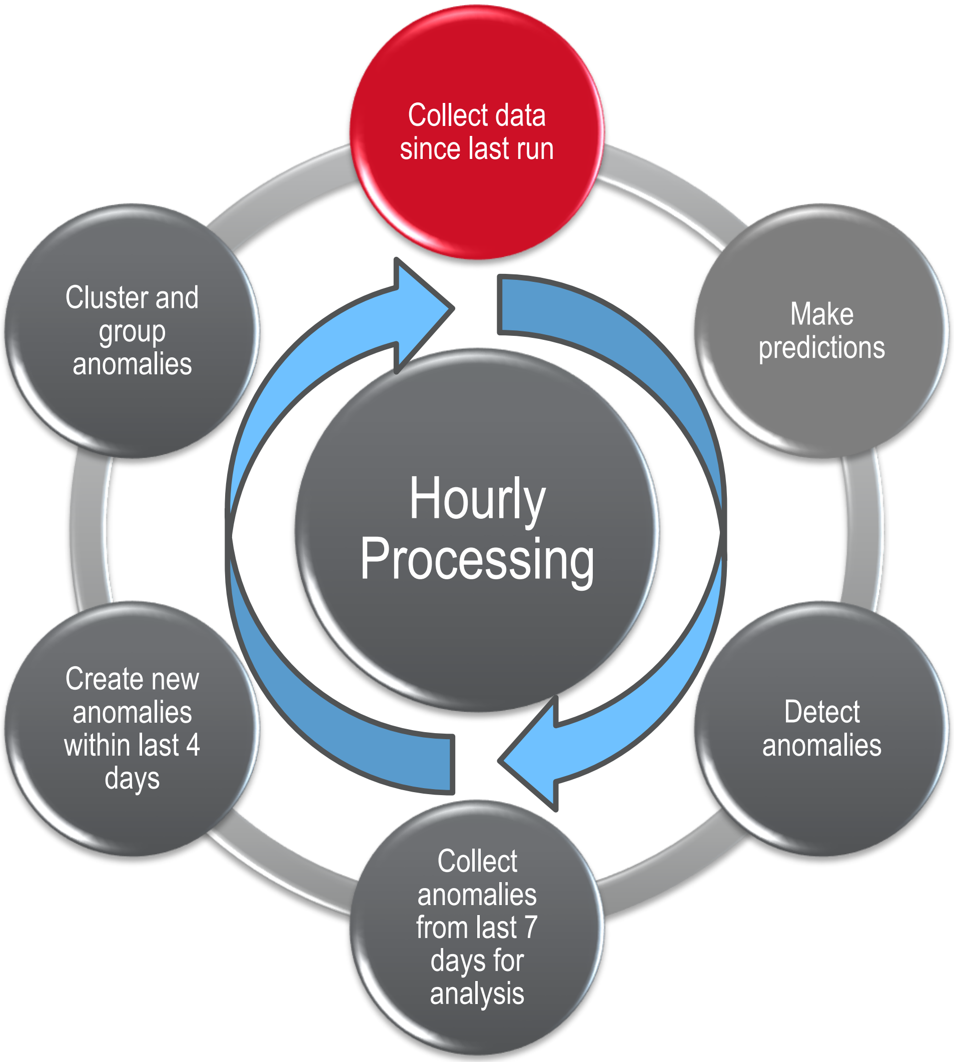
PdP System State Analysis

The Comparison





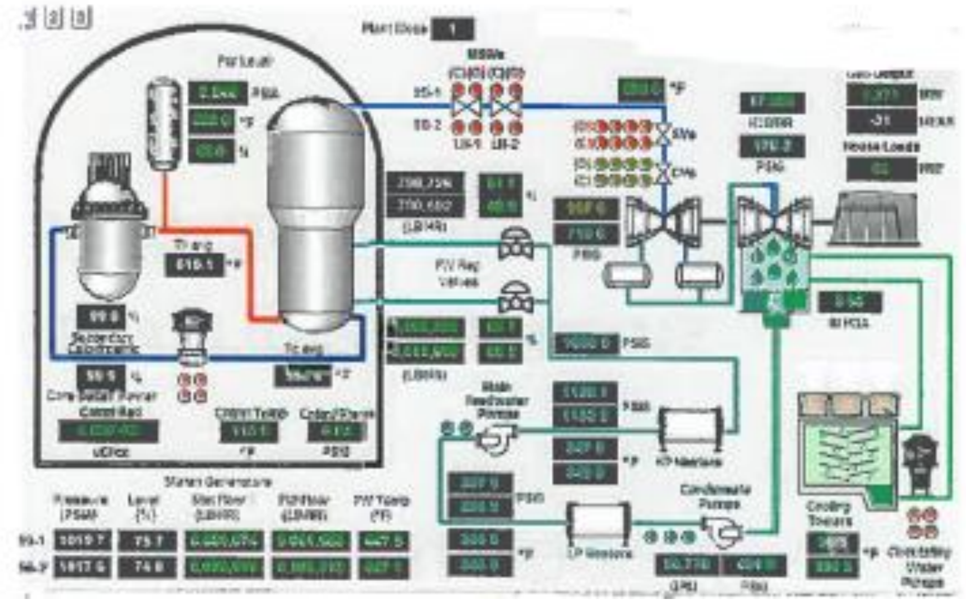
EAD Process Flow



Anomalies are then presented to the user, and the user can provide feedback to adjust sensitivity of algorithm

Limitations in Existing EAD Prototype

- “Kitchen Sink” Approach
- Lack of Investigative Tools
- No User Modeling
- No Sensor Controls



