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Applied AI in Manufacturing

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Why use AI and what benefits does it bring?

Introduction to Applied AI in Manufacturing

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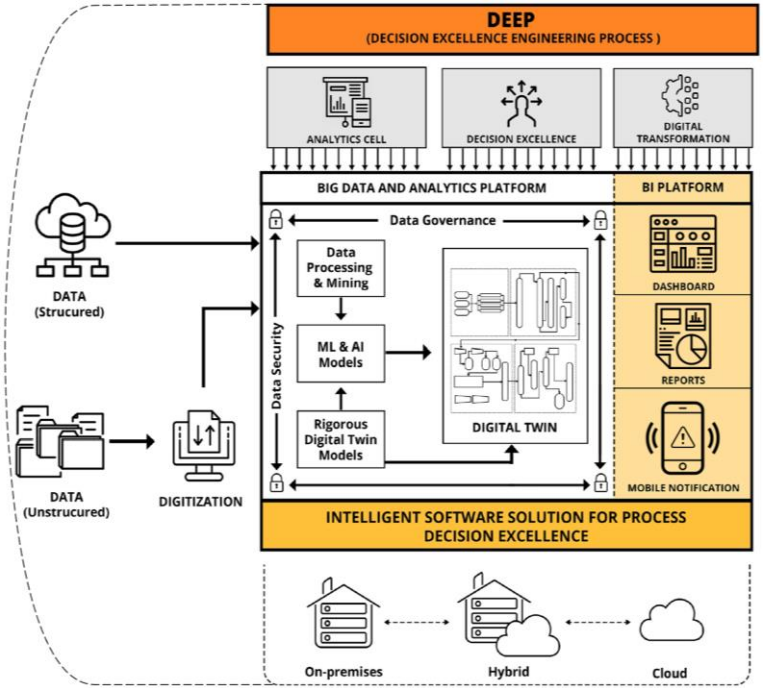
AI/ML-powered solutions drive operational excellence, delivering tangible cost savings, valuable insights, and enhanced decision-making capabilities



Safety - Proactive management of Safety & Compliance

Production - Optimization

Reliability - Asset Management

Yield - Enhanced Product Recovery

Efficiency - Raw Material Management

Reliability - Predictive and Preventive Maintenance

Efficiency - Improvement in Efficiency and Cost Reduction

Sustainability - Better tracking, visibility and control on GHG emissions

Why AI Matters in Manufacturing Today

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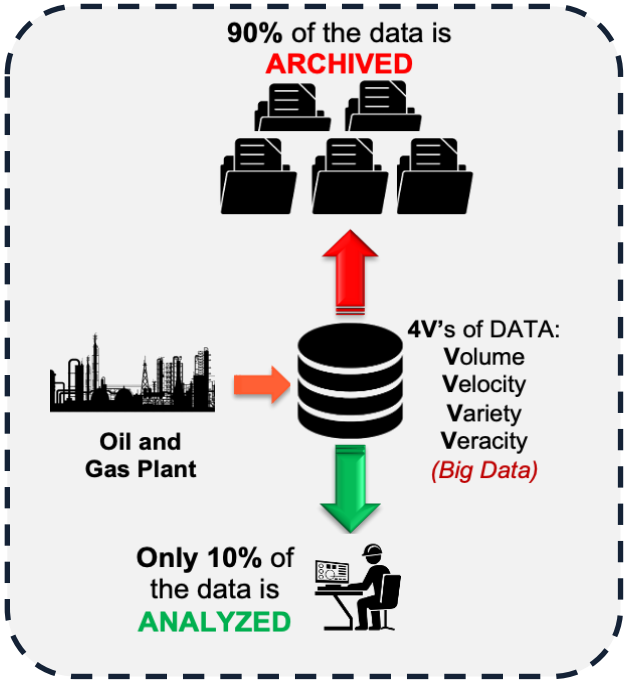
The abundance of manufacturing data can be utilized to identify and solve operational problems

"If you always do what you've always done, you'll always get what you've always got."
- Henry Ford

- Manufacturing operations teams deal with several daily pain points in process plants
- Relevant data can help provide insight about these pain points
- **In today's age, there is no scarcity in the availability of data, but it is not always utilized**



- Data points that go under screening are only 10% of the total
- Almost 90% of the remaining data points are ARCHIVED.

Empowering Engineers and Operator in AI Tools

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The availability of data and its applied AI-based transformation enhances operations and bolsters decision-making processes

Enhanced Decision Making

- *AI can analyze vast amounts of sensor data to detect anomalies and inefficiencies before they escalate.*
- *ML algorithms can predict equipment failures and optimize maintenance schedules, reducing downtime.*

Improved Safety and Emissions

- *Developing AI-powered alarm guidance applications to help operators make decisions during critical events*
- *Using AI for predictive maintenance to prevent equipment failures and safety incidents*

Optimized Production

- *Analyzing data such as flow rates, temperature, and pressure to optimize operations in real-time.*
- *Using ML to optimize flow rates, pressure, and other variables for maximize lifetime and production.*

Digital Twins and Simulations

- *Creating digital twin technologies for virtual testing of AI solutions*
- *Allowing AI systems to control parameters of physical assets to meet organizational goals*

