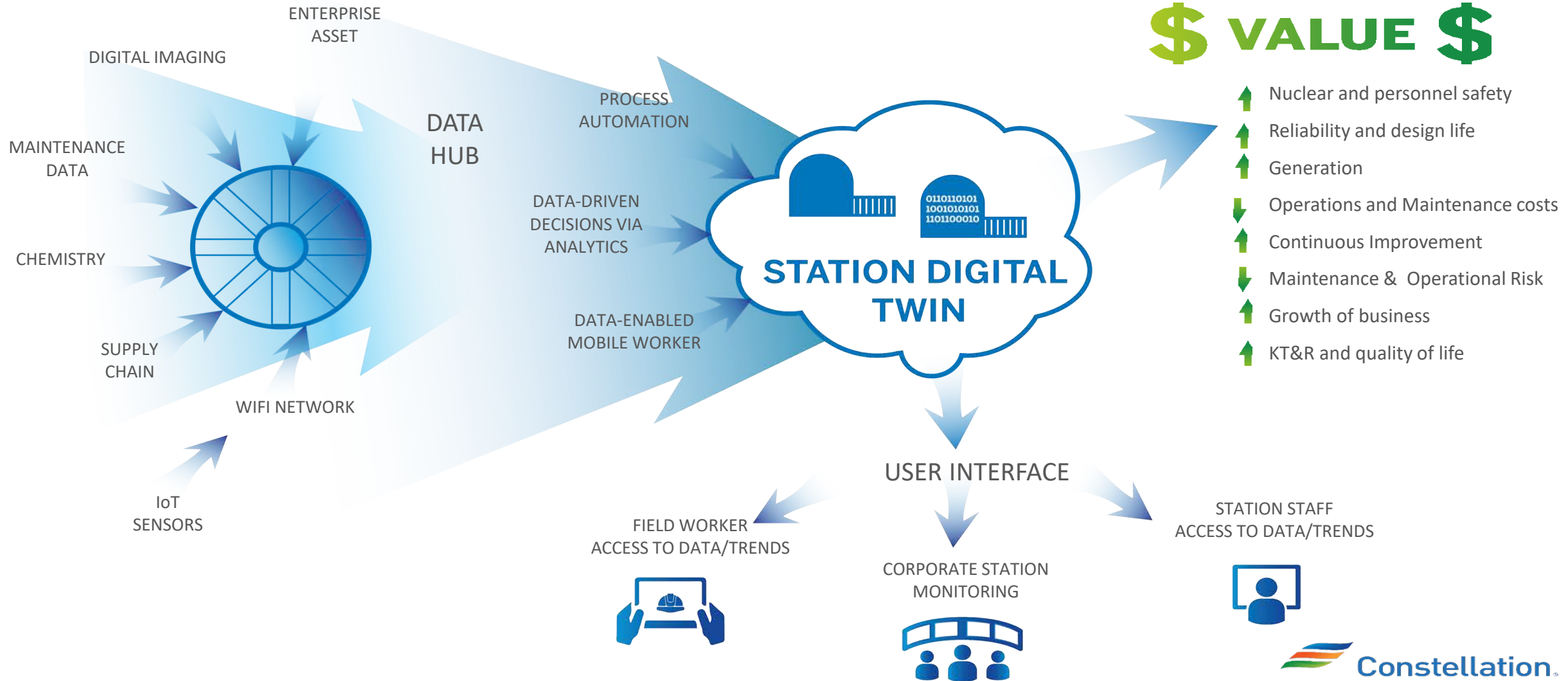# V&V of Data-driven Decisions using Artificial Intelligence/Machine Learning

March 14, 2023

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Constellation Energy Generation

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Jensen Hughes

# CONSTELLATION NUCLEAR DIGITAL TRANSFORMATION

ENTERPRISE ASSET

DIGITAL IMAGING

MAINTENANCE DATA

CHEMISTRY

SUPPLY CHAIN

IoT SENSORS

WIFI NETWORK

DATA HUB

PROCESS AUTOMATION

DATA-DRIVEN DECISIONS VIA ANALYTICS

DATA-ENABLED MOBILE WORKER

STATION DIGITAL TWIN

0110110101
1001010101
1101100010

## $ VALUE $

- Nuclear and personnel safety
- Reliability and design life
- Generation
- Operations and Maintenance costs
- Continuous Improvement
- Maintenance & Operational Risk
- Growth of business
- KT&R and quality of life

USER INTERFACE

FIELD WORKER ACCESS TO DATA/TRENDS

CORPORATE STATION MONITORING

STATION STAFF ACCESS TO DATA/TRENDS

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# Current Analytics Examples

