



ARCHIVE EDITION

How Digitalisation is Driving Remote Condition Monitoring of Plant Assets

Complex plants, remote location, continuous operation

Suprit Pal Singh

Talk at the ARC seminar, 9 December 2021, for PT Panca Amara Utama (ESSA Group)

ARC DTC Asia Webinar-DECEMBER 2021 Edition
An End Users' Specific Event

"How Digitalization is Driving Remote Condition Monitoring of Plant Assets"

December 9th, 2021

India: 1:30 PM-2:30 PM (IST)

Thailand: 3:00 PM-4:00 PM (THA)

Singapore: 4:00 PM-5:00 PM (SST)

China: 4:00 PM-5:00 PM (CST)

Japan: 5:00 PM-6:00 PM (JST)

Australia: 7:00 PM-8:00 PM (AEST)



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ARC Advisory Group's Digital Transformation Council (DTC) seeks to enable industry, energy, and public sector professionals driving or impacted by digital transformation to keep abreast of the many emerging technologies and business trends, to learn from others on similar journeys, and to leverage these trends and technologies to achieve transformational growth.

Coordinators:

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How Digitalization is Driving Remote Condition Monitoring of Plant Assets

Complex Plants , Remote Location , Continuous Operation

PT Panca Amara Utama (ESSA Group)
(9th December 2021)

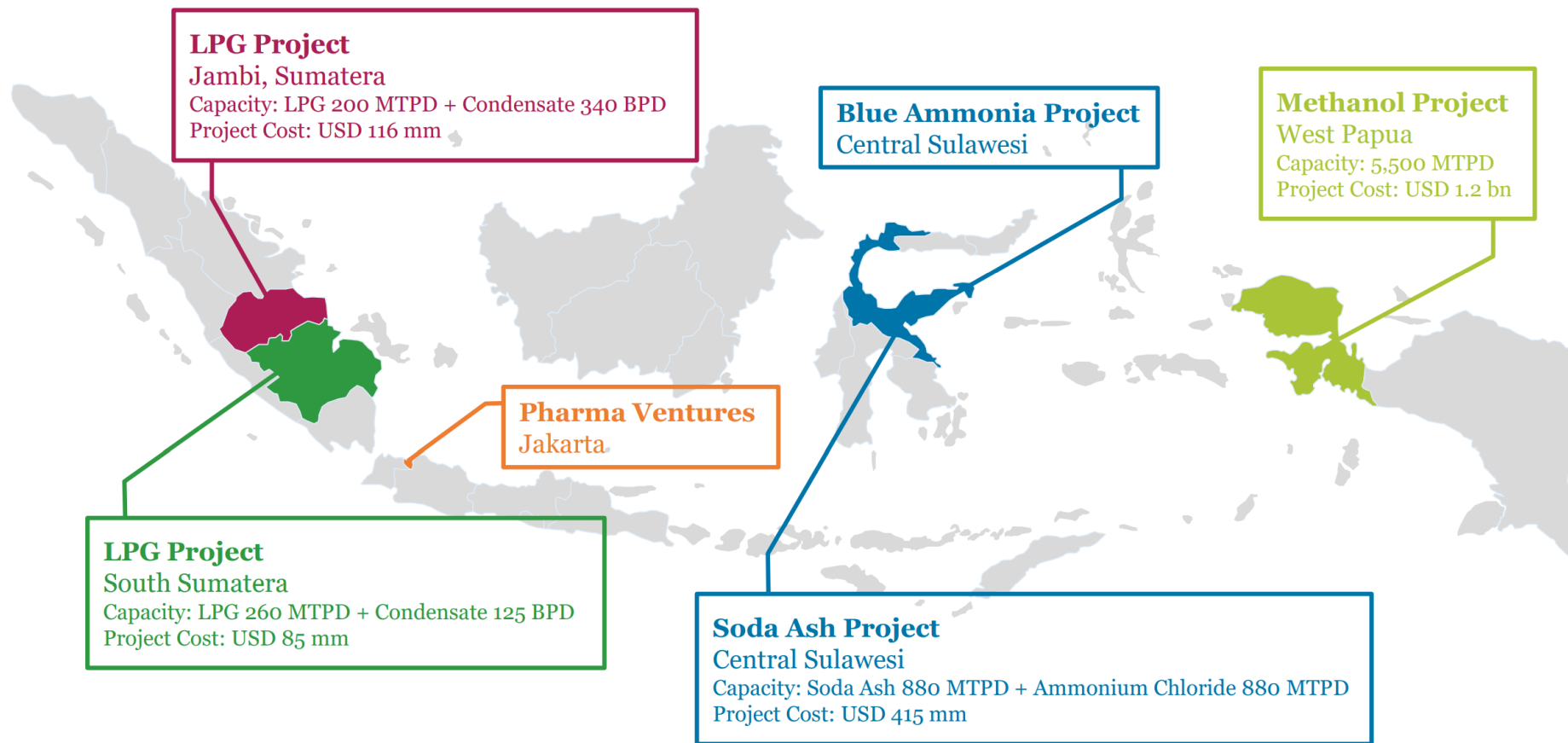


Agenda



- 1. The Basics - Company Introduction - Monitor or Parish**
- 2. The Pyramids and Timings – Know your Resolution**
- 3. Diagnostics to Prognostics – Know Before you Break**
- 4. Sensors – Small is Beautiful and Powerful**
- 5. The Data Conduits & Batteries – The Exquisite Ballance**
- 6. Remote Monitoring & Cloud - The marriage in Air , On-shore , Off-shore & Undersea**
- 7. Analytics and Methods - How is Real is Artificial Intelligence**
- 8. Uniquely Remote examples – Under the Sea and On Islands**
- 9. The Digitalised Maintenance Future – The Heart of Vibration and Pulse**

New Projects in Indonesia currently Pursued



ESSA gp. is actively pursuing new projects in Indonesia

PT Panca Amara Utama : Remote Location Plant



Luwuk Airport is Nearest. Luwuk is 30,000 population small Town

PT Panca Amara Utama – Flagship of ESSA Group

- 1. PT Panca Amara Utama (“PAU”) is a 700,000 metric tons per annum (MTPA) capacity greenfield ammonia plant in Batui District, Banggai Regency, Central Sulawesi, Indonesia (“Project”). Promoted by ESSA with Mitsubishi Gp. and Adaro Gp.**
- 2. Natural gas for the plant is supplied by Senoro-Toili gas fields, operated by JOB Pertamina-Medco E&P Tomori Sulawesi. Plant in operations from first quarter 2018. PT Rekayasa Industri, a national contractor was sole EPC Contractor for the project.**
- 3. PAU received debt financing arranged by the International Finance Corporation (“IFC”, member of the World Bank Group). The syndication includes seven international banks such as ANZ, HSBC, KDB, OCBC, SMBC, Standard Chartered and UOB. IFC also holds an equity position in PAU in the form of a subordinated loan. This represents the IFC’s largest greenfield project funding in Asia over the last decade.**
- 4. Technology for the plant has been licensed from Kellogg Brown & Root (USA), and PAU is the first in the world to apply KBR’s patented KRES + Purifier technology together. leading edge Technology with various innovations to be most energy efficient.**
- 5. PT Panca Amara Utama (PAU) is a 60% subsidiary of Indonesia’s largest private LPG refiner, PT Surya Esa Perkasa Tbk. (ticker: ESSA).**

PT PAU is the largest Exporter of Liquid Anhydrous Ammonia from Indonesia

Plant with Many Firsts , Including some in Data Handling



- 1st in Indonesia with 100% LED Lighting.
 - 1st in World with DTS Based ammonia Remote Leak Detection System (with Yokogawa)
 - 1st in Indonesia with Top End Temp. and Pressure Transmitters from Yokogawa
 - 1st in Asia using KRES + Purifier technology from KBR , 1st in Asia to use Insite KBR Remote Plant Monitoring
 - 1st in Indonesia with Super Duplex Sea Water Pumps
 - 1st In Indonesia with Under-Insulation Corrosion Resistance Paints on Piping
 - 1st in Indonesia with 100% Local EPC and Detailed Engineering (PT Rekayasa Industry)
 - 1st in World to use Aquamodems for pulse Flowmeter data acquisition with remote monitoring
 - 1st in World to use Tidal Depth Level Measurement with Remote Data Acquisition , Cloud Dashboards
- One of the Largest IFC (World Bank) funded Project in SE Asia in 100% Private Sector.

The Plant @ Remote with Usual Head Aches



Usual Integration Head Aches

- a) Control Systems DCS
- b) HSE Systems
- c) Utilities not on DCS
- d) Operations Systems not Integrated
- e) Cost Systems Opaque
- f) Production Planning not Integrated
- g) ERP Systems Direct Data Pick up missing
- h) Asset Management Systems Discrete from DCS
- i) Several Metered Data Manually Input for Reports

3000 +/- I/o DCS Systems Yokogawa with Exa Quantum Server
1000 +/- Pressure & Temp Transmitters
1200 +/- Control Valves , 3000 Manual Valves , 300 +/- Pumps , 500+ Motors
10,000 Ton Piping
128 Tons / Day Boilers, Steam Systems , 5 large Compressor Systems , 5 Large Critical Pumps
24 Mwe Captive Power Plant , Steam Turbines and Gas Engines
Large Deslination Plant with 3 Trains
Larges Sea Water Intake , Chemical Injections , Flow Meters , Catalyst Management
Dedicated Jetty , Civil Structures , Reactors and Vessels
Large Cryogenic Tank Storage etc etc.

Target is to have Digitised Remote Monitored Plant. HO is 3 hrs Flight Away @ Jakarta

Remote Condition Monitoring

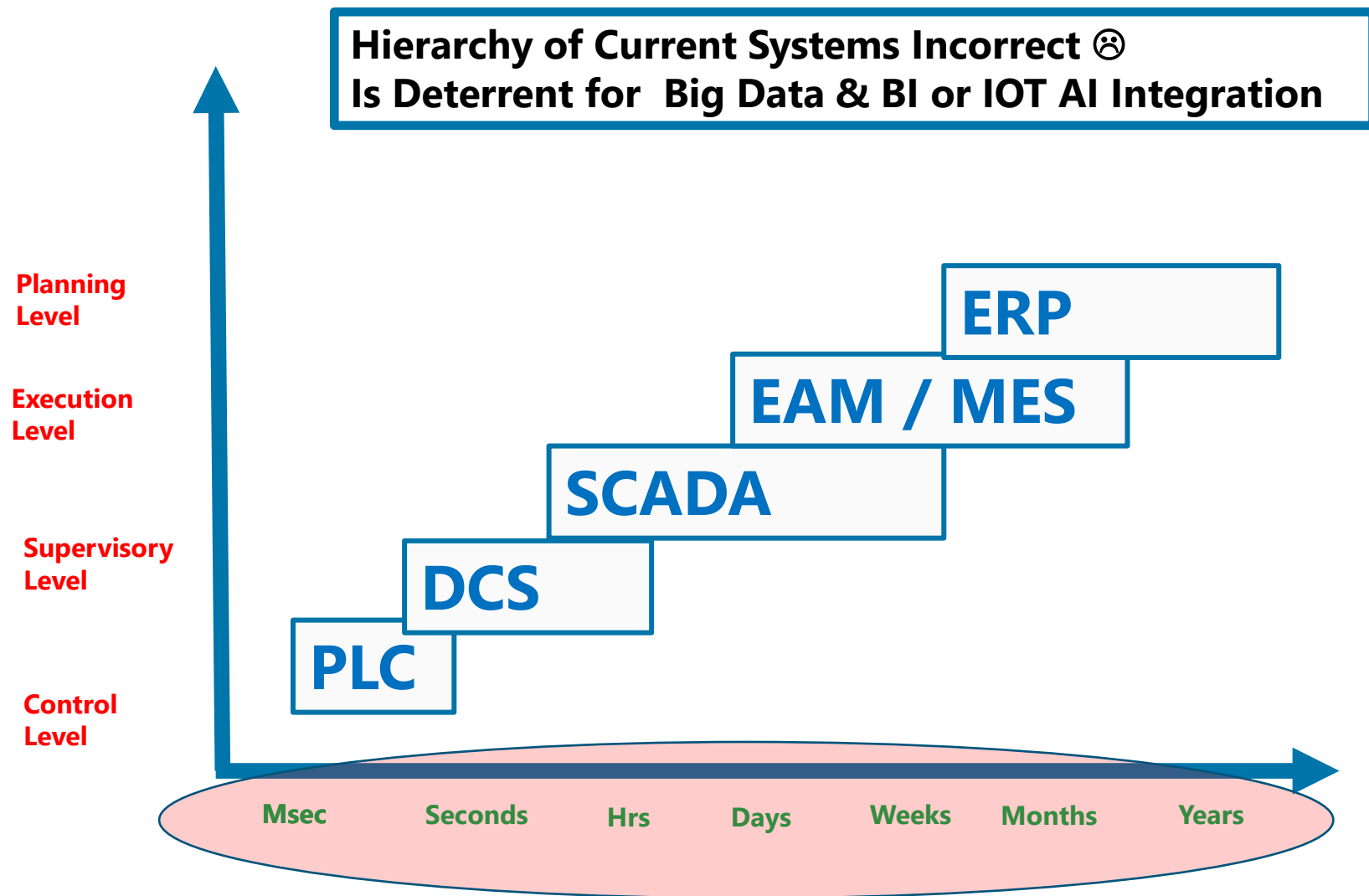
- 1. **Data acquisition (information collecting)**, to collect the analogue data of the working conditions from machines and convert the data to the digital data.
- 2. **Data Processing (information handling)**, to convert the digital data to real quantities of working conditions of machines.
- 3. **Decision-making (fault diagnosis and/or system control)**, to determine the nature of the machine fault when it is detected, analyze with Rules: Human/ AI / ML / Rules- Empirical or First Principles , recommend efficient maintenance policies, and take appropriate measure such as a control.
- 4. **Decision-Communication (Remote or In-situ)** , to transmit data/information, such as machine's operation status and alarm conditions, through the network.

Key: IOT, Cloud, Wireless Sensor, Remote Monitoring , Reaction Time, Acquisition Time

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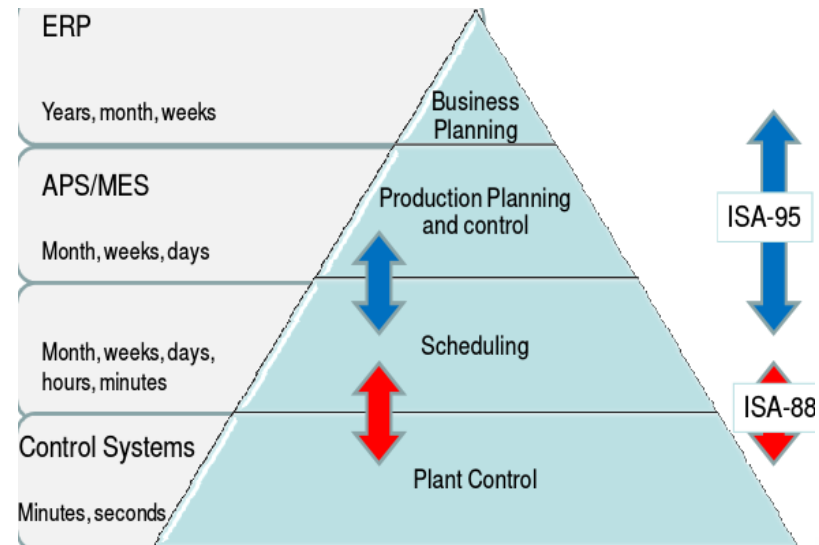
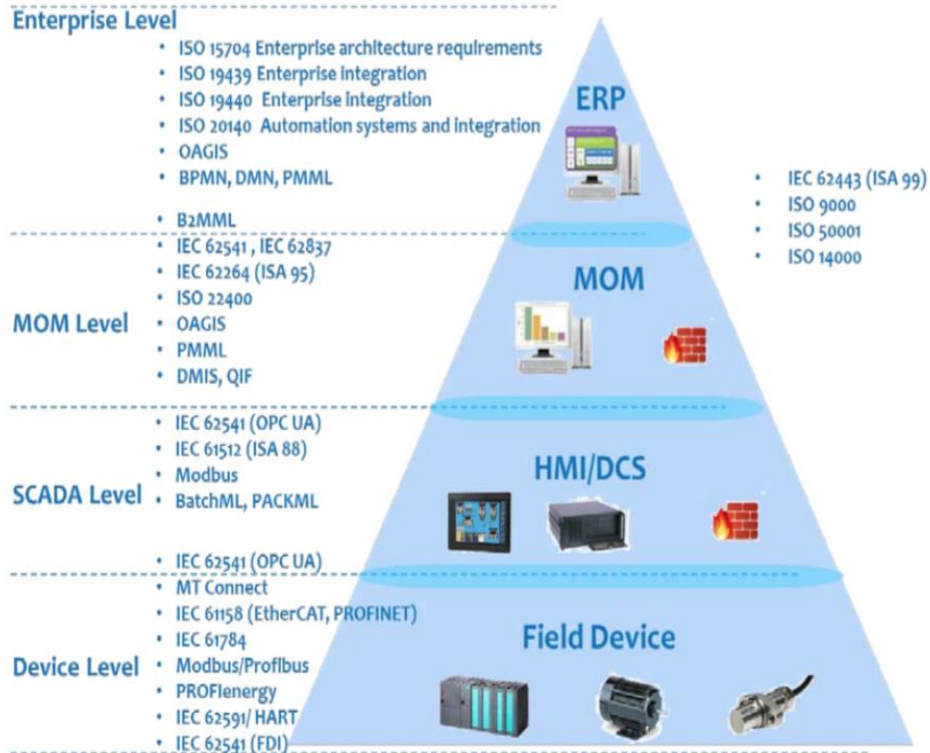
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How to Digitise the PT PAU Plant ?