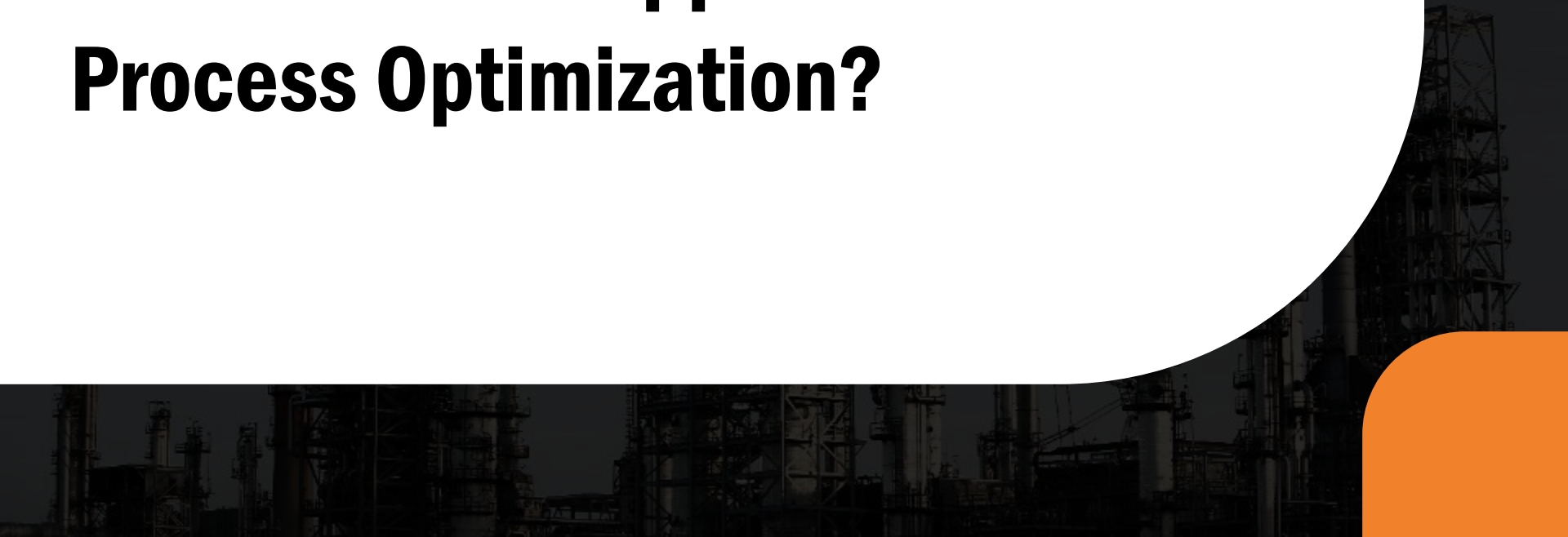
Knowledge Capture and Chatbots

- *By developing knowledge management systems that digitize domain expertise.*
- *Accelerating the learning curve for new operators by providing AI-assisted guidance based on historical data.*

Predictive Analytics

- *Forecasting equipment failures, commodity price changes, and customer demand.*
- *Enabling proactive maintenance and optimization of process operations.*

How can AI be applied for Process Optimization?



Process Optimization – Dynamic Benchmarking

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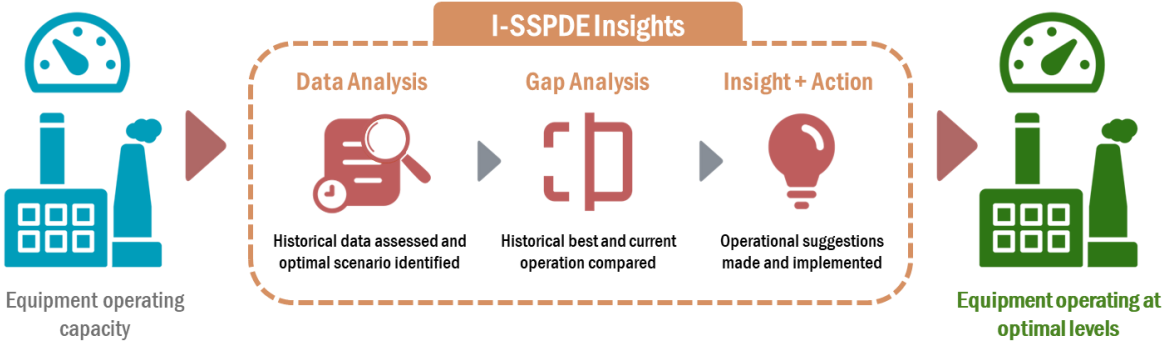
The comparison of historical operational data and current data are the basis for benchmarking analysis



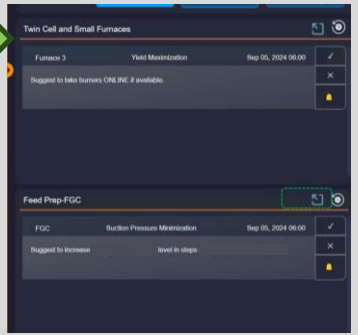
Dynamic benchmarking optimizes operational parameters based on production goals while gaining insights to address current bottlenecks

Live GAP Analysis

Shows live operational gaps in between optimal and current operations

Plant Bottlenecks

Gap Analysis can help address plant bottlenecks and help in solving these issues



Live Recommendations

Based on the gathered information, there are live recommendations made

Process Optimization – Augmented Intelligence

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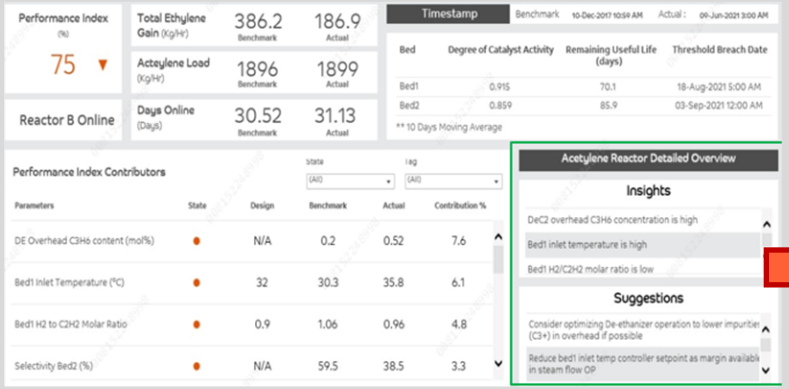
Augmented Intelligence provides actionable insight to improve reactor operations and decision-making



1. LIVE identification of operational gaps
2. Predicting run length/catalysts
3. Automated alerts to capture issues in real time
4. Insights on optimization and stability

Recommendations based on analytical insights

- Reduce Bed-1 Temperatures
- Adjusting molar ratio
- Optimize CO
- Track and improve selectivity

Realized Gains

732 T (185%) Ethylene

61 T (16%) Hydrogen

200 MW (9%) Energy

14 T (9%) Fuel Gas

475 T (25%) less CO2 Emission

717 T (22%) Ethane Recycling cost

Process Optimization – Sustainability

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Applied AI can provide optimization insights; plants can save costs and improve sustainability

STEP 1: *Tracking*

STEP 2: *Optimizing*

STEP 3: *Reducing emissions*

Where has AI been applied effectively?

Process Optimization – Efficiency and Profitability

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Applied AI can provide optimization insights; plants can save costs through efficient production, energy reduction, and profit maximization

Power Plant - An optimizer model with smart displays to help optimize plant operation, increase profits and meet the critical demands.

Solution Overview

Operator Level Screen

Engineer Level Screen

Plant Level Screen

Powered by advanced algorithms providing real-time insights

Key Features

- Real Time Optimizer solution – live with insights.
- Feature to utilize LIVE PRICING
- Ability to define dynamic constraints.
- Comparison on Actual and Optimized profitability
- Customized report for individual equipment and overall plant
- Live dashboards for all units and overall power optimization
- What-if capability to evaluate different scenario with changing conditions

