IIoT – Introduction to Industrial Analytics

IIoT Solves OLD problems in new and innovative ways

Leverages key developing technologies

- High bandwidth communications and massive cost-effective storage in the cloud
- Low-cost pervasive sensor technology
- Advanced analytics (big data) technologies and machine learning
- Device inter-operability standards

Changes the way of how and where work is done

- Remote collaboration (owner / vendor / OEM)
- Enables Center of Excellence
- Captures and applies knowledge
- Routine monitoring done by machines
Addressing Core Industry Problems using the IIoT

HCP Analytic Solutions

Visualization | Machine Learning | Predictive Analytics | Cloud Storage | KPI Management | Notification | Collaboration

Production Efficiency
- Operator Effectiveness
- Reduce Off - Spec
- Optimize Process

Process Reliability
- Asset Surveillance
- Predictive Maintenance
- Expert Guidance

Supply Chain Optimization
- Planning & Scheduling
- Inventory & WIP Reduction
- Enterprise Supply Chain Execution

Connected Process + Connected People + Connected Assets = Connected Plant
IIoT Connection Architecture

Inspire Service Platform
- Uniformance Insight®
- Asset Sentinel
- PKI Manager
- Pulse

Big Data Analytics
- Cognitive Learning
- Tableau, R, etc

Digital Twin
- UniSim®
- 3rd Party Models

3rd Party Apps
- INspire™ Partners

3rd Party Vendors
- INspire™ Partners
- Supply Chain
- Service Management Platforms

Cloud Historian

Secure Data Exchange

Asset Health and Diagnostic Data

Stranded Assets

IIoT

SDX

DCS

MES

ERP

LIMS

Sentience™ Cloud Platform

3rd Party Apps
- INspire™ Partners

3rd Party Vendors
- INspire™ Partners
- Supply Chain
- Service Management Platforms

IIoT

SDX

DCS

Historian

Plan

IIoT

DCS

IIoT

IIoT

DCS
The Digital Twin

- Unifies existing data silos into a virtual entity
- Federates data across different applications to drive end-to-end integration
- Leverages process simulation technology beyond current scope of process design
- Utilizes Cloud to overcome maintainability issues and enables 3rd party expertise

CAPTURING THE COMPLEXITY OF AN ENTIRE PROCESS INTO A SCALABLE DATA MODEL
Big Data Analytics Myths

• Storing big data in the cloud is cheap or free

• Big Data / Analytics replaces the need for process knowledge / engineering experience

• Data Analytics is a replacement for fundamental models

• You don’t need GOOD data as long as you have a LOT of data

• You don’t need to change your work processes to get full value from big data

• All analytics software is about the same – it is all shareware downloaded from the internet

All Not True
Without Insight - Big Data Analytics is a solution looking for a problem to solve
Runtime Analytics Platform

- Connect process intelligence to business KPIs
- Apply powerful analytics to detect and predict issues
- Organize and visualize data in asset context
- Capture real-time process and event data
- Collaboration Across Functions
  - Engineering
  - Operations
  - Management
  - Maintenance & Reliability

Visualization

Ad-hoc Analysis
KPI Dashboard
Notifications
What do Industrial Analytics Offer?

- **Optimisation:** “What’s the best action?”
- **Random Testing:** “What if we try this?”
- **Predictive Modeling:** “What will happen next?”
- **Statistical Modeling:** “What is the pattern?”
- **Discovery/Alerts:** “Where should we look?”
- **Query/Drill Down:** “Why did it happen?”
- **Ad Hoc Rpt/Scorecards:** “How many, when, where?”
- **Standard Reports:** “What happened?”

**Prescriptive Analytics**
- First Principles Modeling: Uses known physics & chemistry

**Predictive Analytics**
- Random Testing
- Predictive Modeling
- Statistical Modeling

**Diagnostic Analytics**
- Discovery/Alerts
- Query/Drill Down

**Descriptive Analytics**
- Ad Hoc Rpt/Scorecards
- Standard Reports
Process Analytics Overview

Run-time Analytics
Unit / Site

- Event Detection
  - Deviation Detection
    - Heuristic
    - Trained

- Model
  - Normal & Abnormal
    - First Principles
    - Statistical
    - State estimation

- Process Data
  - Real-time & Historical
    (Small Data)

Off-Line Analytics
Unit / Site / Multi-Site

- Visual Data Analytics
  - Pattern search
  - Value Search
  - Combinations
  - Cleanse / Filter

