Data-Driven PHM Applications for Oil & Gas Industry

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Digital Accelerator Program Manager
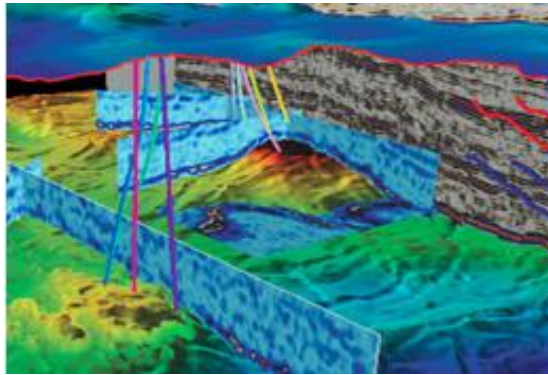
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Agenda

- Background

- Our Vision & Mission, Team, Process

- Applications

  ➢ Failure Detection for Drilling Tool

  ➢ Condition Monitoring for Blow-Out Preventers

  ➢ Overviews: Frac Pumps, beyond Equipment

- Closing Remarks
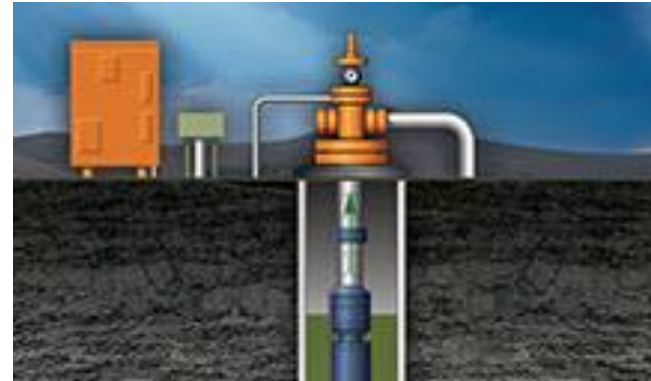
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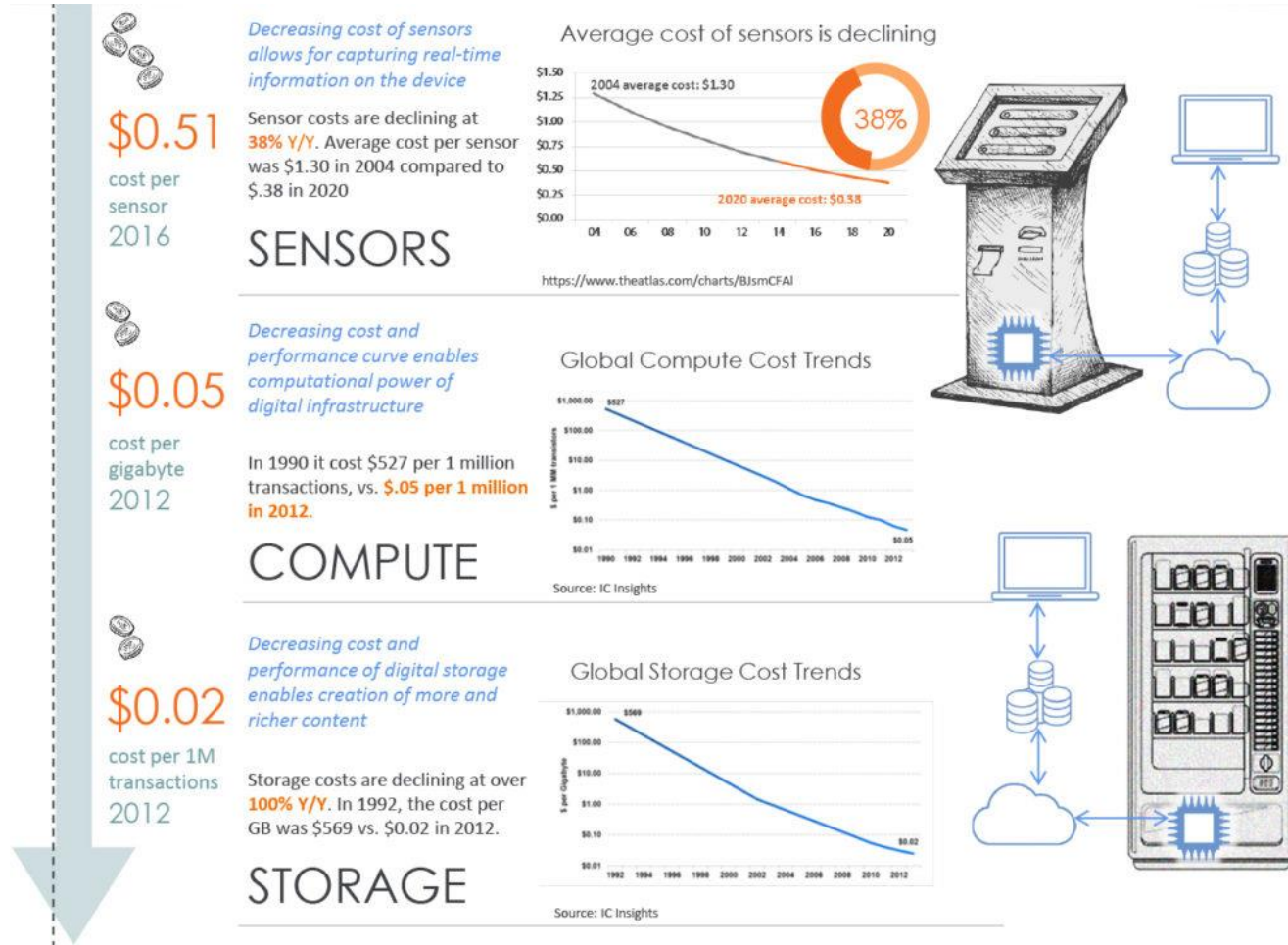# Background – Oilfield Technologies