Process Optimization – Refinery Coker Unit

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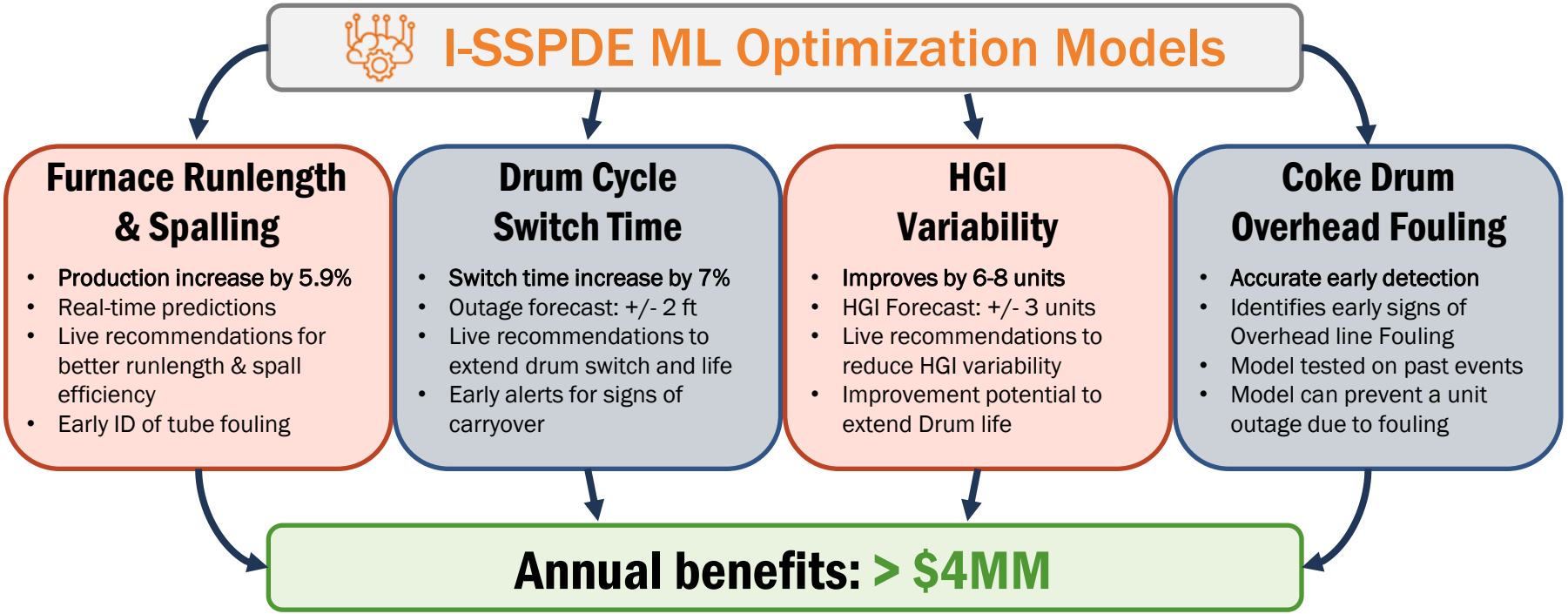
A US refinery major implemented I-SSPDE to great success – furnace optimization of runlength, spalling, drum cycle switch time, and fouling detection.



Process Optimization – Cell Monitoring

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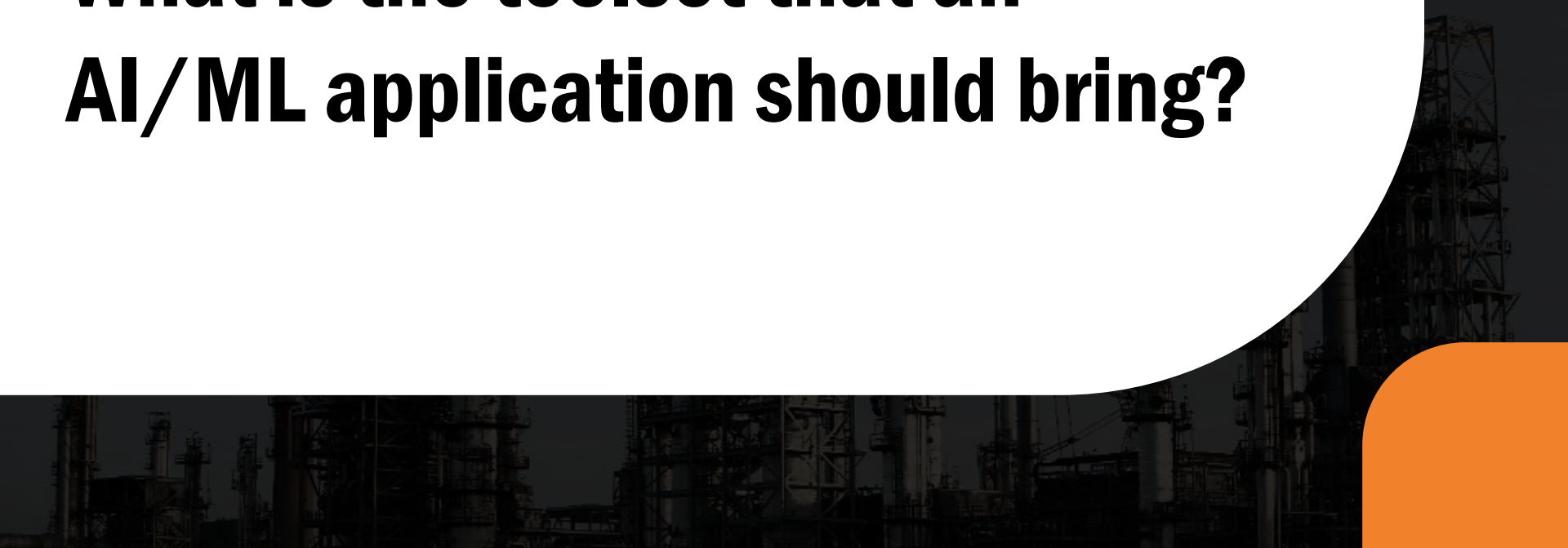
Interactive dashboards help monitoring vast data from different sources in an efficient way

Key Features

- The dashboard runs on the latest available data with specific inputs from IP21 (Tags, LIMS & PRIDE) and CCMS database
- The integrated dashboard provides a comprehensive view of all the cell parameters, along with:
  - Highlighting deviations in cell parameters for all circuits, and
  - Further drill downs to electrolyzer as well other individual elements.
- Provides quick-view lists of “Good Electrolyzers”, “Electrolyzers having opportunities” and “Electrolyzers need immediate action”.
- Provides user-specified graphs and trends for all the cell parameters displayed.
- Provides insights on historical trends for these cell parameters to help identify electrolyzers performance in longer run.

Quick analysis and decisions related to doping → Reduces time for analysis + helps focused decision making

What is the toolset that an AI/ML application should bring?



