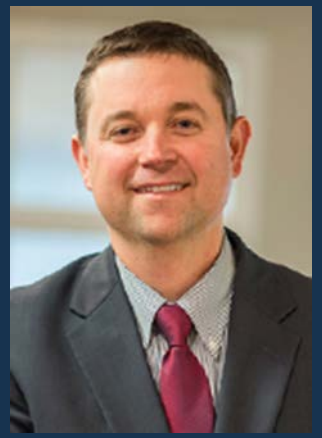
INNOVATING NUCLEAR TECHNOLOGY

ANALYSIS AND MEASUREMENT SERVICES CORPORATION

Online Monitoring System to Support Autonomous Remote Microreactor Operations



Presented by:

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Senior Engineering Manager

AMS Corporation

Presented for:

DOE-NE Microreactor Program Winter Review Meeting

March 5, 2024

We Test the I&C Systems of Nuclear Power Plants

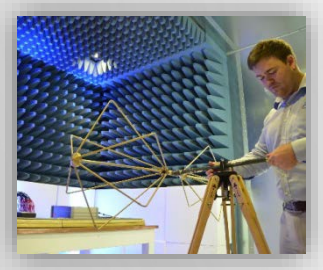
- *All U.S. nuclear power plants*
- *Nuclear plants in Europe, Asia, Middle East, and South America*
- *DOE Facilities including Y-12, Sandia, Savannah River, HFIR/ORNL, and ATR/INL*

I&C MAINTENANCE

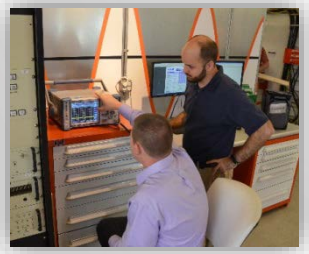
ROD CONTROL

CABLE TESTING

SOFTWARE RELIABILITY



EMC/WIRELESS



DIAGNOSTICS

MATERIALS TESTING

ONLINE MONITORING

What is On-Line Monitoring (OLM)?

Methods for evaluating the health and reliability of …

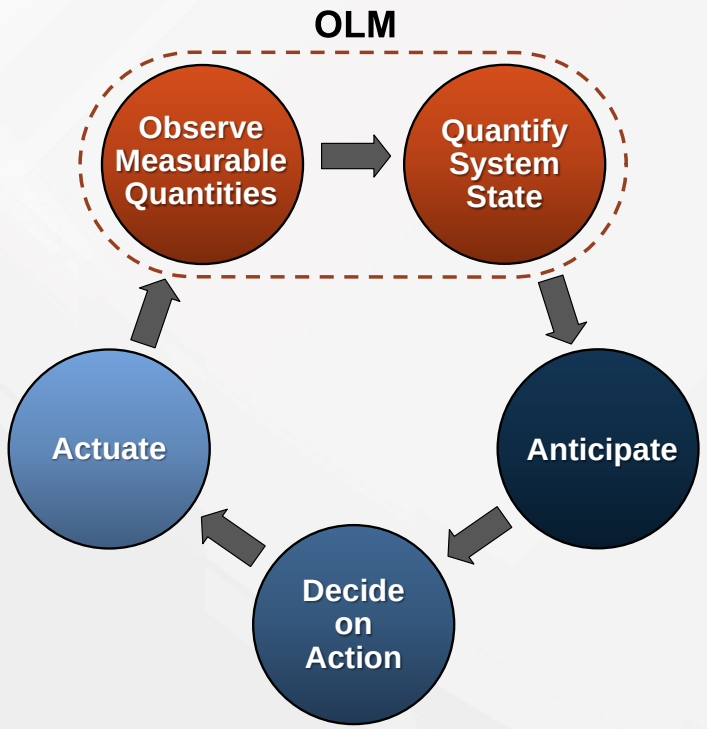
- Plant Sensors and Equipment
- Reactor Processes
- Structures, Systems, Components

… while the plant is operating.

