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End-to-End Pump System Analytics

June 2018

Agenda

- The Business Value: Why should you care?
- The Technical Journey: from streaming data to advanced analytics
- The Operational Journey: pump condition & performance monitoring
- Key Lessons and Q&A

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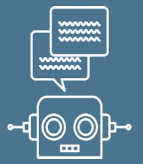
Technology megatrends are reshaping the world

Increasing availability of sensors

More connected machines & people

Cheaper data storage & compute

More automation & faster decisions



Sophisticated machine learning techniques

Significant business opportunities

New products / New processes / New business models

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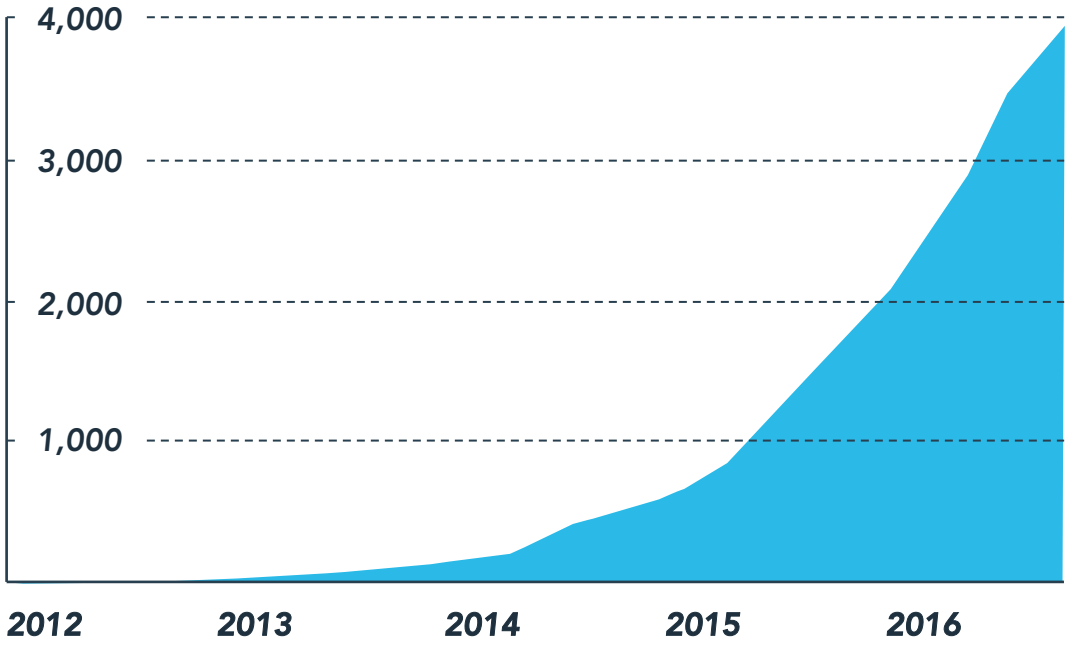
IoT and machine learning are rapidly growing in many verticals ...

Growing use of deep learning at Google

# of directories containing model description files



Across many products / areas

- Android
- Apps
- Drug discovery
- Gmail
- Image understanding
- Maps
- Natural language understanding
- Photos
- Robotics research
- Speech
- Translation
- YouTube

.....

Source: Google

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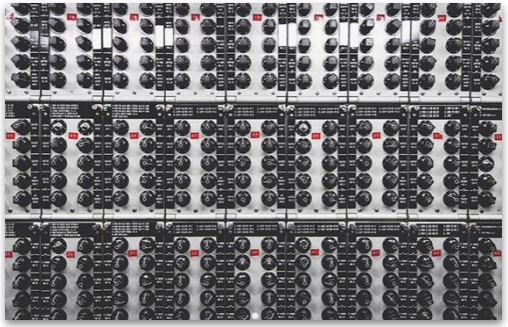
… however, the pump industry faces unique challenges to adoption