Practical Approach – Ingenero I-SSPDE

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Ingenero follows a multifaceted approach that results in improved efficiency and production

Actionable Intelligence
Smart analytical engine

Hybrid Models
AI/ML + 1st Principle

Data Historian Agnostic
Wide compatibility

Smart Dashboards
Interactive levels

Financial Optimizer
Cost savings analysis

False Positive Resistant
Real and accurate

Real-time
Live data solutions

Multi-dimensional
Covers wide spectrum

Soft sensors
Address drift/anomalies

Actionable Intelligence

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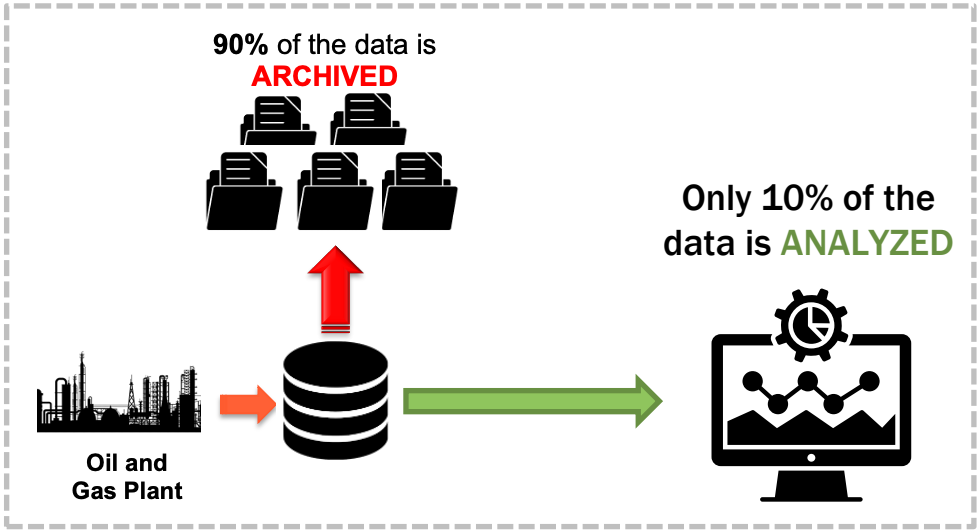
A smart analytical engine will deliver actionable insight from data

Basic information collection

In order to get required information, an operator predominantly utilizes DCS along with:

- APC
- Analyzers
- Historian
- Lab Analysis and field data (TMTs, Delta P)

Is collecting data enough?



Actionable Intelligence

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AI solutions generate easily interpreted insights that can be applied by effectively combining human intelligence and control systems...

Intelligence to analyze available data and solve challenges such as:

- Identify differential coking
- Instrumentation and analyzer issues
- Process control variations
- Impact on run length
- Optimal parameters to maximize yield and capacity

Identifying Differential Coking

Where is the coking happening fast?
Why is the issue occurring?

ML/AI Modeling	Kinetic Modeling
• Identify faulty instrumentation • Heat Flux and hot spot issues • De-coking process effectiveness	• Predict conversion and COTs • Effluent analyzer – soft sensor • Run length prediction

Actionable Intelligence (Example)

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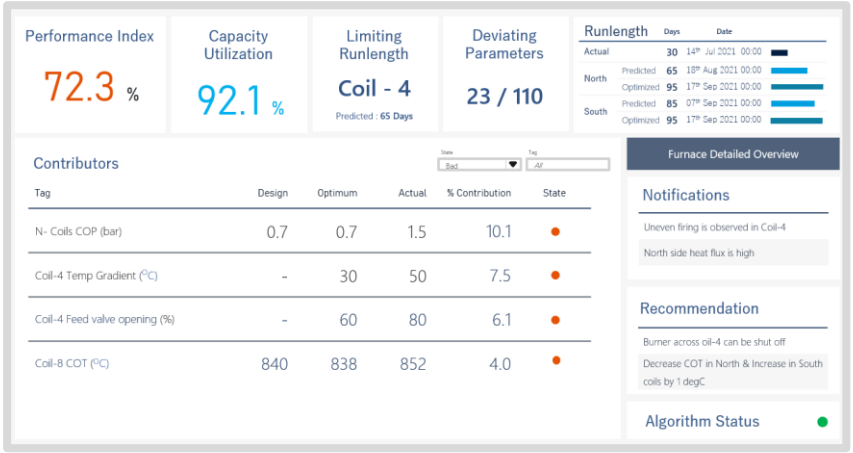
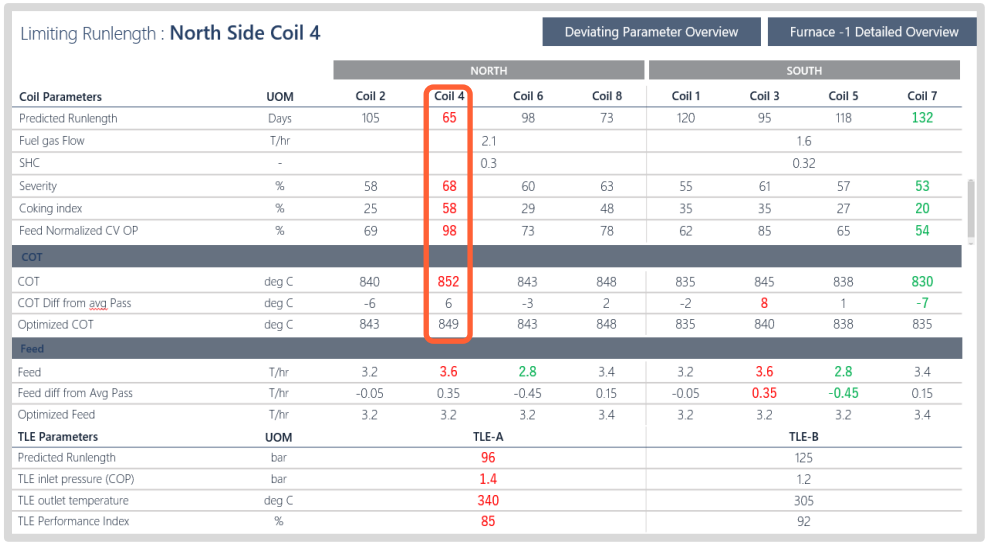
...such as providing the necessary intelligence to improve Overall Asset Effectiveness (throughput x yield x availability)





1. LIVE identification of operational GAP's
2. Prediction of coking and run length
3. Automated alerts to capture potential issues in real time
4. Insights on furnace scheduling and stability

Hybrid Models

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Combining AI, ML, and 1st principle models leads to best results

The traditional approach
(Standalone models)

While operations are set up to be stable, there are a few complications:

- Conservative limits set up
- Limits the scope of your results
- Limits success rate for certain situations

The improved approach
(Use of AI/ML, hybrid models and analytics)

- Increased capacity
- Improved efficiency
- Ensured on-spec production
- Maximized product recovery
- Optimal energy utilization
- Avoid unplanned downtime

Hybrid Models (Example)

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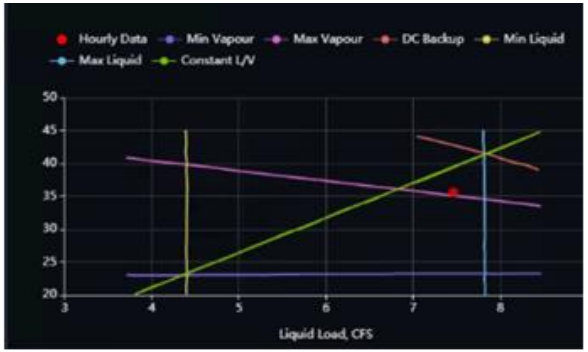
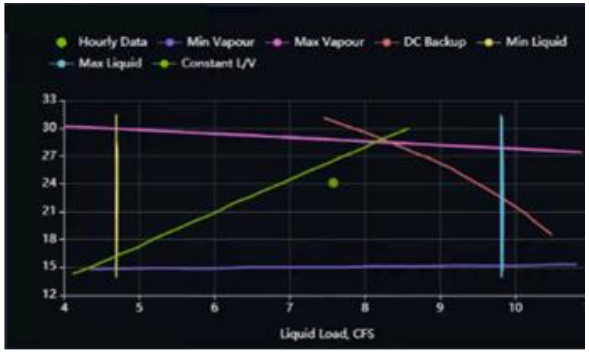
AI provides LIVE hydraulics, tray loadings at different sections of a column and prescriptive guidance to maximize capacity and ensure on-spec product