Benefits of OLM:

- ✓ Early degradation/failure warning
- ✓ Supports condition-based versus time-based maintenance
- ✓ Enables autonomous operations

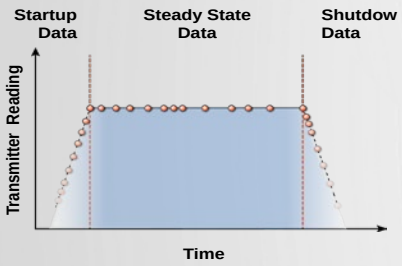
Generic Sequence of Operations for Autonomous Systems*



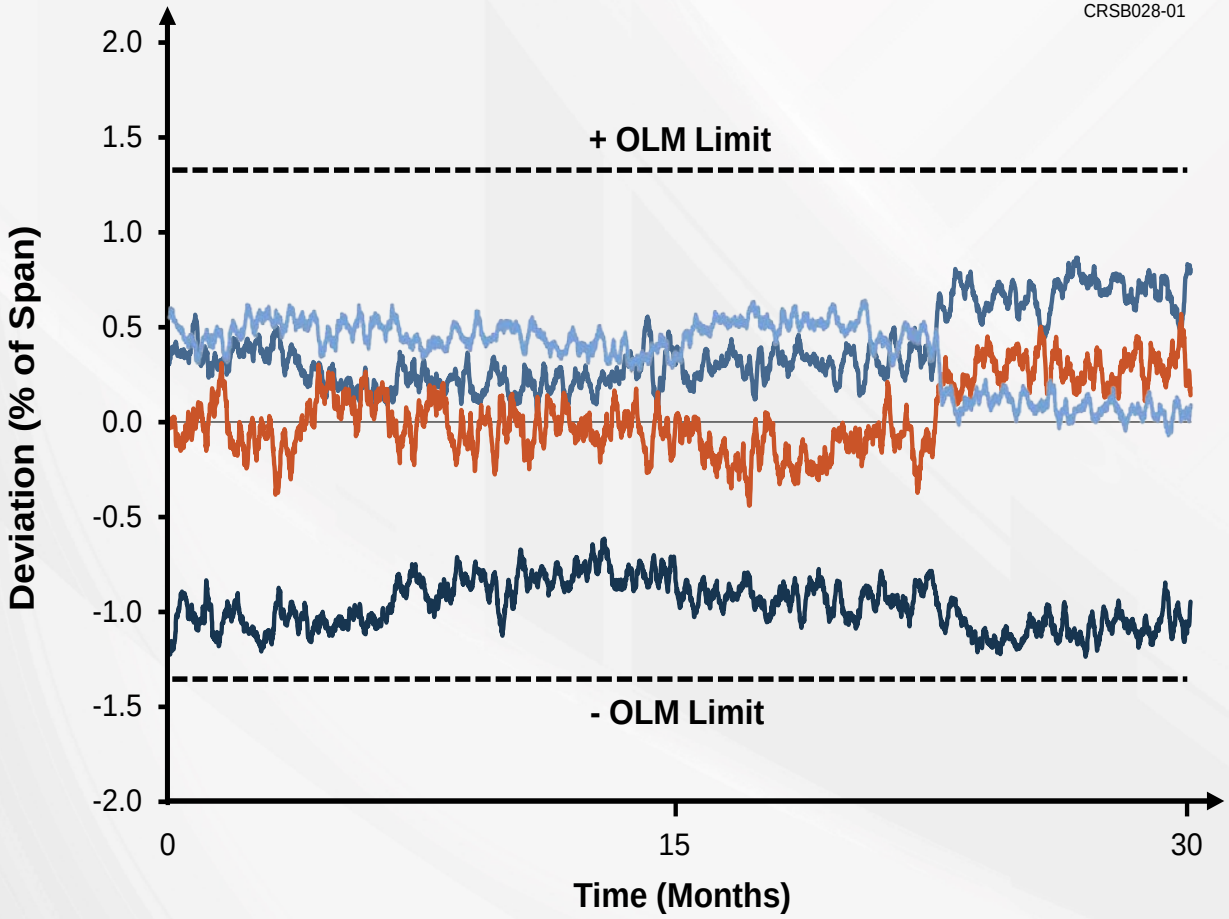
*Ramuhalli, P. and Cetiner, S., *Concepts for Autonomous Operation of Microreactors*, ORNL/TM-2019/1305, 2019

OLM Implementation in Nuclear Facilities

Data Historian



Item	Group Name	Tag Name	Result
1	SG A OUTLET PRESSURE	PT0474	Good
2	SG A OUTLET PRESSURE	PT0475	Good
3	SG A OUTLET PRESSURE	PT0476	Good
4	SG A NARROW RANGE LEVEL	LT0474	Good
5	SG A NARROW RANGE LEVEL	LT0475	Good
6	SG A NARROW RANGE LEVEL	LT0476	Good
7	PRESSURIZER LEVEL	LT0459	Good
8	PRESSURIZER LEVEL	LT0460	Bad
9	PRESSURIZER LEVEL	LT0461	Good