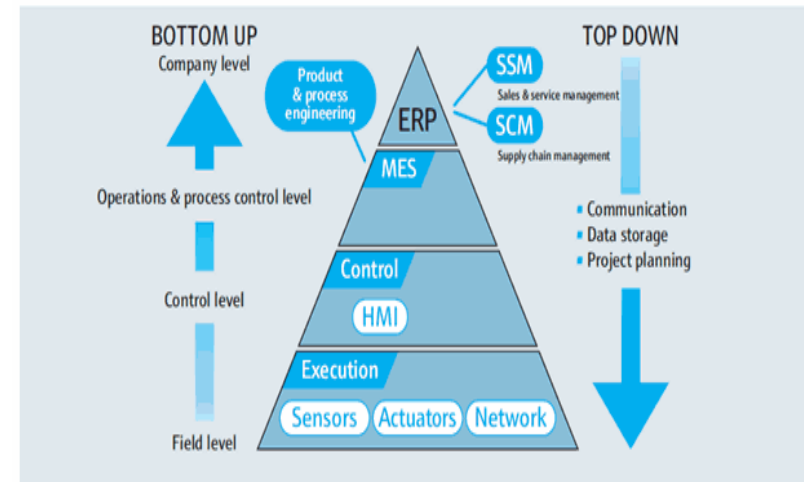


PT PAU divides its Data Between different Levels and makes Protocols for Interchange

The Pyramids of Data Acquisitions

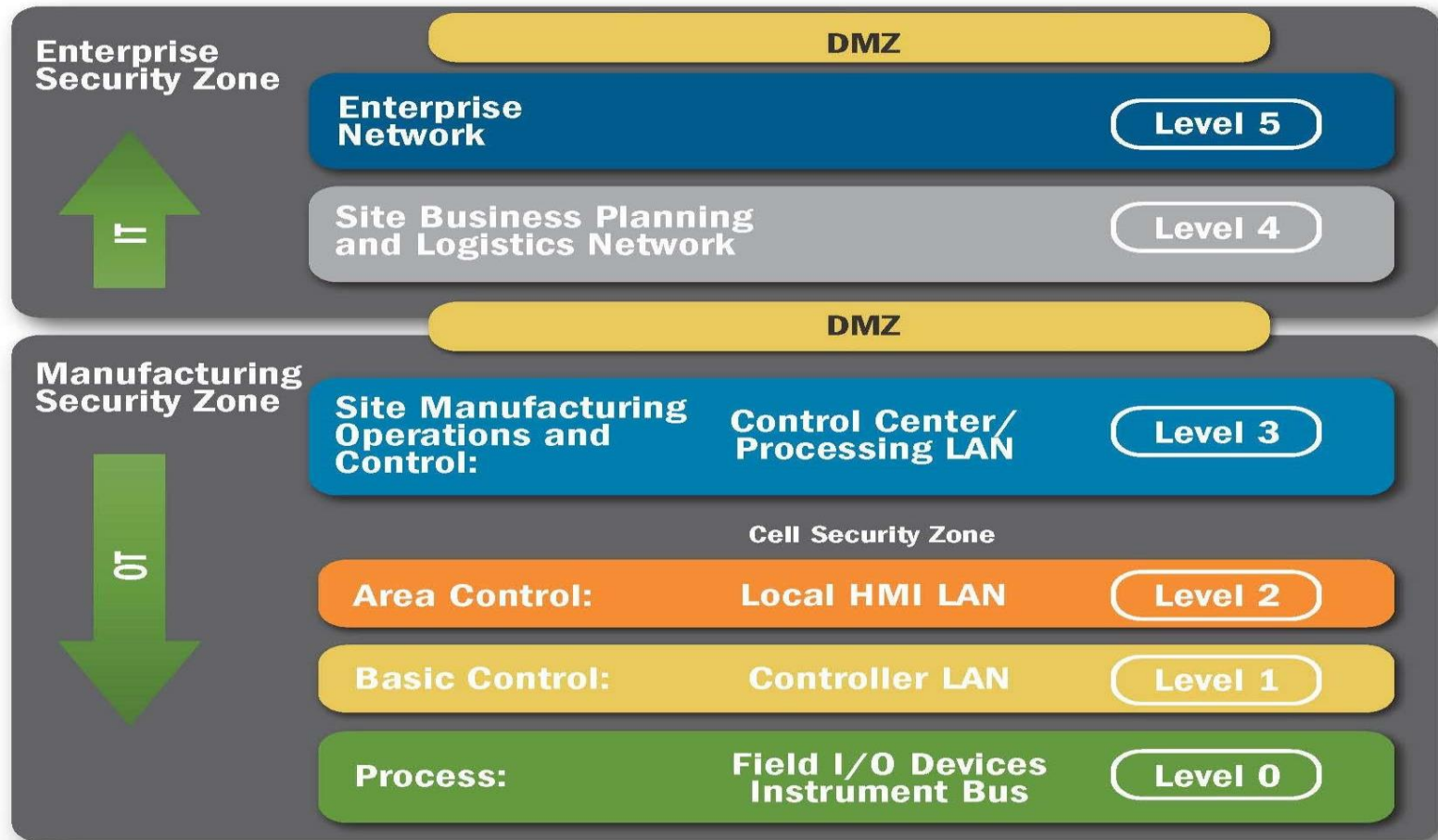


ISA 95 Informatiemodel



Server update Timing Needs for Data Acquisition & Standards Adhered to by PT PAU

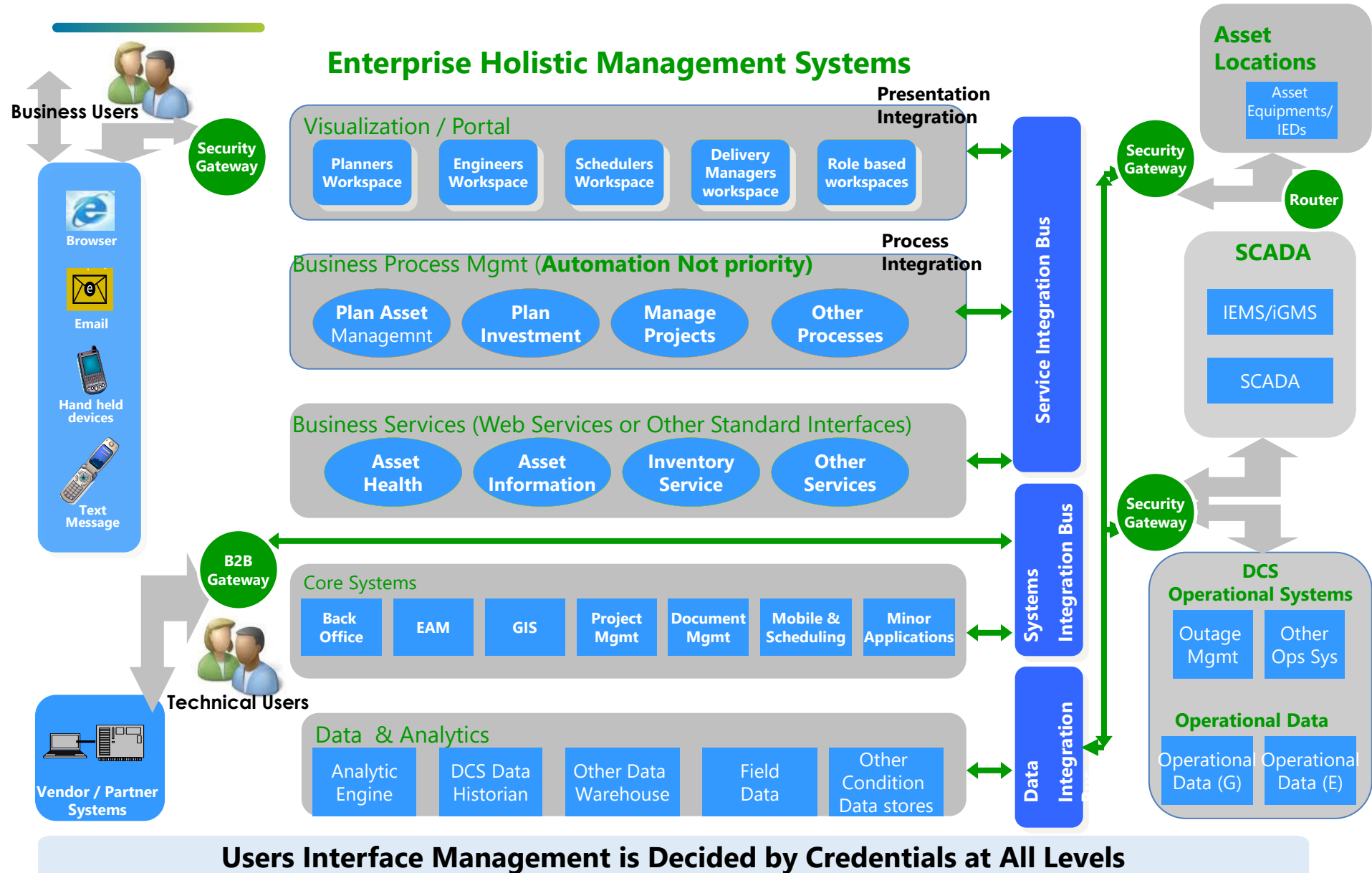
Data Security View



Department of Homeland Security (DHS) National Cybersecurity and Communications Integration Center (NCCIC) and Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) Recommended Practice: Improving Industrial Control System Cybersecurity with Defense-in-Depth Strategies

Different DMZ Zones for Data Security at PT PAU-Follow Dept. of Homeland Security Protocols

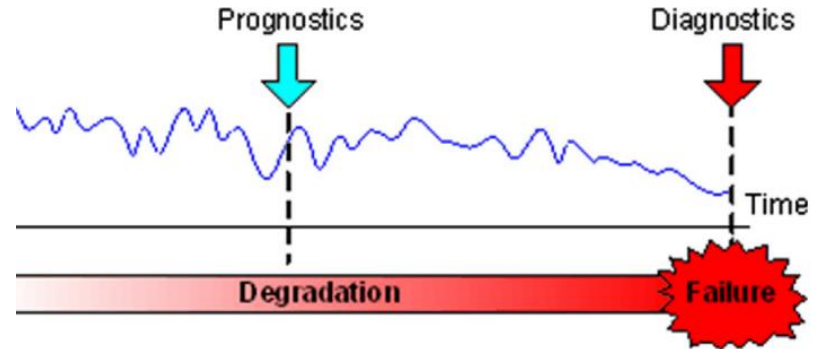
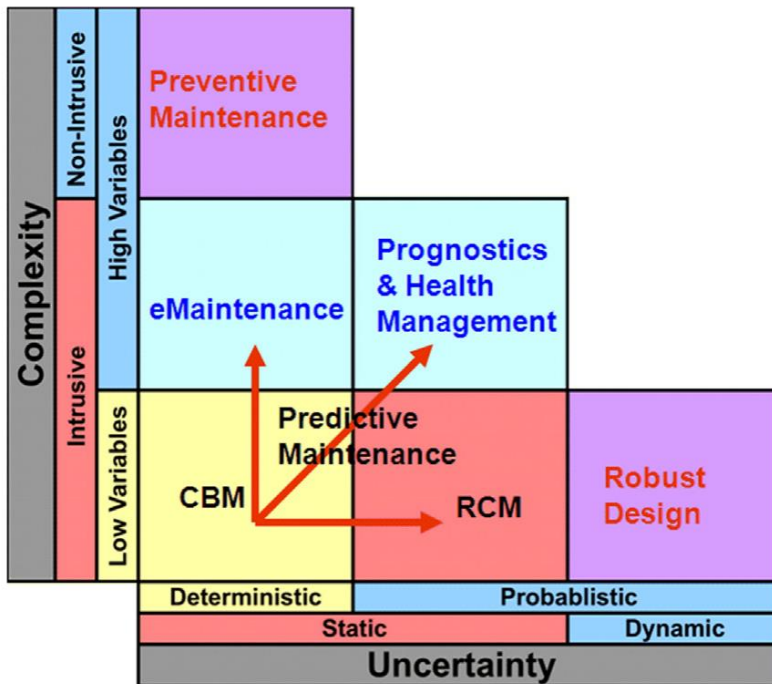
Current Complexity



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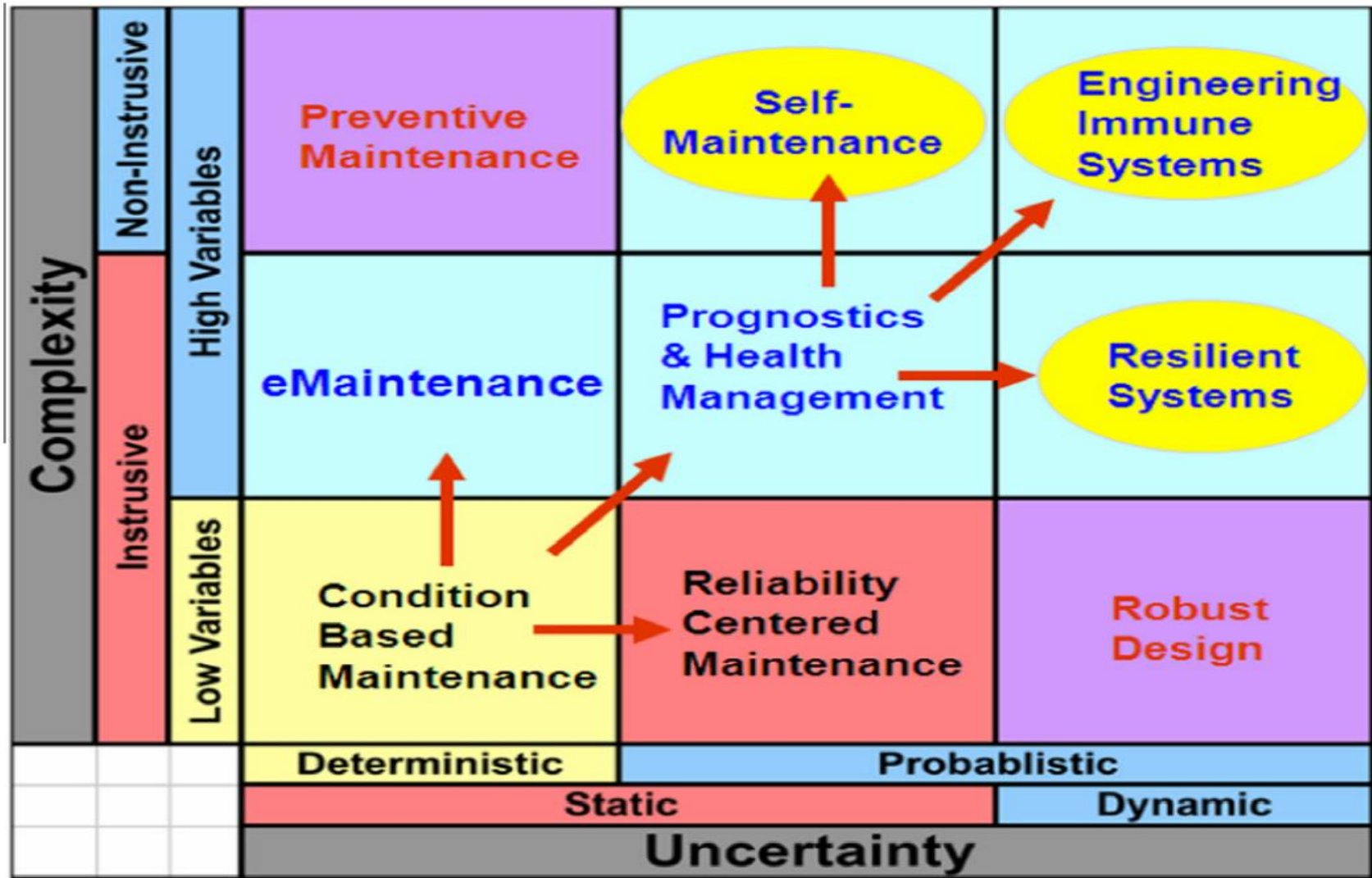
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PT PAU Targets for Future



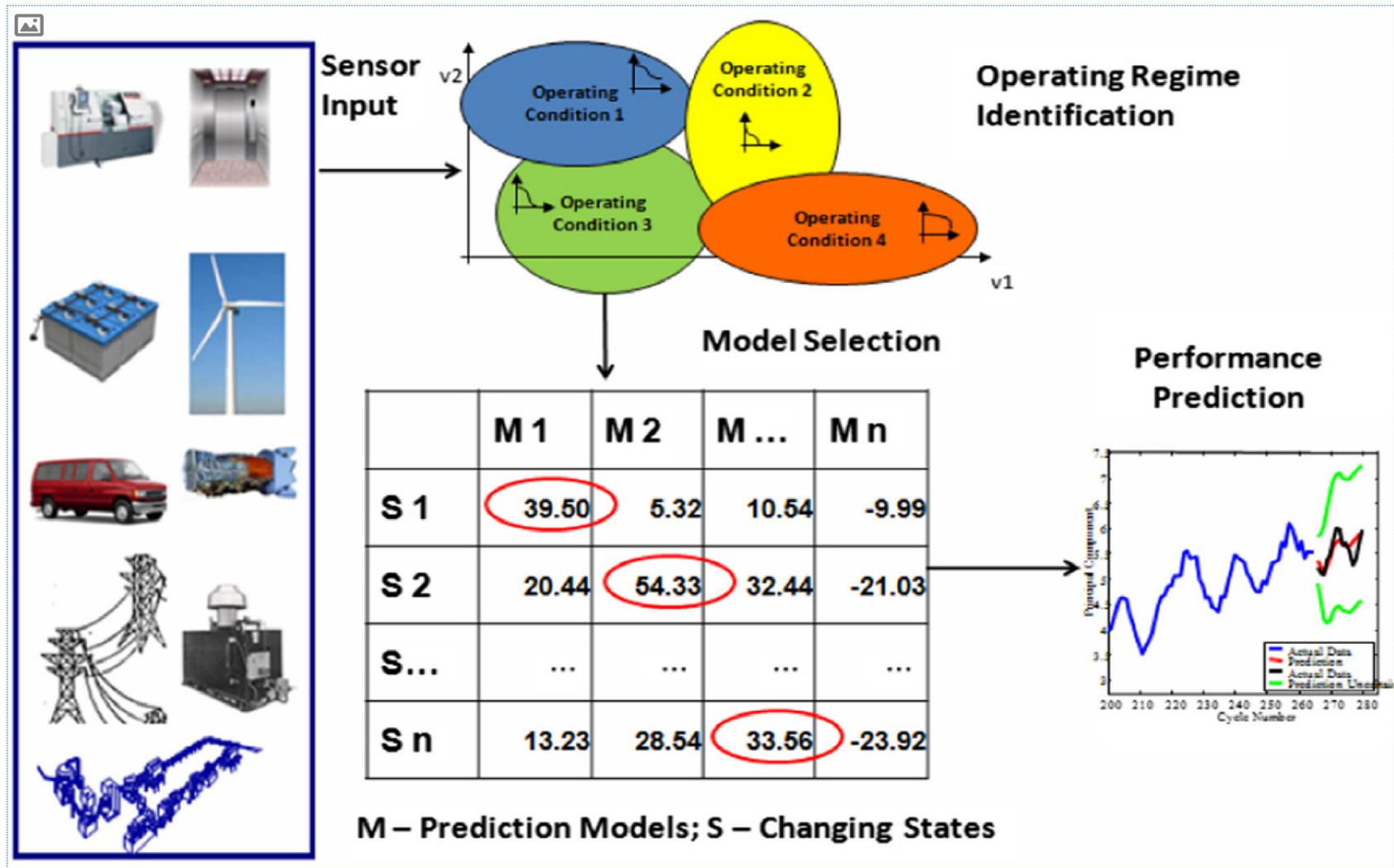
Predict Failure to Maximum Level Before & Prepare Logistics/Technical Solutions