Reservoir Characterization

Drilling

Production

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Background – Falling costs of sensors, computing, storage

Decreasing cost of sensors allows for capturing real-time information on the device

Sensor costs are declining at **38% Y/Y**. Average cost per sensor was $1.30 in 2004 compared to $.38 in 2020

$0.51 cost per sensor 2016

SENSORS

Average cost of sensors is declining

2004 average cost: $1.30
38%
2020 average cost: $0.38

https://www.theatlas.com/charts/BJsmCFAl

Decreasing cost and performance curve enables computational power of digital infrastructure

In 1990 it cost $527 per 1 million transactions, vs. **$.05 per 1 million in 2012**.

$0.05 cost per gigabyte 2012

COMPUTE

Global Compute Cost Trends

Source: IC Insights

Decreasing cost and performance of digital storage enables creation of more and richer content

Storage costs are declining at over **100% Y/Y**. In 1992, the cost per GB was $569 vs. $0.02 in 2012.

$0.02 cost per 1M transactions 2012

STORAGE

Global Storage Cost Trends

Source: IC Insights

*Source: Banyanhills.com

Analytics is radically changing all economic activities – at a fast pace

- Business Analytics
- Equipment Analytics
- Social Media Analytics

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Data Driven Equipment Monitoring – The Big Picture
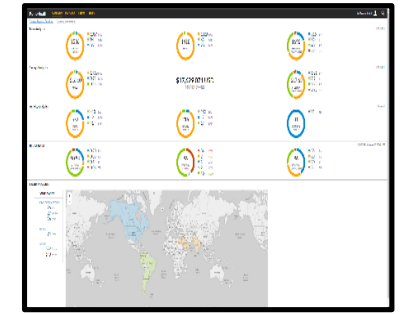
VISION

Data driven decision making with zero unplanned down time

MISSION

AVOID or MITIGATE Non Productive Time
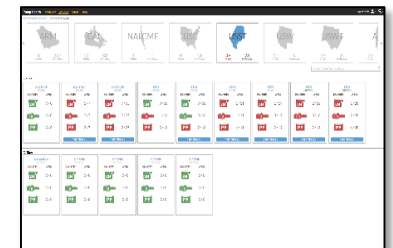
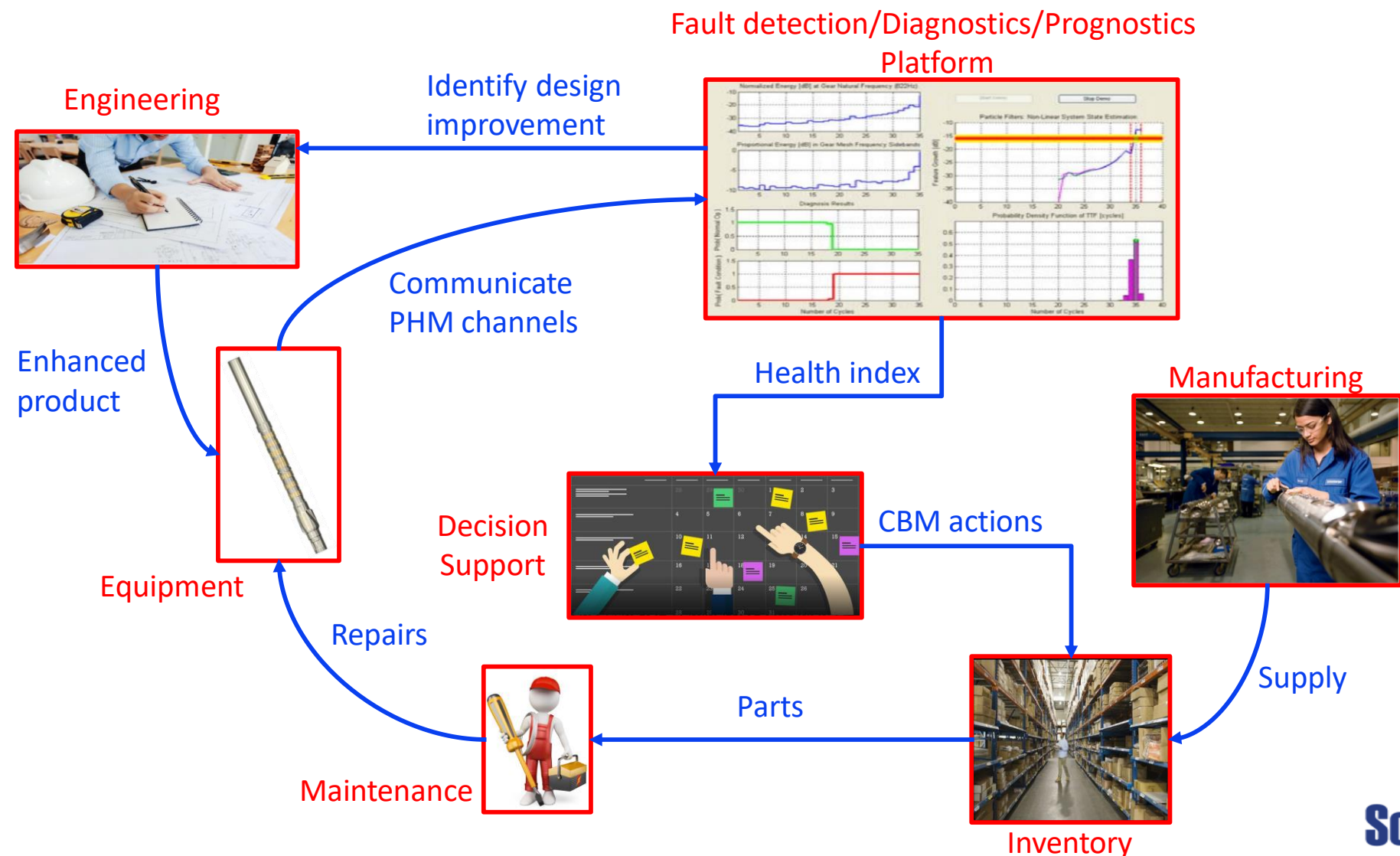REDUCE Total Cost of Ownership