- Data Driven Analytics
  - Multivariate statistical
    (PCA, PLS…)
  - Black-box (Neural Nets…)

- Machine Learning Big Data
  - Data vol. & variety
    (unstructured / text)
  - Feature Selection / Extraction
  - ML (Random Forest,
    SVM, Naïve Bayes…)

Additional Models / Rules

Time Required / Skillsets Required

Process Engineer

Data Scientist

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# Run-time Predictive Analytics Approaches

<table>
<thead>
<tr>
<th>Approach</th>
<th>Application</th>
<th>Technology</th>
<th>Complexity</th>
<th>Applic-ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physical Model (1st Principles)</td>
<td>Basic perf mon for broad set of assets &amp; detection deviation from predicted vs actual</td>
<td>Embedded &amp; External via UniSim</td>
<td>Low</td>
<td>Many</td>
</tr>
<tr>
<td>2. Univariate Prediction</td>
<td>Predicting single variable time to reach a value – e.g. predict heat exchanger fouling</td>
<td>Regression w error correction (H_TimeFit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Adaptive Filtering/Thresholding</td>
<td>Anomaly detection for Equipment (temp, press, vib)</td>
<td>Data cleansing &amp; compare current to historical averages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Multivariate Pattern</td>
<td>Detect behavior of group of sensors according to learned/historical expectations</td>
<td>Detected patterns (equations) with rules detecting abnormal relationships</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Data Driven - Multivariate Early Event Detection</td>
<td>Broad set of process and equipment monitoring scenarios</td>
<td>Statistical pattern detection and recognition including OLS, PLS, PCA, Neural Nets, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Machine Learning</td>
<td>Capture insights from Big Data to build better algorithms (e.g. Aero APU example)</td>
<td>Big Data using variety of data sources including maintenance and reliability data</td>
<td>High</td>
<td>Few</td>
</tr>
</tbody>
</table>
Continuous Calculations & Monitoring

Embedded Models
- Gas / Steam Turbine
- Pump
- Compressor
- Furnace
- Heat Exchanger

Calculations
- $Head = 3960 \times HP$
- Flow

Fault Models

Make Problems Visible
- Dashboards
- Notifications

Continuous Trends

Single Version of Truth

Process Intelligence
- Rollup KPIs
- Rollup Metrics

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Solution Architecture & Flow

Customer Site

Data Lake

Data Cleansing
- UniSim
- Asset Sentinel

Model Tuning
- UniSim

Prediction
- UniSim

Optimization
- UniSim

SDX
- Mass balance, Reconciliation

PHD

UniSim

Scheduling, Data interchange & Data Model

Asset Sentinel

Hadoop

Analytics

Rendering

Asset Sentinel

Complex SS Model

Complex OPT Model

Analytics
### Industrial Analytics Projects

<table>
<thead>
<tr>
<th>Supply Chain Integration</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What is it:</strong> ..... Three manufacturing sites in supply chain. Move data from sites to enterprise cloud and optimize the value chain using Data Analytics.</td>
<td></td>
</tr>
<tr>
<td><strong>Technology:</strong> ..... Sentience Cloud / Analytics for insight and overall quality model and batch tracking, on-line predictive analytics and alerts</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reactor Uptime Optimization</th>
<th>Reliability/Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What is it:</strong> ..... Data Analytics to determine optimal reactor change out time to increase OEE and reduce CAPEX.</td>
<td></td>
</tr>
<tr>
<td><strong>Technology:</strong> ..... Visual, Statistical, Big data, Analytics, performance models, on-line predictive analytics and alerts</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heat Exchanger Optimization / Monitoring</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What is it:</strong> ..... Online monitoring using process analytics, leading to event based maintenance of fouling.</td>
<td></td>
</tr>
<tr>
<td>- Avoid excess corrosion events.</td>
<td></td>
</tr>
<tr>
<td>- Optimize cost of lost HX performance vs maintenance/cleaning costs</td>
<td></td>
</tr>
<tr>
<td><strong>Technology:</strong> ..... UniSim, Visual, Statistical Analytics, predictive modeling</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shift Handover &amp; Rounds Management:</th>
<th>Operations Excellence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What is it:</strong> ..... Implement OM-Pro &amp; Movilizer for electronic records.</td>
<td></td>
</tr>
<tr>
<td>- Future use of cognitive analytics / NLP for productivity improvement &amp; knowledge capture</td>
<td></td>
</tr>
<tr>
<td><strong>Technology:</strong> ..... Visual, Statistical, Big data, Analytics, Multi-variate Models.</td>
<td></td>
</tr>
</tbody>
</table>
### Industrial Analytics Projects