Maintenance Regimes (Past , Present & Future) for PT PAU



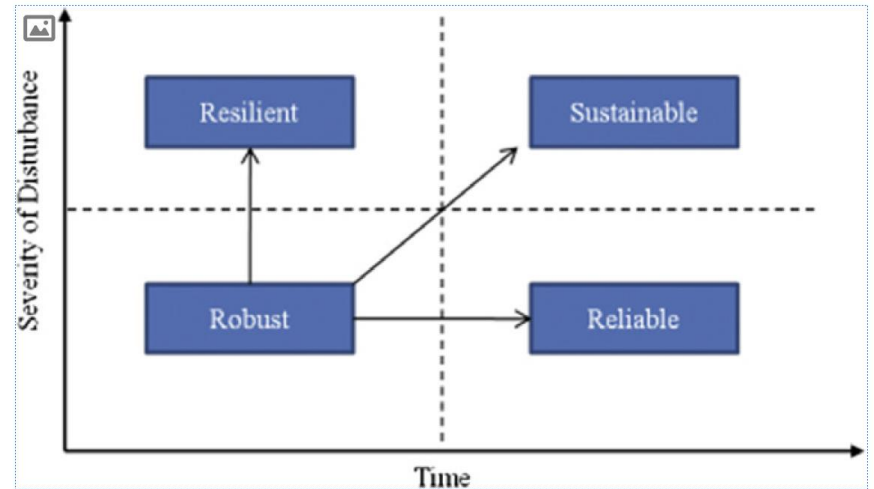
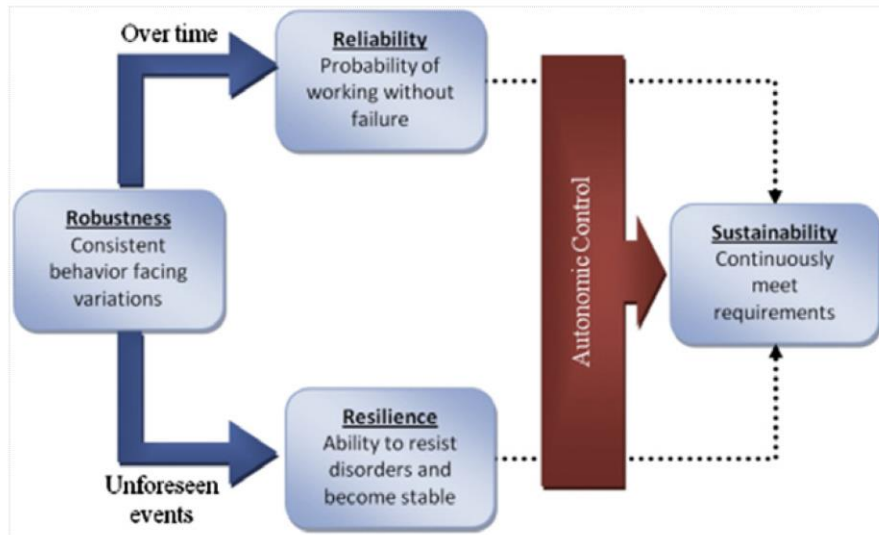
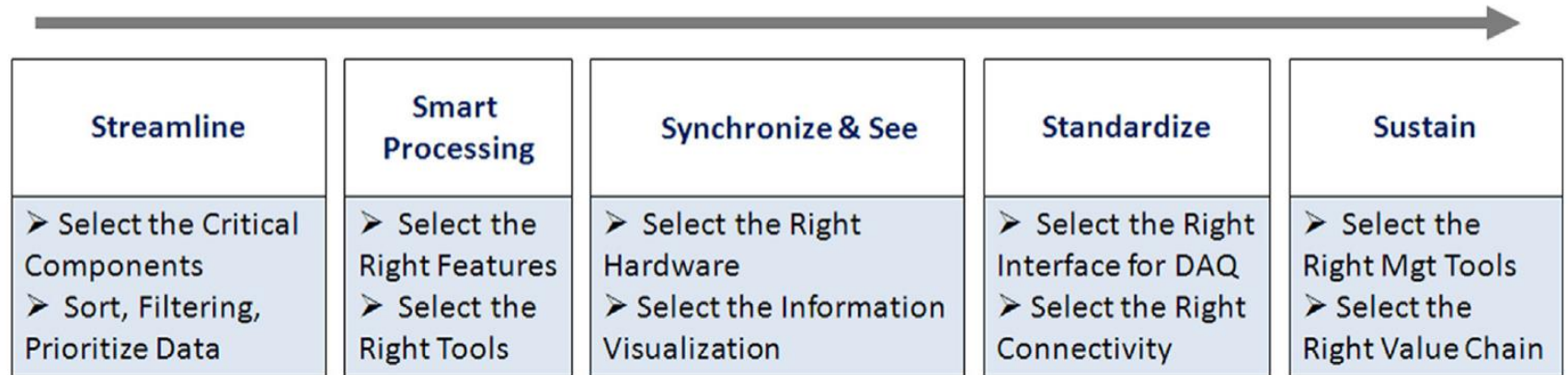
The Plant should have a degree of Engineering Immunity to Failures

The Immunity is Based on Operating Conditions



Each Operating Condition Band requires and dictates a Window of Reliability

Autonomous Health Monitoring



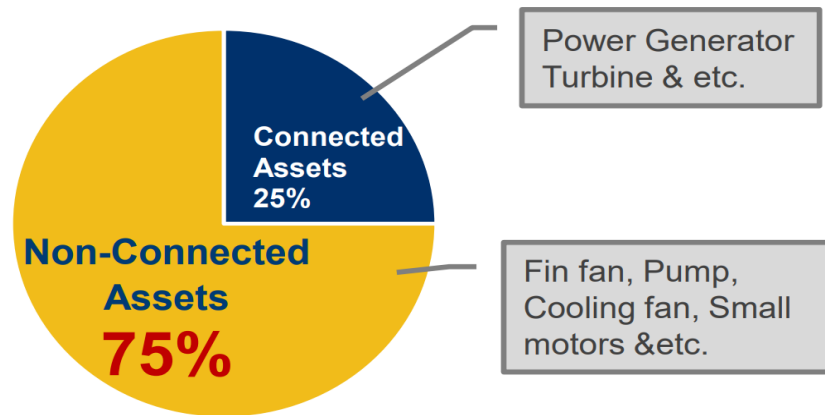
Delicate Balance of right kind of Data Acquisition and Analysis

Agenda

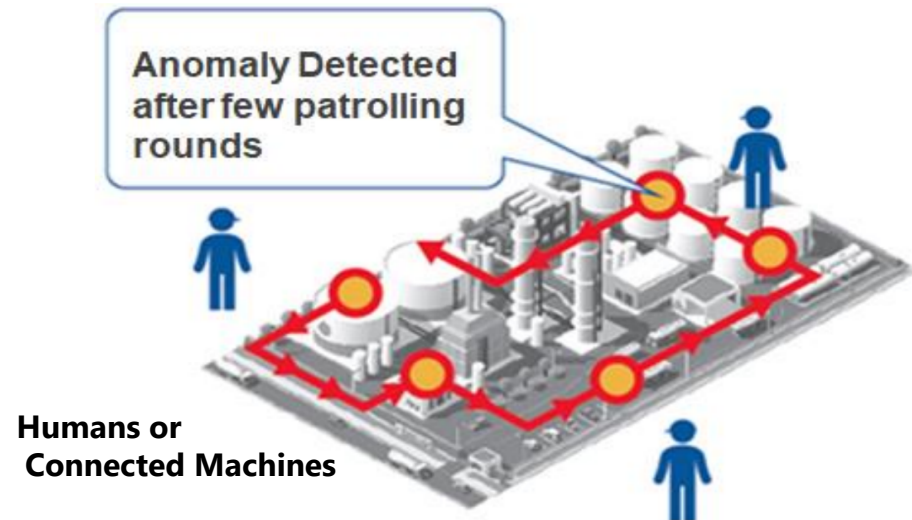
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Need More Economical Sensors , To Connect Everything

Every Plant has assets & managing these assets efficiently is directly proportional to industrial yield & profitability



Source: Frost & Sullivan 2018



- (1) Use the IIoT to automatically measure the state of facilities and continuously collect and record digitized measurement data.
- (2) Use AI to analyze changes in data, objectively judging the tendency of equipment degradation, and proposing effective measures.

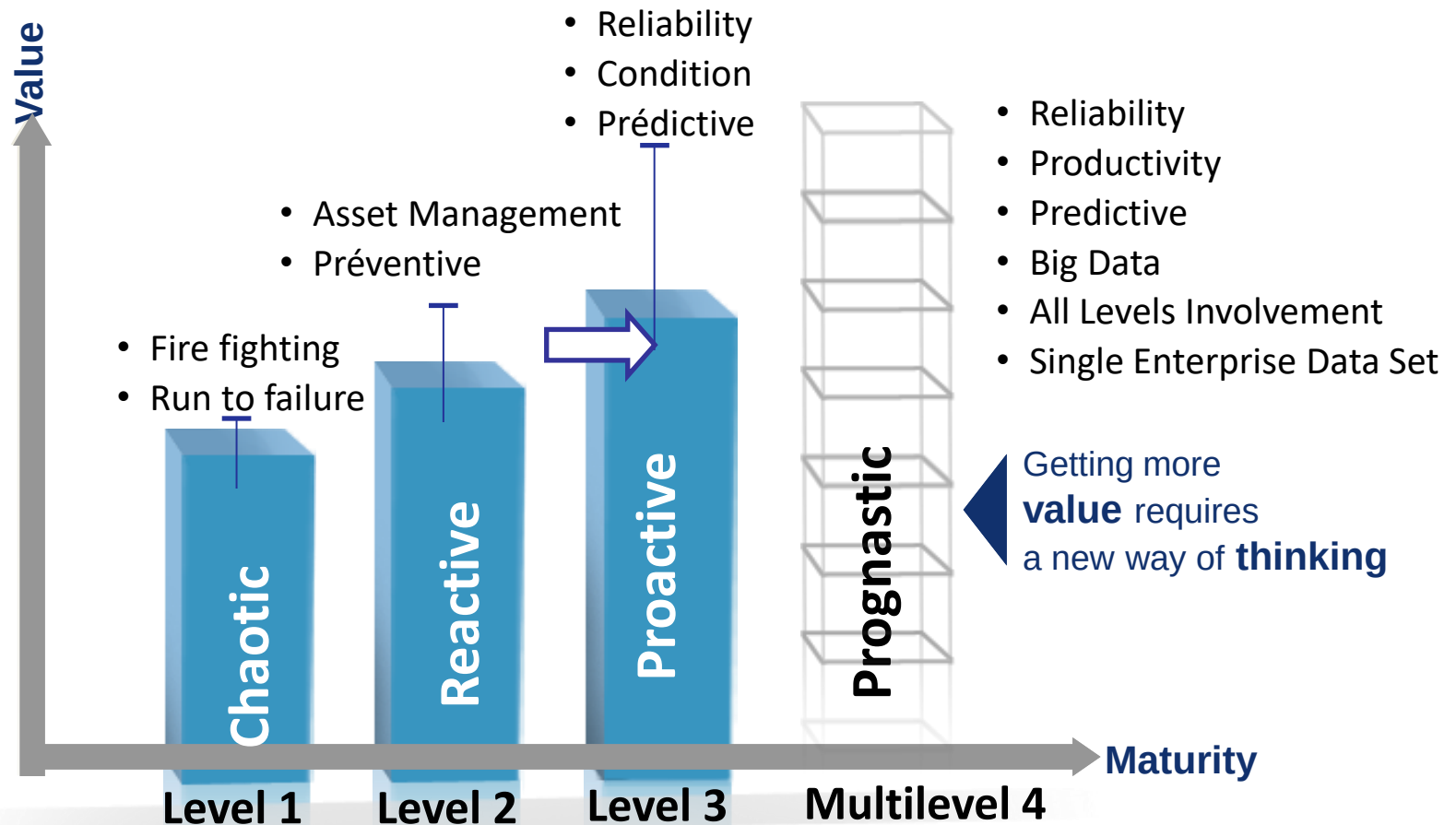
Related Customer Concerns;

- ◆ Missing Anomaly
- ◆ Too many equipment to check
- ◆ Know-how & inspection skills
- ◆ Incidents at aging plants
- ◆ Shortage of field patrol frequency
- ◆ Tremendous amount of Data
- ◆ **Value / Outcome**

From Single Asset Based Monitoring to Whole Plant Monitoring ??

Asset Monitoring Maturity Levels

Strategic aim is to be the foremost – PT PAU wishes to be much ahead in EAM Maturity as compared to global landscape. Start Ab –Initio at a Maturity Level 2 and aspiring to go beyond Level 3 and Interconnected Meshed Enterprise Asset as well as Productivity Management

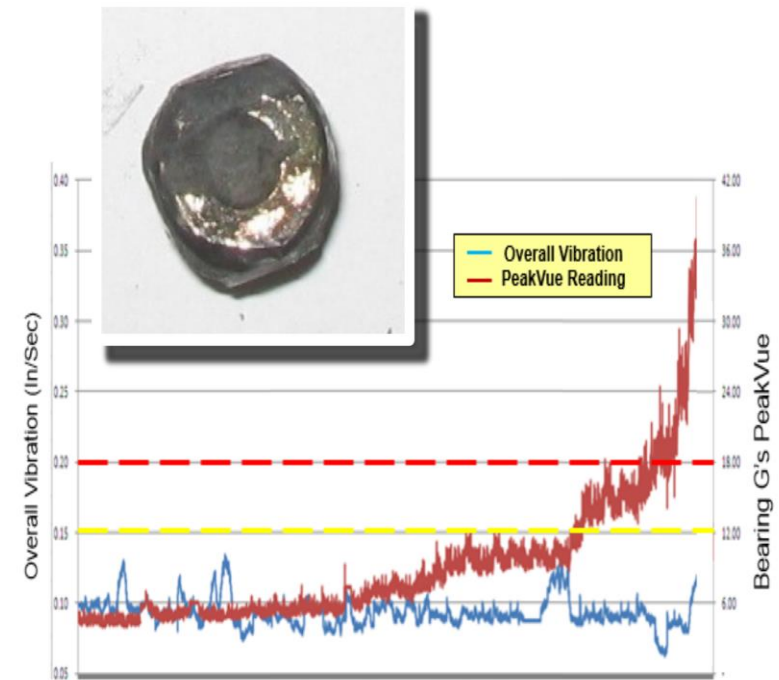


WIRELESS SENSORS – Example Vendor Y

AMS Wireless Vibration Monitor – Trend Values

13 Trend Values

Shaft Condition	✓ X-axis Overall Velocity
	✓ Y-axis Overall Velocity
	✓ Z-axis Overall Velocity
Impacting	✓ Z-axis PeakVue Acceleration
Lower Frequency Faults	✓ Velocity Parameter 1
	✓ Velocity Parameter 2
Higher Frequency Faults	✓ Acceleration Parameter 1
	✓ Acceleration Parameter 2
Prescriptive Diagnostics	✓ Bearing/Mechanical Severity
	✓ Lubrication Severity
RPM	✓ Calculated Speed
Friction	✓ Skin Temperature
Battery Life	✓ Supply Voltage



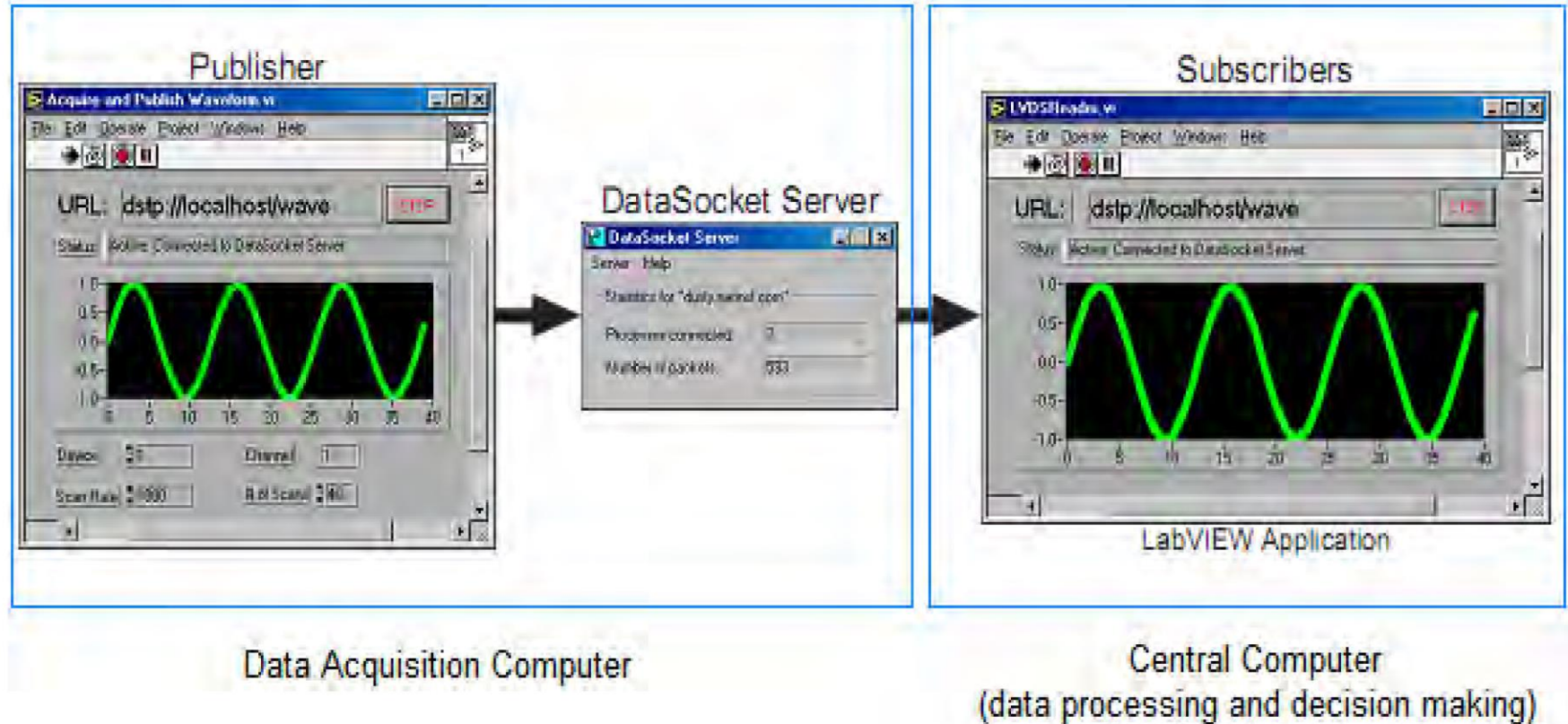
Badly Damaged Bearing Fault Not Visible in Overall Trend (Blue)