- Advance Pattern Recognition (APR) – *averts equipment failures*

- Initial License Training analytic – *improves student pass rates*

- Maintenance Rule Functional Failure analytic – *streamlines categorization*

- Condition Report Screening analytic – *streamlines screening*

- License Extension reviews – *automates data collection*

- Preventive Maintenance Optimization – *optimizes maintenance frequencies*

- Work Order optimization – *automates work order/planning process*

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# Requirements and Guidance on Quality Assurance

- Software used by NPPs for safety-related processes must comply with the requirements established in 10 CFR Part 50 Appendix B

  - Focused on traditional modeling and analysis software

- There is no clear industry-specific V&V guidance for:

  - Software that is not directly related to facility safety

  - Software that is driven by DA/AI

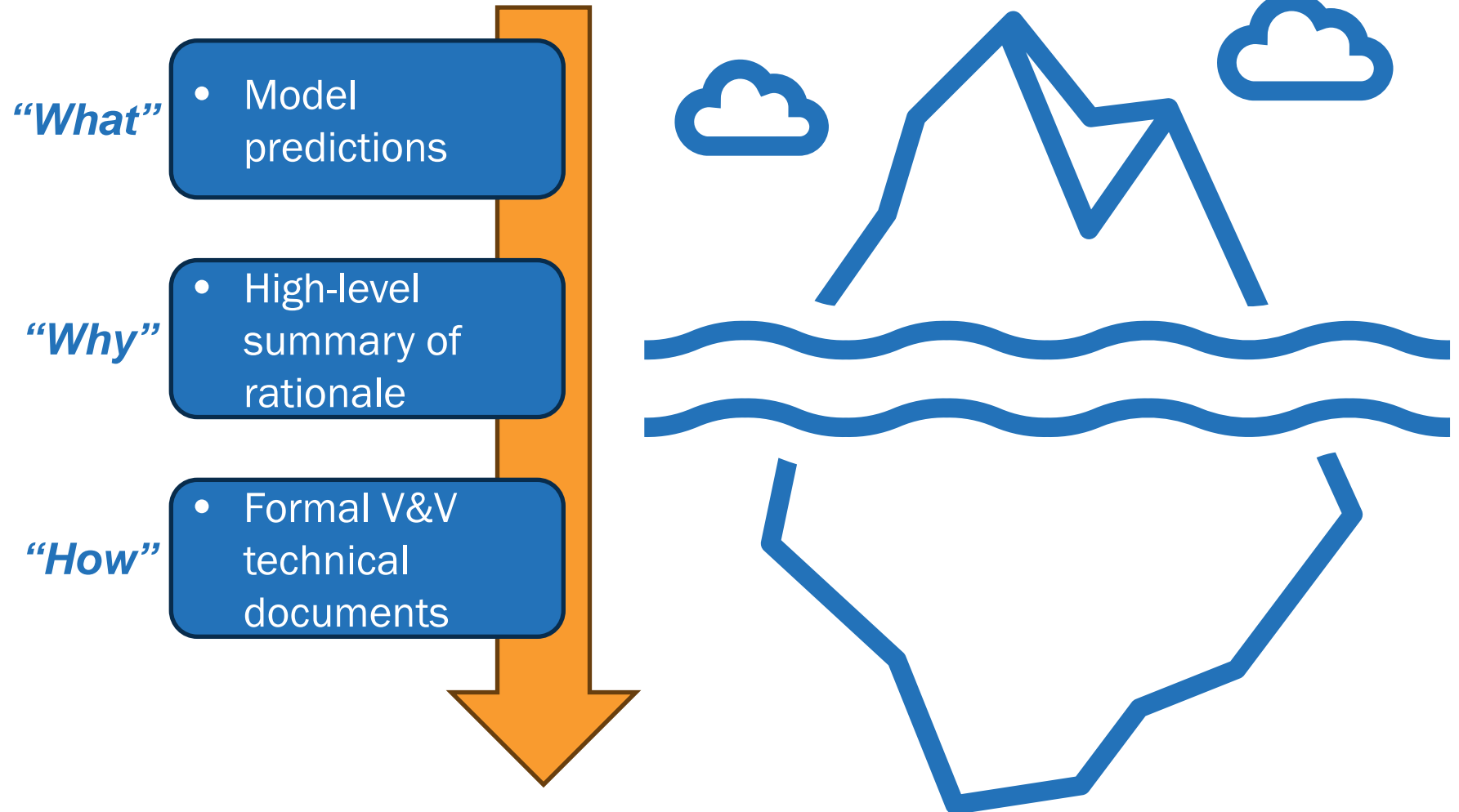- The methodology and techniques presented here provide an example of V&V for DA applications deployed at NPPs

# Who Needs to Know What... The Explainability Iceberg

**Goals of the V&V**

- Building trust in the algorithm
- Auditing the predictions
- Technical basis for use

**Differs by role and responsibilities**

- Licensees
- Individual users
- Dispensation committees
- Program owners
- Regulator

*"What"*
- Model predictions

*"Why"*
- High-level summary of rationale

*"How"*
- Formal V&V technical documents

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# Facilitate CR Routing and Committee Review