IMPROVE Efficiency

Management

Failure Prediction

Components/Issues and Trends

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Data Driven Equipment Monitoring – The Big Picture

Fault detection/Diagnostics/Prognostics Platform

Engineering

Identify design improvement

Communicate PHM channels

Enhanced product

Equipment

Health index

Manufacturing

Decision Support

CBM actions

Repairs

Parts

Supply

Maintenance

Inventory

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The Analytics Team

Global footprint

Houston, US
Pune, India
Clamart, France

Multidisciplinary

Comp Science

Elect Eng.

Stats

Mech Eng.

Control Systems

Optimi-zation
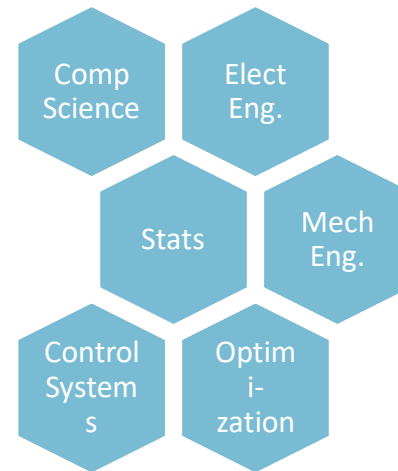
Agile, Highly Competent Data Science & Digital Product Development Team
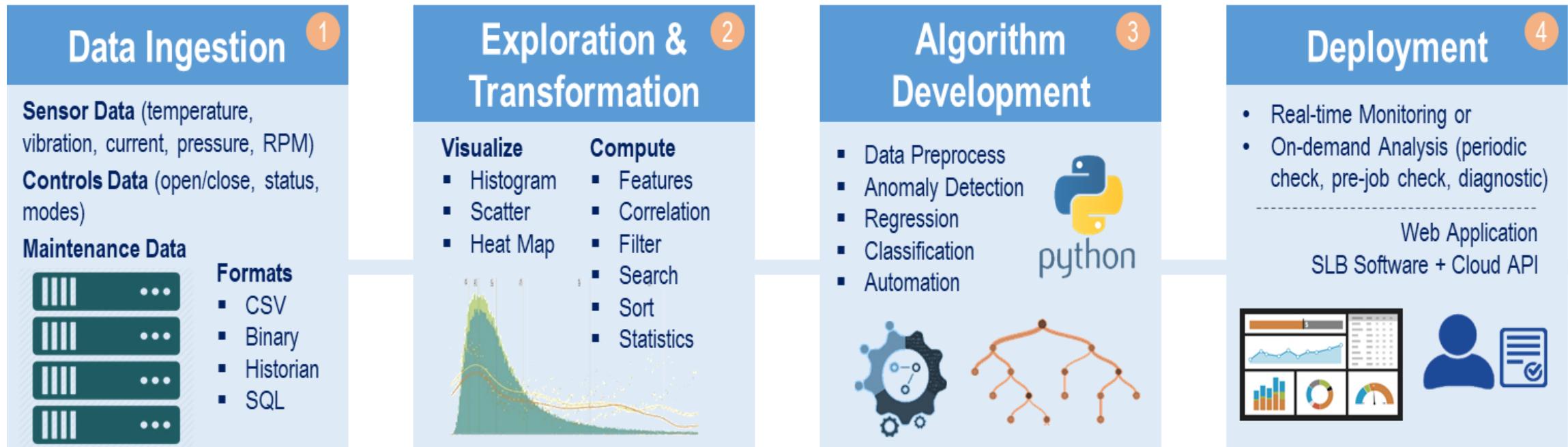
Top schools