Legacy physical assets weren't built for IIoT



Complexity in existing IT infrastructure

Perception: large IT **"plumbing" investments** needed to capture value

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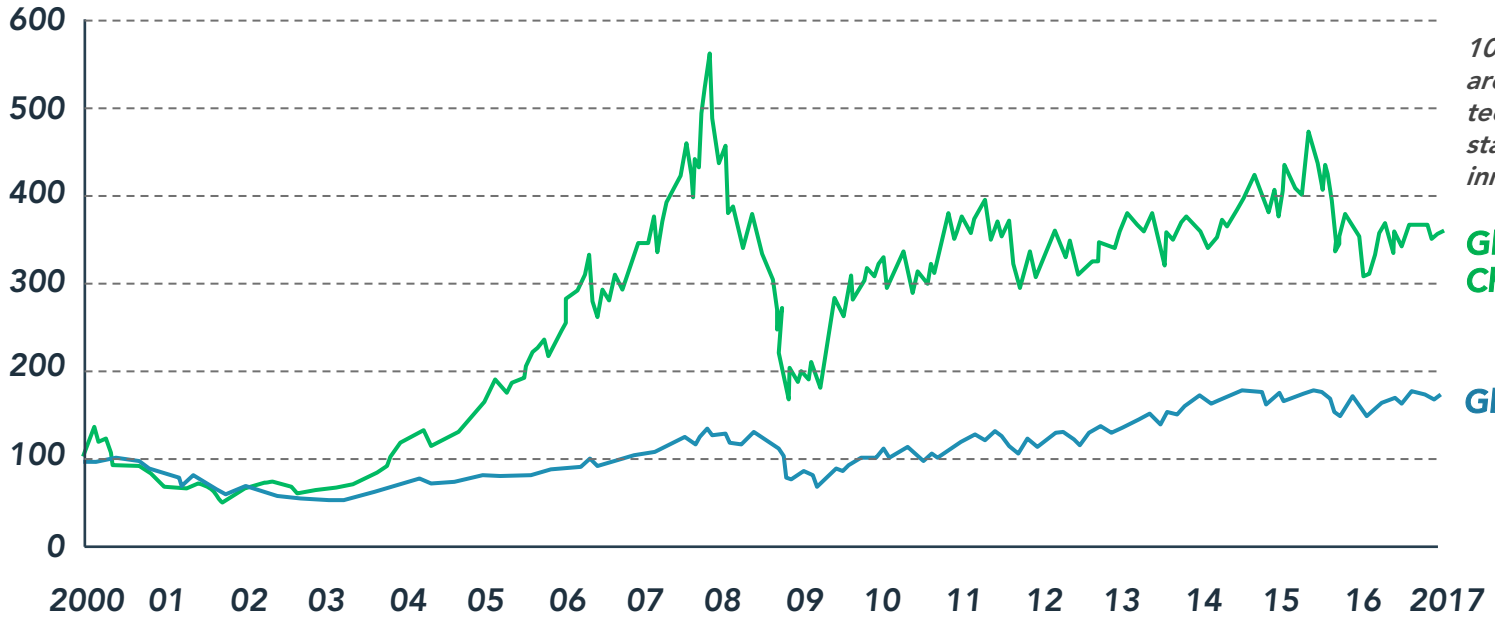
Over the last 20 years, digital adopters have strongly outperformed their peers

Total shareholder return 2000-2017 (Indexed to 100)



100 companies that are leveraging digital technology to set new standards of innovation

Global Challengers

Global Peers

Source: Datastream; Boston Consulting Group
Note: All indexed were weighted by the market capitalization of their constituent stocks. Global challengers' performance is based on data from 92 publicly listed global-challengers companies. Global peers are 230 multinational companies that operate in the same industries as the global challengers. TSR is based on US dollars.