Current crop of wireless sensors with Multiple Parameters & Tri-Axial Measurements

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DATA CONDUITS – OPC UA and DA (Non-Proprietary)



PT PAU Wishes to Use OPC UA and DA for on-line Monitoring

Choice : Proprietary , HART , ISA100 , 4/5G , LoRa , BLE

One Shoe Does not Fit all

Criteria		WirelessHART	ISA100	5G (NB-IoT)	LoRa	Bluetooth/BLE
Design	Original Use Case	Designed for the industrial automation space	Designed for the industrial automation space	Designed for cell and web communication with large scale implementation	Designed for automated meter reading (AMR), not instrumentation (single point distributed)	Designed for short range, mobile connectivity between connected devices
	Applications	Critical Asset Monitoring Safety Non-Critical Control	Critical Asset Monitoring Safety Non-Critical Control	Cell Phones Public Networks Remote Monitoring	Low Cost, Low Rate Wireless Remote Monitoring	Mobile Communication Provisioning Maintenance
Industrial Automation Features	Topology	++ Self Organizing Mesh	-- P-P or Manual Mesh	-- P-P	- P-P	-- P-P
	Battery Life	++	-- (In manual mesh mode)	--	-	--
	Reliability	++	-	-	-	-
	Security	++	++	+	-	--
	Scalability	++	+	--	--	-
	Interoperability	++	--	+	-	+
	Range	++	-	++	++	--
	Update Rate	++	++	-	--	+
Key Messages		99% reliability guarantee - Rock solid security that is easy to use - Easily interoperates with other WirelessHART devices - Supports fast update rates and ranges applicable to field and plant networks	- Point-to-Point network topology is limiting in plant environment - Manual mesh supported but is complex and painful - Interoperates poorly with other ISA100 devices. No defined command protocol - Supports fast update rates and ranges applicable to field and plant networks	- Lease bandwidth (pay by the byte) - Targets very small payloads - Very low speed, a few measurements a day (hour) - Limited downstream capacity	- Very low speed, a few measurements a day (hour) - Does not support asset monitoring capabilities - Long range communication focused on limited number of applications - No asset management capability	- Focused on small footprint operations and mobile workforce - Vulnerable to a large variety of security threats - Strong use case in wireless provisioning and maintenance operations

Check Battery Life/Size, Reactivity, Reliability, Latency, Loading, Availability, etc

Monitoring System Data Load , Battery & Granularity

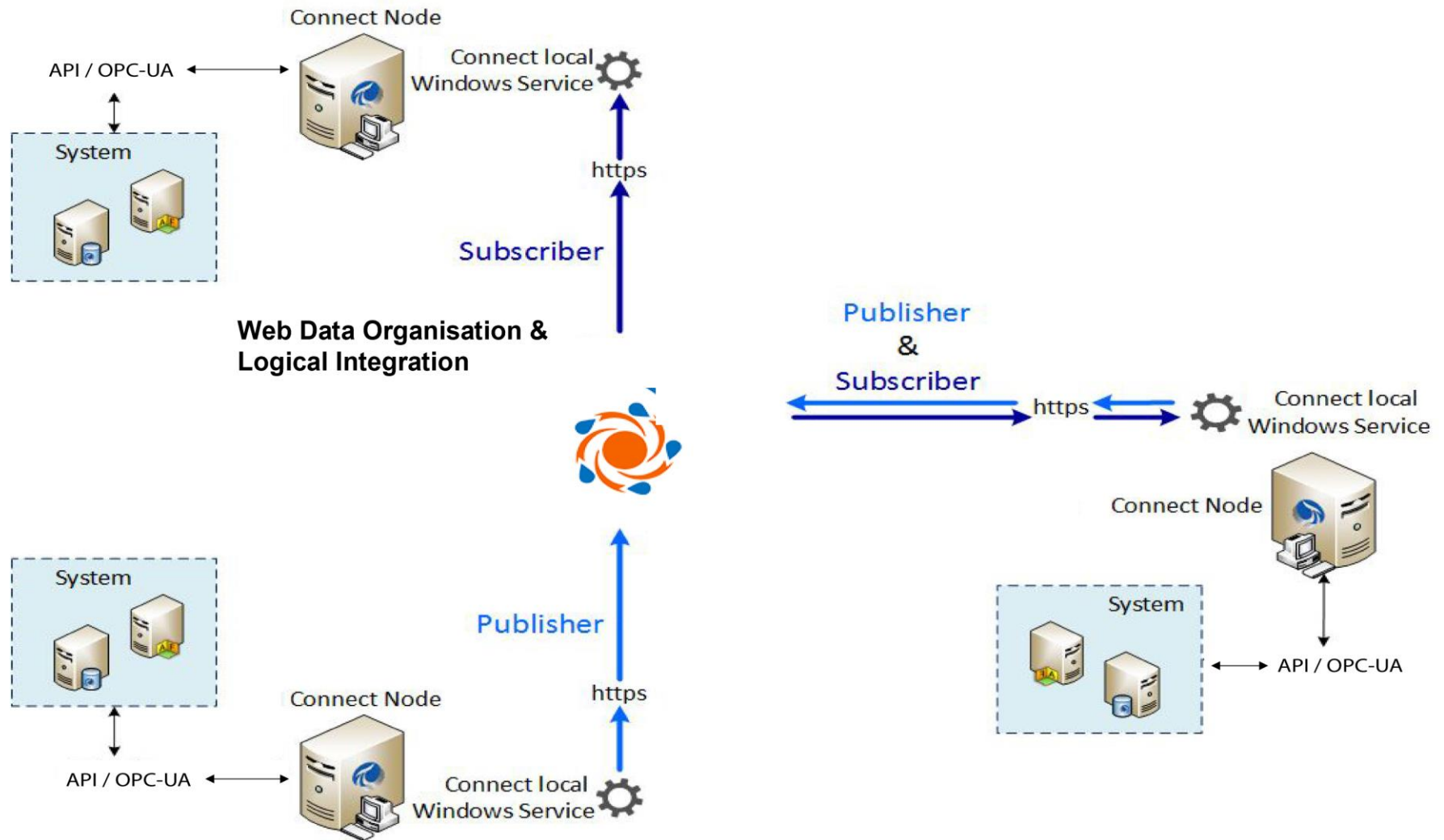
Vibration Monitoring System	Wireless Battery Powered Vibration Monitor	Wireless Powered Vibration Sensor	Wired Online with Prediction & Millisecond Granularity
Advantages	• Smallest footprint – just mount the monitor directly onto machine casing, a few repeaters needed to send the data via wireless HART to Gateway , or LoRa WAN • Single monitor will give triaxial measurement – 13 trend values including diagnostics (lubrication/bearing severity) • Easy for Remote Monitoring • Ubiquity	• Improvement on update rate to once every 1 min, but this will require line power 24Vdc • Can integrate with existing AMS Machinery Manager software at Plant for advanced diagnostics if available. • Stronger transmission range of up to 228m compared to +/-100m range for pure Battery powered. • Remote Monitoring Still generally Possible. • Lower Ubiquity	• Best update rate as it provides continuous monitoring • Some Legacy components may exist in the plant. Teams already familiar with the same. • Need Proprietor In-situ Analytics Manager software can be used. • Remote Monitoring is tougher and sometimes prohibitive to implement. • Not Ubiquitous
Disadvantages	• Fastest update rate is once every 60 min • Additional software needed for advanced diagnostics – AMS Machine Works	• More transmitters needed for same nos. of measurement points – May Require Multiple 2 or 3 x single-axis accelerometer	• Need to be installed in a field enclosure – expensive • Fiber Optic cabling needed to connect to DCS/AMS software
Pricing	• Most economical solution	• More expensive as more units and accessories needed (sensors and cables)	• Upfront Sensor maybe Cheaper but Installation is a Pain with installation will be the most expensive solution

Ubiquity, Frequency , Granularity Dictate what is best for which Machine

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We connect Everything by OPC UA and/or OPC DA



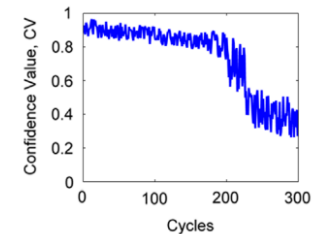
Low Cost Web Platform to Acquire OPC UA Data & Depict it on Remote Dashboards

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Types OF Automated AI Algorithms for Areas

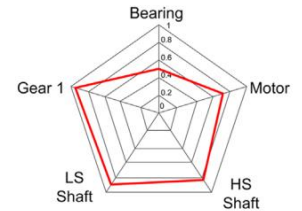
Customer Requirements and Application Conditions		Importance	Algorithms	Ranking	Catalog	Suggested Tools		
Available Signal	Vibration	5	Fourier Transform Analysis	4	Signal Processing & Feature Extraction	Wavelet Packet Decomposition		
	Acoustic Emission	1	STFT Analysis	2				
	Oil Debris	1	Wavelet Packet Decomposition	1				
Working Condition	Load Magnitude: Heavy	3	Autoregressive Modeling	3	Performance Assessment	Statistical Pattern Recognition		
	Load Magnitude: Light	1	Logistic Regression	3				
	Load: Constant	1	Feature Map	2				
	Load: Variate	5	Statistical Pattern Recognition	1				
	Speed: High	3	Hidden Markov Model	5	Diagnostics	Neural Network		
	Speed: Low	1	Particle Filter Performance Assessment	4				
	Speed: Constant	1	Feature Map	2				
	Speed: Variate	5	Hidden Markov Model	5				
System Dynamic	Stationary	1	Bayesian Belief Network	4	Diagnostics	Neural Network		
	Dynamic	5	Neural Network	1				
			Support Vector Machine	3				
Historic Data & Expert Knowledge Availability	Sufficient	3	Autoregressive Moving Average	3	Prognostics	Elman Neural Network Prediction		
	Insufficient	1	Match Matrix Prediction	2				
Other Process Property	Multi-stage	1	Fuzzy Logic Prediction	4			Prognostics	Elman Neural Network Prediction
	Single-stage	5	Elman Neural Network Prediction	1				
	High Frequency Signal	1						
	Low Frequency Signal	3						



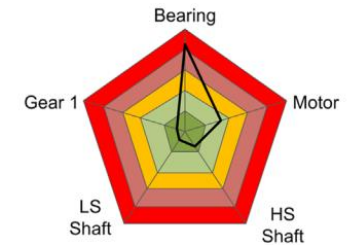
Degradation Chart



Classification and Fault Map



Performance Radar Chart



Risk Chart

Learning and Long Term Analysis

AI learns normal data and automatically detects anomaly

- ✓ Effective if there is a clear difference of normal and abnormal
- ✓ Effective for the aged deterioration or unexpected troubles

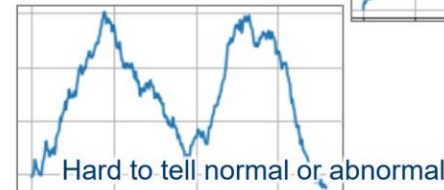
■ Effective wave pattern

- ◆ Consecutive and normalcy is stabled
- ◆ Whole measurement tendency is changing



■ Unsuitable wave pattern

- ◆ Normal value is changing continuously
- ◆ Non-consecutive data like batch process



Long Term Trend Analysis needs Autonomous Health Monitoring

Many Methods & Few Experts

Introductory summarization of PHM tools of critical components.

Component	Issue and failure	Characteristic	Common measures	Common features	Common algorithms used
Bearing	Outer-race, inner-race, roller, and cage failures	Raw data does not contain insightful information; low amplitude; high noise	Vibration, oil debris, Acoustic emission	Vibration characteristic frequency, time domain statistical characteristics, metallic debris shape, size, quantity, sharp pulses and rate of development of stress-waves propagation	Fourier Transform (FT), Short Time Frequency Transform (STFT), Wavelet Transform (WT), Empirical Mode Decomposition (EMD), Bispectrum, Autoregression (AR) Frequency Spectra, Hilbert Spectrum, Instantaneous Power Spectrum, Hilbert-Huang Transform (HHT), Neural Networks (NN), Hidden Markov Modeling (HMM), Fuzzy Logic, Support Vector Machine (SVM), Genetic Algorithm (GA), Rough Set, Autoregressive Moving Average (ARMA), Stochastic Model, Principal Component Analysis (PCA)
Gear	Manufacturing error, tooth missing, tooth pitting/spall, gear crack, gear fatigue/wear	High noise; high dynamic; signal modulated with other factors (bearing, shaft, transmission path effect); gear specs need to be known	Vibration, oil debris, acoustic emission	Time domain statistical features, vibration signature frequencies, oil debris quantity and chemical analysis	FT, STFT, WT, EMD, HHT, NN, Fuzzy Logic, Neuro-Fuzzy Hybrid Model, Energy Index Analysis, Kalman Filter, SVM, Autoregressive Model, Particle Filter
Shaft	Unbalance, bend, crack, misalignment, rub	Vibration signal is relatively clean and harmonic frequency components of rotating speed can indicate the defects	Vibration	Vibration characteristic frequency, time domain statistical characteristics, system modal characteristics	FT, WT, Wigner-Ville Transforms (WVT), EMD, Analytical or Numerical Models, NN, Fuzzy Logic, Support Vector Regression (SVR), GA, ARMA
Pump	Valve impact, score, fracture, piston slap, defective bearing and revolving crank, hydraulic problem	Pump's dynamic responses, generated by a wide range of possible impulsive sources, are very complex; nonlinear, time-varying behavior	Vibration, pressure, acoustic emission	Vibration characteristic frequency, pressure time domain statistical characteristics, sharp pulses and rate of development of stress-waves propagation	FT, STFT, WT, Envelop Analysis, NN, Fuzzy Logic, Neuro-Fuzzy Hybrid Model, Rough Set, PCA
Alternator	Stator faults, rotor electrical faults, rotor mechanical faults	Currents and voltages are preferred for noninvasive and economical testing	Stator currents and voltages, magnetic fields and frame vibrations	Specific harmonic components, sideband components	FT, WT, Instantaneous Power Fourier Transform, Bispectrum, High Resolution Spectral Analysis, Expert Systems, NN, HMM, Fuzzy Logic, GA, Higher Order Statistics, Park's Current Vector Pattern, Petri Net, Kalman Filter

“Experience repeatability” means Cloud Solutions can be cost Effective , Trade-off Your Data is read and kept by “Vendors”

We need More Analytics ?

Most companies are aware of wasted work efforts and seek to eliminate it

Traditional preventive maintenance embraces a time based approach

- Consuming expensive resources
- Potentially introducing failure by disrupting stable systems

40% of preventive maintenance costs are spent on assets with negligible affect on uptime ¹

30% of preventive maintenance activities are carried out too frequently ²

45% of all maintenance efforts are ineffective ²

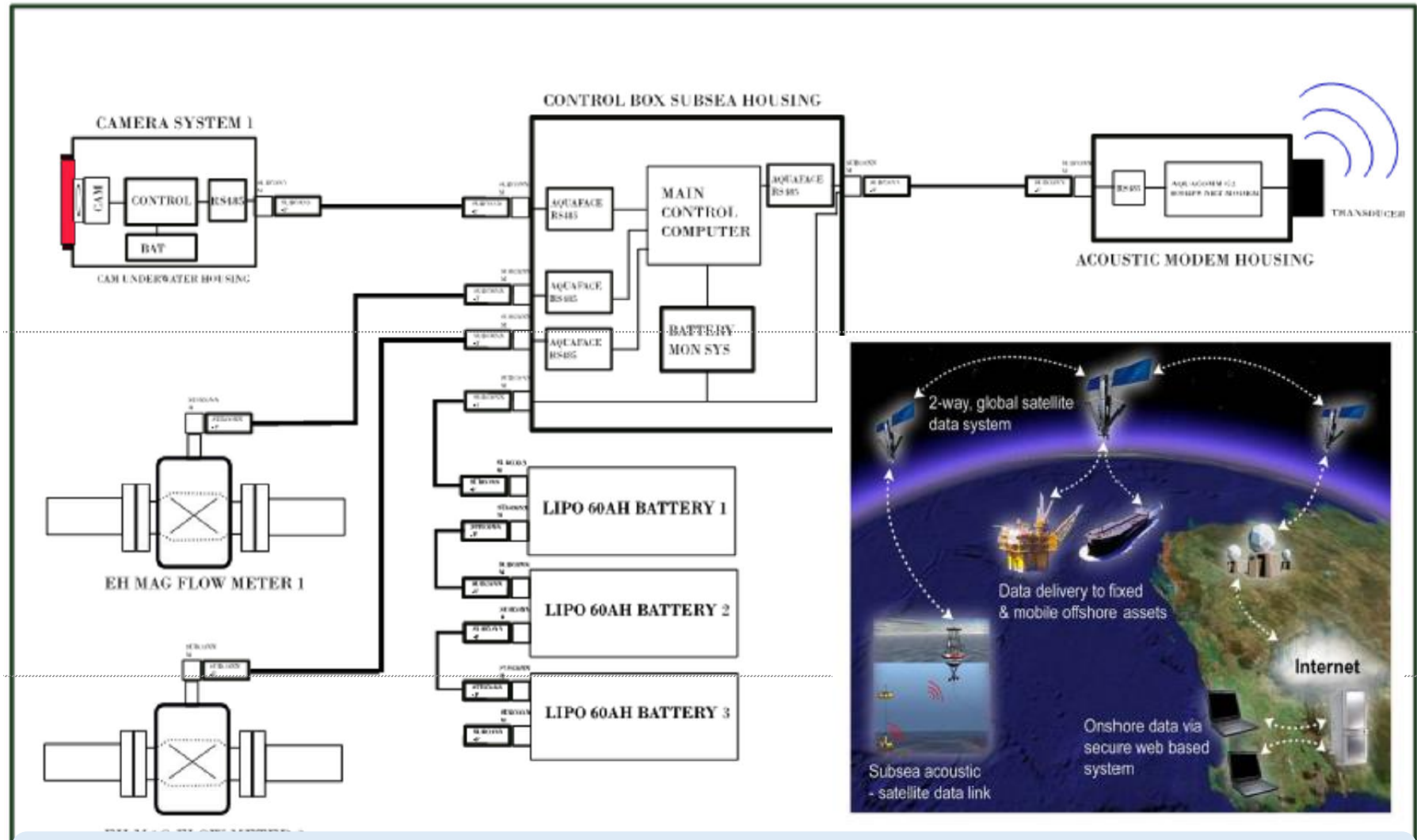
Need Service Provider Independent of Equipment Vendor
True Independence Hard to Get

Analytics Help , Resident Analytic expert is limited in his Knowledge , Trade-off dependence on Vendor

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9. The Digitalised Maintenance Future – The Heart of Vibration and Pulse

Aquamodem @ PAU for Undersea Flowmeters & Cameras



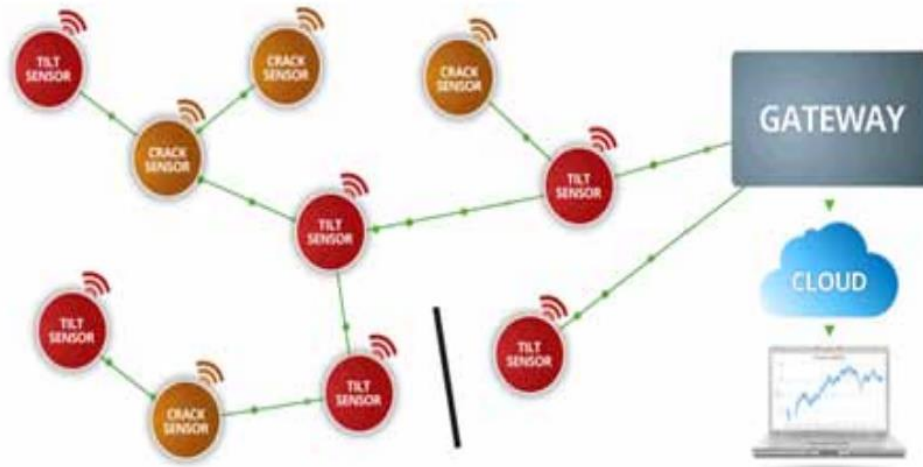
Undersea Camera & Flow meter Data Acquisition , Every Minute , Every Day , 365 Days

Piezometer Depth Tide – To Cloud Dashboard Logging

A wireless mesh network, the network connect is spread out among dozens or even hundreds of wireless mesh nodes that communicate with each other, thereby sharing the network connection across a large area.