Utilizing Hybrid models to

- Identify anomalies and take corrective actions
- Clear alerts and warnings on deviations in operating points
- Flooding limits and predictive advice





ML Model + Hydraulic Model

- Provides optimal set-points for product draw rate and control tray temperature to **avoid off spec product**
- Predicts operating points which helps monitor hydraulics and **take pro-active actions to prevent flooding**
- Utilizes first principle model results and **find operating point on real time operation**

Smart Dashboards

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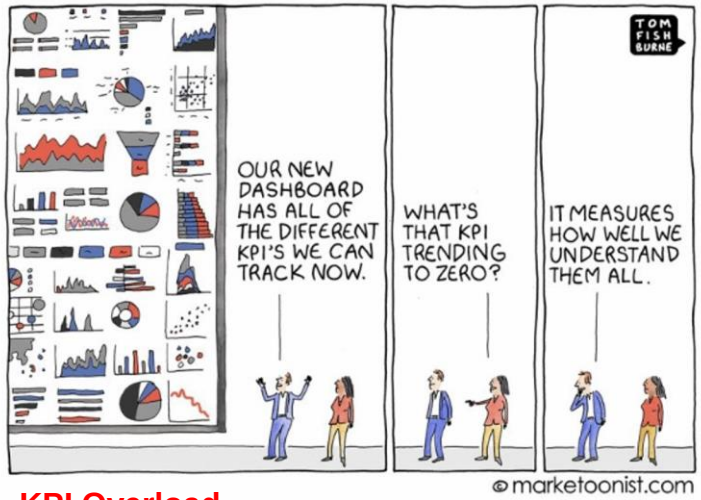
Smart dashboards with interactive levels provide insights to enhance decision making and drive operations to an optimal level

Limited time, too much data, little understanding!



KPI Overload

Smart dashboards with relevant insights

A well-designed, functional dashboard has:

- Refined UI & UX with concise representation
- Information sorted by relevant hierarchies
- Customized KPIs based on requirement

It avoids and eliminates:

- Broad records
- Outdated methods, e.g., tracking sheets
- Cluttered data representation

Smart Dashboards (Example)

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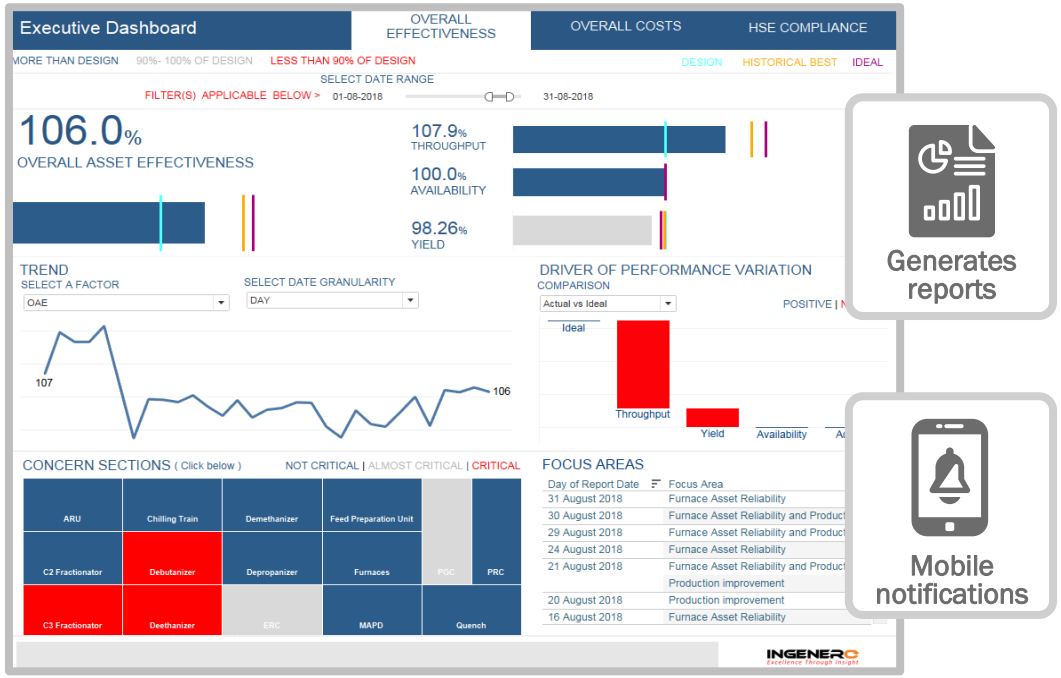
A bird's eye view and drill down level views with an interactive interface is provided



Key elements for an effective smart dashboard:

- Interactive date range selection
- KPI tracking based on need and actual use
- Color coding indicating degree of criticality
- Drill down capability
- Data errors removed instead of raw data

Smart Dashboards (Example)

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Multi-level dashboards with insights can optimize operations (e.g. steam balance)

Overview with alerts, recommendations and observations

Equipment level alerts and insights to drive improvement

Drill down to various steam header pressure levels

LIVE Gap analysis with dynamic benchmarks and optimal set points

Financial Optimizer

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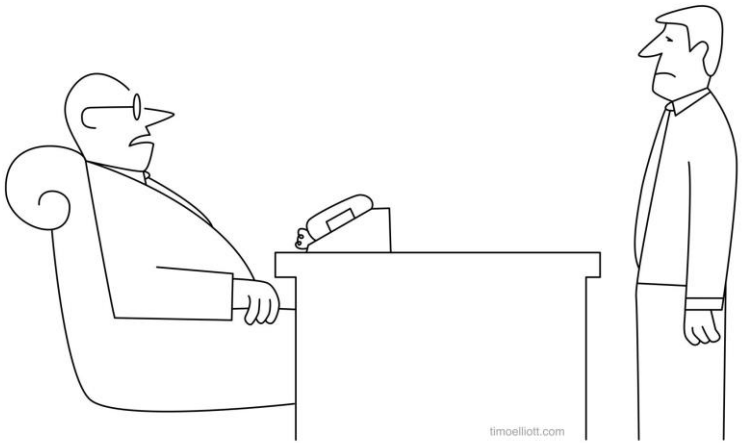
Financial insights are key drivers of improvement

Siloed information results in ineffective optimization

- Process optimization in one part of process equipment can impact other parts, leading to decreased output and productivity
- Results from the lack of an end-to-end operations view



"The only Big Data letters I care about are the four Ms — Make Me More Money!"