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The pump industry requires a unique journey to benefit from IoT analytics

Current state

- *Periodic data collection*
- *Pre-set high/low thresholds for key physical measurements*

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- *Reactive process*
- *Inefficient relative to value created*

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Future state

- Real time streaming data
- Data-driven decision making

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Future opportunities

- Insights tailored for local installation/system
- Proactive process
- Optimized for value capture

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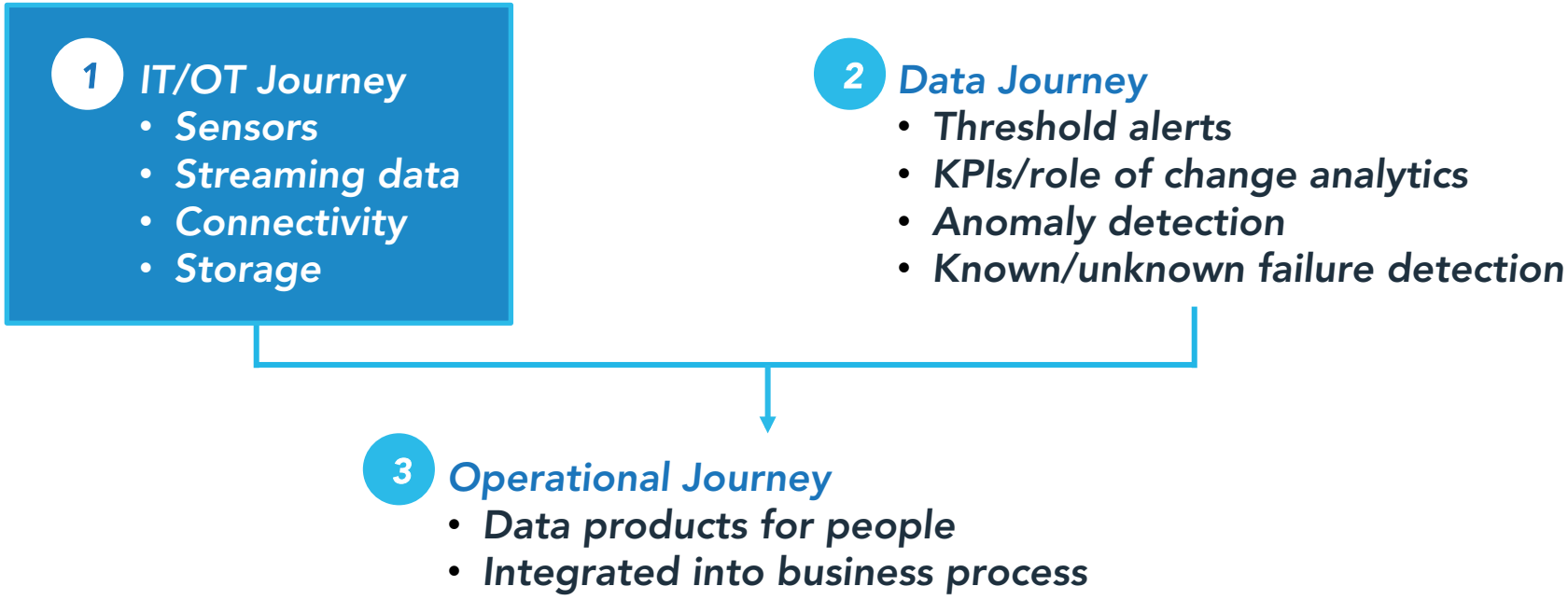
Getting from “current” to “future” involves diverse capabilities and understandin



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How should we start to collect streaming data values?

Which values should I collect? How many sensors per asset? How often do I sample?