The design of the system lends itself to the rapid development of new interfaces, as the designed wireless module is common across the product range.

Over 100 nodes can talk communicate with a single gateway, meaning that many sensors can be placed in a relatively small area allowing for Relative Measurements



Nodes Available:

- Vibrating Wire
- Tiltmeter
- Laser Distance & Tilt
- 4-20mA/1-5V
- Foil Strain Gauges
- Visual Node for Alarming

Tiltmeters:

- Uniaxial/Biaxial
- Standard & Mini tiltmeter
- MEMS Based technology
- Accuracy: 0.01 Deg
- Resolution: 0.0025 Deg

Vibrating Wire:

- Single/Four/Eight Channel Nodes
- Range: 400-6000Hz
- Accuracy: 0.015% at any reading
- Resolution: 0.002Hz @ 400Hz

Laser Distance & Tilt Node:

- No special reflector required, just a non-reflective surface.

Laser:

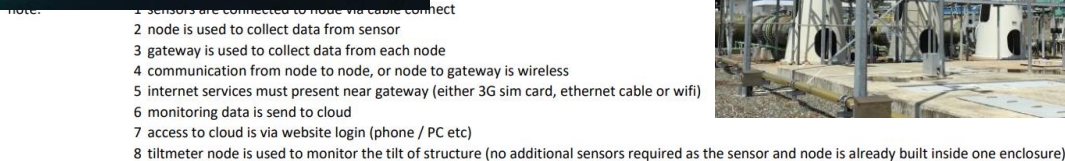
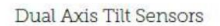
- Range: 0.05-33m
- Accuracy: +-0.5mm
- Resolution: 0.1mm

Tilt:

- Accuracy: 0.04
- Range: -30 to 30
- Resolution: 0.0025

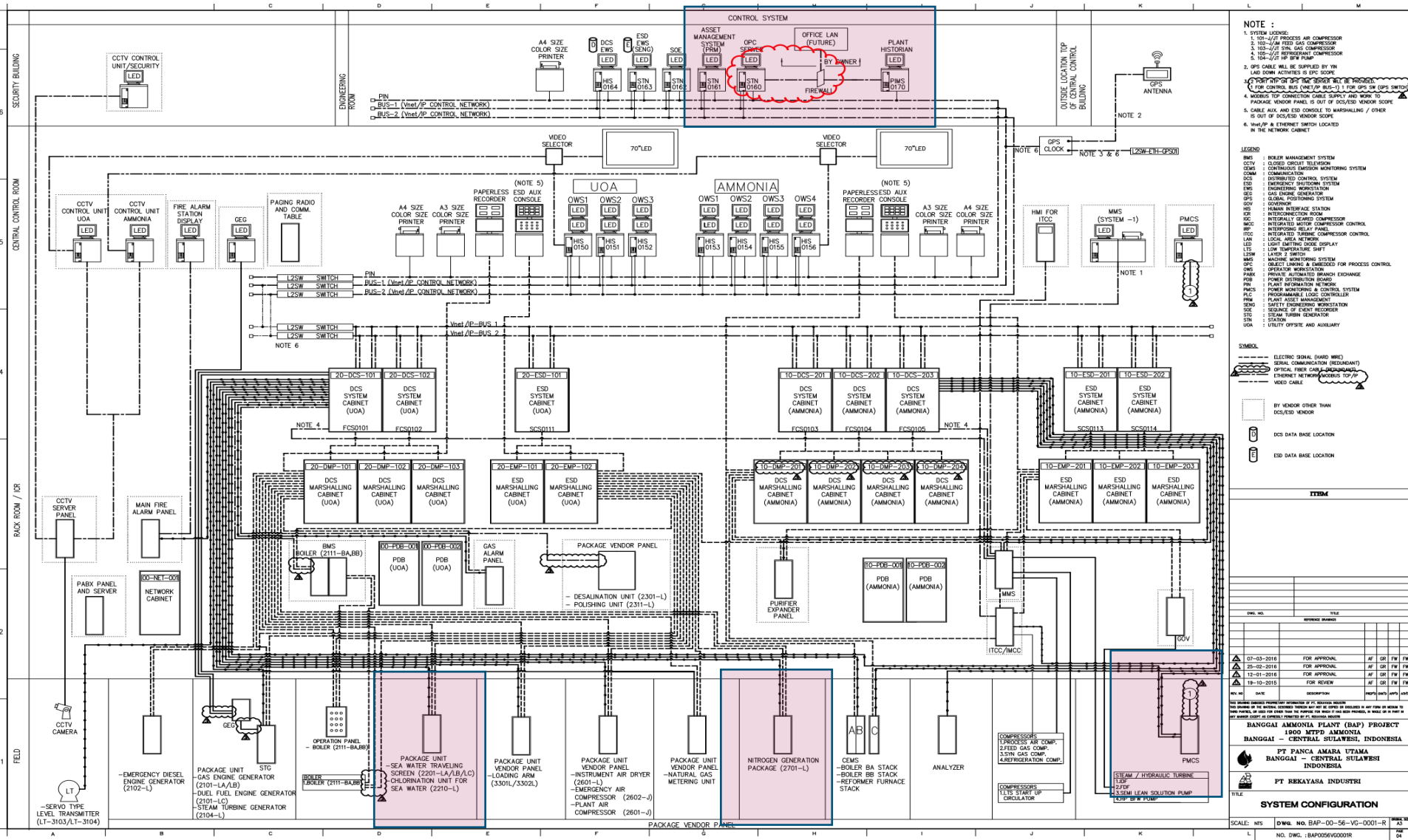
Mesh-net System Gateway to GSM – Civil Structure Remote Monitoring

node 1



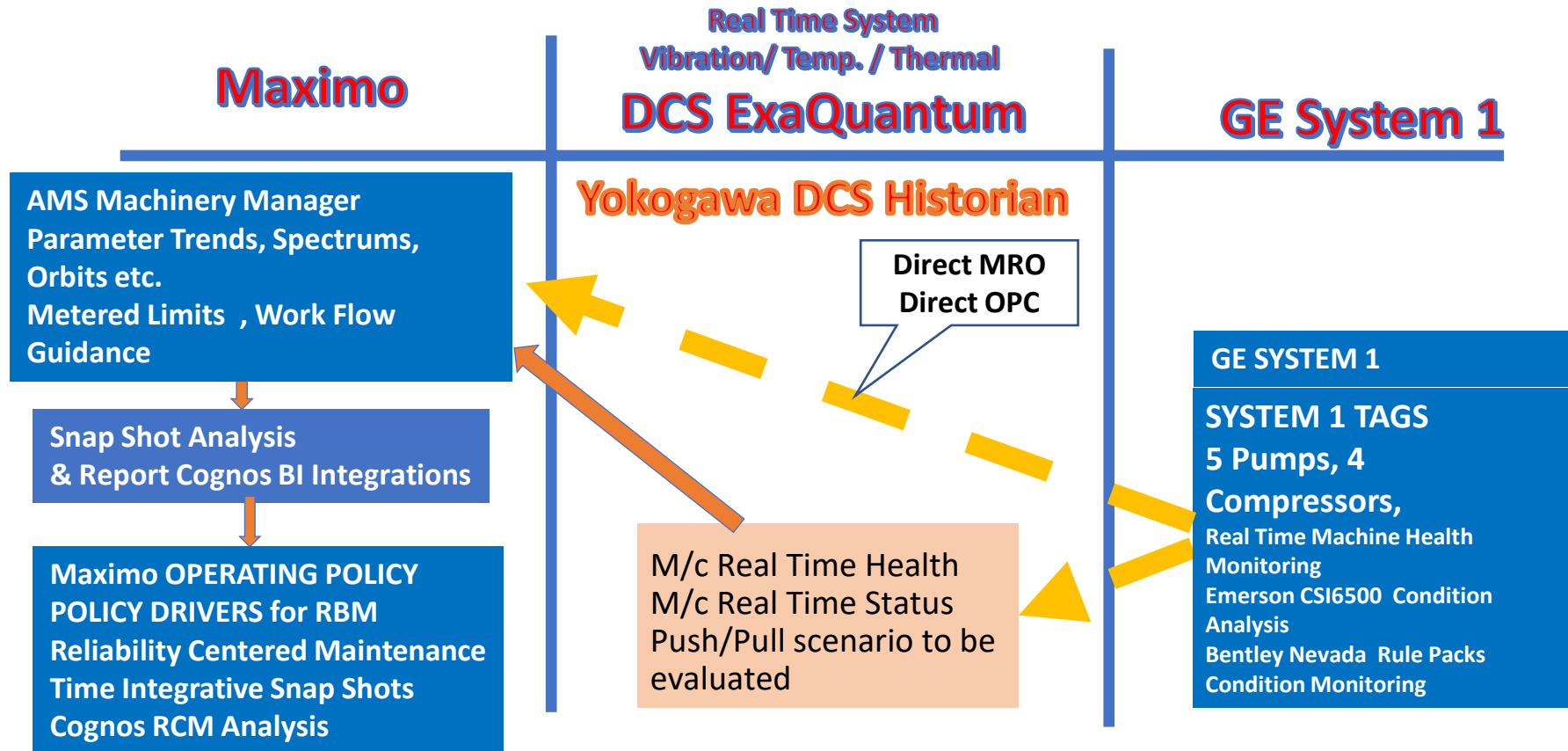
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DCS on Remote Dashboards with OPC Publisher (@ PAU)



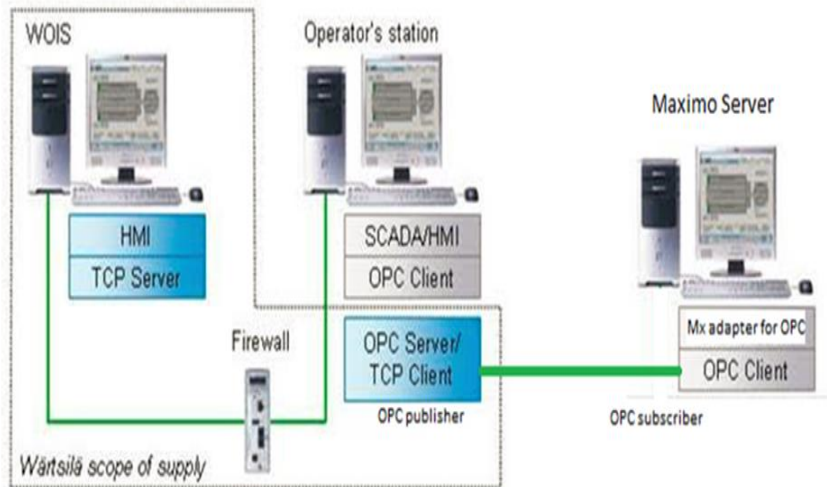
Complexity means One Shoe Does not Fit All – You always would need Specialist Interconnections

DCS to Maximo Dashboard of All



Everybody with Credentials Can see the History – Restricted to His/Her Area

32 Mwe Captive Wartsila (Remote) OPC Conduit to IBM Maximo



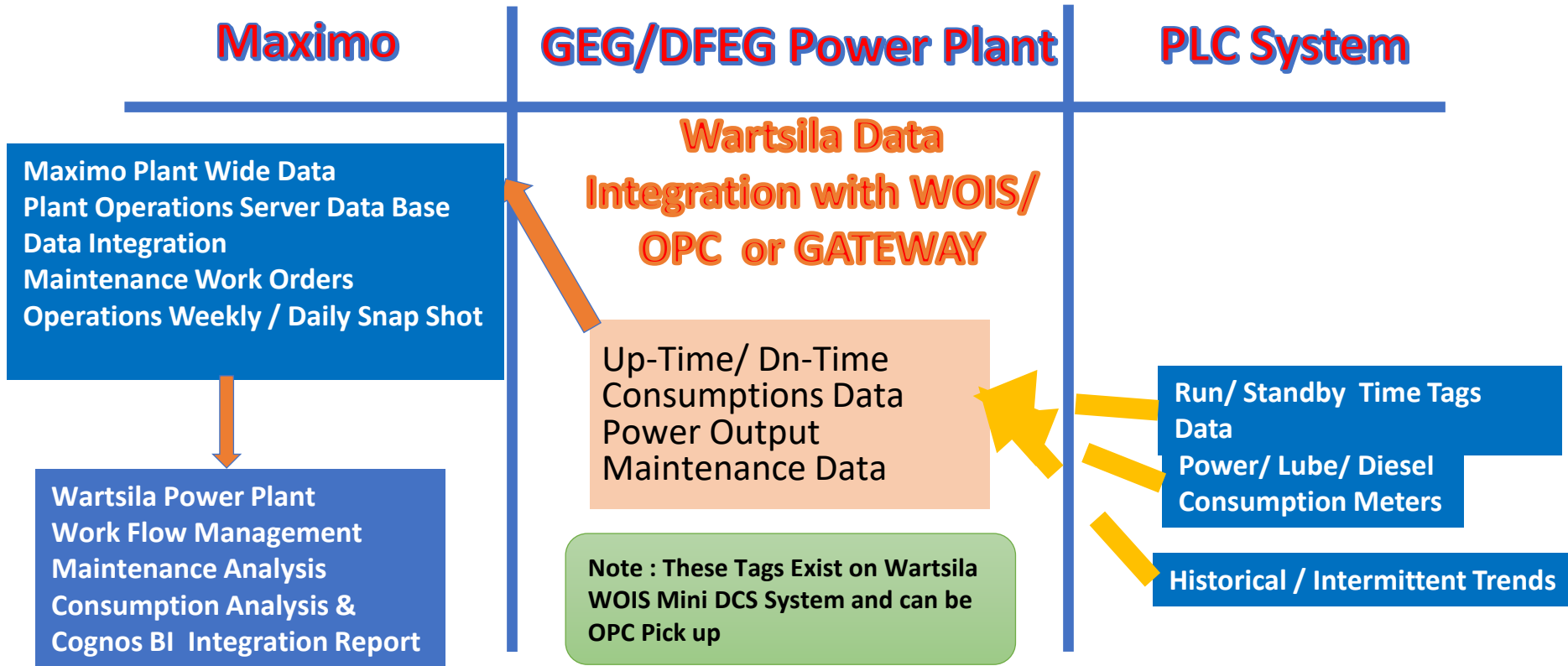
- a. 450 Digital Tags on OPC UA/DA including Alarms
- b. 30 Analog Tags on OPC UA
- c. 4 Power trains , with 480 Tags each

