The Evolution of the PI System at EQT in Support of our Digital Transformation

Presented by
Oscar Smith
Sr. Principal Engineer
EQT Midstream

Brian Morel
Manager Drilling Engineering
EQT Production
Overview of Presentation

- EQT Corporation Overview
- EQT Midstream Objectives
- The Journey
- Example Case Studies and Benefits
- Next Steps
- EQT E&P’s Journey
EQT Corporation Overview
Two Integrated Business Units

Natural Gas Exploration, Development, and Transportation

- Headquartered in Pittsburgh, PA
- 2018 marks our 130th Year in Business.
- Operations Across Appalachian Region & Texas
- Largest Natural Gas Producer in the United States
- More than 1,800 Employees
- Innovative Techniques & Strategies Employed Across Two Distinct Business Units
  - EQT Production-Natural Gas Exploration, Drilling, & Development
  - EQT Midstream-Natural Gas Gathering, Transportation, & Storage
Role in the Natural Gas Value Chain

- **Gas Gathering**
  - Reciprocating Compressors/Engines
  - Pipelines
  - Measurement

- **Transmission & Storage**
  - Reciprocating & Centrifugal Compressors
  - Large Pipelines
  - Storage Facilities

- **Approximately +2.0 BCFD Marcellus Gathering Capacity**

EQT Midstream
PARTNERS, LP

Brian

Oscar

EQT's PARTICIPATION IN THE VALUE CHAIN

1 Drilling Rigs

2 Production

3 Gathering & Compression

4 Gas Processing

5 Natural Gas Long Haul Transmission

6 Natural Gas Transmission Headers

7 Natural Gas Storage

8 NGL Mix Transportation

4 NGL Fractionation

5 NGL Storage

6 NGL Product Transportation

EQT Investments

EQT Investments
EQT Midstream Objectives
Midstream Goals & Focus

Objectives – Build Exceptional Operational and Business Intelligence

• Provide Natural Gas Gathering & Transportation Services
  - Health & Safety #1 Priority
  - Customer Service Focus
  - High System Availability & Capacity
  - Provide Value for Customers & Shareholders

• Strategy
  - Operate & Maintain Assets Efficiently & Cost Effectively
  - Apply Innovative Technologies to All Facets of the Business
  - Maintain High Expectations of Quality & Integrity

• Plan & Implementation
  - High Reliability – Compressors & Pipelines
  - Data & Analysis for Operational Awareness & Excellence
  - Transform the Business from Reactive to Proactive (Predictive) Model

Maximize Throughput & Asset Efficiency
Optimize Asset Reliability & Availability
Cost Effective Operation & Maintenance
EQT Midstream’s PI Implementation Journey

Started in 2015 with Proof of Concept Project

ONE Gathering Facility – Saturn Compressor Station

<table>
<thead>
<tr>
<th>YEAR</th>
<th>STATION</th>
<th>ENGINE/COMP UNITS</th>
<th>TAGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>Saturn</td>
<td>7</td>
<td>9287</td>
</tr>
</tbody>
</table>
EQT Midstream’s PI Implementation Journey

By End of 2018 Significantly Increased PI Digital Footprint

1. **40 Locations**
   - 16 Gathering Facilities
   - 9 Transmission Facilities
   - 1 Storage Facility
   - 10 M&R Sites
   - 4 Interconnect/Distribution Sites

2. **More than 100,000 Tags every Second**

3. **PI AF Metrics to Date:**
   - 1397 Analysis Templates
   - 16751 Analysis
   - 186 Element Templates
   - 4173 Elements
   - 828 Notification Rule Templates
   - 9160 Notification Rules
EQT Midstream’s PI Implementation Journey

PI System Digital Footprint

**EQT PI System Metrics per Year**

- **TAGS (X 1000)**
- **Sites**
- **Engine/Compressors**
- **Total Assets**

<table>
<thead>
<tr>
<th>Year</th>
<th>TAGS (X 1000)</th>
<th>Sites</th>
<th>Engine/Compressors</th>
<th>Total Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>11</td>
<td>1</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2016</td>
<td>124</td>
<td>29</td>
<td>6</td>
<td>29</td>
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<tr>
<td>2017</td>
<td>124</td>
<td>29</td>
<td>17</td>
<td>45</td>
</tr>
<tr>
<td>2018</td>
<td>320</td>
<td>217</td>
<td>40</td>
<td>67</td>
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</table>