Global Tech Centers

Product Deployment Across Segments

**Working on high-impact problems across many Schlumberger Product Lines**

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Phases in our projects

Data Ingestion [1]

Sensor Data (temperature, vibration, current, pressure, RPM)

Controls Data (open/close, status, modes)

Maintenance Data

Formats
- CSV
- Binary
- Historian
- SQL

Exploration & Transformation [2]

Visualize
- Histogram
- Scatter
- Heat Map

Compute
- Features
- Correlation
- Filter
- Search
- Sort
- Statistics

Algorithm Development [3]

- Data Preprocess
- Anomaly Detection
- Regression
- Classification
- Automation

python

Deployment [4]

- Real-time Monitoring or
- On-demand Analysis (periodic check, pre-job check, diagnostic)

Web Application
SLB Software + Cloud API

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Application 1: Logging-while-drilling (LWD) tool

Problem description & relevance

- Multifunction Logging-While-Drilling (LWD) tool

- Focus subsystem: Pulsed Neutron Generator **PNG** - self-contained particle accelerator

- Typical cycle: 100 hours at temp 150C, pressures of 20,000psi, significant shock & vibration

LWD tool

Pulsed Neutron Generator
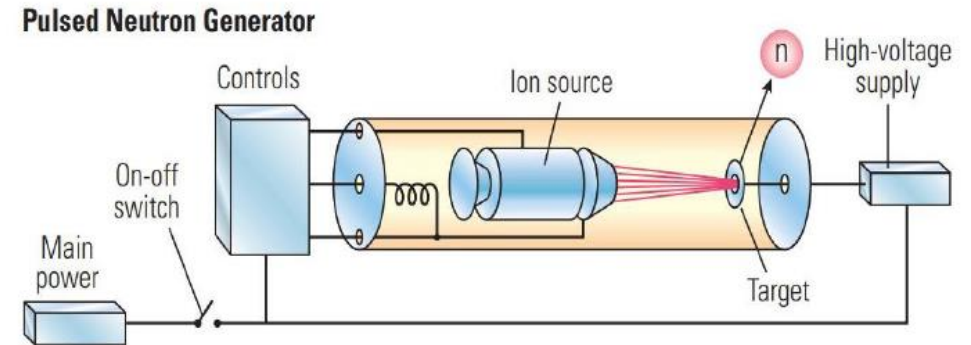
- Acquire 1,000 tool channels during runs

- After each job, technicians in Maintenance Base use tool data to decide on maintenance needed before tool is sent for next job

- PNG functionality is critical to core tool measurements

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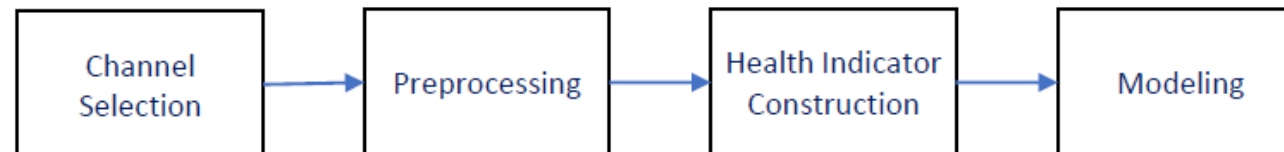# Application 1: Logging-while-drilling (LWD) tool

Previous solution – manual data analysis by experts

- Data analysis done manually: very time consuming, prone to error
- Large number of potential failure modes, many intermittent or only evident under the stress of down-hole conditions
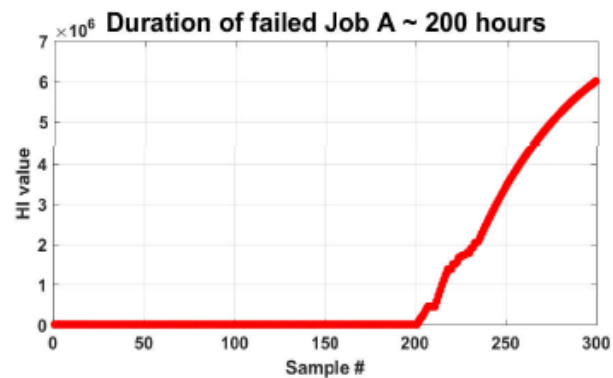- Experts added personal biases – need objective approach

