



Compressor Shutdown Digital Transformation – Integrating the PI System to Maximo

Nick Galizia, Jonathon Vincent, Matt Whiteman



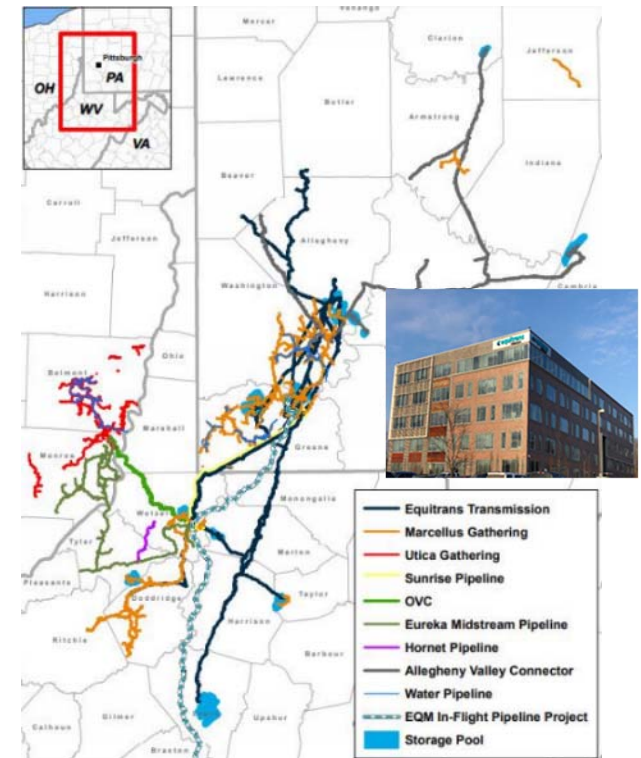
Agenda

- Equitrans Company History
- Equitrans PI System Background
- Application of PI system to Compressor Shutdown Process
- Implementation Details
- PI System Capabilities Leveraged
- Lessons learned, results obtained & next steps



Equitrans Midstream Corporation (NYSE: ETRN)

- Premier natural gas midstream company in the Marcellus and Utica shale
- Operate both gathering & transmission assets
- 910 miles of high-pressure gathering pipeline
- 950-mile FERC-regulated interstate pipeline
- ~ 700,000 HP of Compression



Operations Intelligence System Journey

2015

The Pilot (POC) – One Gathering Site

- Saturn Compressor Station
- 7 Engine/Compressor Units
- ~9,000 TAGS

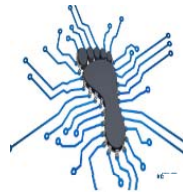


OSIsoft
PIWorld SAN FRANCISCO 2020

2020

41 Compressor Stations

- 130 Engine/Compressor Units
- ~700k Horsepower
- 31 Gathering facilities
- 10 Transmission facilities
- Localized and centralized data collection



■ Reciprocating ■ Centrifugal

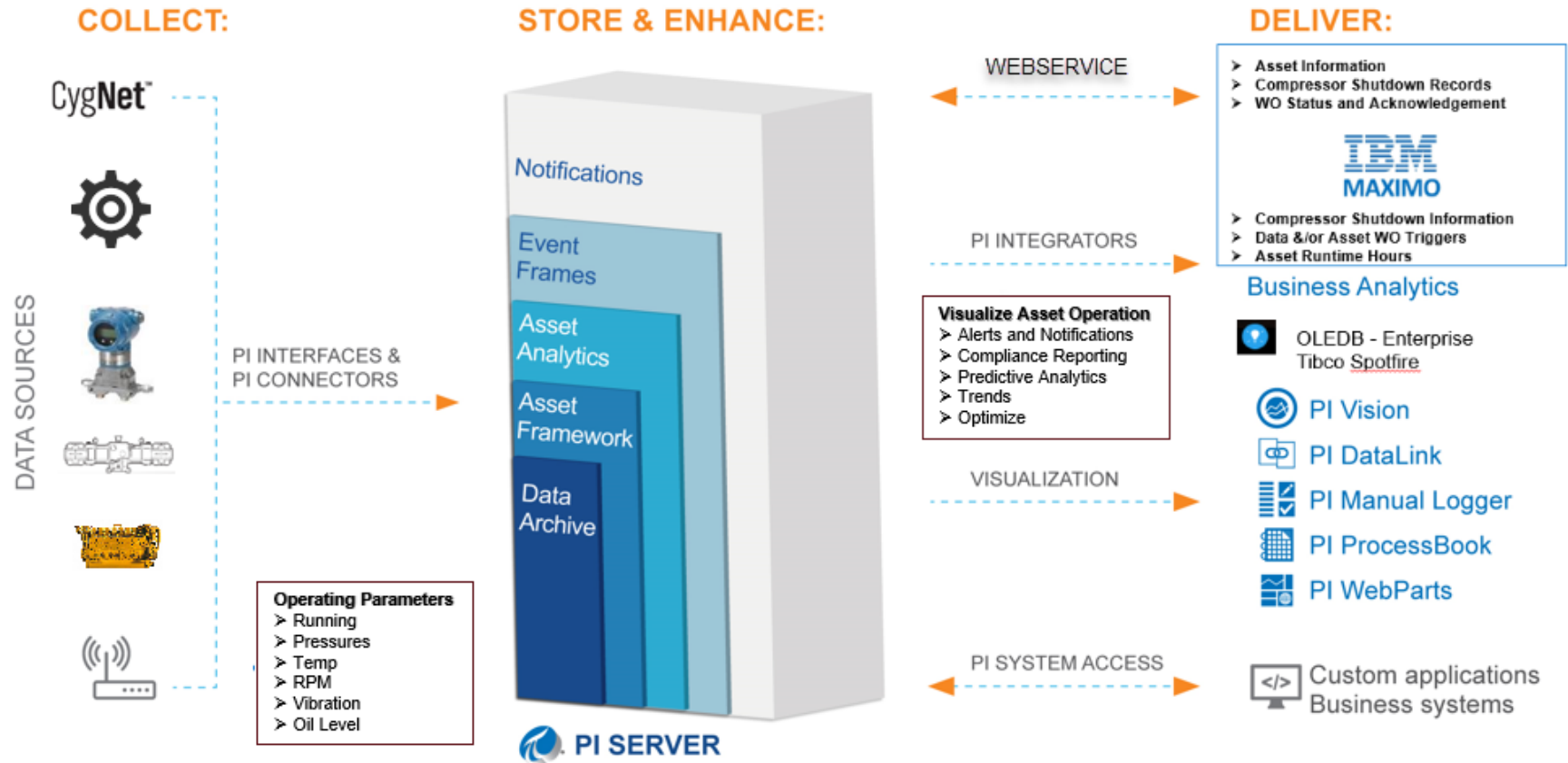
Key Points

More than 150,000 TAGS / sec

- 2,143 Analysis templates
- 39,036 Analyses **(16X)**
- 192 Element templates
- 5,959 Elements **(32X)**
- 1,167 Notification rule templates
- 19,357 Notifications **(16X)**
- 1.2+ MM Event Frames **(manage by exception)**
- **Supported by 2.5 FTE resources**
- **SME Enablement**

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PI System Components



2020 PI System Initiatives Support Equitrans Priorities

Priorities:

- Support Equitrans Strategic Priorities
 - Act with Fiscal Discipline
 - Optimize Operations

Initiatives:

- New & legacy station PI implementation
- **Compressor Shutdown Process**
- Environmental Reporting
- Ultrasonic Meter Diagnosis
- Pigging Analysis

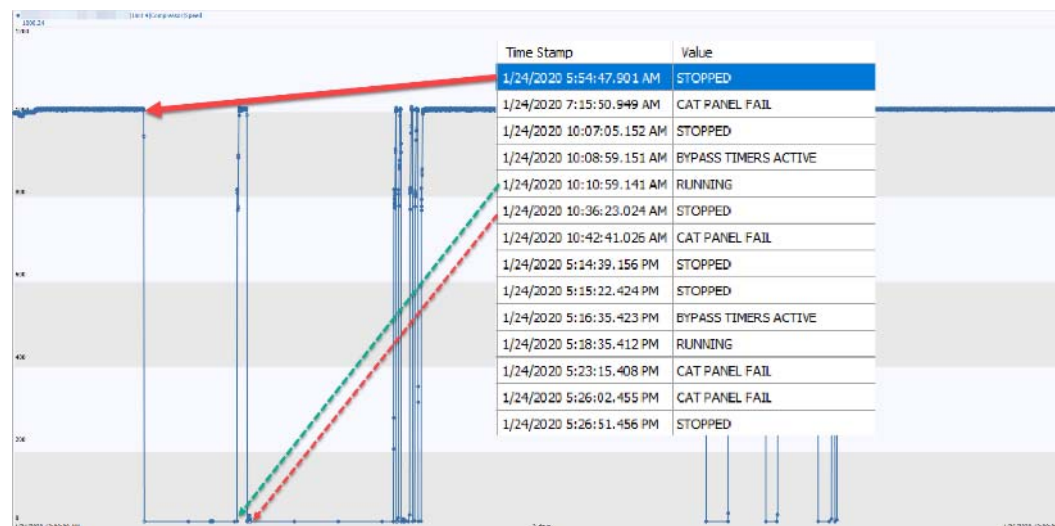
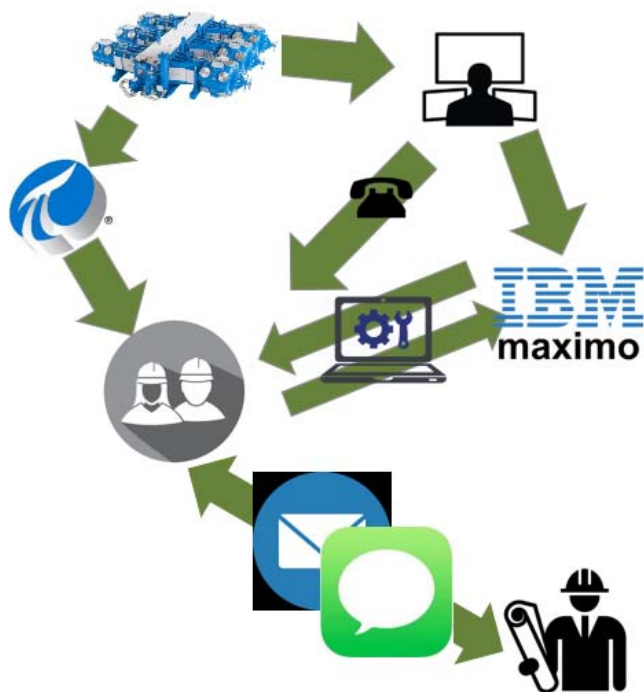


Digitally transform Equitrans business functions with a focus on efficiency by eliminating manual, redundant processes

What Happens When a Compressor Shuts Down?