Sizewell B Nuclear Power Plant (UK)

First commercial implementation (2005)

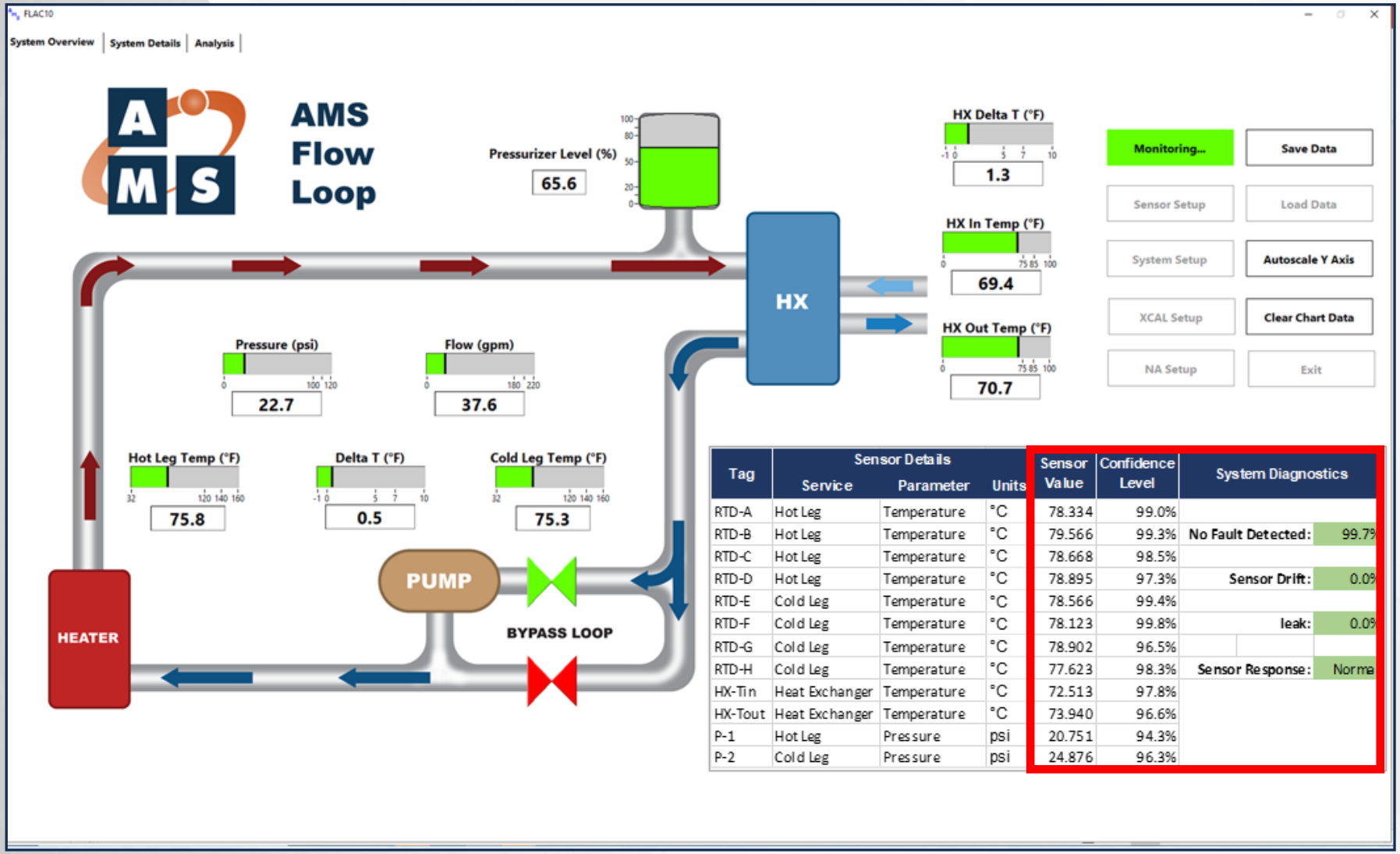
Advanced Test Reactor (US)

First U.S. implementation (2015)

Southern Company (Vogtle)

Latest (2019)