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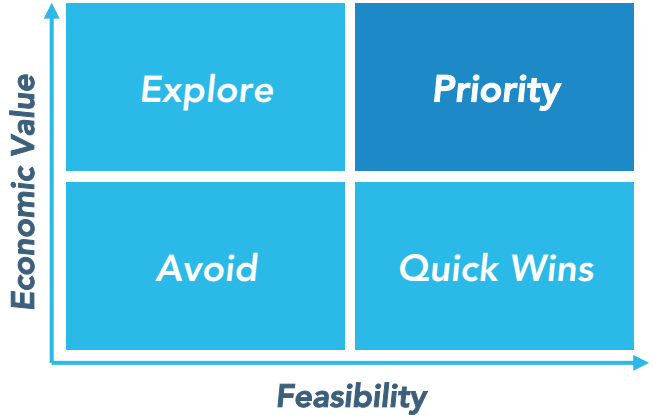

- Focus on value capture
- Start with low-risk moves
- Learn and iterate

Once data is streaming, a new set of challenges come up

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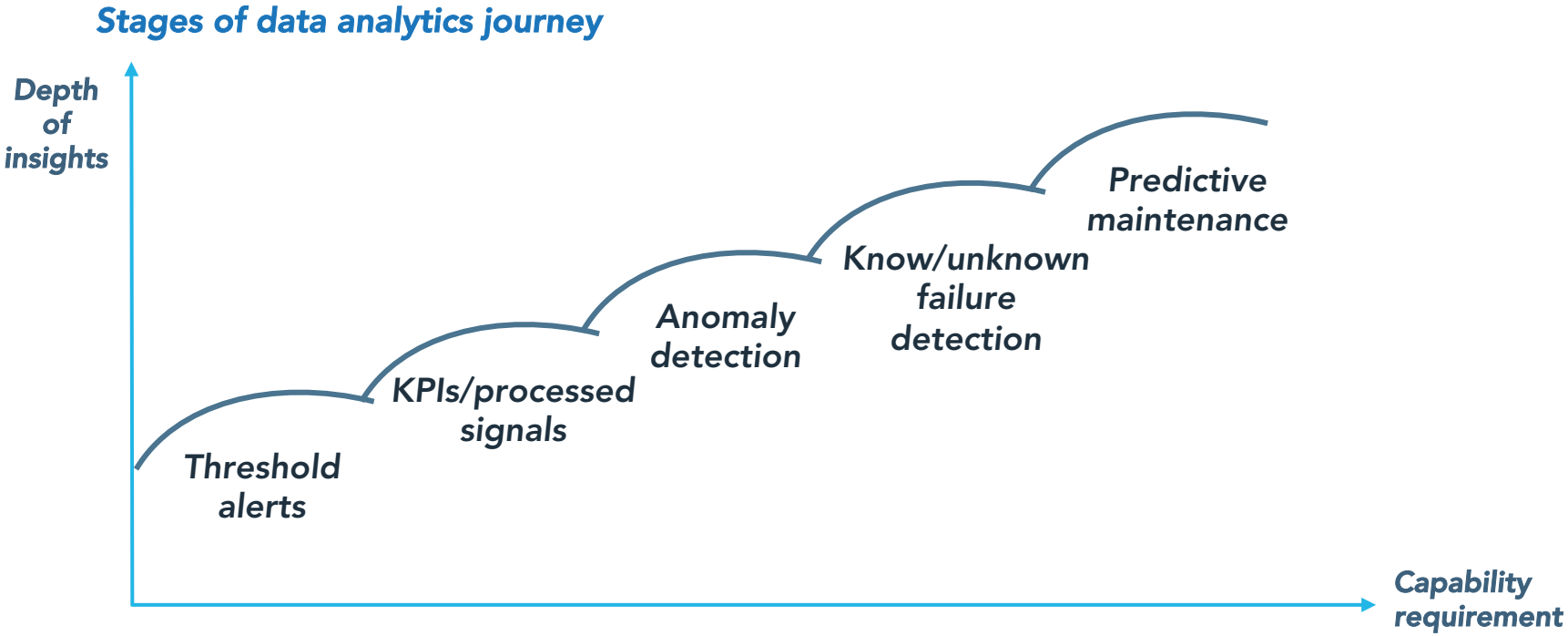
How to play with the streaming data?