Asset Shutdown Process (Integrate PI Event Frames with Maximo EAM System)

Previous Process



Challenges:

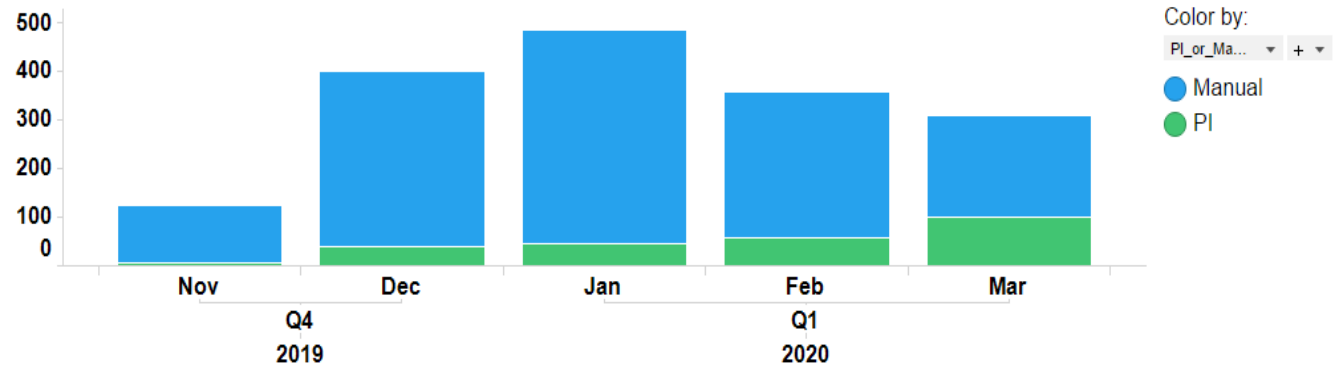
- Previous process was manual
- Did not leverage existing technology and PI System data
- Data inaccurate and subjective
- No hard link between Work Order Events and PI System data

Why Automate the Current Process?

>200 Units

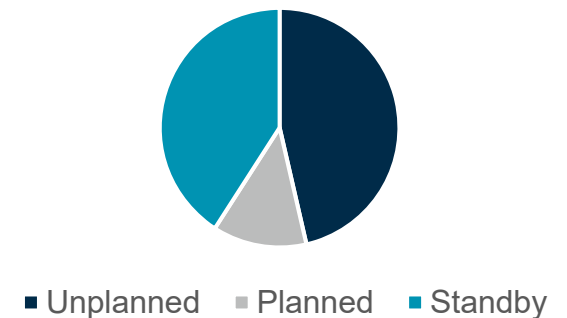
~700,000 Horsepower

70 Locations



- Equitrans manages > 5,000 compressor shutdowns per year
- Manually entered by gas control into Maximo for field to respond (est. 2,500 hours per year)
- Reliability team relies on good data to analyze shutdowns and perform corrective action

Shutdown Types



Approach Utilizing all Stakeholders & OSIsoft Tech Svs

Asset Shutdown Process (Integrate PI Event Frames with Maximo EAM System)



Investigate / Plan

Collaborate (Feb 2019)

Test / Pilot
Oct-Nov

Implement

Nov – 2020

What Information do we Need & Why Important?



- Run hour data used for:
 - Environmental reporting
 - Maintenance scheduling
- Root cause analysis
- Codes and type used for root cause analysis
- Shutdown type used for contractual requirements



Where Could We Get the Information to Automate?



Data Type	Source	Method
Asset Info	Maximo	PI AF/SQL Table
Planned/Unplanned/Standby	PLC, Maximo	PI Calculation (Flags)
Shutdown Code	PLC	PI Tag
When?	PLC	PI Event Frame
Responding Operator	Gas Control <i>Future automation planned</i>	Manual Entry in Maximo
Run Hours	PI Virtual Meter Tag	PI Event Frame

Planned Shutdowns from Maximo Table

Database Query Date Back Check In Refresh New Table Search Tables

Library

Maximo SR Scheduled

General Table Define Table Version

Name: Maximo SR Scheduled

Description: Shutdown Records for Scheduled or New Events

Categories:

Connection: Linked - Maximo

Query: Linked - SELECT * FROM Where status = 'SCHEDULED' or status = 'PLANNED' and templateid = 'PLANNED' Order By targetstart DESC

Time Zone: <None> ☒ Convert To Local

Cache Interval: 1 Minutes

General Table Define Table Version

Maximo SR Scheduled

Filter

assetnum	asn	csn	csnunit	csrefc	csrc	csr	siteid	location	description	status	eqtactualstart	eqtactualfinish	targetstart	targetfinish	affecteddate	statusdate
1242779							OH	1100886	5381528 Compression shutdown - PLANNED COB-UNIT-...	SCHEDULED						
1037650							NWV	1000312	5381527 10K and comp packing - PLANNED SAT-UNIT-2...	SCHEDULED						
1178736							PA	1062800	5381359 Maintenance - PLANNED MCI-UNIT-2400	SCHEDULED	2/13/2020 6:15:...					
1148219							PA	1016073	5365914 5000/hr pm - PLANNED HAL-UNIT-2200	SCHEDULED						
1174130							NWV	1059794	5380715 20K PM & quad O - PLANNED JAN-UNIT-2400	SCHEDULED						
1218469							OH	1084188	5380816 Lease PM - PLANNED ZIN-UNIT-2400	SCHEDULED						
1072803			266...		S...		NWV	1011991	5380939 5000/hr PM - PLANNED SAT-UNIT-2500	SCHEDULED	2/10/2020 12:0...					
1174964							PA	1060372	5380139 Compression shutdown - PLANNED PET-UNIT-...	SCHEDULED						
1174868							PA	1060188	5380246 5000 hour PM - PLANNED BLM-UNIT-2300	SCHEDULED						
1037631							NWV	1000293	5330147 9,000hr PM - PLANNED HUH-UNIT-2100	SCHEDULED						
1215468							OH	1081602	5380167 Fuel System Upgrade - PLANNED CAI-UNIT-2500	SCHEDULED						
1174961							PA	1060369	5379708 5000/hr pm - PLANNED PET-UNIT-2200	SCHEDULED						
1215467							OH	1081601	5379607 Lease Fuel System Upgrade - PLANNED CAI-U...	SCHEDULED						
1174867							PA	1060187	5379713 automation Upgrade - PLANNED BLM-UNIT-2200	SCHEDULED						
1174870							PA	1060190	5379716 Automation upgrades - PLANNED BLM-UNIT-2...	SCHEDULED						
1215464							OH	1081598	5375051 Leased Fuel System Upgrade - PLANNED CAI-U...	SCHEDULED						
1194740							OH	1067356	5379273 Compression shutdown - PLANNED COB-UNIT-...	SCHEDULED						
1194742							OH	1067358	5379272 Compression shutdown - PLANNED COB-UNIT-...	SCHEDULED						
1174874							PA	1060212	5329842 9,000 hour PM - PLANNED FLM-UNIT-2900	SCHEDULED						
1242778							OH	1100885	5377995 500 hour pm - PLANNED COB-UNIT-2400	SCHEDULED						
1242779							OH	1100886	5377997 500 hour pm - PLANNED COB-UNIT-2500	SCHEDULED						
1174871							PA	1060191	5377658 4500/hr pm - PLANNED BLM-UNIT-2600	SCHEDULED						
1174866							PA	1060186	5377657 4500hr pm - PLANNED BLM-UNIT-2100	SCHEDULED						
1174964							PA	1060372	5332323 4500 hr PM - PLANNED PET-UNIT-2500	SCHEDULED						
1037677							PA	1000342	5376815 Compression shutdown - PLANNED JUP-UNIT-...	SCHEDULED						
1147874							PA	1015811	5376741 PI TEST - PLANNED JUP-UNIT-2400	SCHEDULED						
1037650							NWV	1000312	5376537 9000/hr pm - PLANNED SAT-UNIT-2200	SCHEDULED						
1194742							OH	1067358	5376126 4500/hr - PLANNED COB-UNIT-2300	SCHEDULED						
1167027							NWV	1024322	5376130 Comp Rod packing - PLANNED JAN-UNIT-2200	SCHEDULED						

Elements

- Event Frames
- Library
- Unit of Measure
- Contacts
- Management

PI System Calculation to Determine Shutdown Flag

Name	Value
_Planned Shutdown Flag	Off
Planned Shutdown - Unit Stopped	Off
_Running Flag	On
_Standby Flag	
_Unplanned Flag	

General	Child Elements	Attributes	Ports	Analyses	Notification Rules	Version																								
<div> <div> </div> <div> <div>Name</div> <div>Backfilling</div> </div> </div> <table border="1"> <thead> <tr> <th>Name</th> <th>Backfilling</th> </tr> </thead> <tbody> <tr> <td> _SR Planned Shutdown Record</td> <td></td> </tr> <tr> <td> _SR Unit in Standby</td> <td></td> </tr> <tr> <td> _SR Unit in Standby 30 Mins</td> <td></td> </tr> <tr> <td> SR Unit in Standby Delay</td> <td></td> </tr> </tbody> </table>							Name	Backfilling	_SR Planned Shutdown Record		_SR Unit in Standby		_SR Unit in Standby 30 Mins		SR Unit in Standby Delay															
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PI Event Frames Drive Shutdown Records in Maximo

Child Elements Attributes Ports Analyses Notifications Rules Version

	Name	Backfilling
	Pre - Catalyst Temp State Hours Monthly	
	Pre-Catalyst Temp State	
	Shutdown Event - Engine - Engine CAT Panel	
	Shutdown Event - Engine - Engine Coolant	
	Shutdown Event - Engine - Engine Cooler Vibration	
	Shutdown Event - Engine - Engine Exhaust	
	Shutdown Event - Engine - Engine Oil	
	Shutdown Event - Engine - Engine Sensor failure	
	Shutdown Event - Engine - Engine Sequence	
	Shutdown Event - Engine - Engine Vibration	
	Spark Plug - # Req Replace Count - 16 Cylinder	
	Spark Plug - # Req Replace Count - 8 Cylinder	