OLM System Concept



Tag	Sensor Details			Sensor Value	Confidence Level	System Diagnostics	
	Service	Parameter	Units				
RTD-A	Hot Leg	Temperature	°C	78.334	99.0%		
RTD-B	Hot Leg	Temperature	°C	79.566	99.3%	No Fault Detected:	99.7%
RTD-C	Hot Leg	Temperature	°C	78.668	98.5%		
RTD-D	Hot Leg	Temperature	°C	78.895	97.3%	Sensor Drift:	0.0%
RTD-E	Cold Leg	Temperature	°C	78.566	99.4%		
RTD-F	Cold Leg	Temperature	°C	78.123	99.8%	leak:	0.0%
RTD-G	Cold Leg	Temperature	°C	78.902	96.5%		
RTD-H	Cold Leg	Temperature	°C	77.623	98.3%	Sensor Response:	Norma
HX-Tin	Heat Exchanger	Temperature	°C	72.513	97.8%		
HX-Tout	Heat Exchanger	Temperature	°C	73.940	96.6%		
P-1	Hot Leg	Pressure	psi	20.751	94.3%		
P-2	Cold Leg	Pressure	psi	24.876	96.3%		

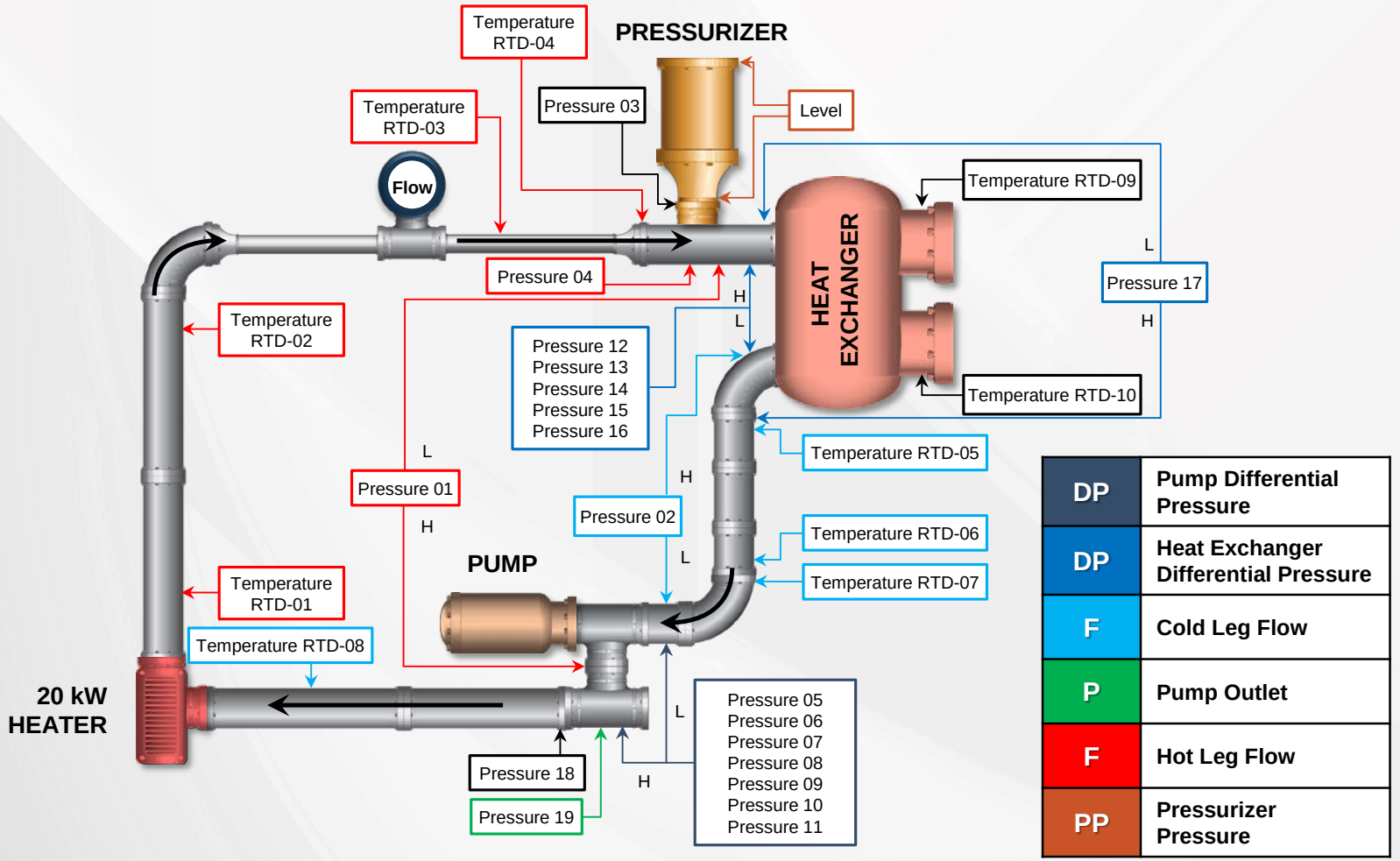
- Data Acquisition
- Configuration
- User Interface
- Real-Time Analytics
- Data Storage