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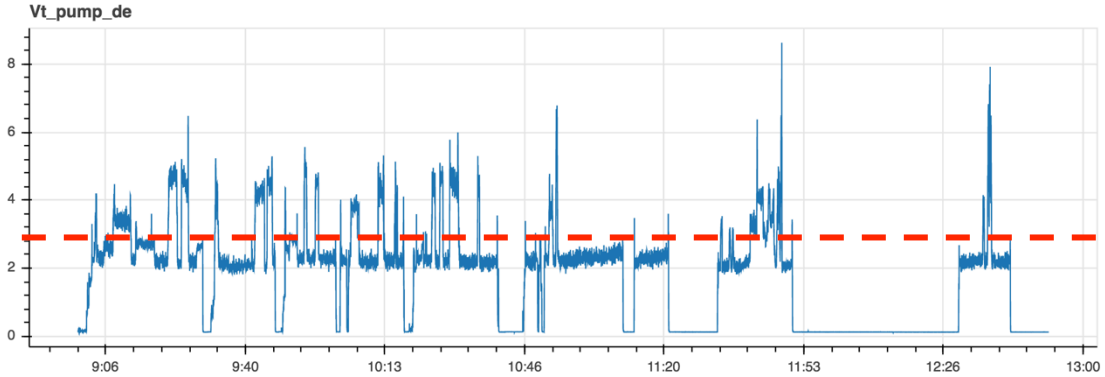
Initial practice usually involves comparisons with threshold for key values such as temperature and vibration



Comparing sensor readings to recommended thresholds

a. *Based on test data*

b. *Based on 3rd party calibration/benchmark*

c. *Calibrated with own data*

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Second opportunity incorporates first principles KPIs

Motor Power

Differential Pressure

Flow Rate

Pool Temperature

***Manipulating/transforming raw sensor data based on engineering insights** (e.g., how fast is a value changing, even if it hasn't breached threshold)*

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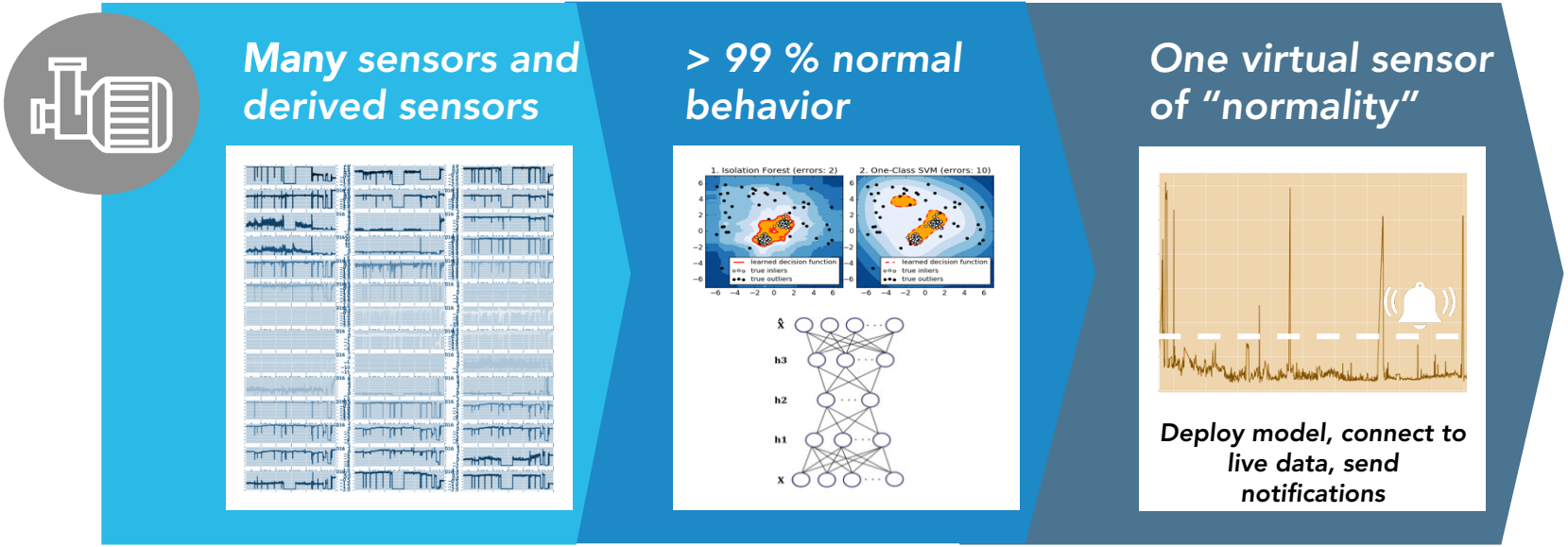
Third opportunity uses machine learning to recognize "abnormal" behavior