Name: Shutdown Event - Engine - Engine Oil

Dispositions:

Categories:

Analysis Type: ☐ Expression ☐ Rollup ☒ Event Frame Generation

[Create a new notification rule for Shutdown Event - Engine - Engine Oil](#)

Generation Mode: Explicit Trigger Event Frame Template: Compressor Unit - Shutdown Event - Comp

Name	Expression	True for	Severity	Value at Evaluation	Value at Last Trigger
<input type="checkbox"/> Variables					
CompStatus	'Compressor Status'			RUNNING	RUNNING
EngStatus	'.. Engine Status'			RUNNING	RUNNING
PrevStatus	PrevVal('Compressor Status', '')			RUNNING	RUNNING
SDCodes	//The list of shutdown codes for this category are stored in an attribute (array of strings) 'EQH_ShutdownCodes Engine Oil Shutdown'			[LOW ENGINE]	[LOW ENGINE]
Match	//The FilterData function will search the array looking for a match, and return another array FilterData(SDCodes, Eval=CompStatus)				
GroupTrigger	//If the length of the returned array has at least 1 item, then a match was found ArrayLength(Match) >= 1			False	False
Speed	'Speed - Actual'			997 rpm	997.8 rpm
DischPress	'.. Compressor Discharge Press - Final'			992.1 psig	991.56 psig
<input type="checkbox"/> Start triggers					
StatusTrigger	GroupTrigger And PrevStatus = "RUNNING" And 'Unit Ready' = "On"	Not Set	None	False	False
<input type="checkbox"/> End trigger					
EndTrigger	(CompStatus = "RUNNING" And 'Unit Ready' = "On") or '.. Standby Flag Standby Flag Delay' =			True	True

Evaluation Time: 2/7/2020 9:59:30 AM Last Trigger Time: 2/7/2020 9:56:02 AM Elapsed Evaluation Time: 32.3ms

[Advanced Event Frame Settings...](#)

Scheduling: ☒ Event Triggered ☐ Periodic

Trigger on: ..|Standby Flag|Standby Flag Delay, Compressor St...

[illegible]

Service Requests																				Filter	1 - 3 of 3			Download	
Service Request	SR Type	Site	Status	Asset	Classification	Owner Group	Reason for Work	Failure Code	Problem Code	System	Component	Target Start	Target Finish	Actual Start	Actual Finish	Contact Name	Reported By	Unavailable Time	Summary						
				SAT-UNIT-2500										>2/8											
5380939	CSR	NWV	SCHEDULED	SAT-UNIT-2500	COSH \ CPLN							2/10/20 08:00:00	2/10/20 16:30:00			PRIMMJ	HUGHESP	5380939 5000/hr PM - PLANNED SAT-UNIT-2500							
5381002	CSR	NWV	RESOLVED	SAT-UNIT-2500	COSH \ CUNP									2/9/20 09:20:18	2/9/20 13:45:00	SMELTZERL	MXINTADM	4.25 5381002 Compression shutdown - UNPLANNED SAT-UNIT-2500							
5381031	CSR	NWV	RESOLVED	SAT-UNIT-2500	COSH \ CSTB									2/9/20 14:16:00	2/9/20 23:34:00		MXINTADM	9.18 5381031 Compression shutdown - STANDBY SAT-UNIT-2500							
Select Records																									

Maximo Integration

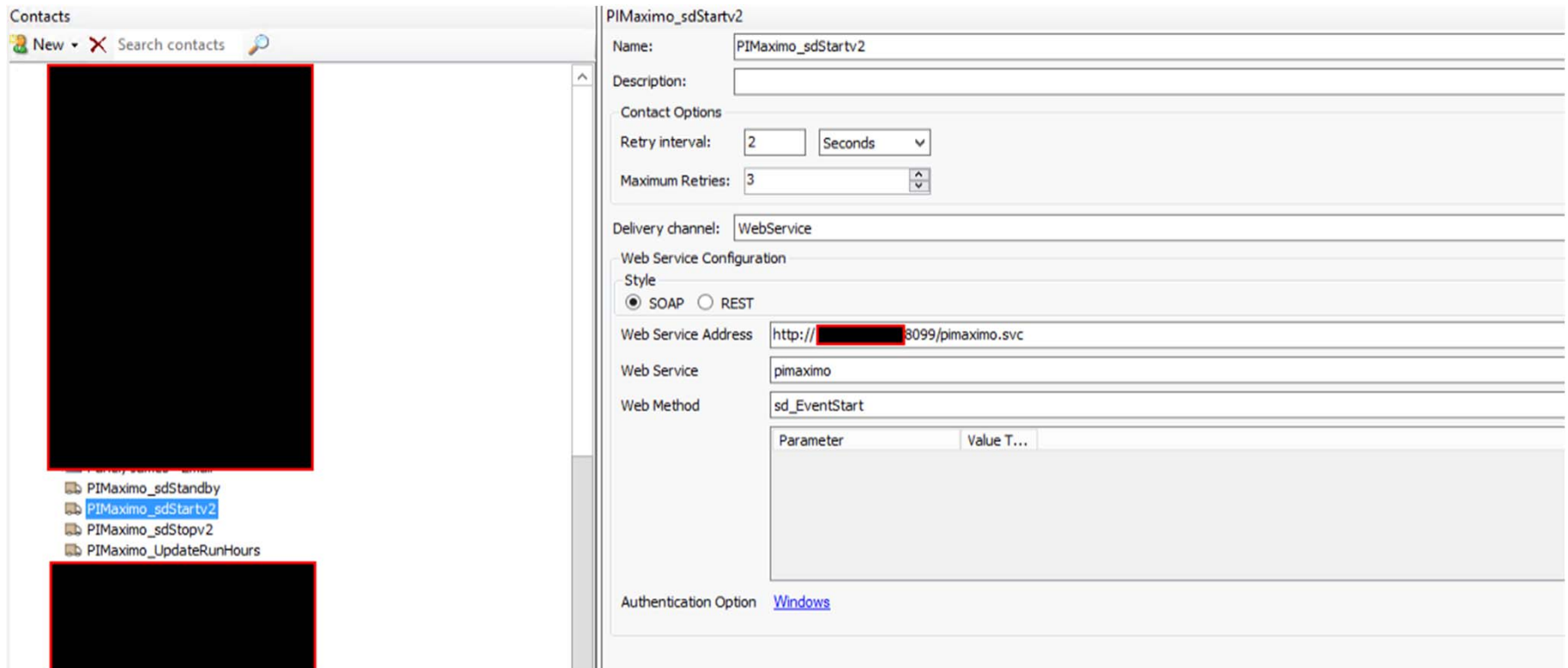
- Maximo integration framework using interface table method
- Checkbox added at "Station Location" which drives integration for shutdowns and run hours

A screenshot of the IBM Maximo 'Station Location' form. The form is divided into several sections. On the left, there are fields for 'Location' (set to 'STATION'), 'Type' (set to '2'), 'Person Group' (set to 'SAT_OPER'), 'Rotating Item', 'Meter Group', 'Area' (set to 'STATION'), 'Map Quad', 'Latitude', 'Longitude', 'Department' (set to 'OPS'), 'Legacy ID', and 'Owner' (set to '32'). In the center, there are fields for 'Site', 'Priority', 'Failure Class', 'GL Account', 'Internal Labor Account', and 'Access Point Information' (including 'Latitude', 'Longitude', and 'Access Method'). On the right, there are fields for 'Attachments', 'Status' (set to 'OPERATING'), 'Status Description' (set to 'Operating'), 'Address', 'Bill to Address', 'Ship to Address', '911 Address', 'City', 'County', 'State', and 'Zip Code'. A red box highlights the checkbox labeled 'Is PI Managed Loc for CSR?' which is checked.

PI System To Maximo Integration Via Delivery Endpoint

- Out of the box functionality with PI AF Notifications
- Ability to trigger data flow upon event frame generation
- SOAP or REST Webservice
 - Simple Object Access Protocol (SOAP)
 - Representational State Transfer (REST)
 - Webservice must be developed using .NET or other supported development platform.

PI System To Maximo Integration Via Delivery Endpoint



Contacts

New X Search contacts

PIMaximo_sdStandby
PIMaximo_sdStartv2
PIMaximo_sdStopv2
PIMaximo_UpdateRunHours

PIMaximo_sdStartv2

Name: PIMaximo_sdStartv2

Description:

Contact Options

Retry interval: 2 Seconds

Maximum Retries: 3

Delivery channel: Webservice

Web Service Configuration

Style
☒ SOAP ☐ REST

Web Service Address: http://[REDACTED]:8099/pimaximo.svc

Web Service: pimaximo

Web Method: sd_EventStart

Parameter	Value T...
-----------	------------

Authentication Option: [Windows](#)

PI System To Maximo Integration Via Delivery Endpoint

Shutdown Event - Compressor - Webservice - Subscriptions

Name	Configuration	Notify Option
PIMaximo_sdStartv2	Configured	Event start
PIMaximo_sdStopv2	Configured	Event end

Contacts

- Vincent, Jonathon
- Escalation Teams
- Groups
- Delivery Endpoints
 - Delivery endpoint 19
 - Delivery endpoint 28
 - Foley, Jeffrey - Email
 - MyStart
 - PIMaximo_debug
 - pimaximo_sdStandby
 - PIMaximo_sdStartv2
 - PIMaximo_sdStopv2
 - PIMaximo_UpdateRunHours
- Dynamic Endpoints
- Contacts Search

PI System To Maximo Integration Via Delivery Endpoint

Web Service Configuration

Web Service Address

http://[REDACTED]/pimaximo.svc

Web Service

pimaximo

Web Method

sd_EventStart

Parameters

Name	Value Type	Value
EventID	String	Event Frame:Unique ID
eStart	DateTime	Event Frame:Start Time
eStartSpecified	Boolean	True
AssetID	String	Asset ID:Value At Start Time
UnitAssetID	String	Asset ID/Unit Asset ID:Value At Start Time
CATCode	String	Not Available
PanelCode	String	Status:Value At Start Time
UnitType	String	Compressor
Location	String	Asset Location:Value At Start Time
SiteID	String	Maximo SITEID:Value At Start Time
EventName	String	Event Frame:Name