PMCS CONTROL I/O LIST HARDWIRED

No.	Unit Generator	Description	Type	Cable
1	GEG A	Enable Load Control Mode	Digital Input from PMCS to GEG	Hardwire
2	GEG A	Enable/Disable Remote MW Set Point	Digital Input from PMCS to GEG	Hardwire
3	GEG A	Enable Droop Control Mode	Digital Input from PMCS to GEG	Hardwire
4	GEG A	Enable/Disable Remote Speed Set Point	Digital Input from PMCS to GEG	Hardwire
5	GEG A	Enable Speed/Iso Control Mode	Digital Input from PMCS to GEG	Hardwire
6	GEG A	Remote Stop	Digital Input from PMCS to GEG	Hardwire
7	GEG A	Load Control Mode Enabled	Digital Output from GEG to PMCS	Hardwire
8	GEG A	Speed/Iso Control Mode Enabled	Digital Output from GEG to PMCS	Hardwire
9	GEG A	Droop Control Mode Enabled	Digital Output from GEG to PMCS	Hardwire
10	GEG A	Remote Speed Set Point Enabled	Digital Output from GEG to PMCS	Hardwire
11	GEG A	Remote MW Set Point Enabled	Digital Output from GEG to PMCS	Hardwire
12	GEG A	STG Run	Digital Output from GEG to PMCS	Hardwire
13	GEG A	STG Trip	Digital Output from GEG to PMCS	Hardwire
14	GEG A	Remote Speed Set Point	Analog Input 4-20mA from PMCS to GEG	Hardwire
15	GEG A	Remote MW Set Point	Analog Input 4-20mA from PMCS to GEG	Hardwire
16	GEG A	Speed (Actual Speed)	Analog output 4-20mA from GEG to PMCS	Hardwire
17	GEG A	MW (Actual MW)	Analog output 4-20mA from GEG to PMCS	Hardwire
18	GEG B	Enable Load Control Mode	Digital Input from PMCS to GEG	Hardwire
19	GEG B	Enable/Disable Remote MW Set Point	Digital Input from PMCS to GEG	Hardwire
20	GEG B	Enable Droop Control Mode	Digital Input from PMCS to GEG	Hardwire
21	GEG B	Enable/Disable Remote Speed Set Point	Digital Input from PMCS to GEG	Hardwire
22	GEG B	Enable Speed/Iso Control Mode	Digital Input from PMCS to GEG	Hardwire
23	GEG B	Remote Stop	Digital Input from PMCS to GEG	Hardwire
24	GEG B	Load Control Mode Enabled	Digital Output from GEG to PMCS	Hardwire
25	GEG B	Speed/Iso Control Mode Enabled	Digital Output from GEG to PMCS	Hardwire
26	GEG B	Droop Control Mode Enabled	Digital Output from GEG to PMCS	Hardwire
27	GEG B	Remote Speed Set Point Enabled	Digital Output from GEG to PMCS	Hardwire
28	GEG B	Remote MW Set Point Enabled	Digital Output from GEG to PMCS	Hardwire
29	GEG B	STG Run	Digital Output from GEG to PMCS	Hardwire
30	GEG B	STG Trip	Digital Output from GEG to PMCS	Hardwire
31	GEG B	Remote Speed Set Point	Analog Input 4-20mA from PMCS to GEG	Hardwire
32	GEG B	Remote MW Set Point	Analog Input 4-20mA from PMCS to GEG	Hardwire
33	GEG B	Speed (Actual Speed)	Analog output 4-20mA from GEG to PMCS	Hardwire
34	GEG B	MW (Actual MW)	Analog output 4-20mA from GEG to PMCS	Hardwire
35	DFEG	Enable Load Control Mode	Digital Input from PMCS to GEG	Hardwire
36	DFEG	Enable/Disable Remote MW Set Point	Digital Input from PMCS to GEG	Hardwire
37	DFEG	Enable Droop Control Mode	Digital Input from PMCS to GEG	Hardwire
38	DFEG	Enable/Disable Remote Speed Set Point	Digital Input from PMCS to GEG	Hardwire
39	DFEG	Enable Speed/Iso Control Mode	Digital Input from PMCS to GEG	Hardwire
40	DFEG	Remote Stop	Digital Input from PMCS to GEG	Hardwire
41	DFEG	Load Control Mode Enabled	Digital Output from GEG to PMCS	Hardwire
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50	DFEG	Speed (Actual Speed)	Analog output 4-20mA from GEG to PMCS	Hardwire
51	DFEG	MW (Actual MW)	Analog output 4-20mA from GEG to PMCS	Hardwire

PMCS System & Managing Maintenance Cycles on Dual Fuel Engines with Wartsila

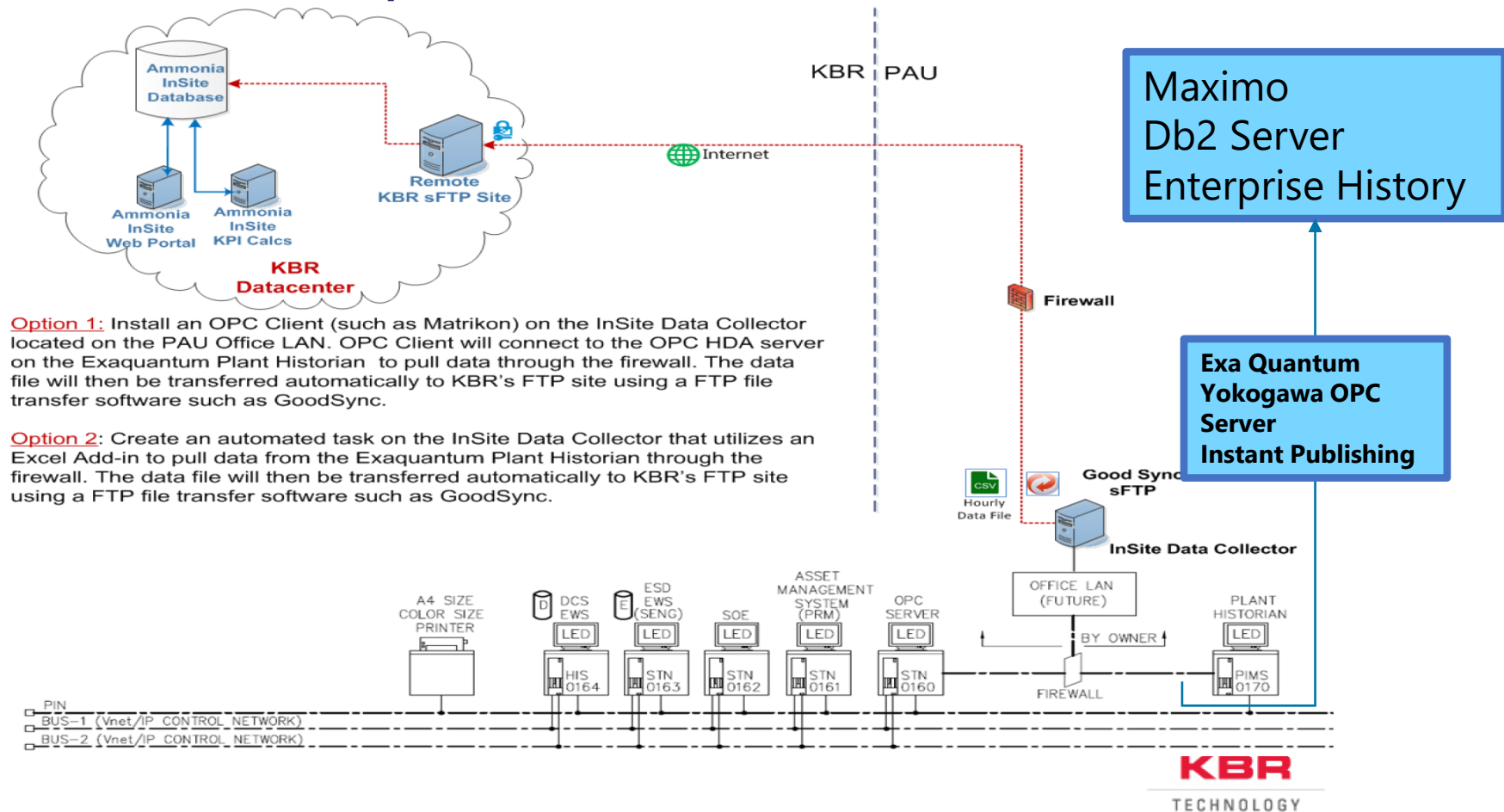
Wartsila Power Plant Integration with EAM – IBM Maximo



All Data available over the Web Browser fro Right Credentials

Technology Supplier Full Plant Reaction DATA @ PAU

Proposed Data Collection



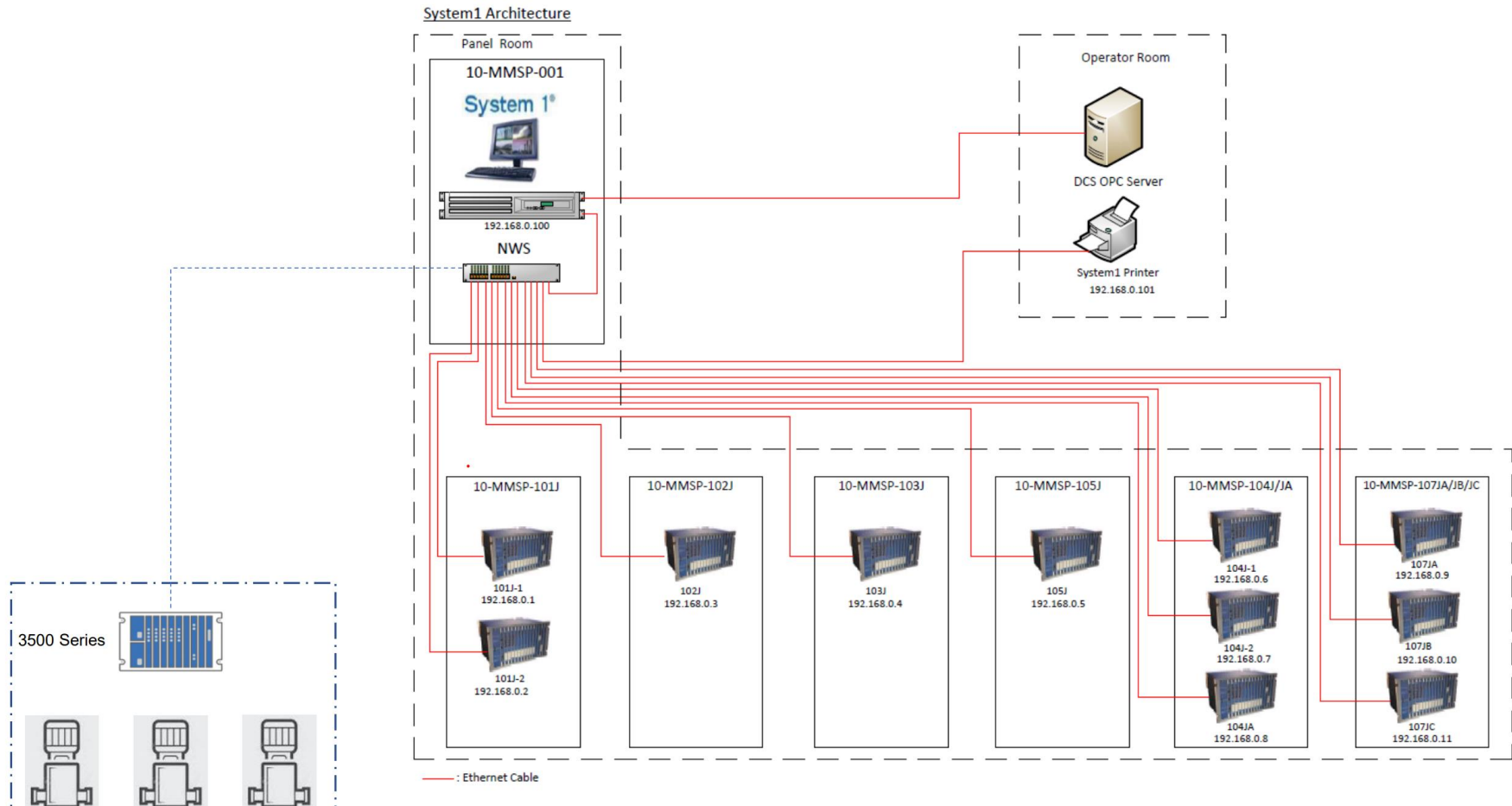
Data Frequency, Latency, Analysis – Long Term Plant & Catalyst Reaction Health

Agenda

1. The Basics - Company Introduction - Monitor or Parish
2. The Pyramids and Timings – Know your Resolution
3. Diagnostics to Prognostics – Know Before you Break
4. Sensors – Small is Beautiful and Powerful
5. The Data Conduits & Batteries – The Exquisite Ballance
6. Remote Monitoring & Cloud - The marriage in Air , On-shore , Off-shore & Undersea
7. Analytics and Methods - How is Real is Artificial Intelligence
8. Uniquely Remote examples – Under the Sea and On Islands
9. The Digitalised Maintenance Future – The Heart of Vibration and Pulse

End of Topics

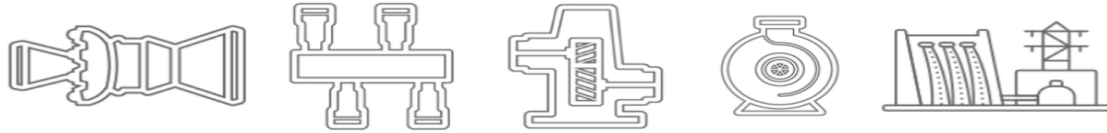
Wired Vibration Sensors – Vendor Z – SWI Intake Large Pumps



Wired Sensors & Benefits of Always "ON" Milli-second Granularity-Trade-off Remote Monitoring

Vibration Sensor & Licensing –Vendor Z (OPC Connect)

Asset-Based: Order by condition monitoring criticality and quantity of assets.



Industry-Based: Order by application industry and size. Includes unlimited data import across all devices.



Device-Based: Order by type and quantity of devices.



License Types

All System 1 Packages can be ordered as Perpetual or Subscription. While System 1 functionality is identical for both license types, key structural differences exist:

Perpetual Type

- Larger upfront investment (one-time CAPEX)
- Must purchase support and updates (M&S) separately (OPEX lower than Subscription)
- Software license does not expire
- Support and updates cease if M&S is cancelled

Subscription Type

- Smaller upfront investment (flat year-over-year OPEX)
- Subscription license fee includes support and updates
- Software stops working if subscription is cancelled

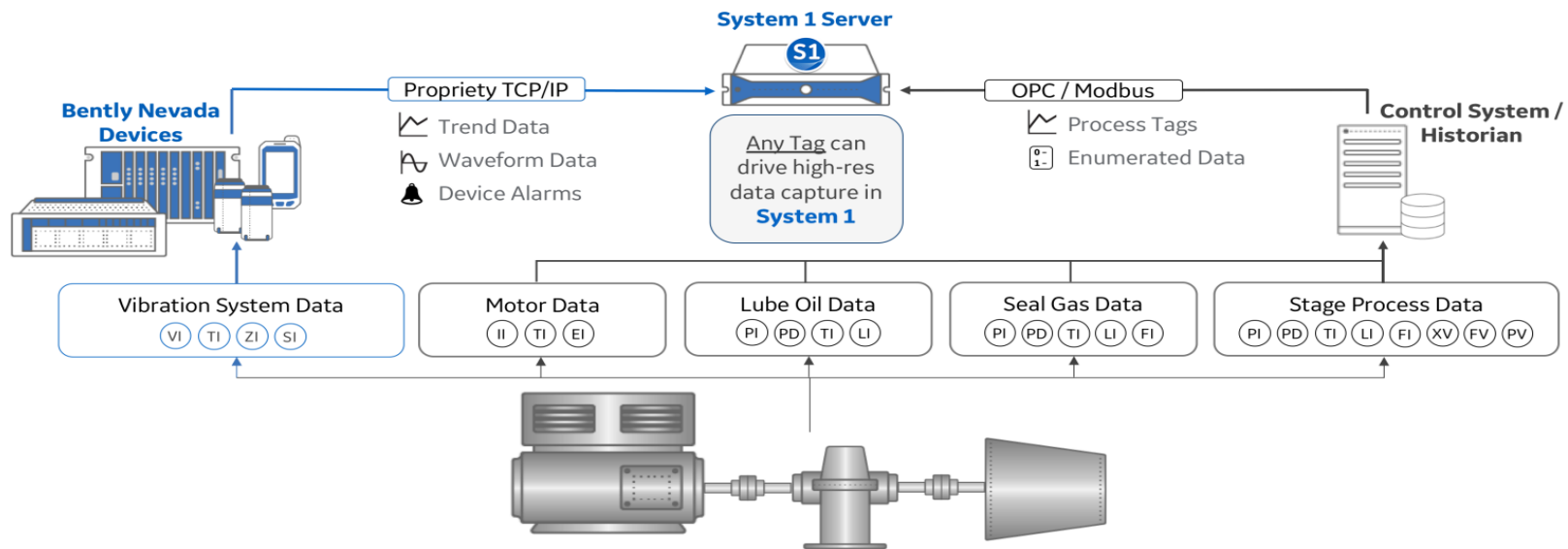
Components Needed & Order Flexibility from Vendor Z

The Full Sensor Set – Vendor Z

Connectivity + Analytics + Visualization = A Complete Solution



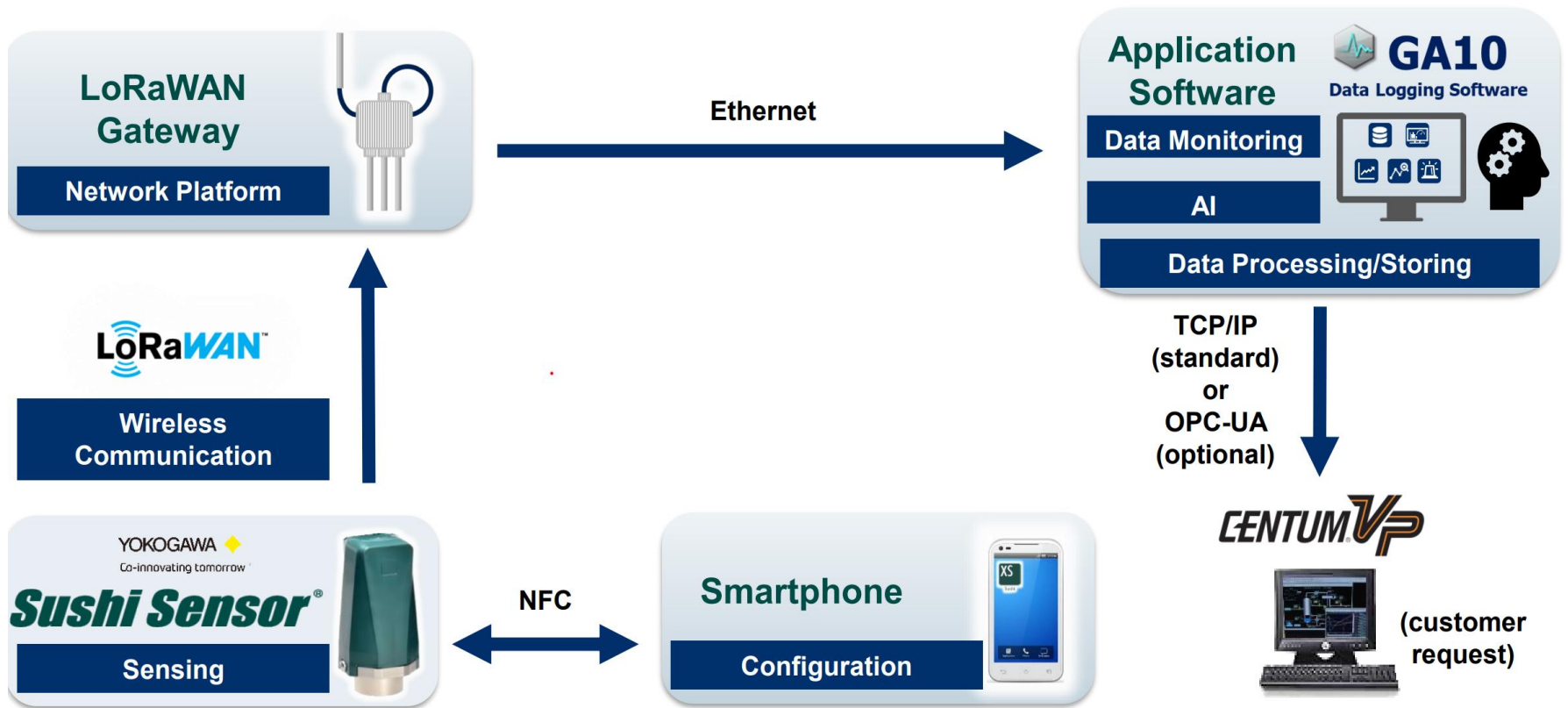
Connectivity



System 1 connects to data sources on the Edge and collects high resolution vibration, process, and control system data. This data can be collected at up to once-per-second from a Bently Nevada Device, such as 3500 or Ranger Pro, from a Programmable Logic Controller (PLC), or from another Historian. In addition, an alarm on any tag mapped to a machine will trigger high-resolution data capture from all other tags, which includes 100ms static data from Bently Nevada's 3500, ADAPT, and Orbit 60 Series devices.