<table>
<thead>
<tr>
<th>Operational Data</th>
<th>Analytics</th>
<th>EBS Alerts</th>
<th>Analysis</th>
<th>Advice/Plan</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near / Real Time</td>
<td>Sentinel for Analytics</td>
<td>Event Management</td>
<td>Analyst</td>
<td>Specialist</td>
<td>Engineer</td>
</tr>
</tbody>
</table>

#### Process Safety: Furnace Flooding
- **What is it:** Data analytics to develop early detection of furnace flooding condition to prevent unsafe operating conditions & reduce production losses
- **Technology:** Analytics for insight and modelling, on-line predictive analytics and alerts

#### Predictive Compressor Faults
- **What is it:** Data analytics to gain insight on Compressor performance decline, On-line performance monitoring with predictive alerts
- **Technology:** Visual, Statistical, Big data, Analytics, performance models, on-line predictive analytics and alerts

#### Aeroplane Brake Disc Manufacturing
- **What is it:** Data analytics to gain insight into unexplained and ongoing issues with batches on stopping distance tests.
- **Technology:** Visual, Statistical Analytics, predictive modeling

#### Supply Chain Insights: Supplier Quality
- **What is it:** Data analytics to analyze yield and defect on key production line parameters in semiconductor fabs tied to upstream feedstock supplier
- **Technology:** Visual, Statistical, Big data, Analytics, Multi-variate Models

#### KPI linkage to Root Cause Analysis
- **What is it:** Visual process data analytics to gain rapid insights linking KPI parameters and process performance to operating variables
- **Technology:** Visual Process Analytics, Statistical Analytics, Predictive

#### Predictive Process Surveillance
- **What is it:** Visual process data analytics to gain rapid insights into process conditions that can be rapidly converted into on-line Sentinel based analytics
- **Technology:** Visual Process Analytics, Sentinel rules, Predictive Analytics

#### Scalability
- **Operational Data**
- **Analytics**
- **EBS Alerts**
- **Analysis**
- **Advice/Plan**
- **Action**

#### Machine Learning
- **Operational Data**
- **Analytics**
- **EBS Alerts**
- **Analysis**
- **Advice/Plan**
- **Action**

#### New Verticals
- **Operational Data**
- **Analytics**
- **EBS Alerts**
- **Analysis**
- **Advice/Plan**
- **Action**
A.I. Based Product Demand Forecasting Model

This model takes derived variables such as differences and ratios of crude oil price index as inputs.

- Nonlinear dependence if feature influences the sales both pos and neg
- Linear dependence if feature influences the sales in one of the directions

<table>
<thead>
<tr>
<th>variable name</th>
<th>type</th>
<th>sensitivity of mod to var</th>
<th>% impacts neg or pos</th>
<th>size of neg influence</th>
<th>size of pos influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>margin_pre_tax_contract_sales_hda_benzene</td>
<td>delayed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>margin_pre_tax_contract_sales_extraction_benzene</td>
<td>delayed</td>
<td></td>
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</tr>
<tr>
<td>dated_less_louisiana</td>
<td>delayed</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>spot_average_ethylene</td>
<td>delayed</td>
<td></td>
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<tr>
<td>primary_energy_imports</td>
<td>delayed</td>
<td></td>
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<td></td>
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<tr>
<td>primary_energy_stock_changes_no_other</td>
<td>delayed</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>margin_pre_tax_contract_sales_styrene</td>
<td>delayed</td>
<td></td>
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</tbody>
</table>

Model sensitivity:  
- High
- Med.
- Low

Influence Type:  
- Positive
- Negative

Delay in term

Term with > 1 var

Honeywell Internal

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New Analytics POC Development Areas

- **Natural Language Processing**
  - NLP Manuals & Operator Logs
  - UOP Russell Gas Plant
  - External customer TBD

- **Forecasting Applications**
  - Product Demand
  - UOP CAS
  - External Client TBD

- **Predictive Analytics**
  - Equipment Health Monitoring
  - Asset component failure
  - Anomaly detection