Test Send

Content

AF Server Properties

Database Properties

Notification Rule Properties

Event Details Hyperlink

Event Frame Properties

Event Frame Attributes [Select an example](#)

Referenced Element Properties

Referenced Element Attributes

_Constants

_Constants|Atmospheric Pressure

_Constants|Blowdown

_Constants|Blowdown|Final Discharge Displacement

_Constants|Blowdown|Final Discharge Displacement|Default

_Constants|Blowdown|Suction Displacement

_Constants|Blowdown|Suction Displacement|Default

_Constants|Disch Temp - Corr X Factor - Throw 1

_Constants|Disch Temp - Corr X Factor - Throw 2

_Constants|Disch Temp - Corr X Factor - Throw 3

_Constants|Disch Temp - Corr X Factor - Throw 4

_Constants|Disch Temp - Corr X Factor - Throw 5

_Constants|Disch Temp - Corr X Factor - Throw 6

_Constants|Disch Temp - Corr Y Factor - Throw 1

_Constants|Disch Temp - Corr Y Factor - Throw 2

_Constants|Disch Temp - Corr Y Factor - Throw 3

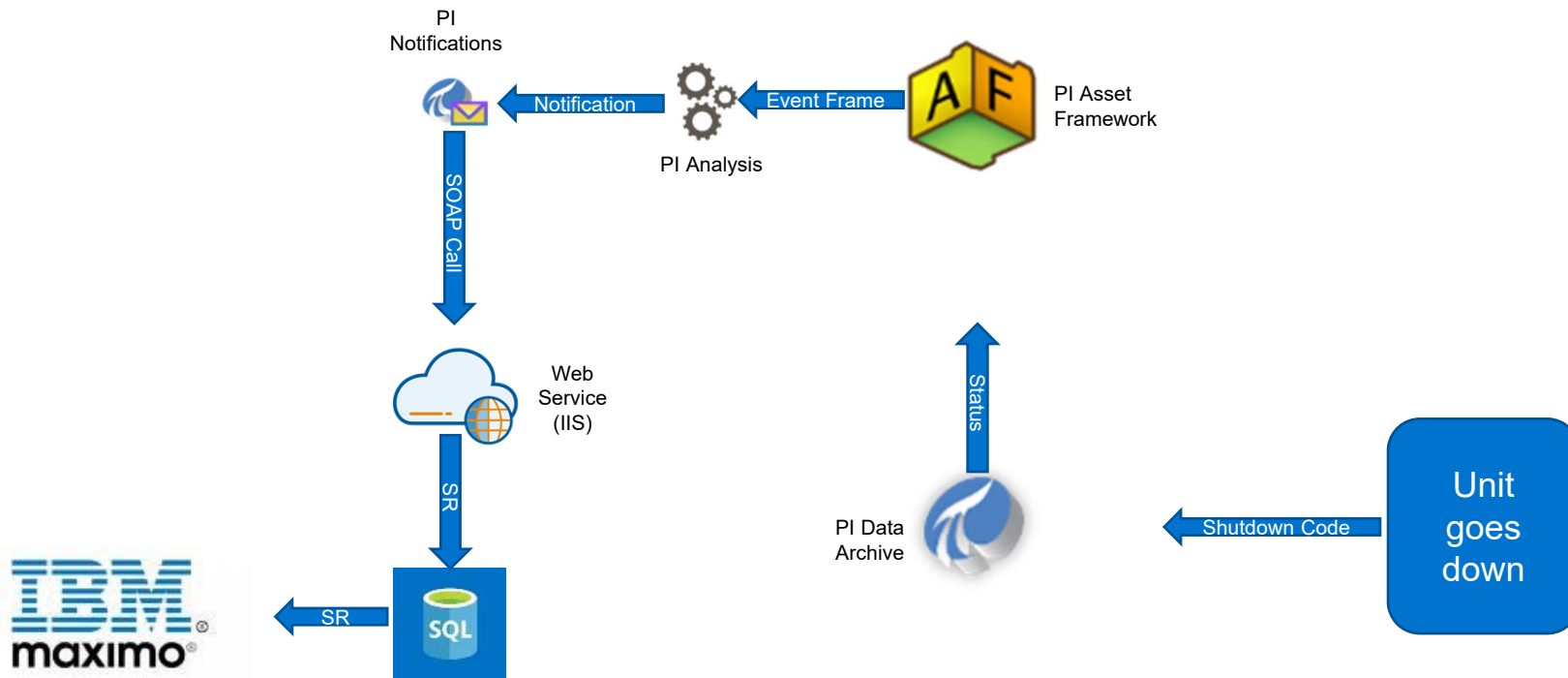
_Constants|Disch Temp - Corr Y Factor - Throw 4

_Constants|Disch Temp - Corr Y Factor - Throw 5

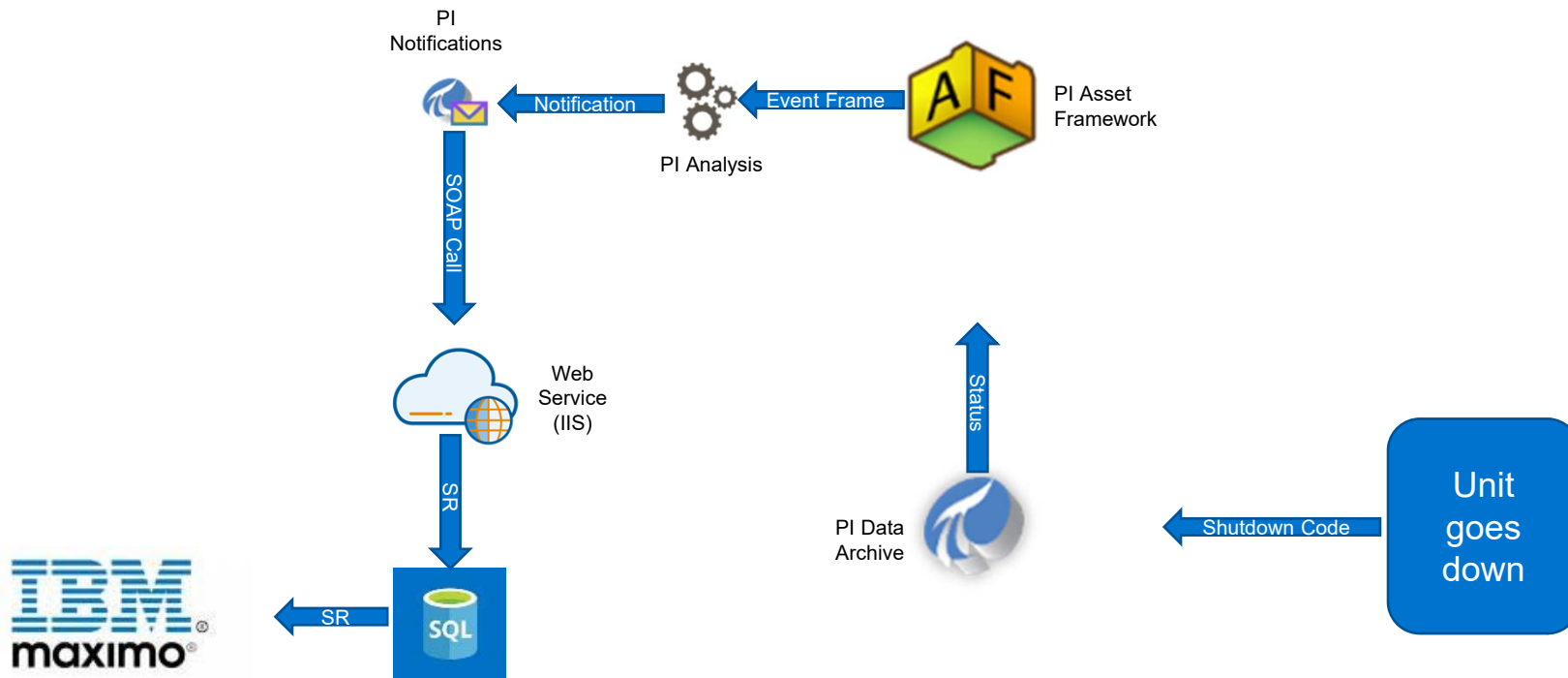
_Constants|Disch Temp - Corr Y Factor - Throw 6