## Focus on the "what"

- Automate routing of CRs
- Reduce number of CRs to be reviewed for specific criteria
- Summarize data for staff and committee review

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# End User Explainability

**Focus on the "why"**

- Provide user information on why a specific determination was made
- Indicate similar records to the one being reviewed
- Support final determination process

# Platform Formal Verification and Validation

Focus on the "how"

- Build trust with the end users of the AI algorithms
- Provide licensee confidence in quality of algorithms
- Provide auditors documentation of methods and statistical performance



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Advancing the Science of Safety

**CONSTELLATION V&V REPORT**
XXXXXX-RPT-XX

Version 1.0
2022

**DATA ADVISR**
Data-Driven Incident Report Classifications

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## CONTENTS

i

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# Summary

- **Constellation continues to explore and deploy artificial intelligence (AI) to streamline business processes and data-driven decision-making**

- **Current projects are giving Constellation experience with AI to inform future decisions on the potential value of AI in other areas**

- **Constellation AI applications are designed to keep subject matter experts fully engaged in the decision-making process**

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# Additional Slides for Q&A

# Definitions

- **Verification – The process used to ensure that the software is operating consistent with the intended design.**

- **Validation – The process of assessing software performance in a test environment under a range of input conditions in order to quantify the level of performance that can be expected.**

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# Example Verification – Implementation

- **Implementation verification involves the comprehensive testing of each software component and function in a development environment**

  - **Coverage**

  - **Unit Tests**

  - **Integration Tests**

Text Field Cleaning

The input text fields in the IRs are cleaned according to the following operations:
1. Remove digits
2. Remove punctuation, brackets, and braces
3. Remove special characters
4. Remove extra spaces
5. Make all text lowercase

| Input Text Field | Expected Output Text Field |
| --- | --- |
| Plant***reactor***1234567890 | plant reactor |
| .!@#$%^&*()---_+={}[]\|\ | |
| GAUGE NOT READING    CORRECTLY | gauge not reading correctly |
| GAGE  #4444 --- 20.0 | Gage |
| pressure exceeded | pressure exceeded |

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# Example Verification – Deployment

- **Deployment verification applies to an installed instance of the software and focuses on testing summary outputs and features which have external dependencies rather than comprehensive testing**

- **Is the application being called at specified interval?**

- **Does the application run to completion?**

- **Are input/output streams being correctly sent/received?**

- **Do classification distributions fall within expected ranges?**

- **Does data sourcing, typing, and processing in production match training?**

INPUT

AI

OUTPUT

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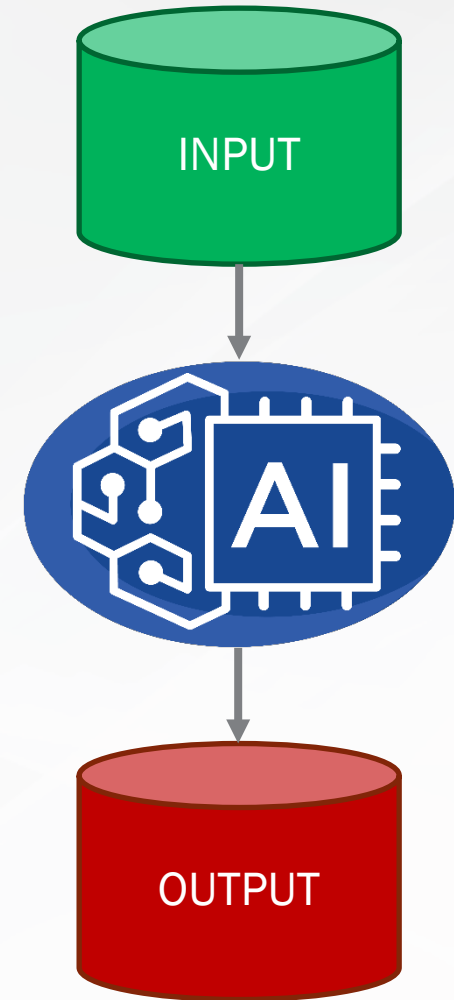
# Example Validation – Performance Quantification

- **Binary Classification Models can be Evaluated using a Confusion Matrix**

- **Type I Errors (False Positive)**

- **Type II Errors (Miss)**

| | Prediction = 0 | Prediction = 1 |
|---|---|---|
| Truth = 0 | True Negatives | False Positives |
| Truth = 1 | Misses | True Positives |

$$\text{Miss Rate} = \frac{\text{Misses}}{\text{Positives}} \; ; \; \text{FP Rate} = \frac{\text{False Positives}}{\text{Negatives}}$$

- **The choice of appropriate performance metric(s) depends on distribution of class values and the cost/benefit of misses and false positives**