Financial Optimizer (Example)

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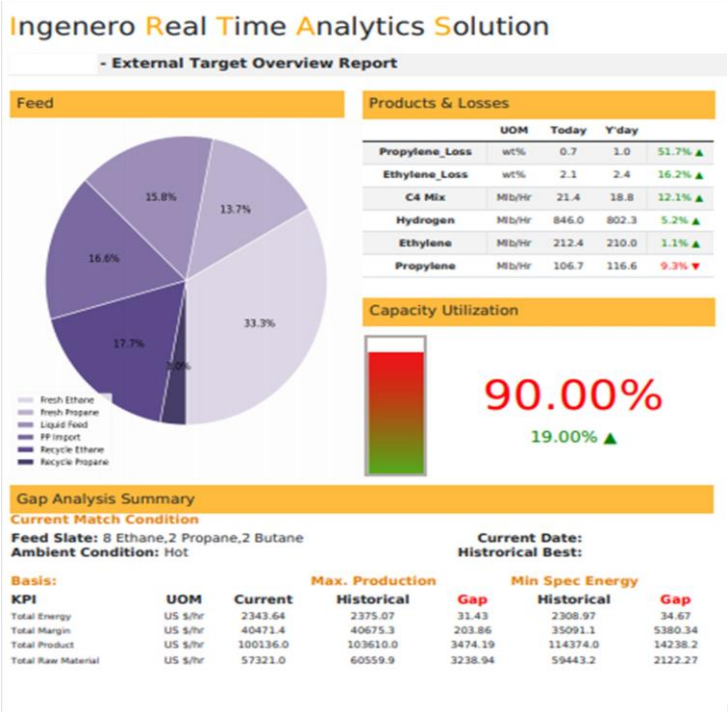
Financial impacts of process change and customizing the AI solution to address the manufacturing problem are critical to capture value



Optimize using financial insights

- Motivates operations to make changes
- Clear cost-benefit analysis
- Impact of change easily observed
- Helps drive performance to actual benefit

Financial Optimizer (Example)

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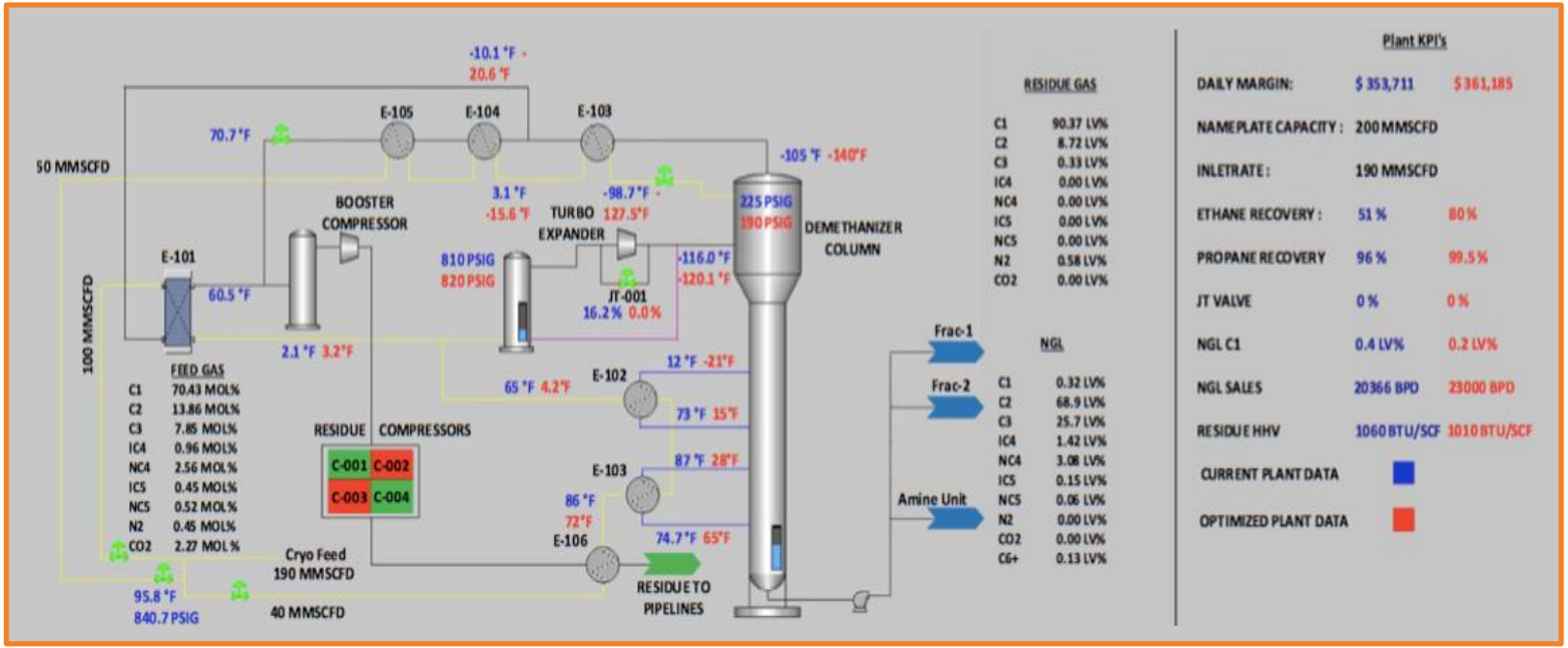
Financial impacts of process change and customizing the AI solution to address the manufacturing problem are critical to capture value



False Positive Resistant

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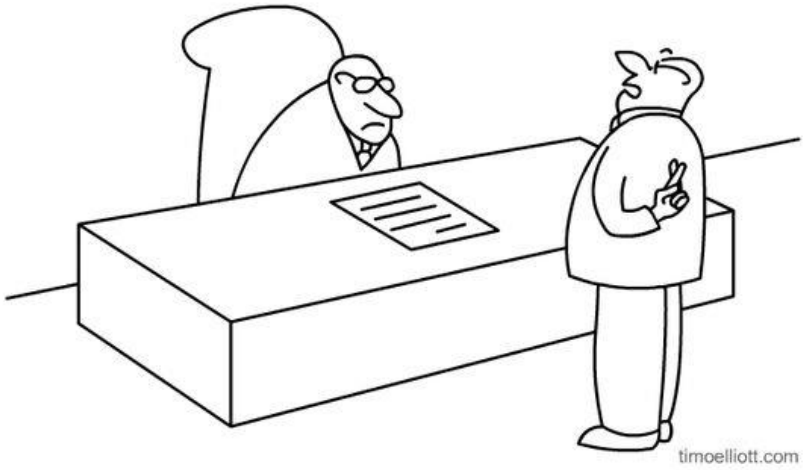
Compromising on accuracy is not an option, as each action has its own consequences, especially in the manufacturing process

Low reliability leads to inaction

- Often, inadequate time is spent to select data for training and ensuring its quality, handling, and testing
- Operators hesitate to utilize inputs on board if there is a lack of dependability.
- **This leads to delayed action or lack of any action**