_Constants|Efficiency

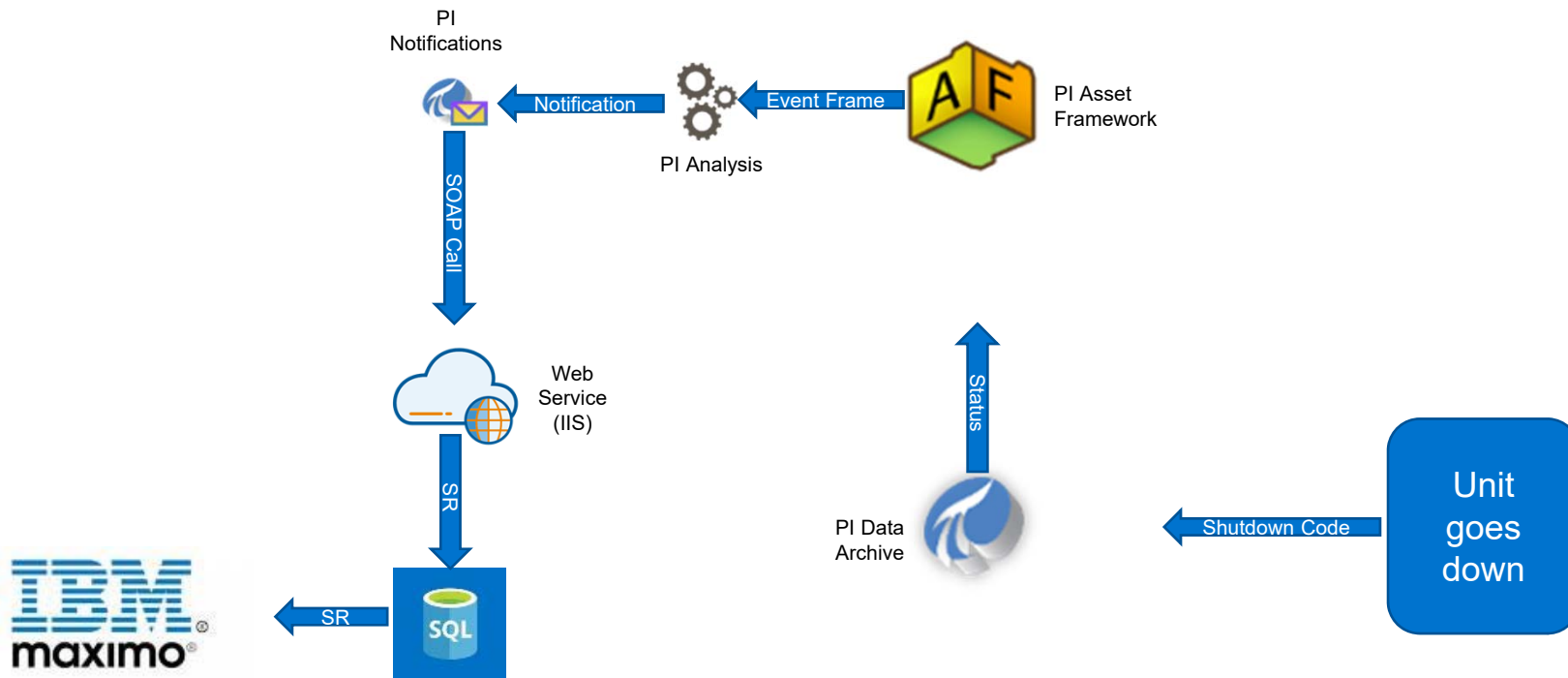
Overview of Integration Process



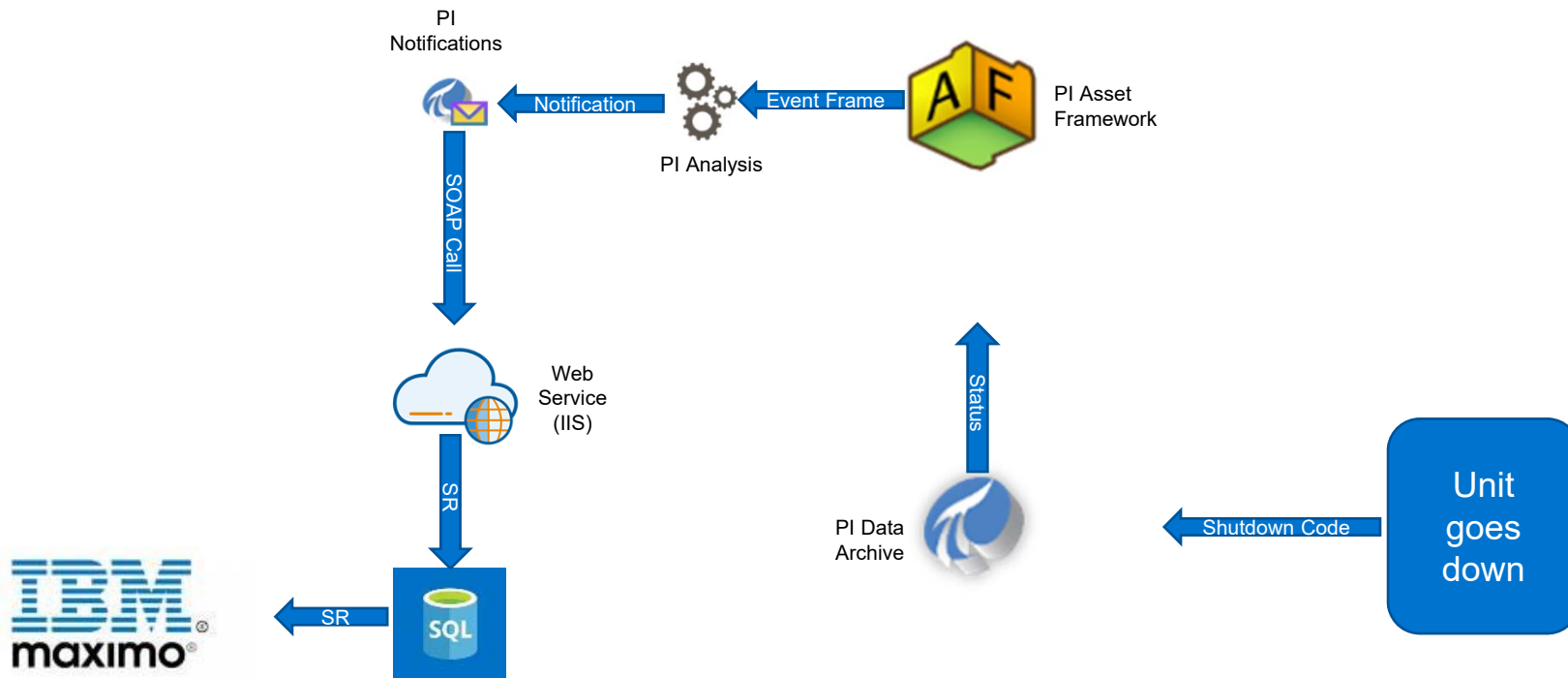
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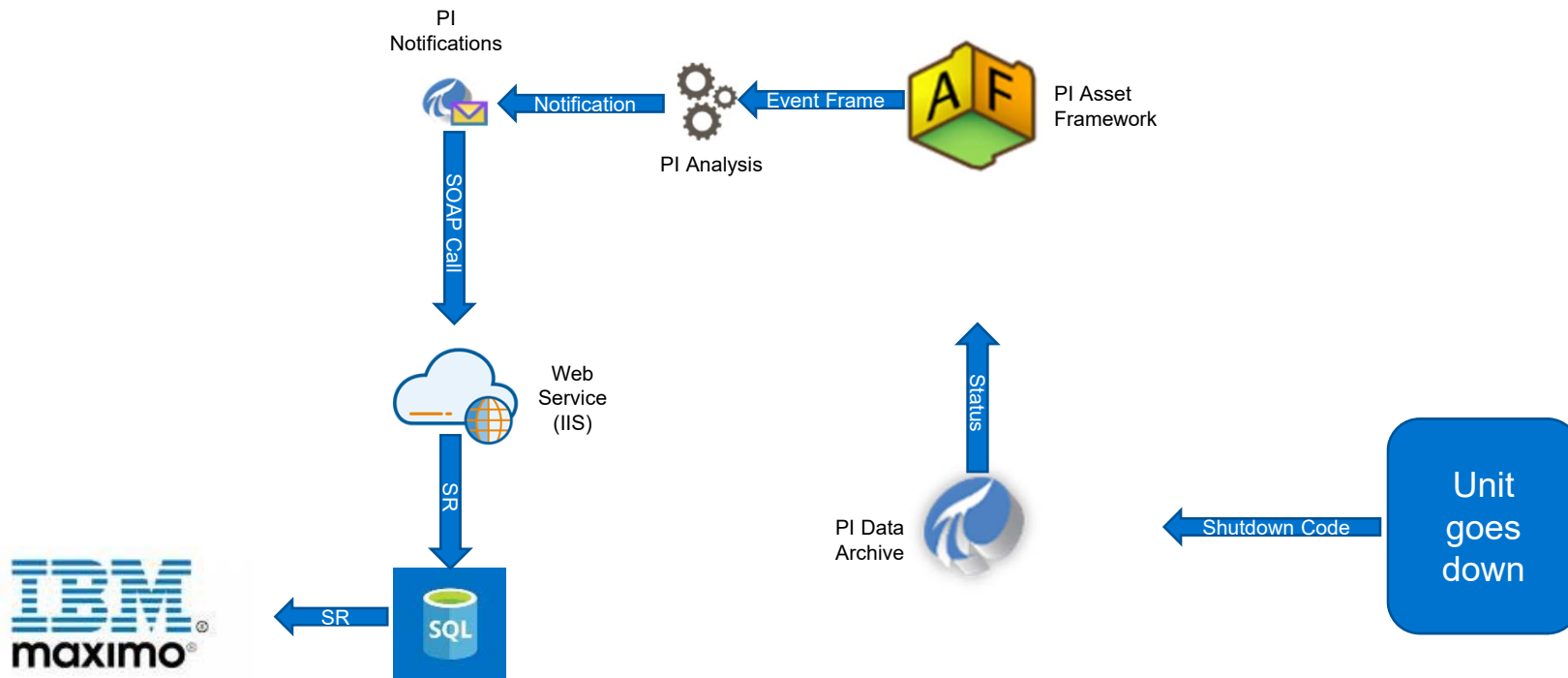
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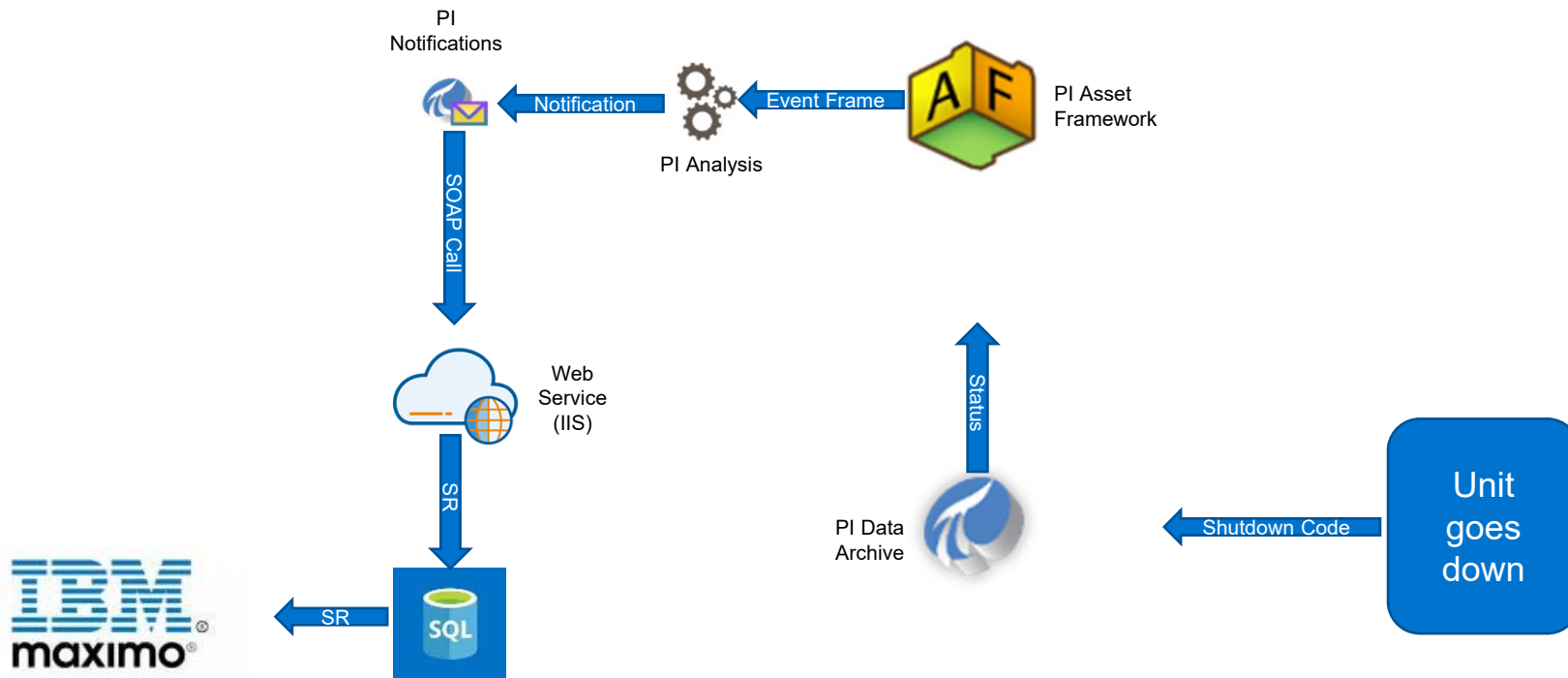