InsightCM™ Online Monitoring Platform

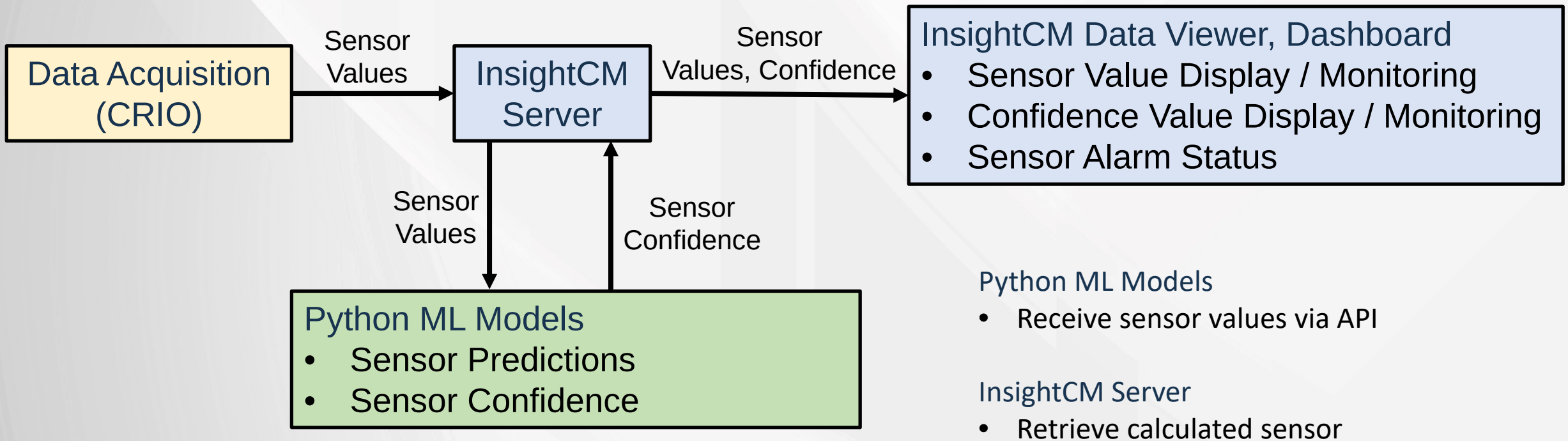
- Customizable data acquisition
- Browser based UI provides remote access with zero client install
- Integrated data storage
- Visualization for subject matter experts
- Automated alerting
- Integrates into existing IT infrastructure with support for:
  - PI & eDNA Historians
  - OPC UA
  - MQTT access