**EQT PI System Metrics per Year**

- **Volume of Gas (Billion Cubic Feet Per Day)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume of Gas (Billion Cubic Feet Per Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>0.2</td>
</tr>
<tr>
<td>2016</td>
<td>1.747</td>
</tr>
<tr>
<td>2017</td>
<td>2.347</td>
</tr>
<tr>
<td>2018</td>
<td>4.782</td>
</tr>
</tbody>
</table>
Typical Facility Overview

Multiple Data Sources – One Point of Access with PI
EQT Midstream’s PI Network Architecture

- Typical High Availability Station
- Redundant PI Remote Collector
- Modicon/Bristol PLC
- CAT Diagnostic Interface
- EQT Local Control Systems
- 24/7 Analytical Server
- MPLS Network
- Redundant PI
- Data Archiving & Visualization
- Enterprise Historian
- Cygnent SCADA Operational Data System
- MAXIMO Work MGMT
- (FUTURE) FlowCal Measurement
- (FUTURE) GIS ESRI System
- Windrock Engine Analyst Data
- Fluid Analysis
- EQT Management KPI Reporting (Sharepoint/Cognos)
- EQT General Users
- EQT Compressor Tech Services
- EQT Operations Center of Excellence Monitoring
- EQT Field Operations
- EQT Midstream's PI Network Architecture

EQT General Users
EQT Compressor Tech Services
EQT Operations Center of Excellence Monitoring
EQT Field Operations

24/7 Analytical Server

Data Archiving & Visualization
Enterprise Historian

Cygnet SCADA Operational Data System

MAXIMO Work MGMT

(FUTURE) FlowCal Measurement
(FUTURE) GIS ESRI System

EQT Midstream's PI Network Architecture

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EQT Midstream PI System Development

Building the Tools for Reliability

**PI Asset Framework (PI AF)**
- Develop Hierarchy of Compressor Station Assets
- Organization of Data Into Useful Sets
- Standardization Across Sites
- Templates for Scalability
- Translation/Integration With Other Business Systems

**PI Vision**
- Dashboards for Operational Monitoring
- Multiple Sources of Data Combined Into Single View
- Pair Analytics w/Real-Time Values
- Single Point Access Across Organization

**PI Event Frames & Notifications**
- 24/7 Monitoring & Communication of Anomalies
- Failure Detection, Efficiency Monitoring, Work Mgmt.
- Improve Operational Awareness
- Eliminate “Digging” for Issues
Original PI Business Justification was based on savings realized by event prevention primarily for Engine/Compression Assets.
Ultra Sonic Meters

Odorizers
Scheduled / Condition Based Maintenance

Captsone - Virtual Run Time - Callisto - Bay A

- Unit Run Hours: 31,501 hr
- Next Maintenance: 498.7 hr
- Next Job Plan: JP1446

- In Service Date: 9/5/2014 4:15:30 AM
- Estimated Next Service Date: 4/30/2018 12:16:00 PM
EQT PI Preventive Maintenance / Work Management
Data Flow and Infrastructure Diagram

- Asset ID’s
- MID #’s
- Asset Theoretical Burn Rates (TBR’s)
- WO Status and Acknowledgement

- Data &/or Asset WO Triggers
- Asset Runtime Hours

Operating Parameters
- Running
- Pressures
- Temp
- RPM
- Vibration
- Oil Level

Visualize Asset Operation
- Alerts and Notifications
- Compliance Reporting
- Predictive Analytics
- Trends
- Optimize
Case Studies and Benefits
# Identification & Diagnosis of “Bad Actors”