New solution approach

Construct Health Indicator (HI) from PNG sensor data

1. Stat summary of selected channels
2. First principal component (PC1) from features
3. Empirical Mode Decomposition: from PC1 to intrinsic mode functions + residual signal
4. Residual signal shows rate of change in variance with time = developing PNG degradation
5. Decision-tree, trained on HIs of different runs labeled as healthy or faulty by expert
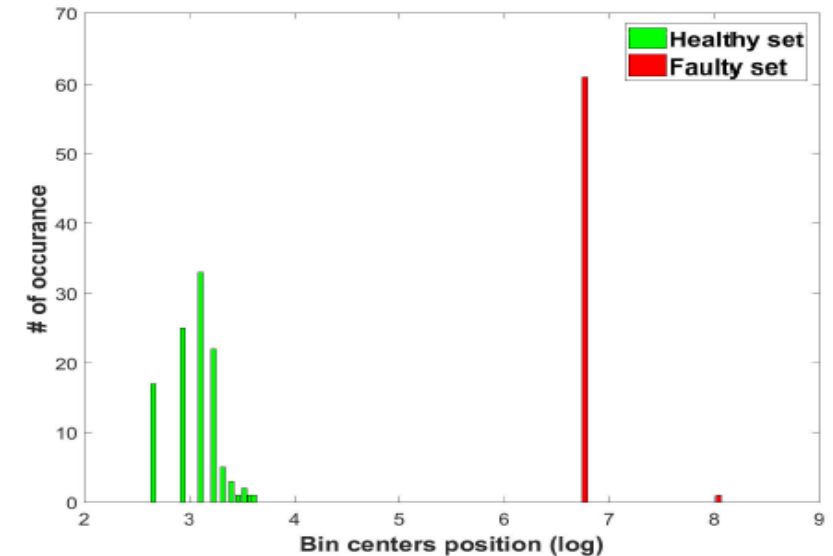
Channel Selection → Preprocessing → Health Indicator Construction → Modeling

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Application 1: Logging-while-drilling (LWD) tool

New solution approach

Duration of healthy Job A ~ 156 hours

Duration of healthy Job B ~ 100 hours

Duration of failed Job A ~ 200 hours

Duration of failed Job B ~ 750 hours

	Correct label		
	Healthy	Faulty	Total
Healthy	34	1	35
Faulty	0	25	25
Total	34	26	60

Predicted label (row labels Healthy / Faulty)

Table 1. Confusion matrix for model testing

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Ref: Data-drive Fault Detection for Neutron Generator Subsystem in Multifunction Logging-While-Drilling Service – by Mosallam, Laval, Youssef, Fulton, Viassolo. 2018 PHM European Conference

Application 2: Automated condition monitoring for BoPs

Blow-out Preventers

BoP is safety-critical drilling rig component; final layer of protection from a hazardous blowout

Annular BoP

Ram BoP

RIG

PIPE

BLOWOUT PREVENTER
SEAFLOOR
5,067 FT.

PIPE

OIL AND GAS
RESERVOIR
18,360 FT.

TO RIG

BLOWOUT PREVENTER — PIPE

ELECTRICAL LINES — HYDRAULIC LINE

YELLOW POD

BLUE POD

CONNECTOR TO WELLHEAD

The blowout preventer is 54 feet tall.

ANNULAR PREVENTERS
Can create a seal around the drill pipe or seal off an open wellbore when there is no pipe.

CONTROL PODS
Receive electrical signals from the rig and direct the movement of hydraulic fluid. Upper portion has electrical parts; the lower portion has hydraulic valves. Only one pod is activated at a time.

BLIND SHEAR RAM
Cuts the drill pipe and completely seals the well.

CASING SHEAR RAM
Cuts drill pipe or casing in an emergency when the rig needs to disconnect from the well quickly.

ACCUMULATORS
Store fluid sent from the rig. During an emergency, pressurized fluid from these canisters can provide force to power the blind shear ram.

PIPE RAMS
Seal off the space between the outside of the drill pipe and the well bore and keep the pipe centered.

TEST RAM
Used to test the rams above it.

Ref: *Towards Automated Condition Monitoring of BOP Wellbore Packers* – by Park, Baker, Kumar Bade, Viassolo – 2018 PHM Conference
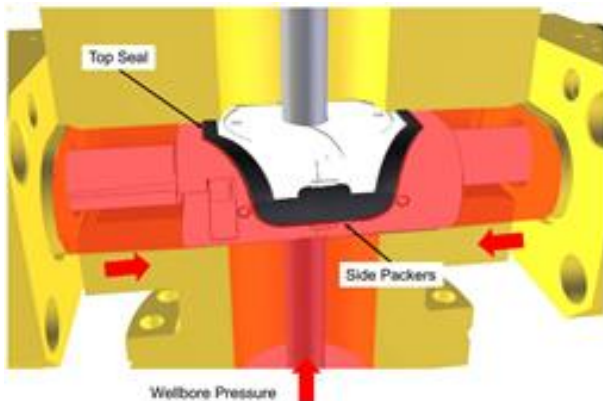
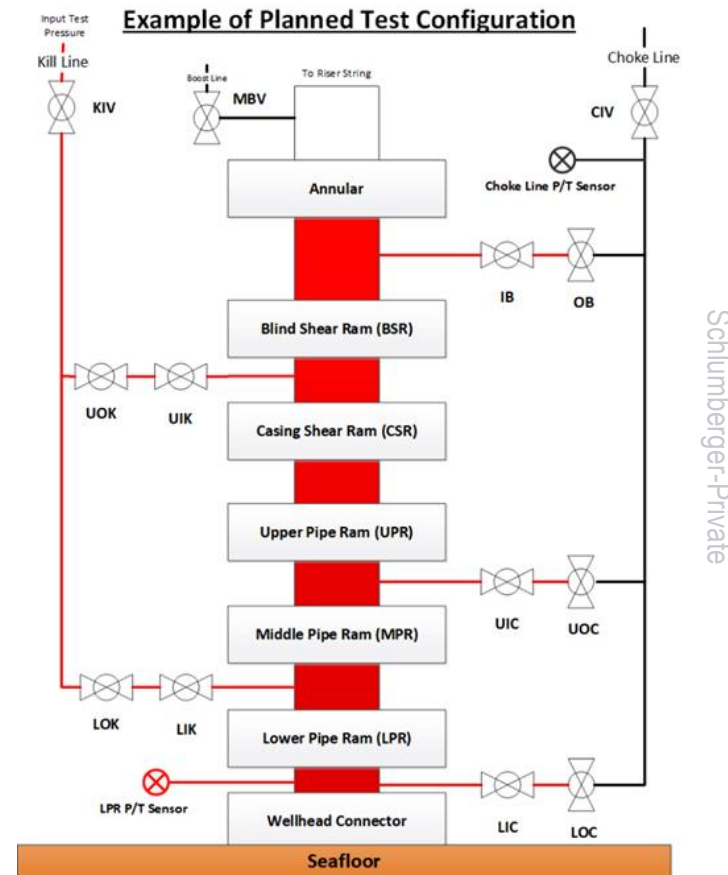# Application 2: Automated condition monitoring for BoPs