Full Diagnostic Wired System – Familiar Mill-second Granularity & Analysis- Trade-Off Ubiquity

Implementation Lorawan – Vendor X



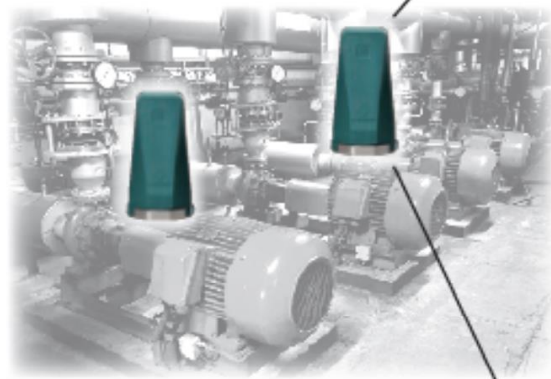
NFC: Near-Field Communication

LoRa (Long Range)
WAN: Wide Area Network

Benefits of Remote Monitoring – Trade-off Less Granularity & Not Always On Connection

Wireless Vibration Sensor Vendor X

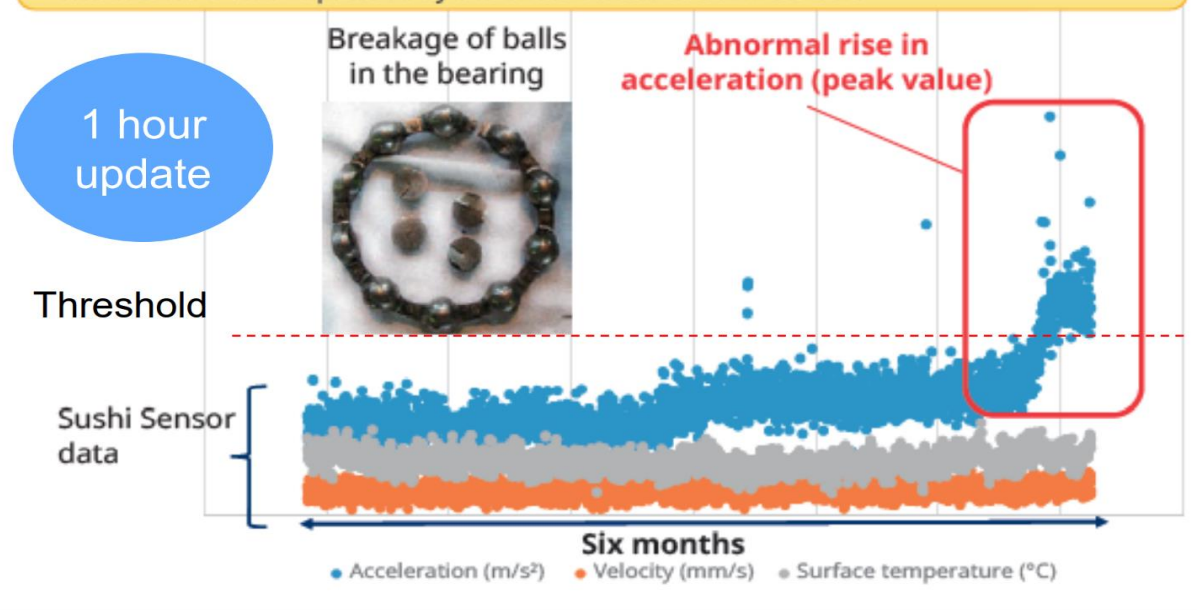
Through hourly measurements, the XS770A detected signs of abnormality in a ball bearing.



The XS770A continuously monitored the acceleration of pumps over six months. Its hourly measurements successfully caught signs of abnormality.

Figure 1 Example of detecting signs of abnormality at a chemical company

- The XS770A monitored the trend of the acceleration of pumps for six months and detected signs of abnormality.
- The customer was impressed by the effectiveness of Sushi Sensor.



Early detection of abnormality enables maintenance to be performed before any actual failure occurs, preventing unexpected shutdowns that would result in losses.

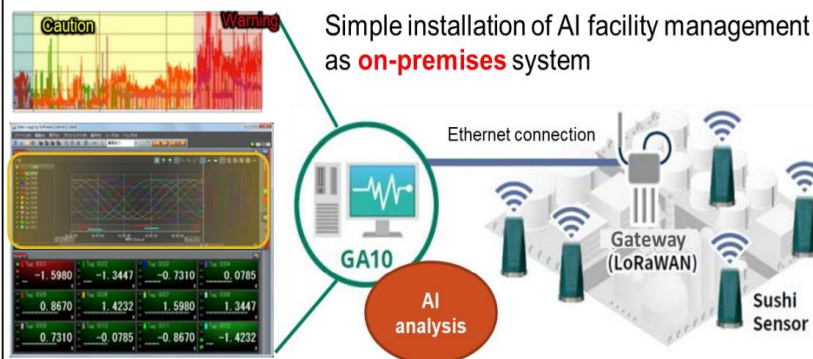
Hourly Measurements – Millisecond Granularity – Trade-Off-Sleep Time , Battery Life

Wireless Vibration Sensors – Vendor X

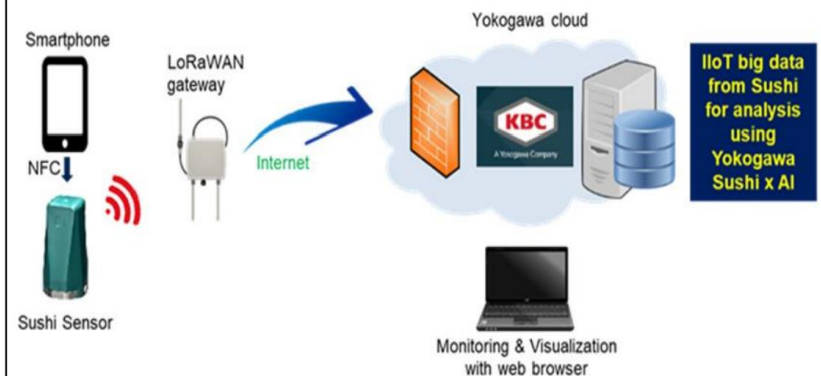
Sushi Solution Package

- 2 types of Solution package
 - ◆ Sushi + On-Premises + AI
 - ◆ Sushi + Cloud + AI

Sushi + On-Premises + AI

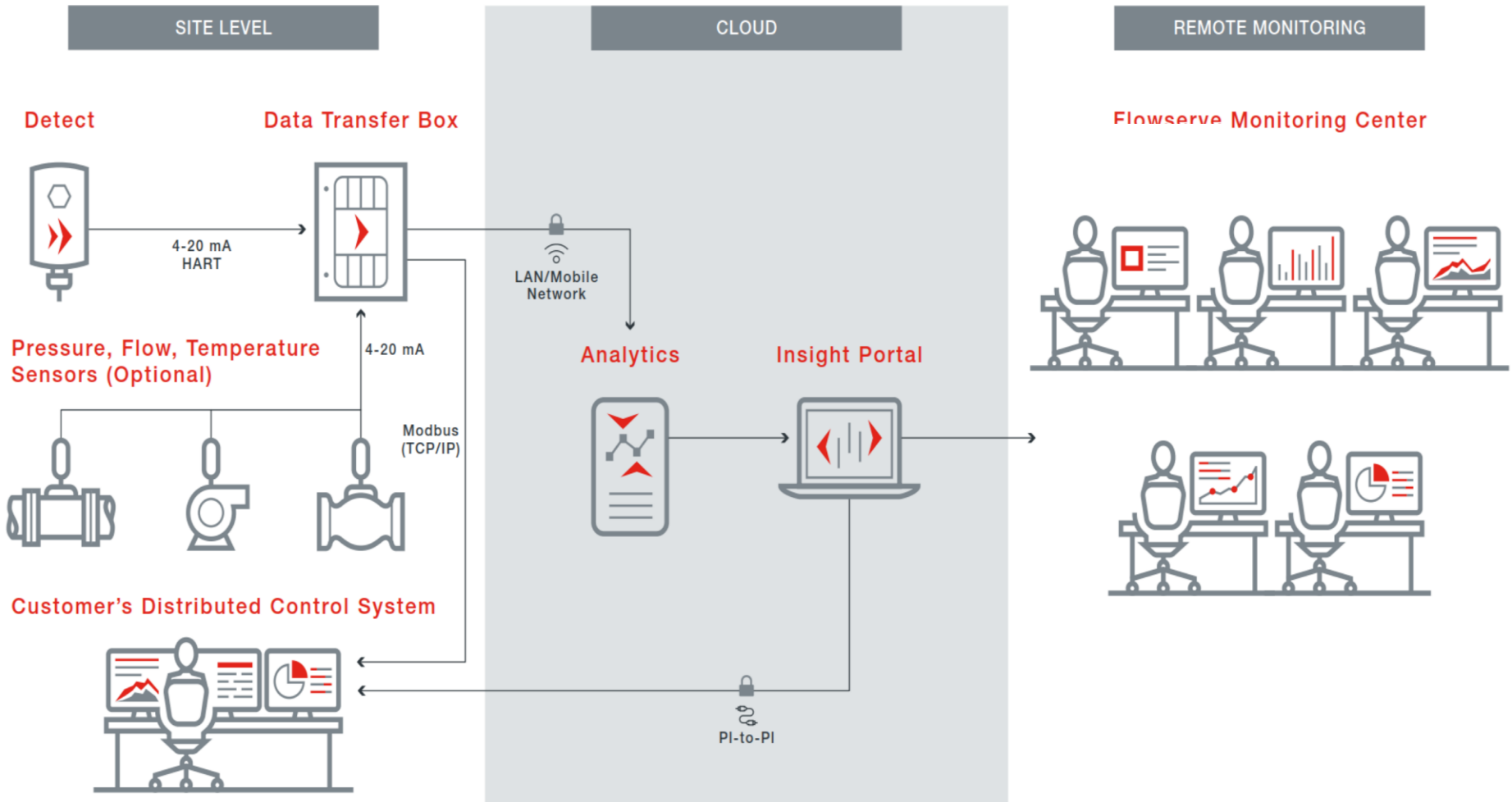


Sushi + Cloud + AI



Plant wide Ubiquity-Remote Monitoring Ease – Trade-off Not always “ON” Millisecond Granularity

Wireless Powered Vibration Sensor Vendor W



Equipment Vendor becomes the Service Provider , Trade-off Dependency & Data Visibility



Thank You

Questions Welcome

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Excellence, Perseverance, Integrity, Care



Characteristics of commonly used algorithms.

Algorithm	What is it used for?	Advantage	Disadvantage
Time domain analysis	– Directly uses the waveform to compare different signals	– Immediately shows the difference of the signals	– Cannot provide enough information (e.g. frequency domain features) for further analysis
Fourier Transform	– To represent a waveform in frequency domain – Decomposes or separates the waveform into a sum of sinusoids of different frequencies	– Appropriate for stationary signals – Presents signal with good spectrum resolution	– Lack of the temporal information – Not appropriate for non-stationary signals
Short-time Fourier Transform (STFT)/ Wigner-Ville Distribution (WVD)	– To represent signals with both time and frequency information simultaneously	– Provides both temporal and spectral information – Present signal with picture-based information – Appropriate for non-stationary signals	– High-load computation is needed – Resolution is not scalable
Wavelet/Wavelet Packet Energies	– To represent the time signals in terms of a finite length or fast decaying oscillating waveform which is scaled and translated to match the input signals	– Very powerful for non-stationary signal analysis – Achieves better resolution than time-frequency analysis (scalable resolution)	– Not easy to determine the optimal parameters for the wavelet filter – May compromise signal mathematical properties
Hilbert-Huang Transform (HHT)	– To decompose complicated signals into a finite number of intrinsic mode functions (IMFs) within the time domain and to represent signals with time-frequency-energy distribution	– Adaptive and unsupervised method – Useful for analyzing non-stationary, nonlinear signals	– An empirically based data analysis method with the difficulty of laying a firm theoretical foundation.
Principal Component Analysis (PCA)	– To reduce the dimensionality by transforming the original features into a new set of uncorrelated features	– Reduces multi-dimensional data sets to lower dimensional data sets	– High-load computation – Its performance varies for different applications
Fisher Linear Discriminant	– To reduce the dimensionality by seeking a projection that best separates the data in a least-squares sense	– Reduces multi-dimensionality – Keep the information that is efficient for discrimination	– Linear transformation – Linear approach
Gaussian Mixture Model (GMM)	– A type of density model which comprises a number of Gaussian functions which are combined to provide a multimodal density – To fuse information	– Mixture of Gaussians can be utilized to approximate an arbitrary distribution within an arbitrary accuracy	– The optimization parameters are sensitive to the initialization methods – Not easy to determine the number of mixtures
Logistic Regression (LR)	– To find the best fitting model to describe the relationship between the input multiple variables and the output variable	– Especially appropriate when the output is constrained between 0 and 1	– Not feasible unless normal feature domain description and unacceptable behavior are both available – Not appropriate when the output is unbounded

Statistical Pattern Recognition (SPR)

- A method to calculate the overlap between the current feature distribution and the normal mode

- Applicable when only normal feature domain description is available

- Not feasible when the feature distribution is not approximately Gaussian (normal distribution)

Gaussian Process Regression/Prediction

- To fit models to data and recover underlying process from noisy observed data based on a particularly effective method for placing a prior distribution over the space of functions
- To perform prediction with Gaussian Processes

- Can adapt to environments and learn from experience

- Need to determine covariance function
- Only suitable for Gaussian likelihood

Particle filter

- Another Bayesian approach to obtain state estimation that represents the probability distribution function of the tracked state by sampling particles recursively

- Applicable for non-linear system and non-Gaussian noise
- Higher accuracy than other existing filtering algorithms
- Sequential importance sampling helps increase accuracy and avoid degeneracy

- Equations governing system dynamic and measurement model need to be defined
- Higher dimension system or more particles require too much computation cost

Kalman filter

- A Bayesian technique that estimates the state of a process and minimizes the covariance of the estimation by incorporating with measurement related to the state

- Able to estimate the current state and also predict the future state
- Corrects the estimate with latest measurement to maintain minimal state error covariance

- System model and measurement model need to be defined
- Noise levels in both models could affect the performance and stability of the algorithm
- Only works with linear system and Gaussian noise

Feature map pattern matching (Self-organizing maps)

- To represent multidimensional feature space in a low dimensional space while preserving the topological properties of the input space

- Unsupervised learning methods (no prior output is needed)

- Lack of standard algorithm to determine the structure and shape of the map

Bayesian Networks

- A directed acyclic graph tool to present the structure of conditional interdependency relations and probability distributions between variables in one domain system

- Reduces number of parameters to learn a domain structure by marginalizing conditional probability distributions

- Learning an unknown structure can be complex and costly
- Relies on certain amount of prior knowledge of the domain

Neural Network

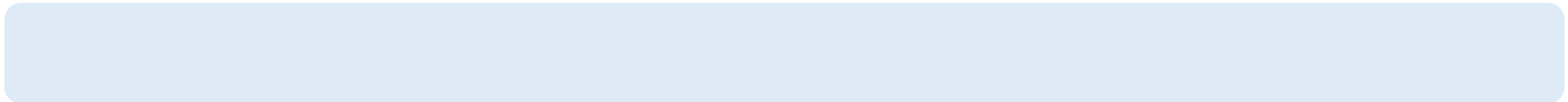
- A model that simulate the structures and functions of biological neural networks