**Using PI Analytics & Notifications to Identify & Diagnose Recurring Issues**

## Case Study: Engine Load/Speed Control - Improve Equipment Availability & Reliability

<table>
<thead>
<tr>
<th>Notification Name</th>
<th>Occurrences in Last 24 Hours</th>
<th>Occurrences in Last Week</th>
<th>Occurrences in Last Month</th>
<th>Occurrences YTD</th>
<th>Date of Last Occurrence</th>
<th>Level</th>
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<tbody>
<tr>
<td>Saturn - Unit 3 - Eng - Speed High Delta Alert</td>
<td>7</td>
<td>64</td>
<td>169</td>
<td>410</td>
<td>10/3/2016 7:26</td>
<td>Level 1</td>
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<tr>
<td>Saturn - Unit 3 - Eng - High Fuel Position % Alert</td>
<td>0</td>
<td>8</td>
<td>11</td>
<td>11</td>
<td>10/1/2016 14:03</td>
<td>Level 1</td>
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<tr>
<td>Saturn - Unit 3 - Comp - Throw High Disch Temp Theo v Actual Alert</td>
<td>0</td>
<td>6</td>
<td>14</td>
<td>275</td>
<td>10/1/2016 21:15</td>
<td>Level 2</td>
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<tr>
<td>Saturn - Unit 3 - Comp - Shutdown Alert</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>51</td>
<td>9/29/2016 20:15</td>
<td>Level 1</td>
</tr>
<tr>
<td>Saturn - Unit 3 - Comp - Low Speed Alert</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>17</td>
<td>10/1/2016 11:25</td>
<td>Level 3</td>
</tr>
<tr>
<td>Saturn - Unit 3 - Eng - Load % Alert</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>9/29/2016 19:08</td>
<td>Level 2</td>
</tr>
</tbody>
</table>

## Background

- Frequent Deviations Indicate Underlying Issues
- Identifying & Detecting Correlation of Deviations Improves Effectiveness of Diagnostics
- Prior to PI – Limited Visibility into Assets

## Solution

- Leverage PI Analytics to Monitor Critical Parameters
- Develop PI Notifications to Alert & Track Deviations
- Reliability Review of “Bad Actors”

## Results

- Reduced Identification & Troubleshooting Time
- Reduce Repeat Shutdowns
- Eliminate Parts Consumption – Replace to Troubleshoot
Analysis of Trends & Operational Issues

Using PI Analytics & Notifications to Detect & Prevent Process Upsets

Case Study: **Hydrate Formation** : Reduce Process Interruptions & Optimize Assets

**Background**
- EQT Midstream Transports “Wellhead” Gas with High Concentration of C3+ Hydrocarbons
- Hydrates Can Form in “Heavy” or “Wet” Gas Applications
- Eliminate or Affect Hydrate Formation Line Via:
  1. Introduction of Inhibitor/Methanol
  2. Change Process to Avoid Hydrate Formation Area

**Solution**
- Leverage PI Analytics to Predict Hydrate Formation Temperature
- Use PI Notifications to Monitor Process/Hydrate Formation Temperature
- Alert Key Personnel to Potential Hydrate Formation
- Modify Process Accordingly to Avoid Interruptions/Upsets

**Results**
- Modify Operations in Response to Notifications
- Reduce Operating Pressures to Avoid Hydrate Formation
- Reduced Capacity Vs. Complete Outage
- Minimize Dependency on Hydrate Inhibitor
  - Reduce Costs & Consumption
  - Eliminate Secondary Impacts of Inhibitor

*Actual Temp ~41 Deg*

*Hydrate formation Temp ~48 Deg F*

*24 hours Process Pressure Control Fluctuations Indicate Actual Hydrate Formation*

*Process Temperature Increase*  
*Control Stability Restored*
Case Study: Compressor Valve Condition – Targeted Use of Resources

**Background**
- Compressor Valves – High Frequency Failure
- Affect Compressor Performance & Efficiency
- Typically Identified by Equipment Analysts on Weekly/Semi-Weekly Field Analysis
- Equipment Analyst Time Valuable & Limited

**Solution**
- Leverage PI Analytics to Predict Theoretical Gas Discharge Temperature
- High Deviation in Actual Temp. w/Predicted Indicates Potential Valve Issue
- Condition Based Analysis Vs. Time Based

**Results**
- Reduce Data Collection Time - Equipment Analyst
- Use PI as 1st Tier Approach to Focus Resources
- Repurpose Analyst Time to Other Areas of Condition Monitoring
- Provide Operations With Tools to Detect Issues Prior to Analyst Visit
Data & Trends for Condition Based Maintenance

PI Trends & PI Analytics to Maximize Component Life & Value

Case Study: Spark Plugs – Insight into Equipment Condition

**Background**
- Spark Plug Life Varies by Application/Site
- Secondary Ignition Voltage – Leading Indicator of Plug Condition
- Voltage Increases Slowly as Plug Decays Over Time
- Plugs Represent Challenge with Utilizing Condition Monitoring & Maintenance

**Solution**
- Use PI Vision & Notifications to Trend Increase in Leading Indicator Value
- Integrate PI AF & Maximo to Generate WO at Defined Conditions
- Apply Spark Plug Philosophy to Other, Higher Impact Systems

**Results**
- Reduce Frequency of Spark Plug Changes
- Eliminate Downtime & Cost of Unnecessary Plug Changes
- PI/Maximo Integration – Develop Tracking System for Reliability Analysis
- Foundation to Begin Assessment of Condition Indicators & Application to Overarching Systems
EQT PI ANNUAL TANGIBLE SAVINGS FROM EVENT PREVENTION

- 2016 Assumptions
- Actual
- Projected Beyond

MILLION DOLLARS SAVED ANNUALLY

- 2015
- 2016
- 2017
- 2018
- 2019
- 2020

- JUL
- NOV
- MAR

$1.18
$1.17
$2.83

SAN FRANCISCO 2018

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Next Steps
Digital Transformation

Where are We Headed?