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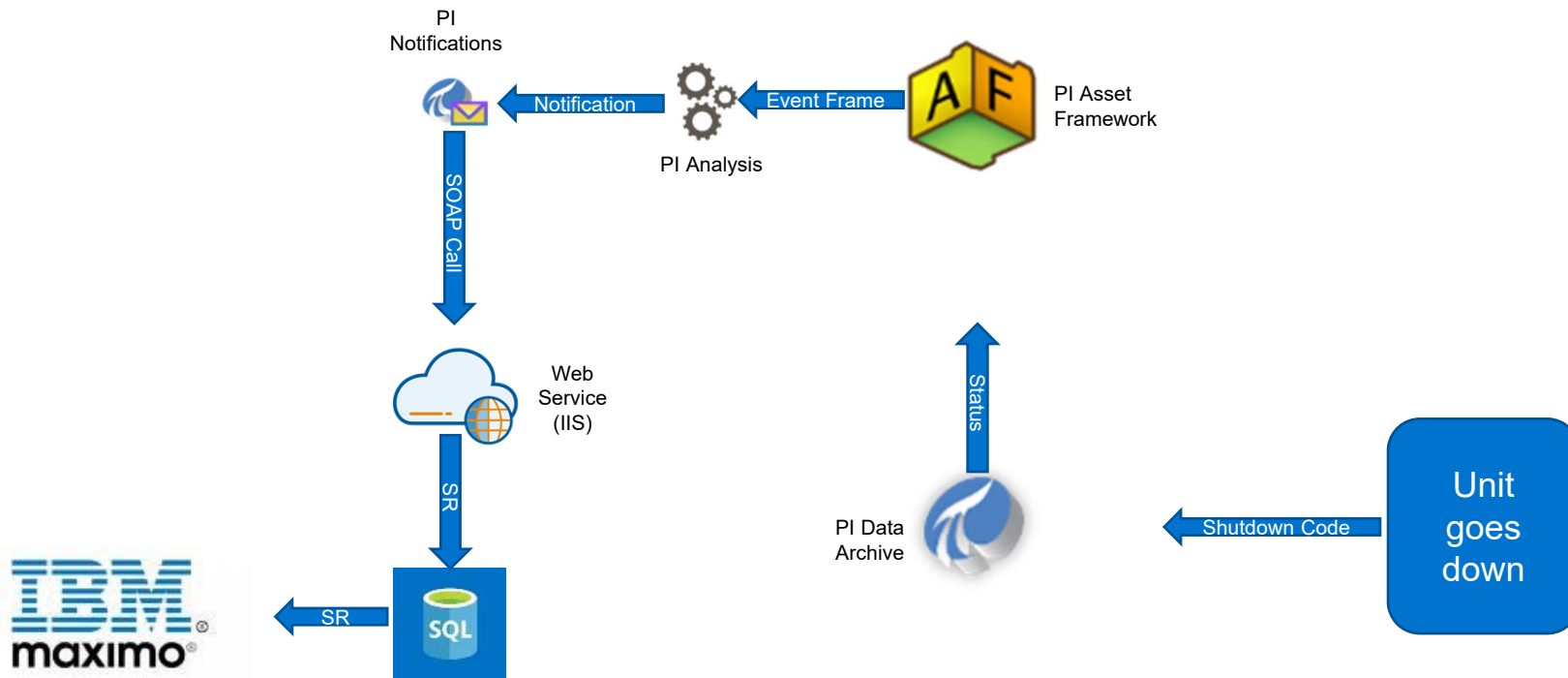
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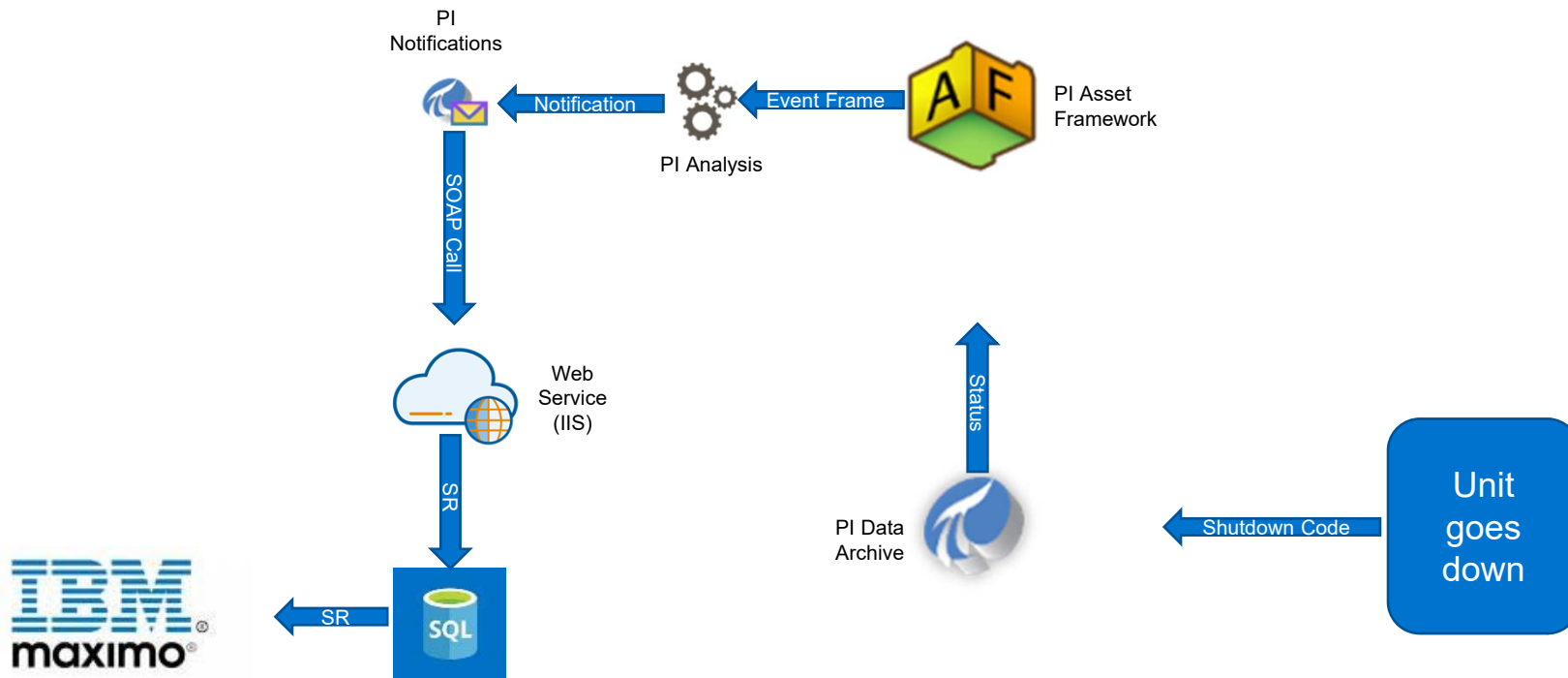
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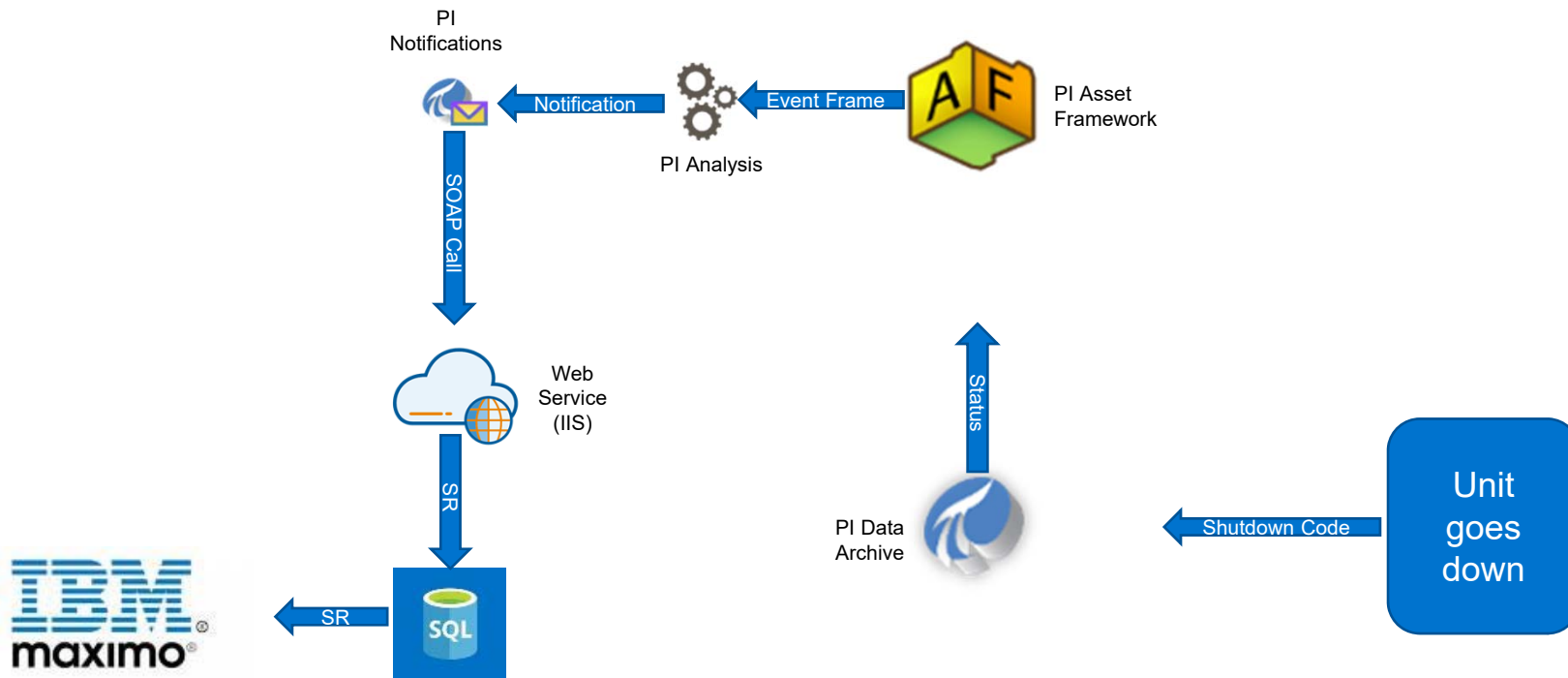
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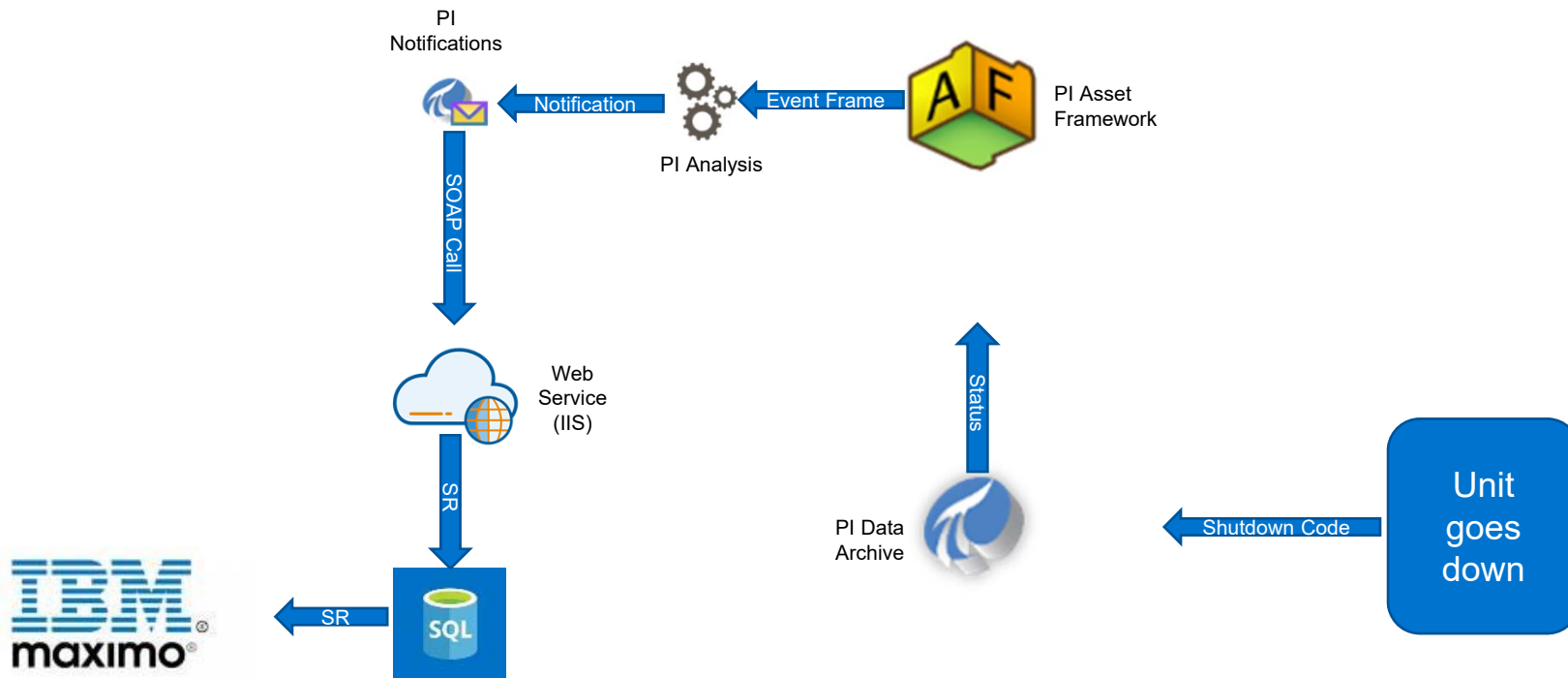