Data-driven model that understands "normal" behavior for a specific pump in a specific location/application (anomaly detection)

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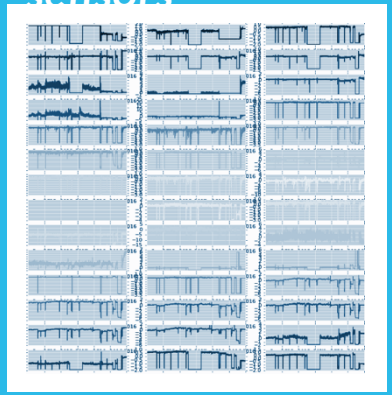
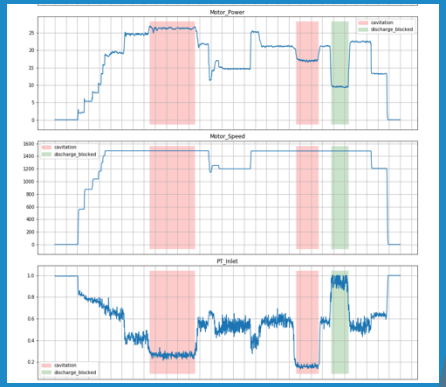
Fourth opportunity uses machine learning for failure mode identification

Many sensors and derived sensors



Labeled known failures



Identifying specific modes of failure in real-time

1. Cavitation
2. Blocked discharge
3. Seal failure
4. Unknown failures

Series of models examining specific modes of failure for the pump (enables easier root cause analysis)

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Fifth opportunity uses machine learning for predictive maintenance

Current status

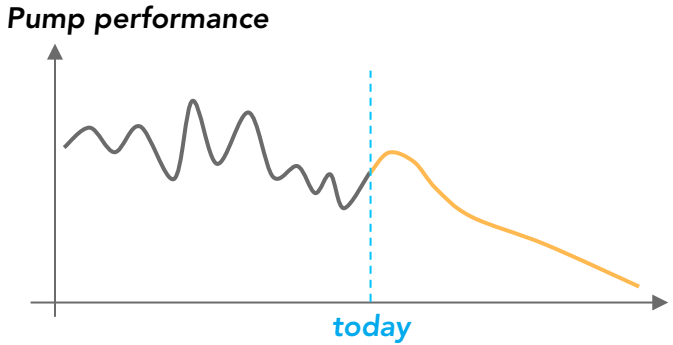
The performance of pump degrades over time due to wear, corrosion and erosion

To counteract this:

- *Regular inspections*
- *Replacement of worn out parts*
- *Reactive maintenance*

Desired outcome

Forecast degradation to assist with scheduling of cleaning together with other maintenance activities