"Yes sir, you can absolutely trust those numbers"

False Positive Resistant

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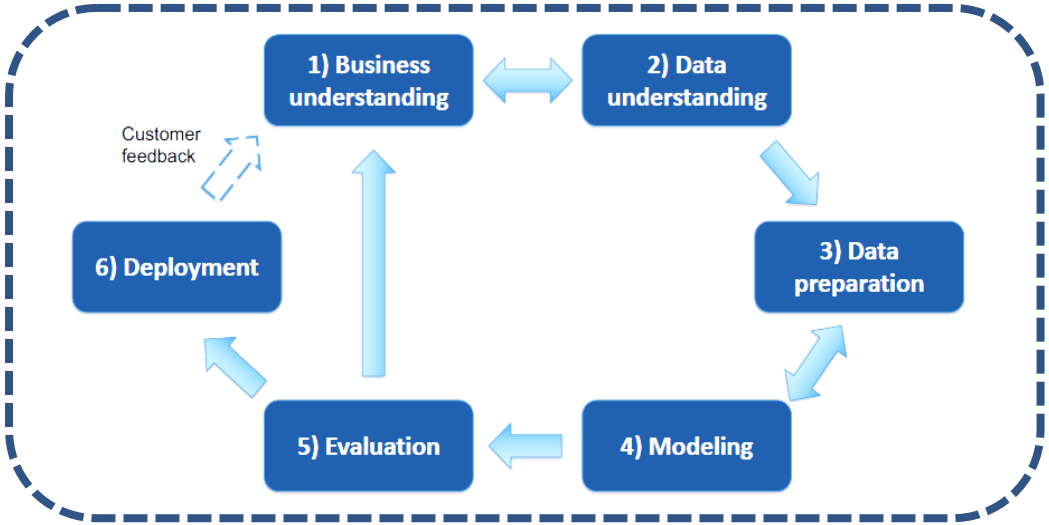
Following the right data science process makes results more accurate

Calibrating towards real and accurate results



A thorough Data Science Process can be followed to get close to real and accurate

Real-time Solution

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AI solutions create maximum impact when they deliver insight on a real time basis

Real-time intervention is crucial!

- Lack of timely intervention can lead to a slowdown of processes
- Slower analysis and implementation timeline
- **This leads to inability to capture value**

With the dynamic nature of manufacturing processes, it is crucial to track data in real-time to be able to understand and act in a timely manner.

Data Tracking

Deviation Tracking

Optimization opportunities/suggestions

Real-time Solution (Example)

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Live display noting deviations and opportunities drives process optimization

Highlights:

- ✓ Operational guidance
- ✓ Actionable insights
- ✓ Gaps and bottlenecks
- ✓ Achieve targets and realize $$
- ✓ Multiple scenarios
- ✓ Dynamic Benchmarks

Multidimensional Solution

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Successful AI solutions address a wide spectrum of areas to glean value

Some solutions only address part of your operations

Focusing on one aspect of a process tends to lead to:

- Suboptimal operational performance
- Lower KPIs
- Decrease in the overall production/yield

A complete solution covers a multitude of operational issues

Multidimensional Solution (Example)

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AI solutions should cover a wide spectrum of KPIs and potential problem areas

Compressor

- Stage efficiency
- Degradation Alert
- Power Pressure Ratio
- Process Deviation
- Triple Point - Design vs Actual
- Mechanical Breach
- Composition

Furnace

- Differential Coking
- Capacity Utilization
- Conversion Yields
- Efficiency
- Stability Index
- Run Length
- Bench-marking

Soft Sensors

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Soft sensors are utilized to generate critical and accurate data insights to address any instrument drift or anomalies

Features

Soft sensor tags
Tracks key operational changes

Key parameter tracking
E.g. TLE Outlet Temp, furnace effluent analyzers, column DP, etc.

Driven by analytical models
Uses state of the art detection and predictive models

Detection models
Identifies instrument drift for furnace feed & dilution steam flow meter, furnace oxygen analyzer

Predictive models
Uses soft sensor tags for TLE outlet temperature, Furnace COT, Furnace effluent, column PDI, etc.

Erroneous instruments can affect process stability and performance

- ✓ Feed and Steam flow meter
- ✓ Critical Temperatures
- ✓ Effluent/Product Analyzer
- ✓ Furnace TLE Outlet Temperature
- ✓ Column Pressure
- ✓ Surface Condenser pressure
- ✓ ΔP for critical Columns

Soft Sensors (Example)

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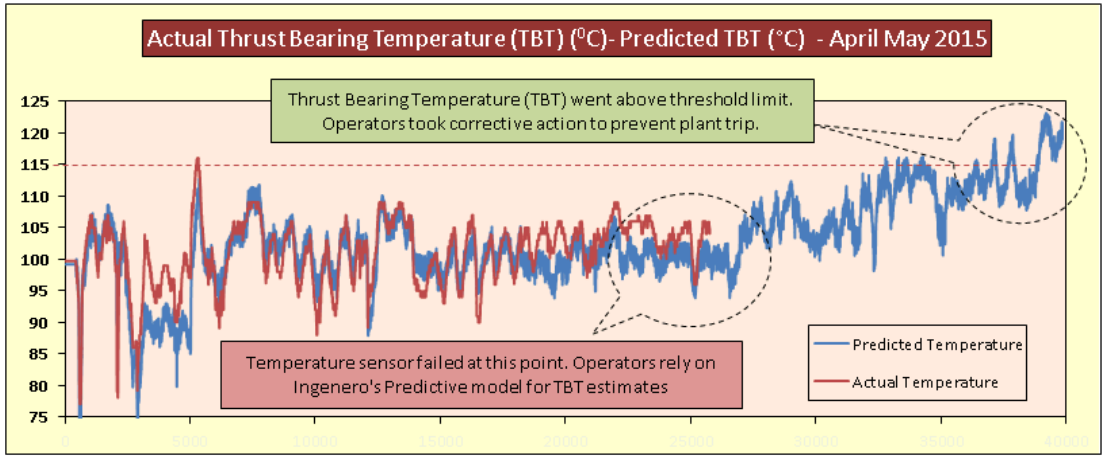
A Soft Sensor for thrust bearing temperature improved process reliability



Problem

- Absence of instrumentation
- Frequent Machine Breakdown

Solution

- Predictive Analytics
- In-house state of art data analytic tools
- Rotary Equipment Domain Specialists

Result

- TBT value available online at DCS
- Helps in identifying overshoot in value and avoiding major upset

- Soft-sensors developed based on ML-AI based models incorporating deep understanding from the domain knowledge.
- Help providing
  - Early warning
  - Timely arrest process upset and loss thereof
- Intuitive representation using advanced charting functionality

I-SSPDE Digital Transformation

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Providing AI for manufacturing plants including for major equipment with multi-faceted approach

Ingenero's Intelligent Software Solution for Process Decision Excellence (I-SSPDE)
enables digital transformation for exponential value capture

Value Example -> Supported ethylene plant site to move from Furnace deficient to surplus condition (6% Capacity Gain without any CAPEX)

Boosting Profitability with AI

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Digital transformation powered by applied AI offers a wide range of benefits that boost profitability while keeping efficiency, sustainability, waste reduction, and reliability in mind

PROFITABILITY

Understand the 'What' and 'Why' of every individual cog in the process to identify the margin improvements of the process by appropriate optimization to achieve overall profitability.