Problem description & relevance
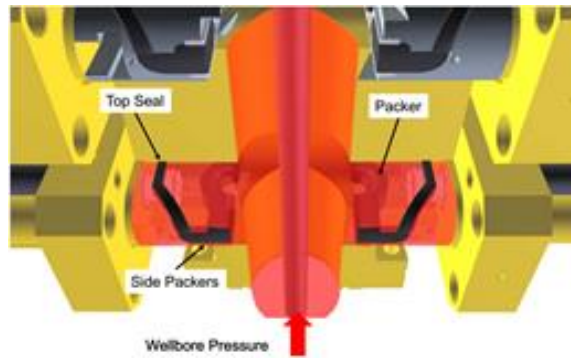
Wellbore Packers isolate pressure from well in event of a 'kick'. Packers during operation (above) and during test or 'kick' (below)
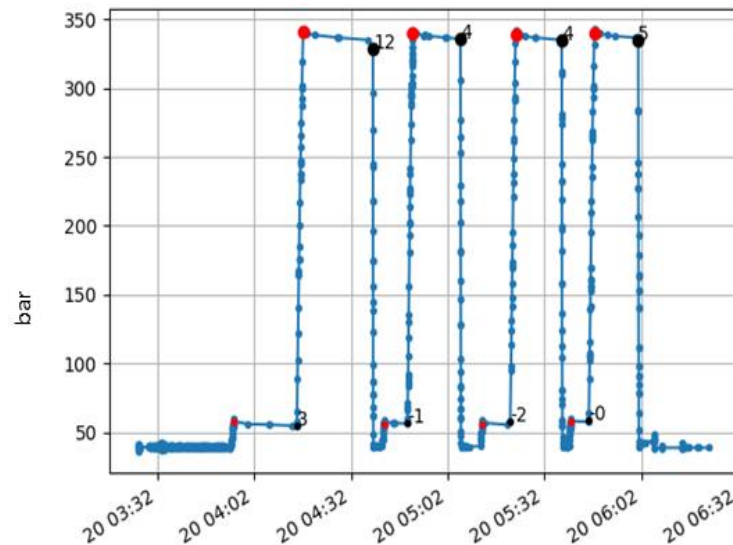

- 45 out of 59 rigs operating in Gulf of Mexico reported component failures of well control related equipment in 2017 (BSEE)

- The integrity of packers (leaks due to aging) must be assessed regularly by simulating pressures on them

- Needs:

1) **Test planning** – to ensure time efficient testing of all critical components

2) Once test data available, generate accurate **Health Index** for each component

BOP Stack with 19x components: 1x Annular, 2x Shear Ram, 3x Pipe Ram, 11x Gate valves and 2x Line isolation valves

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Application 2: Automated condition monitoring for BOPs

Automated Pressure Point identification from test data

Health index evaluation

Configurations

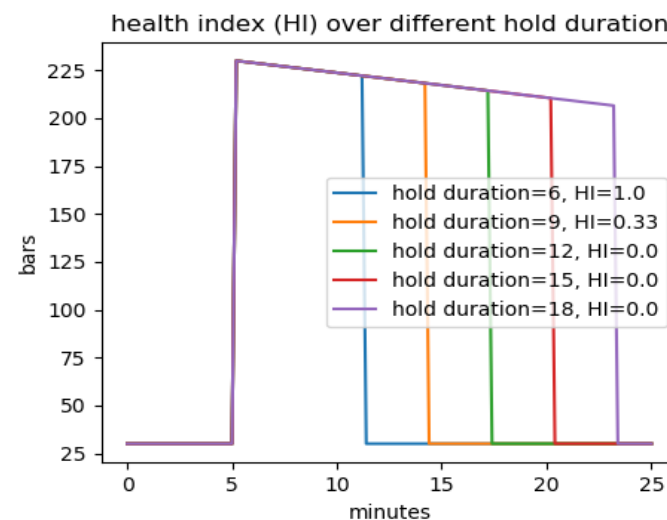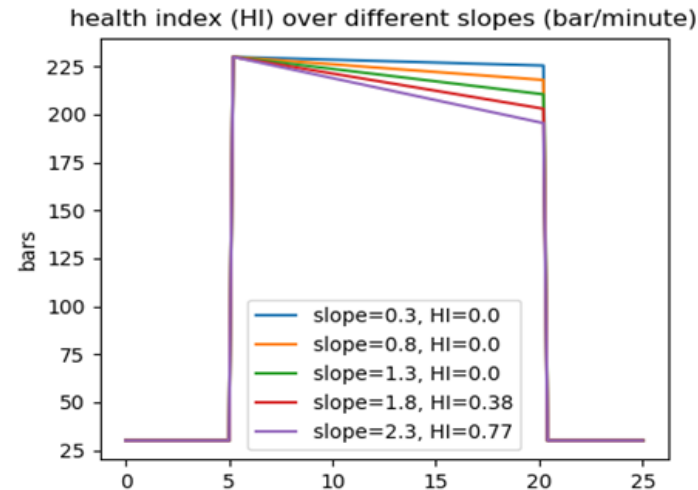*Health indices definition*