CUTSFORTH

AMS Flow Loop



OLM with InsightCM



Python ML Models

- Receive sensor values via API

InsightCM Server

- Retrieve calculated sensor confidences via MODBUS

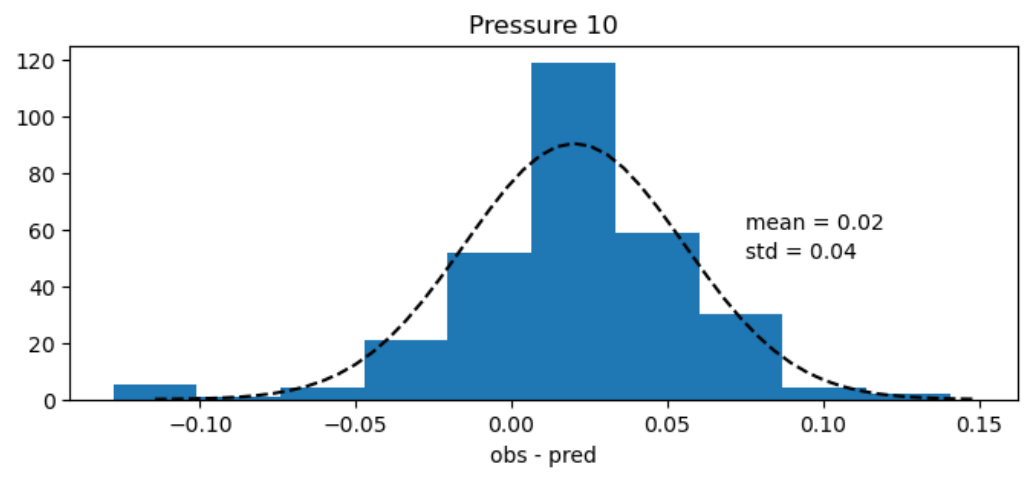
Flow Loop Data Acquisition

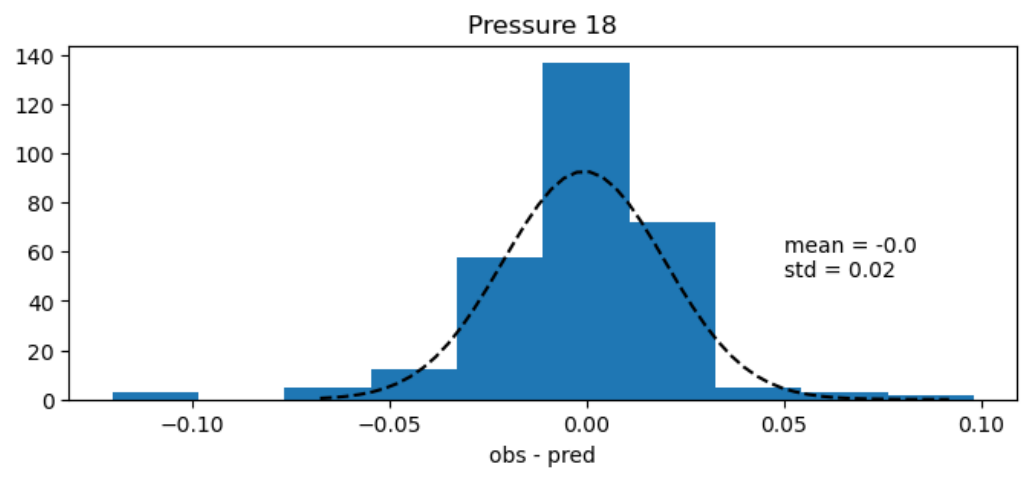
Measurements of values of all flow loop sensors taken under “normal conditions”

- 60 < Flow < 110 gpm
- 40 < Pump Pressure < 60 psi
- Temperature not varied to reduce parameter space
- Used to train Auto Associative Kernel Regression (AAKR) model