- **Machine Learning Artificial Intelligence**
  - Digital Twin Creation
    - UniSIM auto parameter fitting
    - UOP CPS model
    - External UniSIM Client TBD

- **Business Intelligence**
  - Multi-Plant analytics
    - Geismar / Pottsville / Baton Rouge
UOP CPS
Connected Performance Services
Delivering the Connected Plant with CPS

**Solving Key Customer Challenges**

- **Unplanned Downtime**
  - Process issues
  - Equipment failures

- **Underperforming Assets**
  - Sub-optimal operations
  - Performance vs peers

- **Energy and Emissions**
  - Emission standards
  - Energy reduction

- **Human Capital Challenges**
  - Knowledge gaps
  - Operational excellence

**CPS Architecture**

- **Customer Site Secure UOP Cloud**

  - Proactive, ongoing dialogue and recommendations, UOP expert review
  - Ongoing capture of plant (process/lab) data
  - DATA COLLECTION

  - Gross Error Detection
  - Data Conditioning
  - Data Reconciliation

  - DATA CLEANSING

  - Purity
  - Production
  - Energy
  - Capacity

  - ADVANCED COMPUTATION

  - CPS solution-specific calculations and models UOP expert reviews

  - VISUALIZATION

  - Analyze plant performance to reveal full potential through a cloud-based service
    - Around-the-clock monitoring of plant data and rigorous simulations
    - Provides on-going, operational recommendations to close performance gaps
    - Leveraging UOP Process Models & longstanding experience in operational support and troubleshooting

  - Customer value of $0.30-$0.50/bbl in refining & $10-$20/MT in Petrochemicals
CPS – Process Reliability Advisor

What Does It Do?
- Monitoring of unit performance
- Constraint limitations
- Event detection & mitigation
- Knowledge transfer

What Is Behind It?
- Matches unit configuration
- Tuned UOP process models
- Technology specific fault models
- Embedded UOP knowledge, context, and background
CPS – Process Optimization Advisor

• Advisory Service to Maximize Profits as Conditions Change

What Is Behind It?
• Rigorous simulation to match unit configuration
• Tuned UOP process models
• SQP Optimizer driving an economic objective function
• Cloud hosted & Maintained by UOP

What Does It Do?
• Maximize process economics against constraints
• Provide operational recommendations
CPS – Impact of Optimizing an Aromatics Complex

Base Case
- Typical UOP aromatics complex
- Unconstrained feed

Optimization Problem Setup
- Maximize obj. function ($):
  - Products (PX + Bz + By-Products) – Feed – Utilities

<table>
<thead>
<tr>
<th>FEED RATE</th>
<th>PARA-XYLENE</th>
<th>BENZENE</th>
<th>LIGHT NAPHTHA</th>
<th>PROFIT CHANGE ($US million/yr)</th>
<th>KEY ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed A</td>
<td>↑2%</td>
<td>↑1%</td>
<td>↑2%</td>
<td>↑4%</td>
<td>+3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Lower Reflux - Xylene &amp; Raffinate Columns</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>• Reduce Tatoray Conversion</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Enables Increased Feedrate</td>
</tr>
<tr>
<td>Feed B</td>
<td>-</td>
<td>↑2%</td>
<td>↑8%</td>
<td>↓4%</td>
<td>+5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Naphtha Splitter – Increase C6s to Plat</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Enables Feed Increase to Top of Complex</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Debottleneck to Rebalance PIX Loop</td>
</tr>
<tr>
<td>Feed C</td>
<td>↑5%</td>
<td>↑5%</td>
<td>↑4%</td>
<td>↑5%</td>
<td>+9.5</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>• Full Complex under-utilized</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Increase feedrate until constraint met</td>
</tr>
</tbody>
</table>

Assumptions: $380 Naphtha to PX spread, $180 Naphtha to Bz. Complex size 600KMTA
The Future of Industrial Analytics?

• Industrial Analytics is moving fast and increasing pace
• Manually coded Python and R open source code – now embedded in or replaced by highly efficient commercial software offerings
• Machine Learning is reducing the need for Data Analysts in performing big data analytics
• Key areas for industry where analytics will play a key role
  • Predictive Analytics – Forecasting / Equipment Reliability
  • Knowledge Capture – NLP / Deep Learning
  • Collaboration – Cloud / Unstructured Data storage
  • Turning data into Information for IIoT pervasive sensing
  • Enhanced use of new data types – Sound / Images