$$HI(s) = max(T_s - s, 0) / |T_s|$$

$$HI(d) = max(T_d - d, 0) / d$$

$$HI = HI(s) + HI(d)$$

health index (HI) over different slopes (bar/minute)
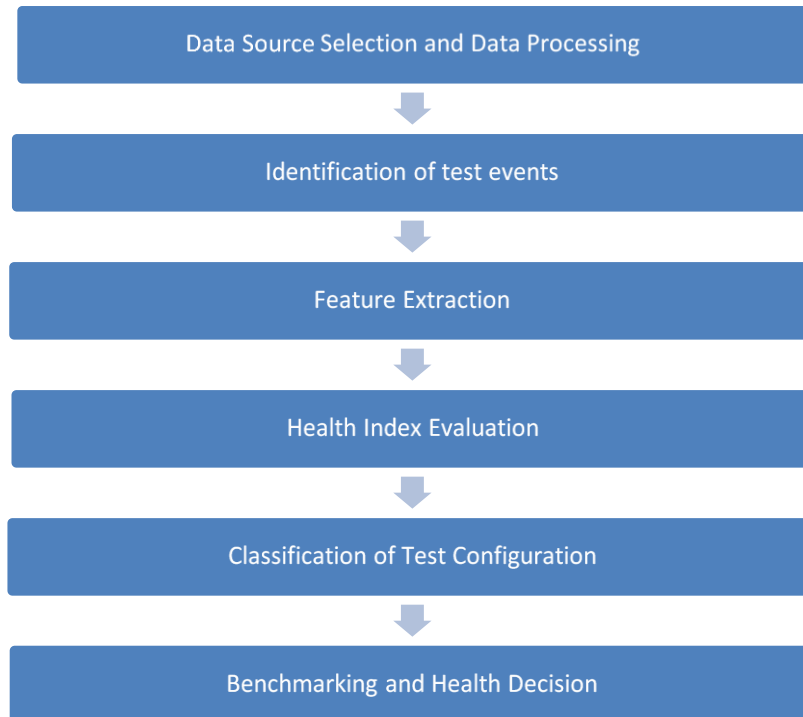
- slope=0.3, HI=0.0
- slope=0.8, HI=0.0
- slope=1.3, HI=0.0
- slope=1.8, HI=0.38
- slope=2.3, HI=0.77

health index (HI) over different hold duration

- hold duration=6, HI=1.0
- hold duration=9, HI=0.33
- hold duration=12, HI=0.0
- hold duration=15, HI=0.0
- hold duration=18, HI=0.0