- Cost Reduction
- Operational Excellence
- Digitally Enabled Operations
- Data Driven Services
- Product Innovation
- Digital Products

Revenue Improvement

JUST DO IT.
A Cultural Change: People, Processes, & Technology

A Sustainable PI System Begins With Details

Long Term Vision & Management Support

Support Business Case w/Value

Communicate Strategy

Identify Resources

Utilize PI System as Tool for a Culture Shift

Identify Critical Data & Build Foundation

Data to Support Business Case

Focus on Data Quality & Integrity from Beginning

Develop Manageable Scope and Scale Up

Develop AF to Support Long Term Strategy & Sustainability

Communication & Feedback

Engage Users in Development

Build Tools & Process with Users in Mind

Feedback Loop for System Improvement & Value

A Sustainable PI System Begins With Details

Engage Users in Development

Build Tools & Process with Users in Mind

Feedback Loop for System Improvement & Value
Looking Ahead: EQT Midstream & The PI System

Visualize Asset Operation
- Alerts and Notifications
- Compliance Reporting
- Predictive Analytics
- Trends
- Optimize

CygNet

PI Interfaces

PI Notifications

PI Event Frames

PI Analytics

PI Asset Framework

PI Data Archive

PI Visualisation Suite

PI Vision

PI ProcessBook

PI DataLink

PI WebParts
Looking Ahead: EQT Midstream & The PI System
The Next Steps in the Journey Towards Digital Business Transformation

“I am learning to trust the journey even if I don’t understand it.”

SUCCESS
what people think it looks like

SUCCESS
what it really looks like

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Enabling Business Transformation with the PI System

COMPANY AND GOAL

EQT Midstream provides NG gathering & transmission services. Desired to transform their business to reduce costs & improve revenue by supporting a culture of digital enablement and empowerment coupled with work process redesign.

CHALLENGE

Desire to leverage digital technology to enable operational excellence to deliver transformative business value:

• Maximize Throughput
• Optimize Asset Reliability & Availability
• Lower O&M Costs thru cost effective operations & maintenance
• Improve asset integrity and overall safety and environmental performance

SOLUTION

Selected the PI System as a strategic enterprise OT infrastructure to provide the foundation for our business transformation journey:

• Initial POC on a compressor station
• Grow capabilities and awareness of the power of the PI System
• SME enablement and empowerment
• Work process redesign leveraging normalized, contextualized data

RESULTS

An estimated Annual Cumulative Tangible Savings from event prevention was estimated at $1M is now projected to be an annual savings of $3M by 2020:

• Rollout to 40 locations
• Reduced O&M cost, safety and environmental incidents
• PI AF templates enable rapid scale and SME enablement
• Changing culture and work processed – a true transformation
EPC Real Time Data
EQT Real Time Operations Center

• RTOC Goals
  • Minimize People on Locations
  • Optimize Field Resources
  • Enhance Collaboration
  • Reduce Inefficiencies & Failures
  • Improve Consistency
  • Maintain Low Costs

• Upstream Direction
  • Drilling
  • Completions
  • Production
  • Logistics
    • Water
    • Construction
Drilling – OSIsoft PI System Trial

- 2016 – Strategy Developed
  - Focused on resource allocation & data driven decisions

- 2017 – Completed 3 Month Trial
  - Resources allocated by OSI and Midstream
  - Completed all trial targets
  - Single EQT resource to develop

- Event Frames - Alerts
  - Performance Roadmaps
  - Best Practices
  - Trend changes
  - Failure Analysis Feedback Loop
  - Drilling State Analytics

- Automated Performance Metrics
  - Footage / ROP details
  - On/Off bottom time
Failure Prediction

• Torque Fluctuation
  • Bit Failure Occurred
  • Surface Measurement
  • Target Value Exceeded