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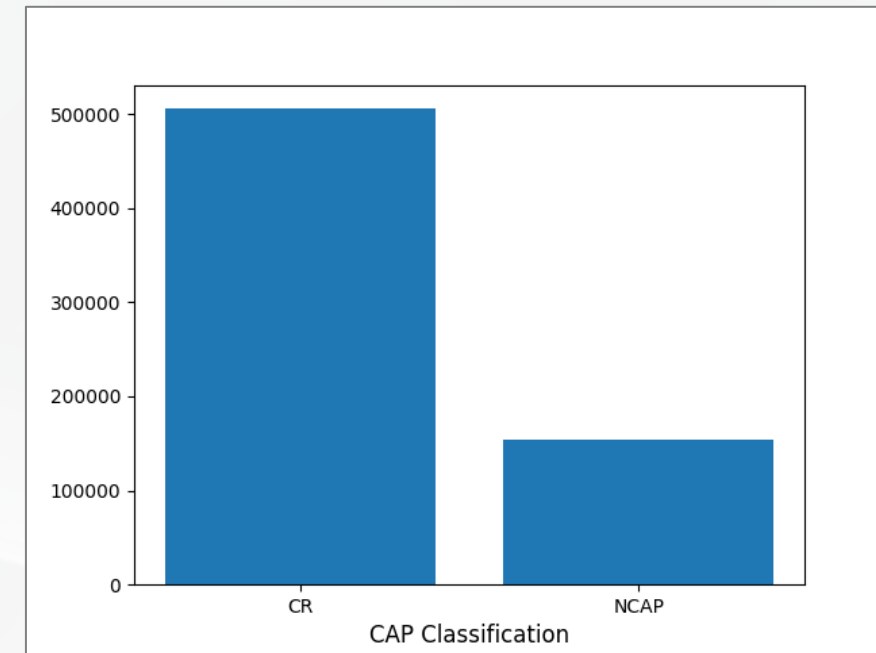
# Example Validation – Sensitivity Analysis

**Input Data Variability**

- **Validate robustness of models by modifying input data during training and testing**

**Model Parameter Variability**

- **Validate stability of models by modifying developer-defined hyperparameters**
- **In addition to validating the platform, parameter sweeps are also useful for optimizing model parameter assignments and identifying problematic aspects of the models**

Example baseline performance:

| Miss Rate | 6.8% |
|---|---|
| False Positive Rate | 25.9% |
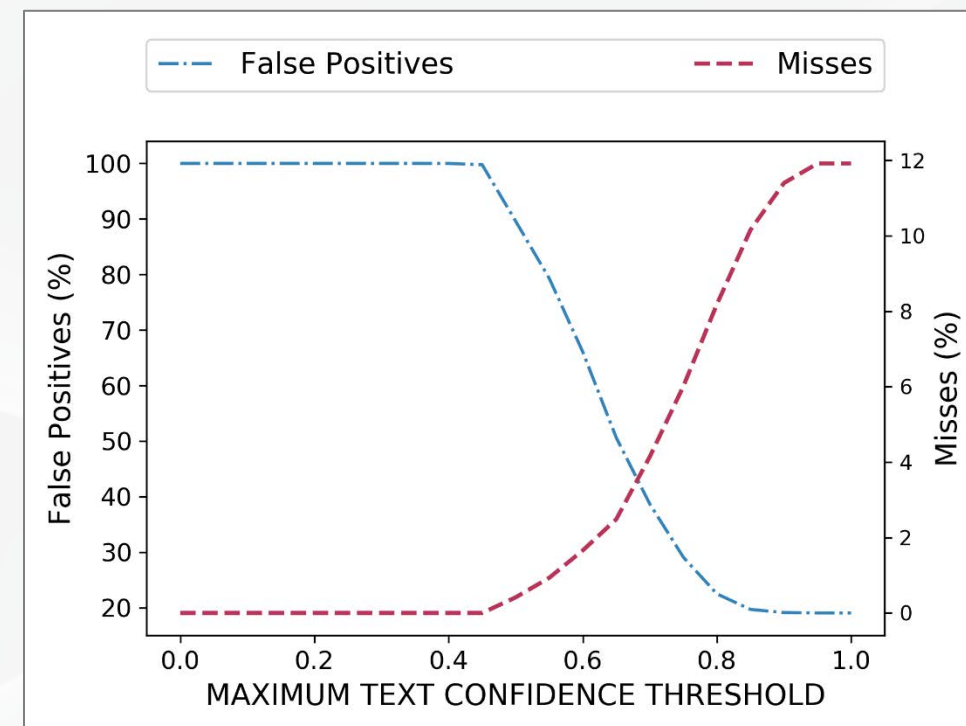
# Prior Screening and Disposition Process