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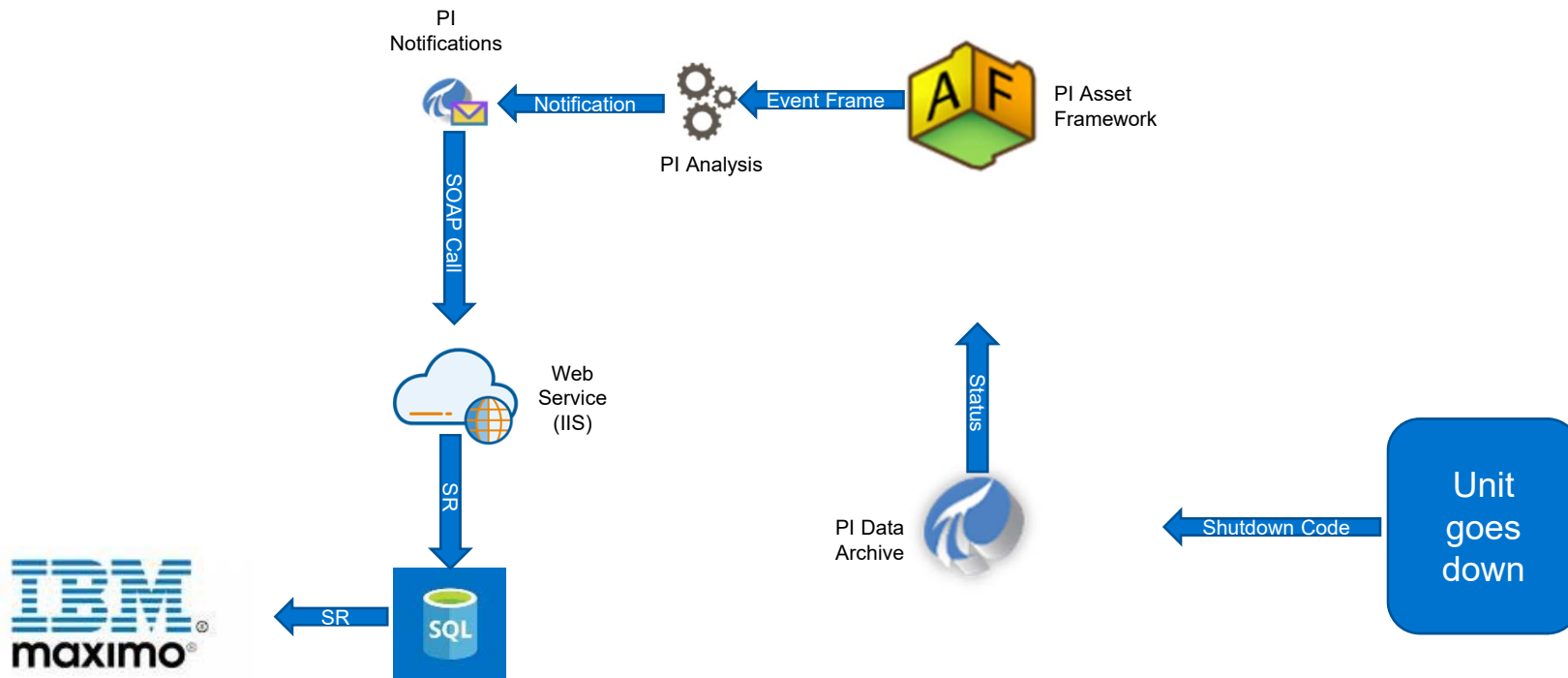
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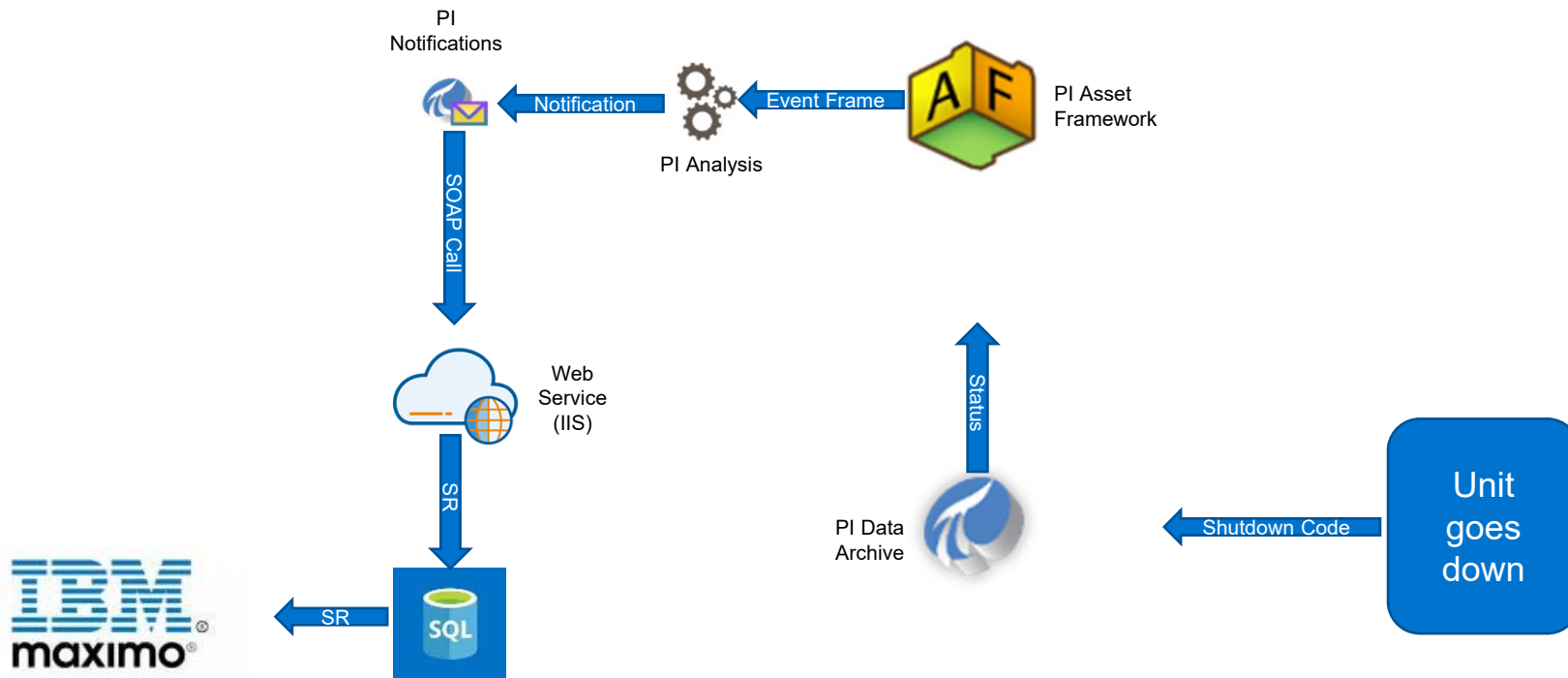
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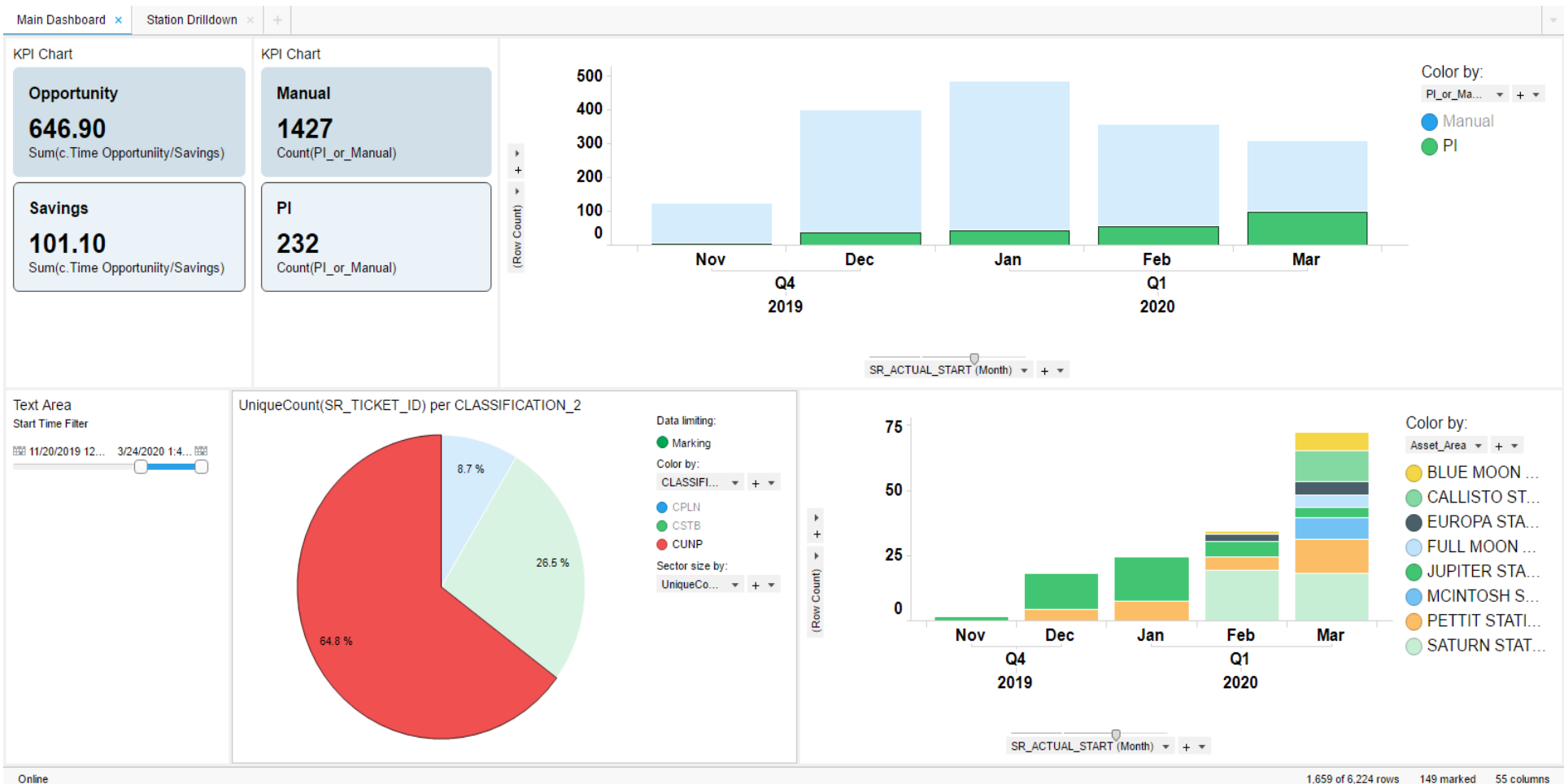