• Alerts
  • RTOC Staff
  • Elevated Alerts
  • Acknowledge
### Failure Prevention

<table>
<thead>
<tr>
<th>Event Name</th>
<th>Asset</th>
<th>Event Type</th>
<th>Start Time</th>
<th>End Time</th>
<th>Severity</th>
<th>Duration</th>
<th>Acknowledged By</th>
<th>Acknowledgement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque Excursion Savannah Drig 803</td>
<td>SAVANNA DRL G 803</td>
<td>Torque Excursion</td>
<td>8/31/2017 4:56:26 AM</td>
<td>8/31/2017 5:17:59 AM</td>
<td>Warning</td>
<td>21m 33s</td>
<td></td>
<td>Acknowledge</td>
</tr>
<tr>
<td>Rotary RPM Excursion Savannah Drig 803</td>
<td>SAVANNA DRL G 803</td>
<td>Rotary RPM Excursion</td>
<td>8/31/2017 4:52:00 AM</td>
<td>8/31/2017 5:18:41 AM</td>
<td>None</td>
<td>26m 40s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UCS Decrease Savannah Drig 803</td>
<td>SAVANNA DRL G 803</td>
<td>UCS Decrease</td>
<td>8/31/2017 4:50:59 AM</td>
<td>8/31/2017 4:56:56 AM</td>
<td>None</td>
<td>5m 56s</td>
<td></td>
<td>Acknowledge</td>
</tr>
</tbody>
</table>

![Graph showing data trends and alerts](image-url)
Future Additions

- Optimization Design Tool
  - Roadmaps
  - Inefficiencies
  - RT Parameter Guidance
    - Machine Learning

- Failure Analysis
  - Event Alerts

- Robust Data Connections
- Collision Avoidance

- Automated Drilling Tools
  - Live Performance Metrics
  - Drilling Parameters
  - Real Time Engineering Tool
Organizational Challenges

- **Culture Change**
  - Vendor Buy In
  - Field Personnel
  - Effective Communication Plan

- **Managing Issues**
  - Power / Facility Interruptions
  - Office Distraction
  - Failures / Hole Problems / NPT

- **Data / IT Requirements**
  - 24/7 Office & Field Support
  - New Technology / Architecture Solutions
  - Data Speed / Volume Requirements
  - Data Sources

- **Field Communications**
  - Standardization
  - Reliability
  - Consistency
  - Push / Pull Capabilities
  - Transcripts
Production Engineering & Operations

**Historian**
- Real time data for existing facilities in Cygnet

**Analytics**
- Development of alarms that require trending or addition computation out of the traditional high/low bounds
- WMO – Asset tracking and automated work order creation with real time data
- Condition based maintenance

**Optimization**
- Reduce downtime when utilizing event frames coupled with Maximo data
- Employing Event Frames to automate artificial lift intervention including but not limited to tubing and plungers
- System volume optimization based on current conditions
Completions RTOC Pilot

- Data Collection
- Scoping Details
  - Chemical Optimization
  - Performance Roadmaps
  - Standardization
  - Basic Failure Prediction

Water Impoundment

Data Van

Wireline

Sand

Chems

Sensors
Enabling EQT E&P’s RT Operations Center with the PI System

COMPANY AND GOAL

Leverage the PI System and partnerships to maintain and improvement upon low development cost model through minimizing people on locations, optimize field resources, enhancing collaboration, reducing inefficiencies & failures, and improving consistency, while minimizing EHS and safety incidents.

CHALLENGE

Main challenges in implementing the RT Operations Center and accomplishing the E&P goals included:

• Cultural Change & Alignment
• Management of “issues”
• Data & IT Requirements
• Remote operations communications

SOLUTION

Leveraged the PI System and experience gained in EQT Midstream to expand into the E&P Division

• Conducted POCs in drilling
• Leverage PI AF to support decisions from new EQT Operations Center
• Developed PI AF templates, analytics, event frames, notifications, and PI Vision displays.

RESULTS

Validated the PI System’s ability to support drilling and completions with real-time situational awareness, analytics, and decision support.

• Expanding portfolio of drilling functionality
• Expanding into Production & Completions
• Addressing challenges to enable a full use of the Real-time Operations Center

Moving from reactive to proactive operations in EQT’s E&P to drive transformative business value
The Evolution of PI at EQT

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  • EQT Midstream

• Brian Morel
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  • Director Drilling Engineering
  • EQT Production
Questions

Please wait for the **microphone** before asking your questions

State your name & company

Please remember to…

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