- For complex systems which involve non-linear behavior and unstable processes

- No standard method to determine the structure of the network

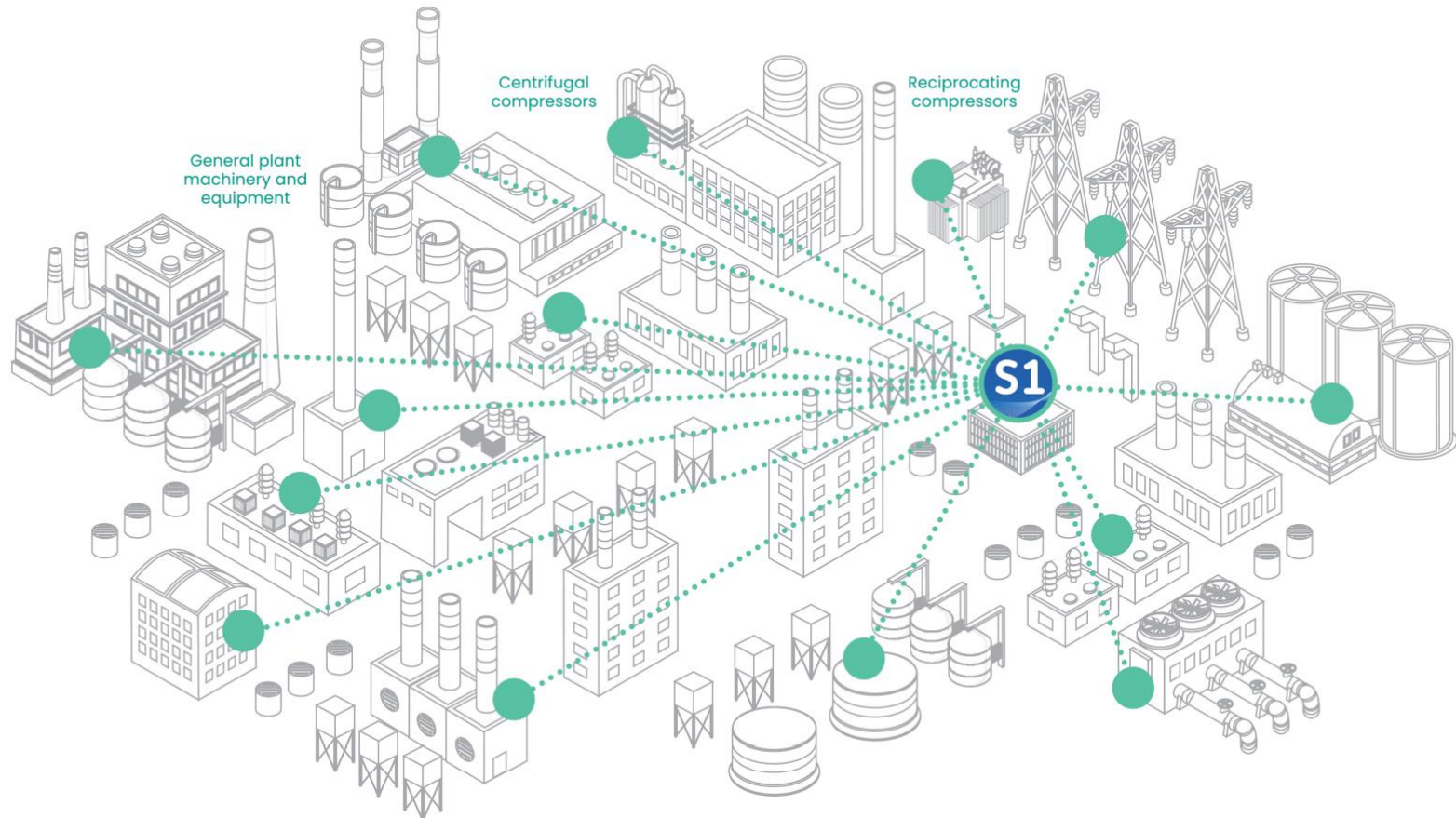


Algorithm	What is it used for?	Advantage	Disadvantage
Decision Trees	- Can learn the knowledge by modeling complex relationships between inputs and outputs and find patterns in data - Make decision or classify data item by starting at the root node of tree and following the assertions down until reach a terminal node (leaf of tree) - A special form of a rule set, characterized by hierarchical organization of rules	- Adaptive system - Good visualization, easy interpretation and quick analysis ability for decision making	- Requires sufficient computational resources - Need high level experience and knowledge to formulate the tree structure
ARMA	Consists of two parts – the autoregressive (AR) part and the moving average (MA) part for modeling and predicting future values in a time series of data	- Applicable to linear time-invariant systems whose performance features display stationary behavior - Utilizes a small amount of historical data	- Cannot provide good long term prediction - Limited for non-stationary and dynamic processes
Fuzzy Logic	- To represent and process uncertainty to make system complexity manageable - Tolerate uncertainty and can utilize language-like vagueness to offer robust, noise tolerant models or predictions where precise input is unavailable or too expensive	- Can deal with incomplete, noisy or imprecise data - Helpful in developing uncertain models of data - More compatible with human reasoning process than traditional symbolic approach - Appropriate for complex/unknown system	- Not feasible in the situation that membership functions are complicated to be determined - Linguistic terms may compromise the accuracy of the model
Rough Sets	- A formal framework for the automated transformation of data into knowledge - For rule induction, fault diagnosis and feature selection	- Useful for rule induction from incomplete data sets - Mathematically relatively simple - No assumptions about the independence of the attributes are necessary nor is any background knowledge about the data	- Cannot be applied to continuous values. - Determination of thresholds may not be reliable
Match Matrix	An enhanced ARMA model which utilizes the historic data from different operations for robust prediction	- Dealing with high dimensional feature space - Provides better long term prediction than ARMA - Feasible for non-stationary processes	- Not appropriate unless sufficient historical data from different operation cycles is available - Historical data must contain degradation data
Support Vector Machine (SVM)	- To project feature space into a higher dimensional space by a kernel function - To find an optimized separation hyperplane in the projected space to maximize the decision boundary	- Achieves better decision accuracy in special cases because of the maximized decision boundary - Efficient for large dataset and real-time analysis	No standard method to choose the kernel function which is the key process for SVM
Hidden Markov Model (HMM)	A statistical model where the system being modeled is assumed to be a Markov process with unknown state space parameters	- Can be used for fault and degradation diagnosis on non-stationary signals and dynamic systems - Appropriate for multi-failure modes	- Not appropriate when the failure state is observable - Large amount of data is needed for accurate modeling



System 1 Analysis

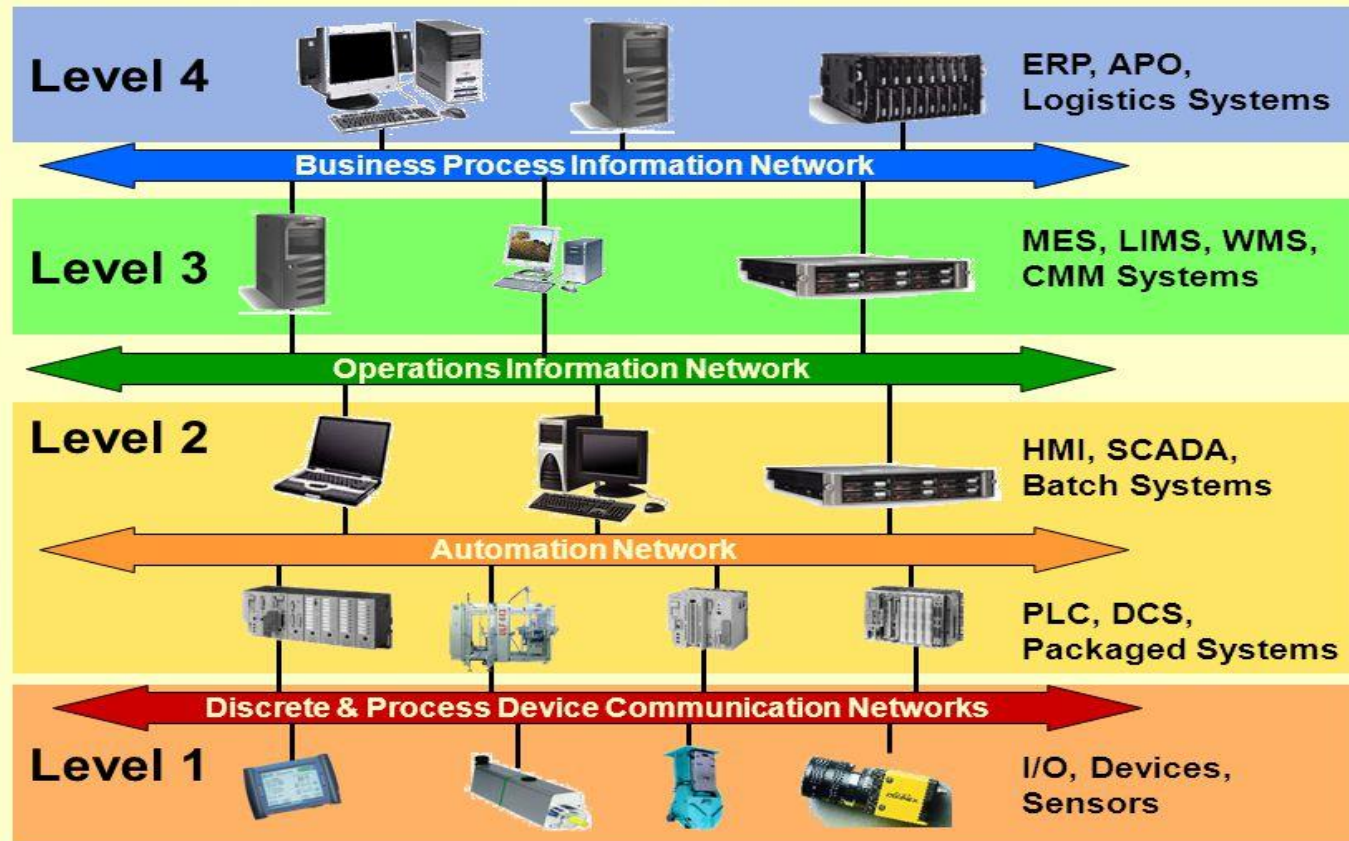
System 1 brings it all together



Old System 1 , Old Wine , New Bottle

Topology of Data from Machines – IT View

Conceptual Topology – IT View

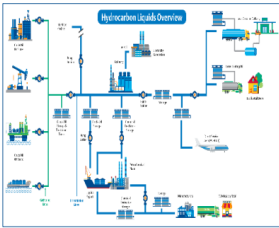
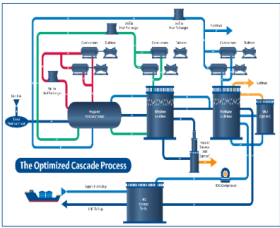
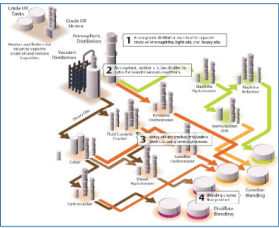
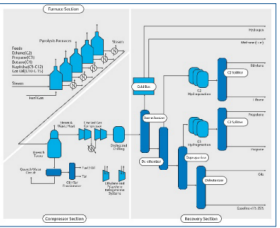
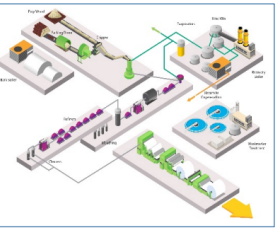
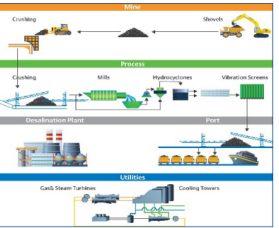


Dennis Brandl & Peter Owen

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Current Data Nomenclature

Connect Everywhere Web Data Organisation & Logical Integration

					
Oil & Gas	LNG	Refining	Chemical	Pulp & Paper	Mining
• Crude Oil Pumps • Oil Transfer Pumps • Water disposal pumps • Blowers • Fin Fans	• LNG Product Pumps • Hot Oil Pumps • Liquefied Gas Pumps • Amine Circulation Pumps • Seawater Pumps • Blowers • Fin Fans	• Boiler Feed Pumps • Crude Oil Pumps • Feed Pumps • Vacuum/Ejector Pumps • Heavy Residue Pumps • Heavy Vacuum Gas Oil Pumps • Light VGO Pumps • Condenser Pumps • Jet/Charge Pumps • Circulation Pumps • Fin Fans • Blowers • Screw compressors	• ID Fans • FD Fans • Bypass Fan • Recovery Pumps • Utilities Pumps • Blowers • Cooling Towers	• Wood Chipper • Belt Conveyors Drive Gearbox & Motor • Refiner • Boiler Feed Water Pumps (Motor or Steam Driven) • Double Suction Pump (Forming) • Paper Machine • ID Fan • FD Fan • Blowers	• Crusher • Conveyors Drive Gearbox & Motor • Booster Pumps • Feed Water Pumps • Vibrating Screen • Reclaimer • Stockpiler • Cooling Towers

Connect Large Plants with Minimal Licensing

LoRaWAN and Small Sensors Provide a Solution



- Online monitoring to improve Asset maintenance and prevent failures
- The wireless function, battery, and sensor are integrated in a single body.



UNMATCHED COVERAGE LONG-DISTANCE COMMUNICATIONS

LoRaWAN communication standard a Low-Power Wide-Area (LPWA) wireless data communication protocol that is optimised for long-distance communications and low-power consumption (**7km LoS, 1km: congested**)



LOW POWER & LONG-LASTING BATTERY

Sushi Sensor is also battery-powered, eliminating the need for an external power supply. (**1hr update for 4 yrs**)



COMPACT AND LIGHT-WEIGHT

Being compact and light-weight, this sensor can be **mounted easily** on all kinds of plant Rotating Equipment.



NO REPEATERS/DIRECT CONNECTION TO GATEWAY

Sushi Sensors are directly connected to a Gateway, not to each other or Repeaters **optimizing CAPEX**. No repeaters are required!!! Each gateway support up to 1000 sushi sensors



SMARTPHONE SETTING & MONITORING

Sushi sensor supports near-field radio communication (NFC), which allows **setting and condition monitoring from a smartphone** via a dedicated app.

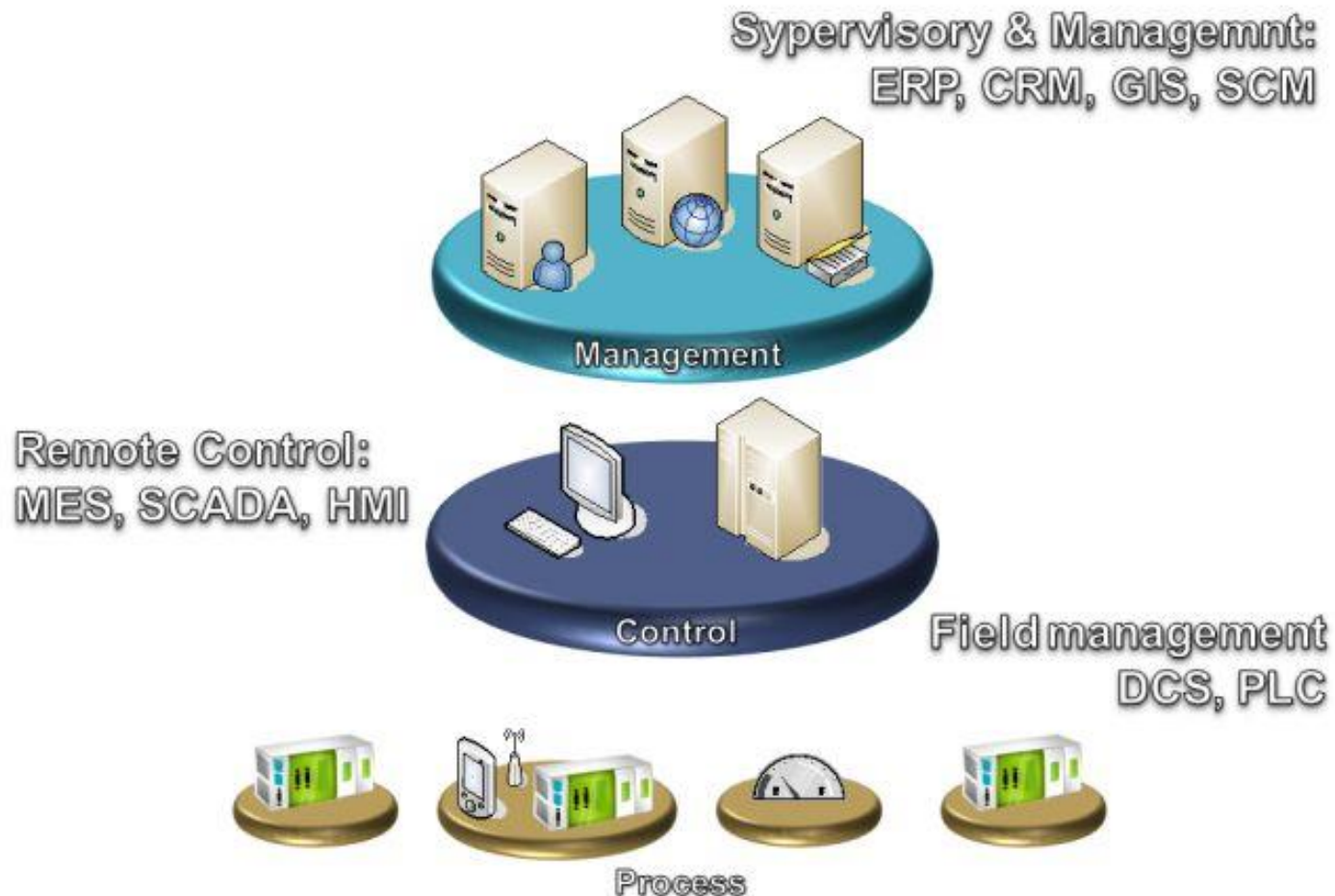


ENVIRONMENTALLY ROBUST

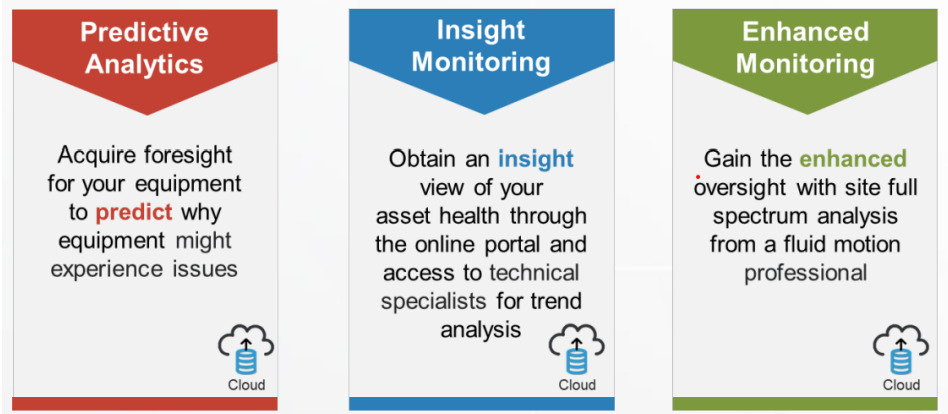
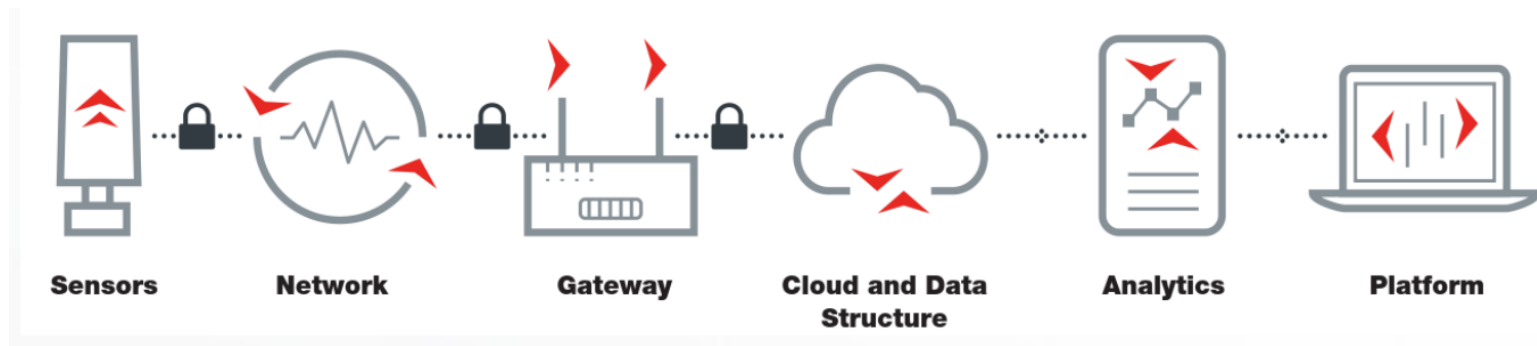
The sensor is environmentally robust and is well suited for installation in harsh locations. (**IP66/67, ATEX, Zone2**)

LoRaWAN

Control Process at What Level ?



Level Controls and Monitoring



Namindo Pty Ltd

Thank you

Suprit Pal Singh, Founder Director

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This archive edition keeps the content as originally presented. Figures and forecasts are of their date.