Commercialization Tasks

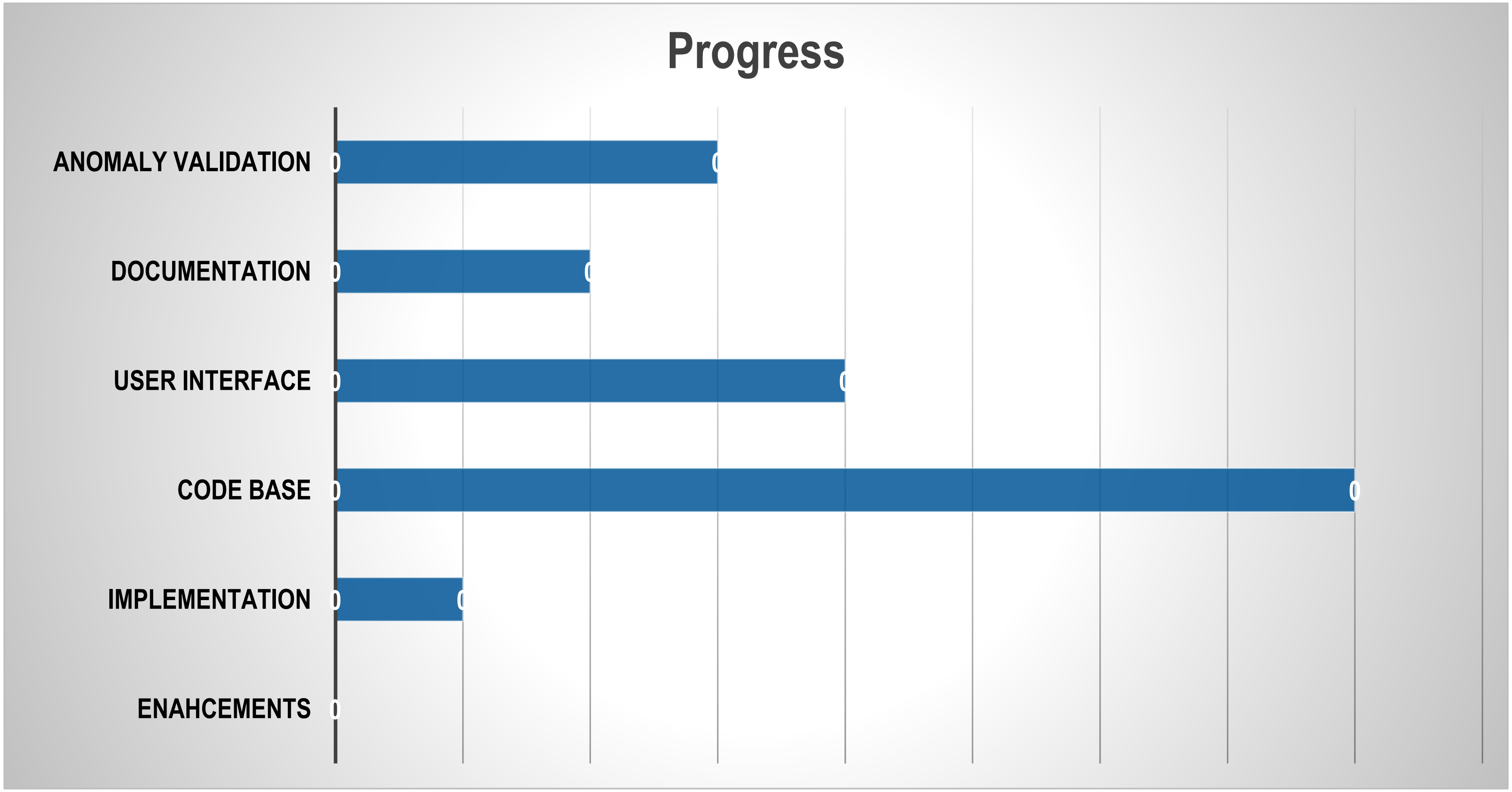
Generalize
- Client-Specific Tools
- Client-Specific Interfaces
- 3rd Party Licenses

Document
- Software Description
- Algorithm Logic
- User Guide

Enhance
- Add User Interface Features
- Add Control Features

Implement
- Implementation Plan
- Support Model

Current Commercialization State



Potential Applications

- Start-Up/Shut-Down Models
- Hydro Plants
- Steam Plants
- Ultrasonic Data Analysis
- On-Board Diagnostics
- Wind Turbines
- Gas Turbines
- Switchyards

Our Present Work

ASHBURN, Va. – December 3, 2019 – Curtiss-Wright's Defense Solutions division, today announced that, through its Reseller Agreement with WOLF Advanced Technology, it has expanded its family of open architecture high performance embedded computing (HPEC) processors designed for demanding ISR applications with the addition of three new NVIDIA Quadro Turing (TU104/6) GPU/inference engine-based OpenVPX™ modules. Curtiss-Wright also announced the availability of a new AMD Radeon™ (E9171) based XMC graphics engine card.

Designed to support compute-intensive ISR and EW systems, the fully rugged VPX3-4925, VPX3-4935, and VPX6-4955 modules feature Tensor Cores (288, 384, and 768 respectively) that are ideal for accelerating tensor/matrix computation used for deep learning neural network training and inference used in deployed and artificial intelligence (AI) applications requiring TFLOPS of accelerated processing. These applications include high-performance radar, SIGINT, EO/IR, data fusion ingest, processing and display, and autonomous vehicles.

https://www.curtisswrightds.com/news/press-release/cw-announces-new-nvidia-quadro-turing-tu104106-gpgpu-processor-modules.html

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Questions?

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