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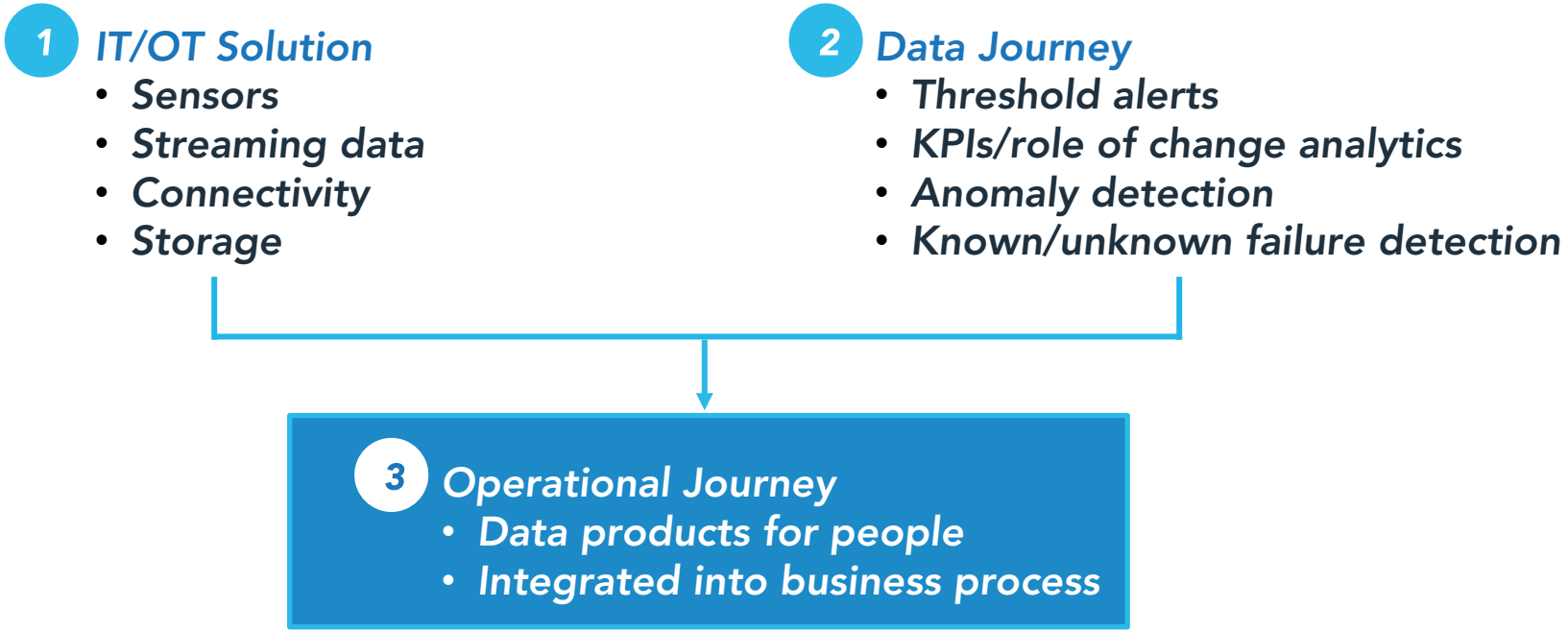
But none of this matters if the business doesn't change



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Discussion of the Operational Journey

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Key Lessons

Consider solution architecture, data analytics, and operational implications together

*Find low-risk ways to **get started** – don't wait for the perfect sensor or instrument*

*Focus on **business value** – what will you change to reduce costs or increase revenue?*

*Create data **products for people**, not models for data*

Contact us at lukasz.mentel@arundo.com, or xinwo.huang@arundo.com

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SURVEY 1

Where is your company in its "Digital Journey"?

A) We are not thinking about it / not applicable
B) We are starting to think about it
C) We have launched pilot projects
D) We have integrated projects into our core business

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SURVEY 2

How are you using field equipment data?

A)We are not doing it / not applicable
B)We are comparing to benchmark thresholds
C)We are feeding physics-based models
D)We are feeding machine learning models

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*provides software products to **enable** enterprise-scale machine learning and advanced analytics applications for **industrial** companies*

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