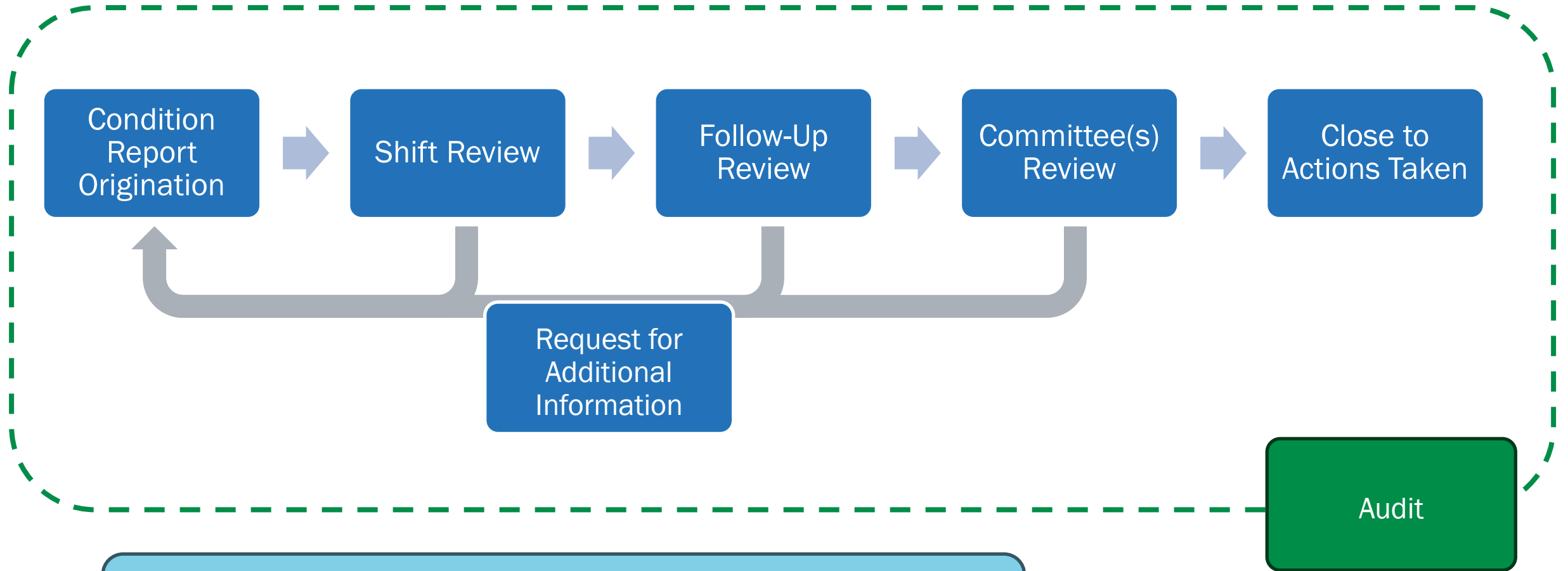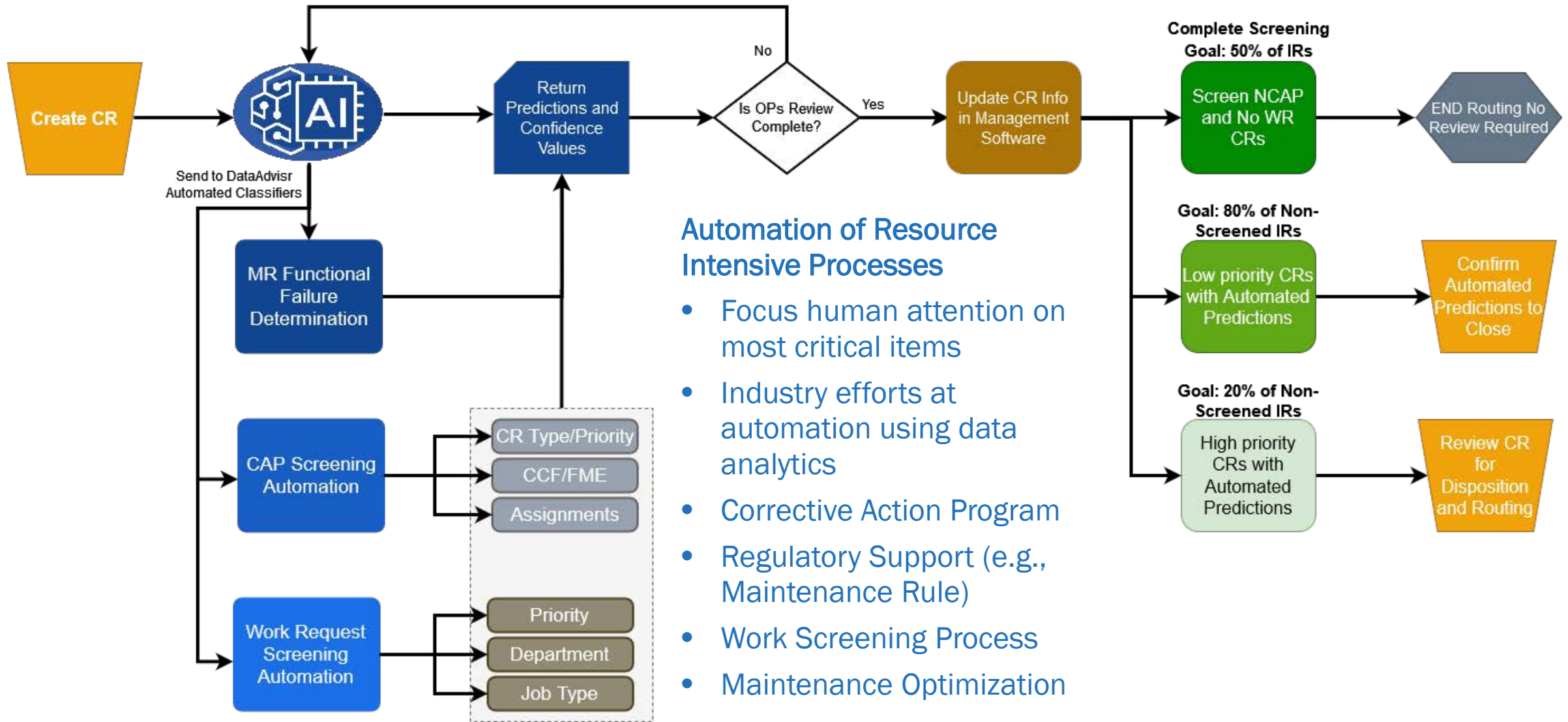Condition Report (CR) process is time consuming and costly.
Estimated man-hours per record X.
ML/AI technologies can provide significant improvements to this process.