Overview of Integration Process



Overview of Integration Process





Online

1,659 of 6,224 rows 149 marked 55 columns

Challenges and Complications

- Need to run both manual and new process
- Don't break existing reporting
- Culture Change – Subjective process to automated process
 - Training, Reinforcement, Communication



Event Name	Asset	Start Time	End Time
Saturn - Unit 4 - Shutdown Event - Engine - Engine CAT Panel	ENGINE	2/8/2020 10:43:34 AM	In Progress
Saturn - Unit 7 - Shutdown Event - Compressor - Standby	UNIT 7	2/7/2020 5:22:00 PM	In Progress
Saturn - Unit 7 - Shutdown Event - Compressor - Compressor Stopped	COMPRESSOR	2/7/2020 10:35:53 AM	2/7/2020 5:22:00 PM
Europe - Unit 1 - Shutdown Event - Engine - Engine Oil		2/7/2020 4:41:31 AM	2/7/2020 6:21:04 AM
BlueMoon - Unit 5 - Shutdown Event - Compressor - Standby	UNIT 5	2/6/2020 2:12:00 PM	In Progress
BlueMoon - Unit 5 - Shutdown Event - Compressor - Compressor Pressure	COMPRESSOR	2/6/2020 10:06:21 AM	2/6/2020 10:11:33 AM
Jupiter - Unit 2 - Shutdown Event - Compressor - Compressor Stopped	COMPRESSOR	2/6/2020 9:59:00 AM	2/6/2020 3:11:54 PM
BlueMoon - Unit 3 - Shutdown Event - Compressor - Compressor Unplanned	COMPRESSOR	2/6/2020 9:29:15 AM	2/6/2020 10:30:15 AM

Lessons Learned

- Benefit to gas control underestimated
- Email and texts are tough habits to break – work order documentation important
- Communicate, Communicate, Communicate
- Try to eliminate legacy processes
- Utilize PI tools & dashboards to monitor process
- Don't try to get it 100% right the first time (Agile)



Active Compressor Shutdown Events						Completed Compressor Shutdown Events			
Event Name	Asset	A Start Time	End Time	Acknowledgement		Event Name	Asset	Start Time	End Time
Unit 5 - Shutdown Event - Compressor - Stand By	UNIT 5	2/6/2020 2:12:00 PM	In Progress			Unit 1 - Shutdown Event - Engine - Engine CAT Pa	ENGINE	2/6/2020 10:40:30 AM	2/6/2020 12:11:50 PM
Unit 7 - Shutdown Event - Compressor - Standby	UNIT 7	2/2/2020 5:27:00 PM	In Progress			Unit 7 - Shutdown Event - Compressor - Compressor Stopped	COMPRESSOR	2/7/2020 18:35:53 AM	2/7/2020 5:22:00 PM
						Unit 1 - Shutdown Event - Engine - Engine Oil		2/7/2020 4:41:31 AM	2/7/2020 5:21:04 AM
						Unit 5 - Shutdown Event - Compressor - Compressor Malfunction	COMPRESSOR	2/6/2020 18:38:21 AM	2/6/2020 10:11:33 AM
						Unit 2 - Shutdown Event - Compressor - Compressor Stopped	COMPRESSOR	2/6/2020 9:00:00 AM	2/6/2020 1:11:34 PM
						Unit 3 - Shutdown Event - Compressor - Compressor Unplanned	COMPRESSOR	2/6/2020 9:29:15 AM	2/6/2020 10:30:15 AM
						Unit 5 - Shutdown Event - Compressor - Compressor Emergency SD	COMPRESSOR	2/6/2020 8:12:54 AM	2/6/2020 12:26:15 PM
						Unit 3 - Shutdown Event - Compressor - Stand By	UNIT 3	2/6/2020 9:26:00 PM	2/6/2020 9:25:00 AM
						Unit 1 - Shutdown Event - Compressor - Compressor	COMPRESSOR	2/6/2020 9:34:00 PM	2/6/2020 4:01:15 PM

Next Steps

- Continue to roll out to more stations (12 down, 28 to go)
- Continue to refine logic for shutdown classification
- Configure process for Turbines (Centrifugal) Compression



■ Reciprocating ■ Centrifugal



Compressor Shutdown Digital Transformation



CHALLENGES

- Over 5,000 shutdowns managed per year across the fleet
- Non-standardized procedures & somewhat subjective process

SOLUTION

- Utilized PI AF, PI Event Frames, Webservice and Maximo Integration to automate compressor shutdown process

BENEFITS

- Standardized, consistent process across Operations
- Reliable Shutdown Data
- Eliminated ~100 hours of Gas Control administrative time
- Improved understanding of shutdowns to enhance ability to prevent



The Compressor Shutdown Process will help us to digitally transform our operations and supports our objectives of optimizing operations and acting with fiscal discipline.



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