SAFETY

Enhance quality and safety assurance enabling quicker decision-making process, proactive management of safety and compliances, and a pro-active handling of operational failures.

EMISSIONS

Measuring and tracking emission quantification in collaboration with continuous emission compliance support aids to create an up-to-date database of plant emissions and provide possible solutions to minimize emissions.

ENERGY

Energy mapping and optimization can realize potential savings in utility consumption for any unit whilst maintaining /improving profitability levels

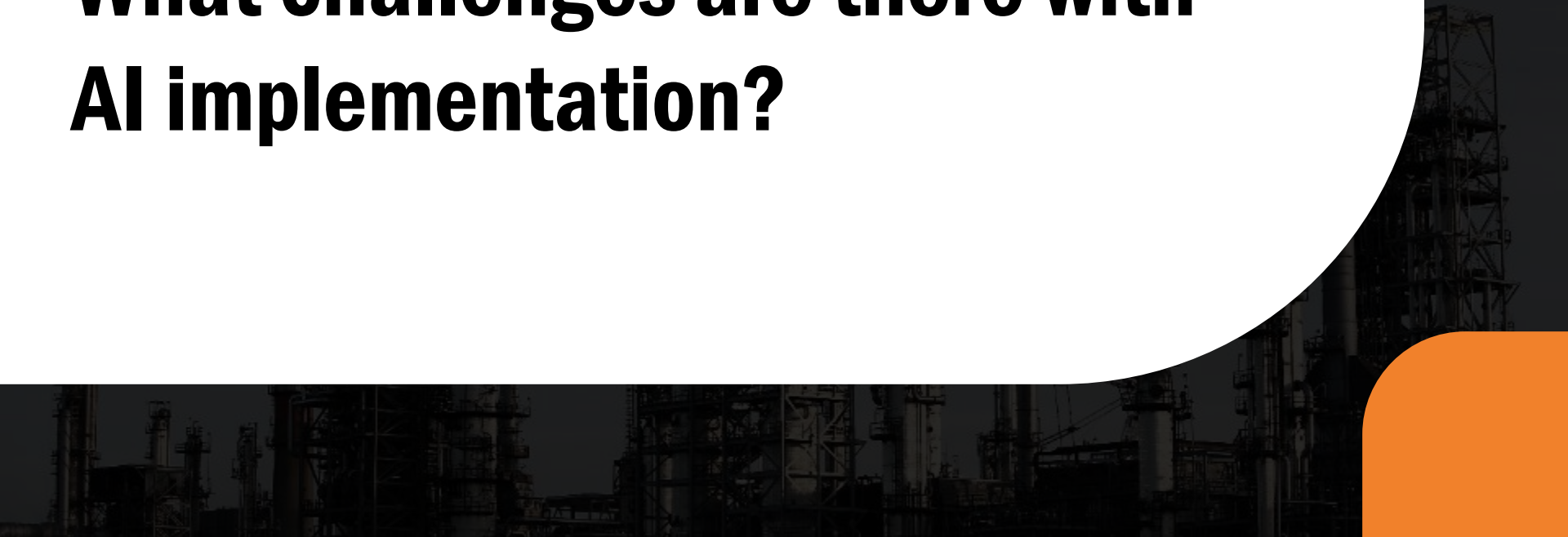
RELIABILITY

Provide monitoring, analytical data supported decisions based on accurate predictive and diagnostic information through constant monitoring of a unit. Resulting in support for decision making and improving asset availability of a unit.

PERFORMANCE

Deeper insights, benchmarking, continuous observations and real-time tracking of each individual unit and its pieces to identify problem areas as well as improvement opportunities.

What challenges are there with AI implementation?



AI Integration - Challenges

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AI implementation can cause problems related to data, technology and infrastructure, and human capital; there are paths forward to address these challenges

	Data	Infrastructure	Human Capital
Challenges	• Data quality, formatting, architecture are different • Need for data cleaning • Mismatch in available data vs end use case application	• Legacy systems may not be up to date with AI applications • New solutions may not integrate easily with existing solutions	• Personnel not trained in AI-specific data analysis and ML techniques • Potential resistance to change
Solution Pathway	• Standardized data collection • Developing specialized tools to handle unstructured data	• Implement middleware solutions to bridge gap between new and legacy systems • Custom UI development	• Change Management • Diversity in team skillsets • Knowledge transfer programs

Extracting Value: The Last Critical Mile

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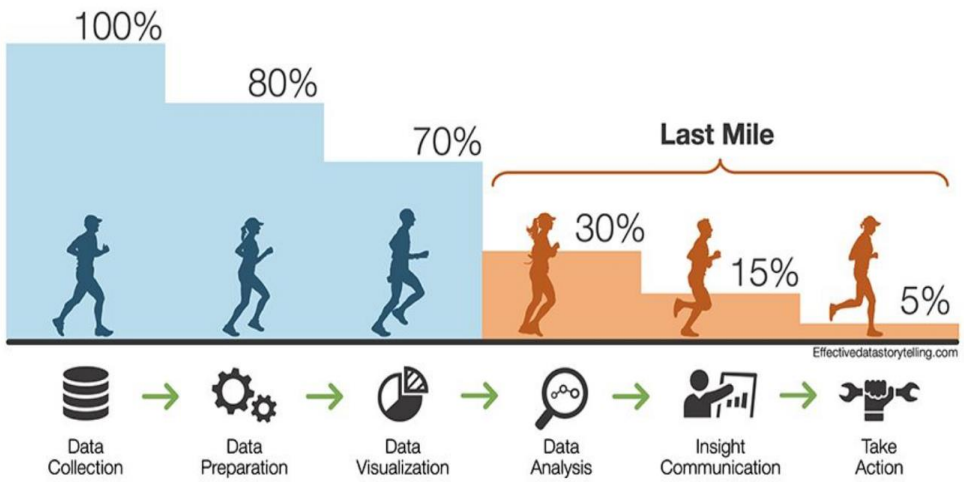
AI is a tool best leveraged with intentional application to yield powerful insights

Conquer the last mile in the Applied AI marathon



- It is not enough to just understand the software and the concepts it applies
- **Utilizing it to solve problems and present the insights in a meaningful way is key**
- **Align with individual-team (internal/external) as an implementation partner, who:**
  - Understands the complexity
  - Has the skill sets
  - Knows the realistic time and effort required
  - Has the expertise, experience and focus required for implementation and continuous improvement

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43,712,570
Data points analyzed daily

2,862,501
Process engineering manhours

61,886
Relief devices handled

1,485
Process Studies conducted

50+
Global Programs Implemented

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