Example of Planned Test Configuration

Example Pressure Test Setup Configuration

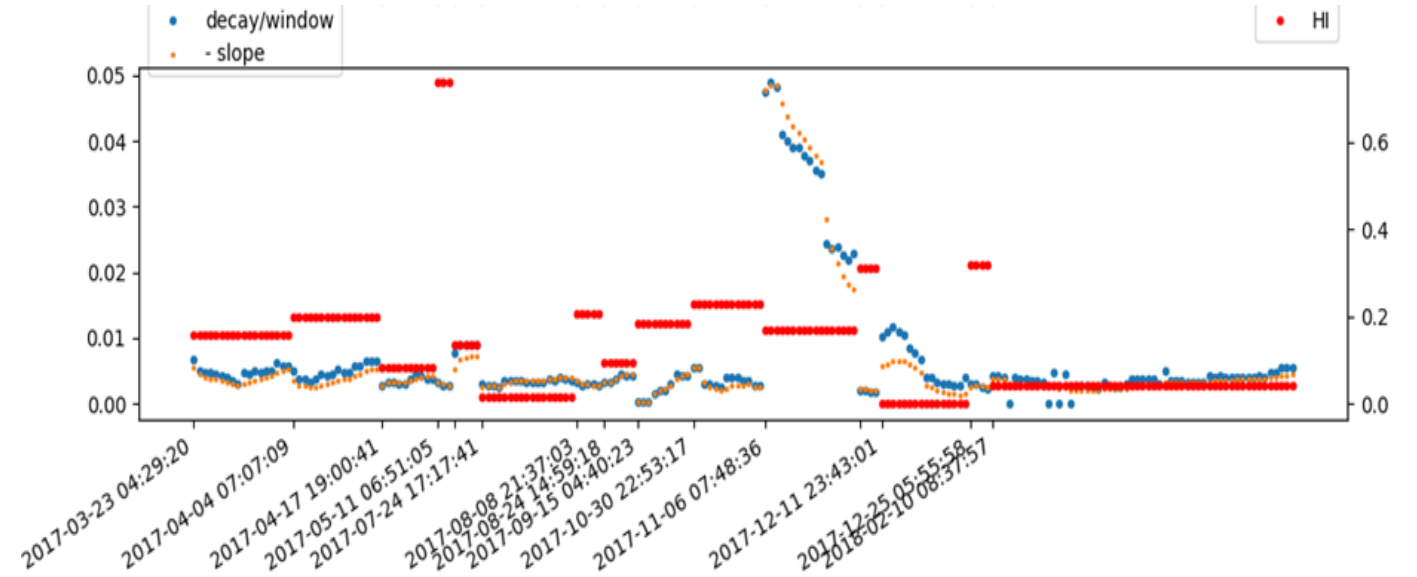| Component	Valve State (0=open, 1=closed)
Annular	1
Blind Shear Ram	0
Casing Shear Ram	0
Upper Pipe Ram	0
Middle Pipe Ram	0
Lower Pipe Ram	0
Upper Outer Choke (UOC)	1
Upper Inner Choke (UIC)	0
Lower Outer Choke (LOC)	1
Lower Inner Choke (LIC)	0
Choke Isolation Valve (CIV)	0
Upper Outer Kill (UOK)	0
Upper Inner Kill (UIK)	0
Lower Outer Kill (LOK)	0
Lower Inner Kill (LIK)	0
Kill Isolation Valve (KIV)	0
Outer Gas Bleed Valve (OB)	1
Inner Gas Bleed Valve (IB)	0
Mud Boost Valve	1

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Application 2: Automated condition monitoring for BOPs

Condition Monitoring Process Flow for BOP Wellbore Packer

Data Source Selection and Data Processing

Identification of test events

Feature Extraction

Health Index Evaluation

Classification of Test Configuration

Benchmarking and Health Decision

Health indices for *Middle Pipe Ram* over Mach 2017 – Feb 2018

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Another application: Frac Pumps

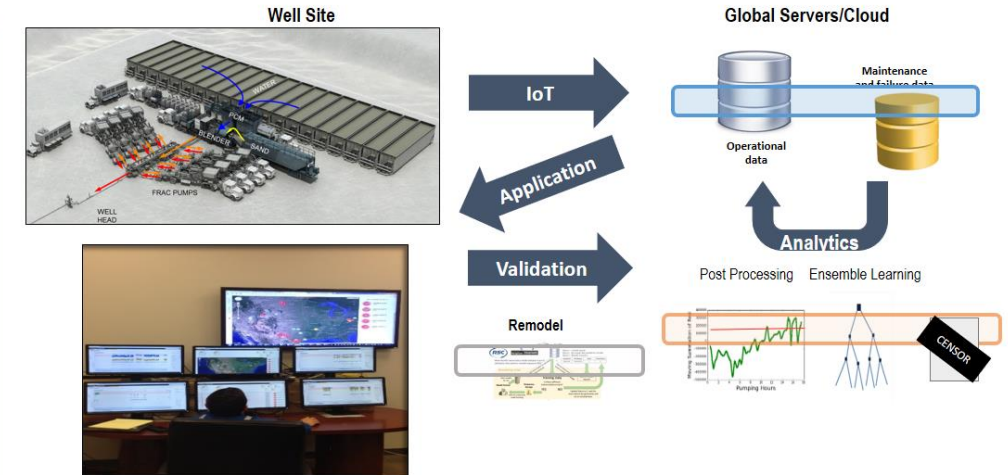## Frac Pumps Monitoring - Impact

Regional Support Centers

1,289 field notifications sent

1,179 incidents avoided

$7.7 million in M&S savings

- **Schlumberger Full-Year 2016 Results**

- ... **The Reliability Support Center in Denton implemented prognostic health management (PHM), using real-time pump data collected from field locations. During the six months after implementation, PHM achieved an estimated $6 million of savings in operation costs ...**

Frac Pump Monitoring – High Level Architecture

Well Site

Global Servers/Cloud

IoT

Maintenance and failure data

Operational data

Application

Validation

Analytics

Post Processing   Ensemble Learning

Remodel

CENSOR

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Many other applications, beyond Equipment

Operation Planning

Staffing Planning

Engineering & Manufacturing

Supply Chain Optimization

Asset & Production Optimization

Research & Innovation

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Closing Remarks

Asset Health Management is a key enabler for:

- Lowering Total Cost of Ownership for O&G Tools and Equipment

- Improve Service Quality

- Reduce NPT

- Enhanced Availability & Productivity

- Situational Awareness and Planning

New Business Models can bring new revenue streams for OEMs via Service Agreements – pay by performance, pay by uptime, lease business models, etc.

Though there are bottlenecks, recent advances in IoT, Cloud and Machine Learning have made it easier to acquire, transmit, analyze and forecast equipment conditions and RUL, enhancing predictive planning & resource management abilities

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