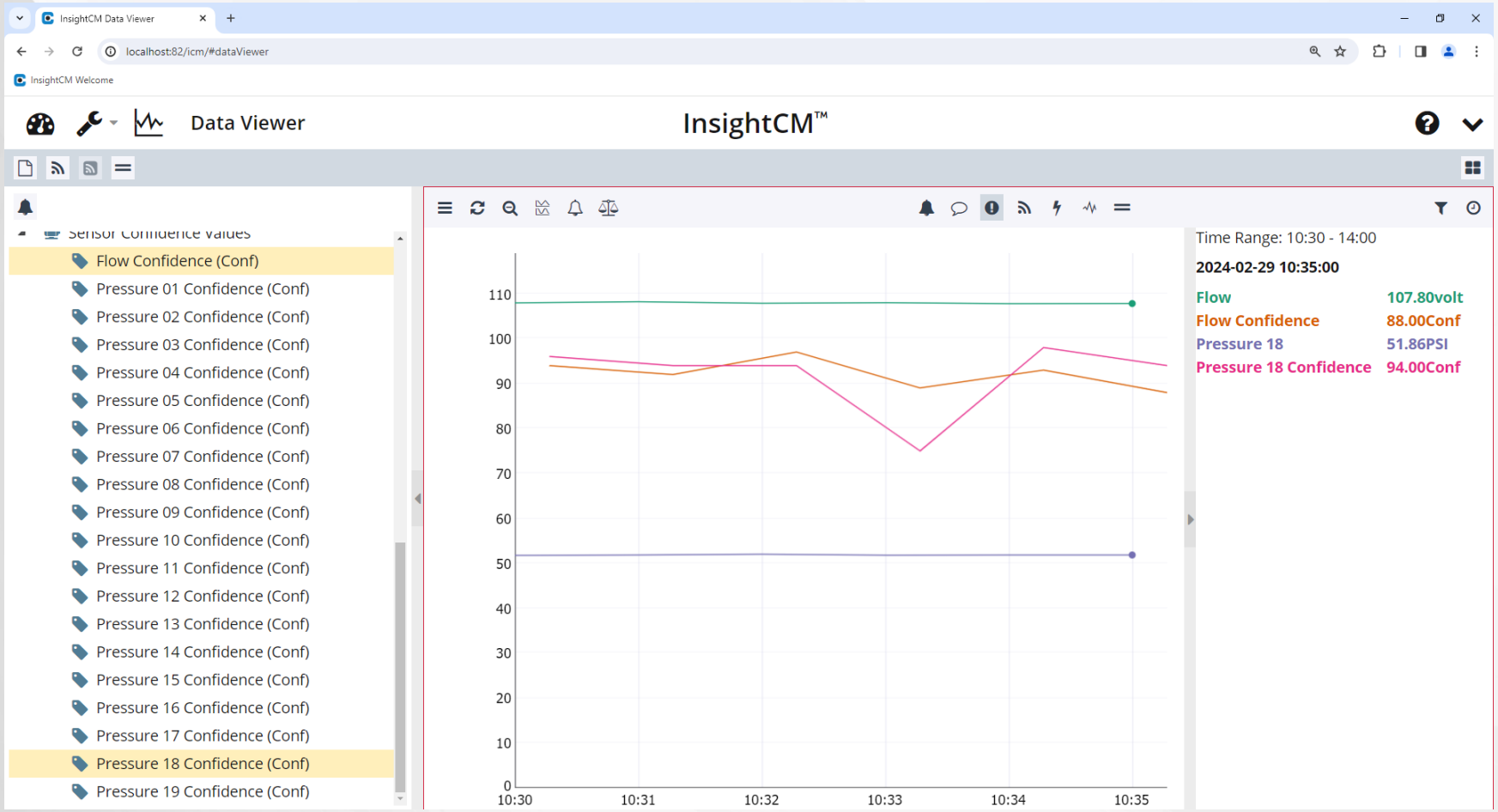
Sensor Monitoring using ML

- Data acquired once every minute and sent through AAKR model
- A small residual compared to testing data indicates current conditions are close to normal conditions
- Confidence level sent back to InsightCM for display and monitoring





Sensor Confidence in InsightCM



Calculated confidence levels from AAKR model shown alongside current sensor values