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# AI-Informed Screening Process



Automation of Resource Intensive Processes

- Focus human attention on most critical items
- Industry efforts at automation using data analytics
- Corrective Action Program
- Regulatory Support (e.g., Maintenance Rule)
- Work Screening Process
- Maintenance Optimization

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# Vision for a Digital Generation Business

| | |
|---|---|
| **Automated Work Processes** | Streamlined workforce |
| Smart Processes | Electronic procedures/work instructions |
| Decision making through analytics/AI | Faster, more accurate decisions by right level |
| Field workers instant access to information | No time wasted, improved HU |
| In-field training through virtual reality and video | More wrench time |
| Predictive plant performance | Zero transients/trips |
| Centralized information backbone | Ability to leverage additional technologies |
| Innovative culture embedded | Workers continuously improving |

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# Equipment Reliability – Advanced Pattern Recognition to Avert Failure
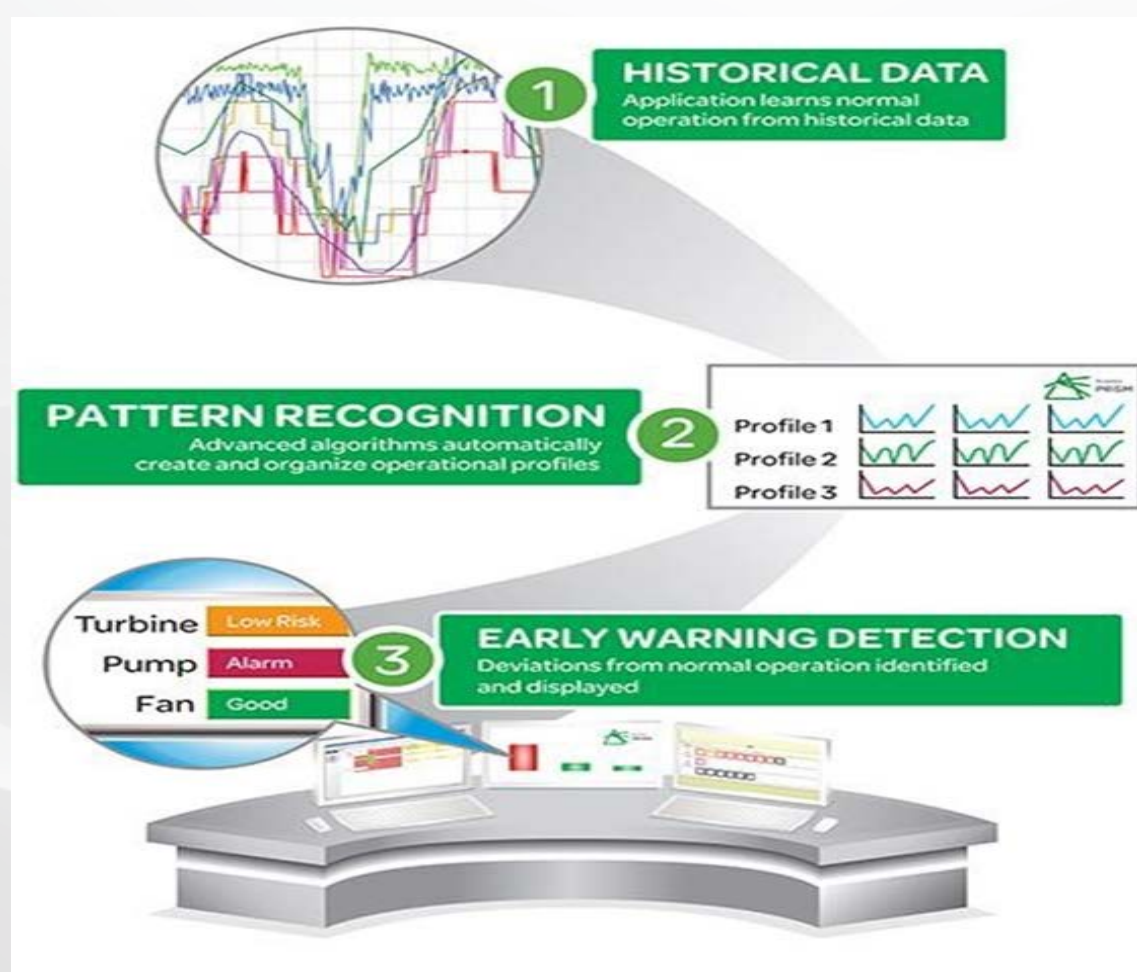
# Initial License Training Student Performance
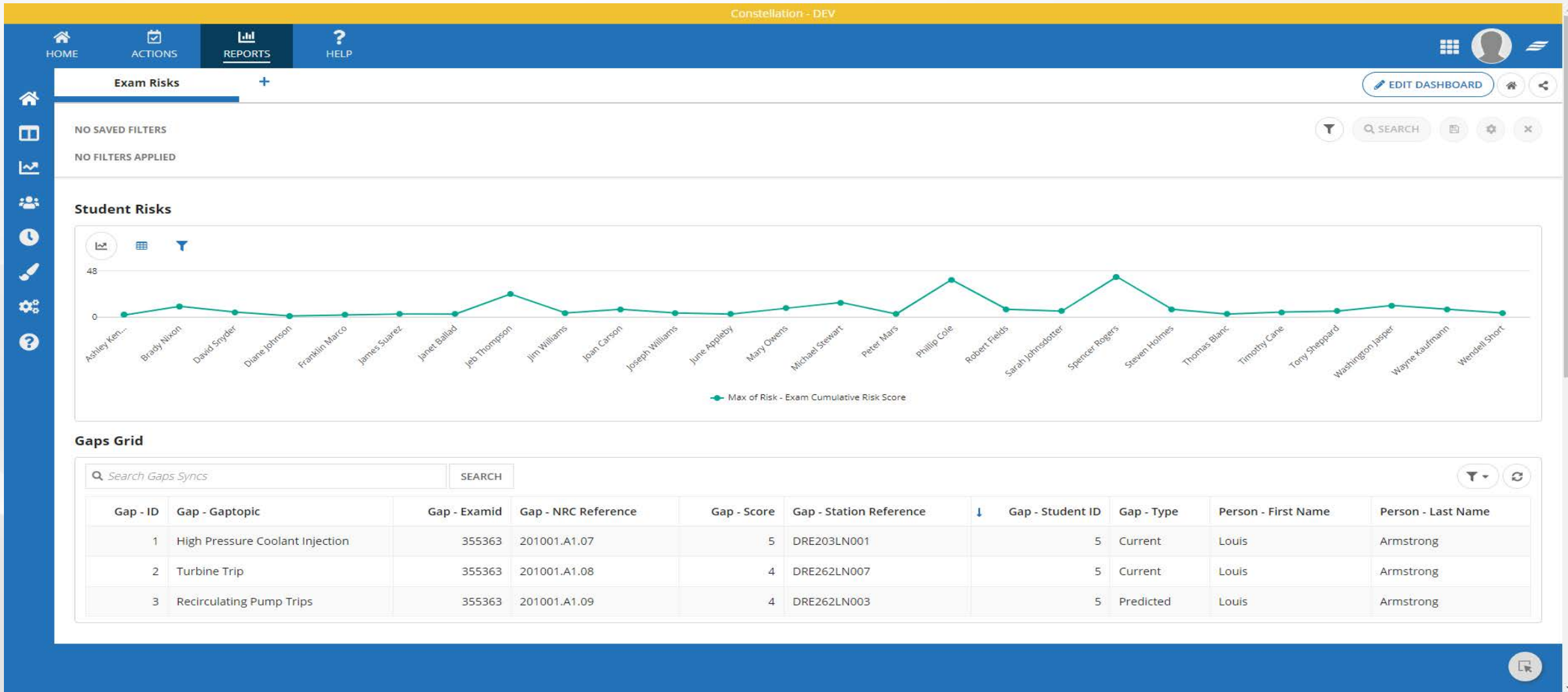
# Maintenance Rule Functional Failure Analyzer