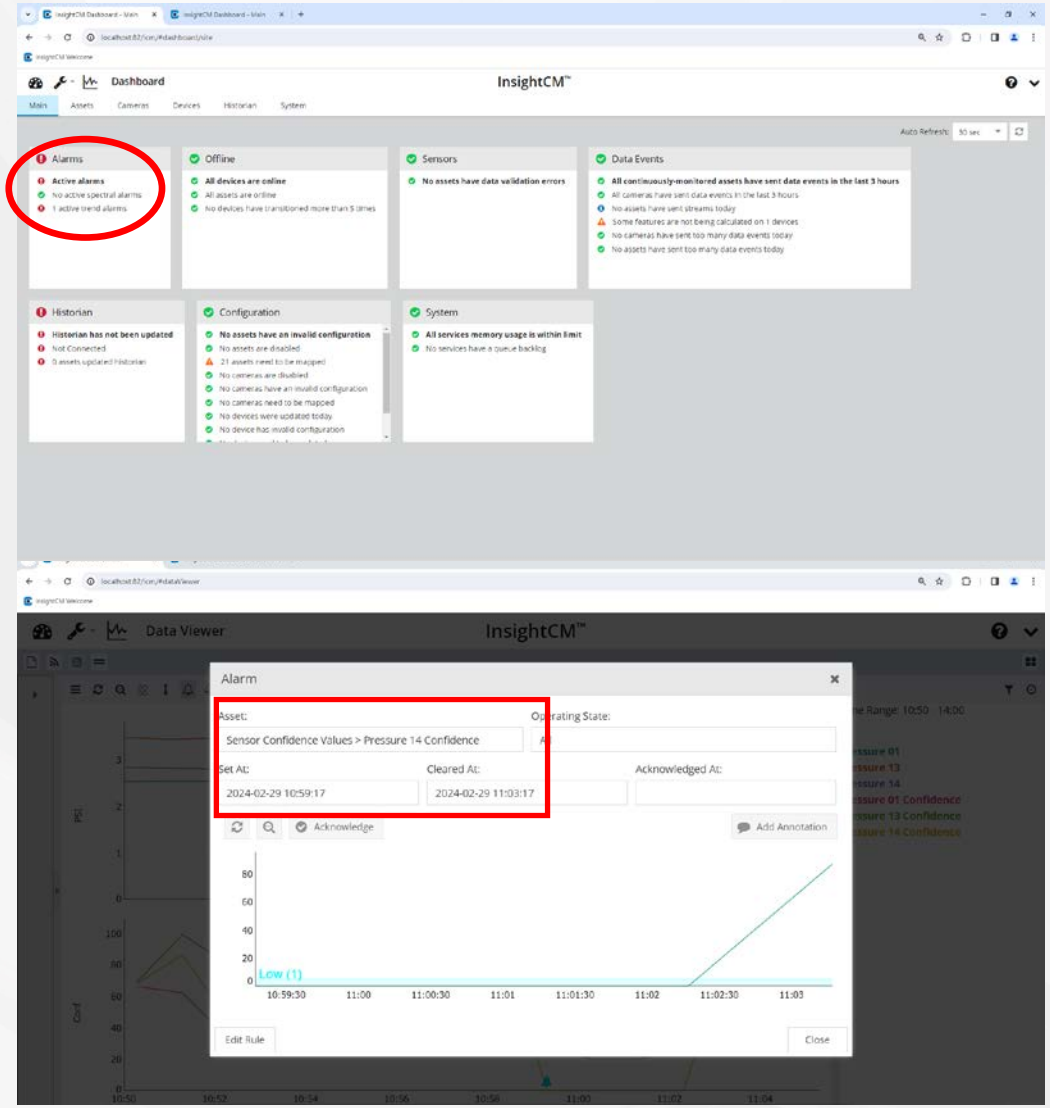
Dashboard and Alarms

Dashboard shows triggered alarm

- Remains active until viewed and cleared
- Can notify user via email

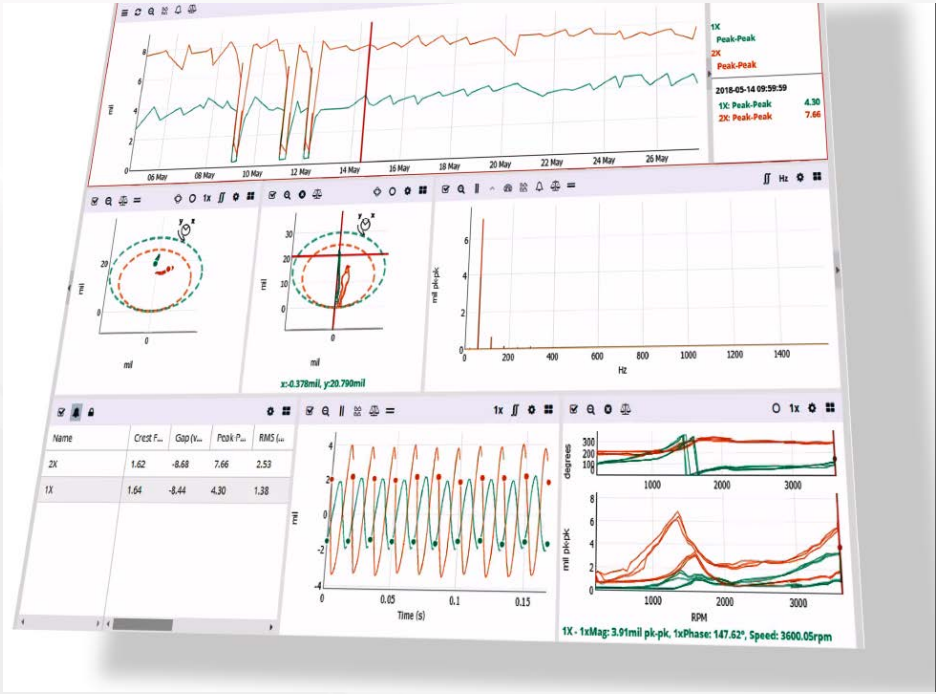
Selecting alarm indicator from data viewer shows details of triggered fault

- Faulted Sensor
- Start time of fault
- End time of fault (if applicable)



Conclusions and Future Work

- InsightCM provides good foundation for OLM system
- Demonstrate on more fault conditions
- Improve AAKR models and confidence calculations
- Integration with historian
- Demonstrate on other test beds



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Thank You

Questions?