- **In place successfully for two years**

- **The software is *not* making failure determinations … it is pre-screening/flagging potential functional failure CR's for human review**

- **Biased towards high safety-significant component failures**

- **Equipment monitoring still occurs (i.e., human element backstopped)**

- **Confidence in results is gained through continuous feedback**

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# Issue Report Screening Analytic

**Displays the "why"**

- Summarize data for user review

- Provide users detailed insights into how the predictions were made

- Indicate potentially similar IRs to the one being reviewed

- Orange means over the threshold for review; blue wouldn't trigger the need for a review
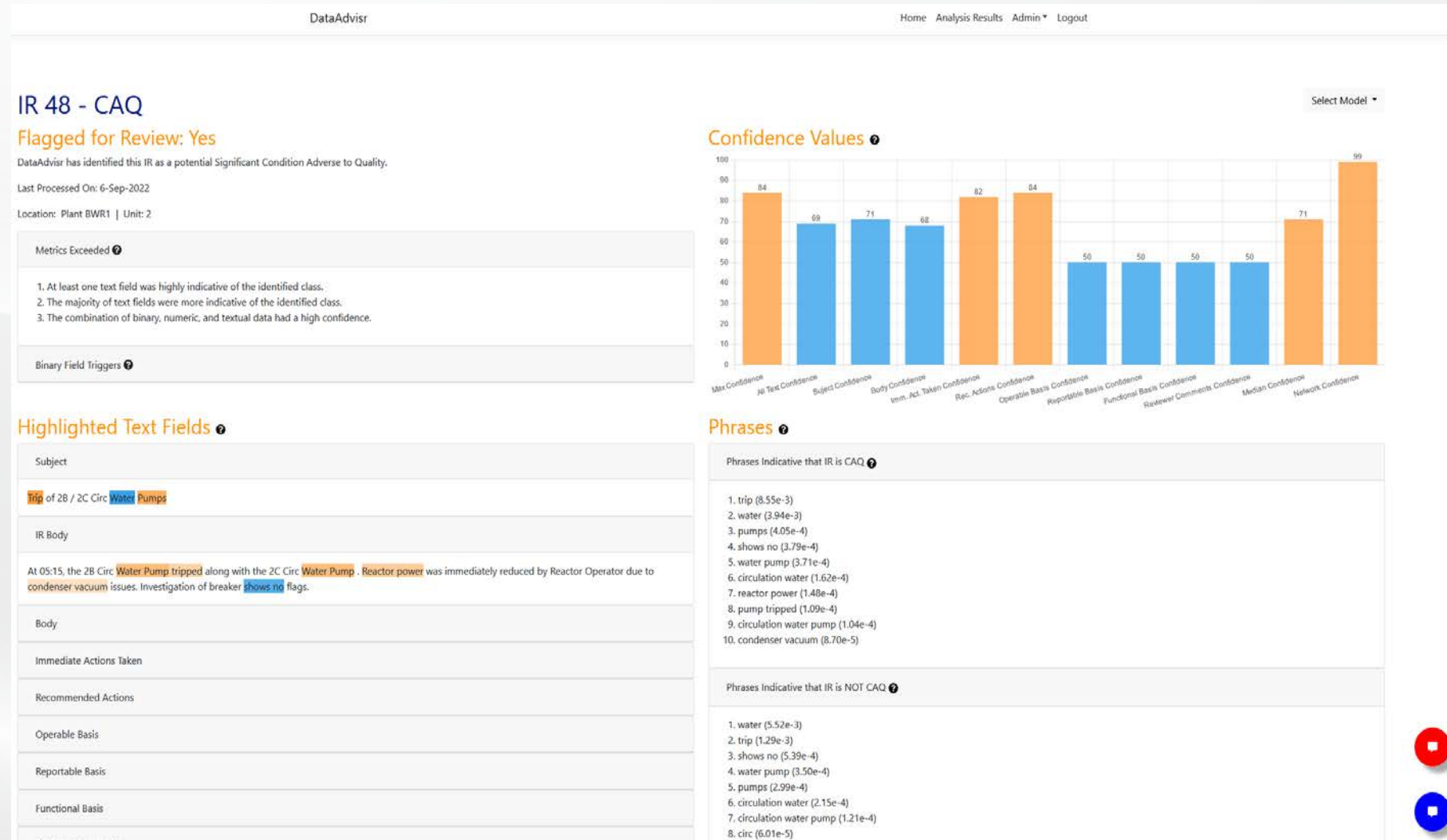
# Future Analytics

- **Predictive analytics –** *Work Order generation*

- **Corrective Action Program –** *Predictive trending to avert operational challenges*

- **Advanced equipment performance analytics –** *avert equipment failure and operational risk*

- **Outage schedule predictions –** *improve outage schedule adherence*

- **No intent to apply artificial intelligence to control the plant**

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