

Smart Automation and IIoT Layers

Case Study of Pilot Cyber-Physical Lab

Dr. Sunil Jha, Professor
Department of Mechanical Engineering,
IIT Delhi, Hauz Khas, New Delhi - 110016
suniljha@mech.iitd.ac.in



IITD-AIA Foundation
for
Smart Manufacturing
www.iafsm.in

Smart Manufacturing

Economic Potential

Ability to **accelerate** corporate **decision-making**
and **adaptation** processes

Agility

Ability to implement **changes** in
the company in **real-time**



Smart Manufacturing

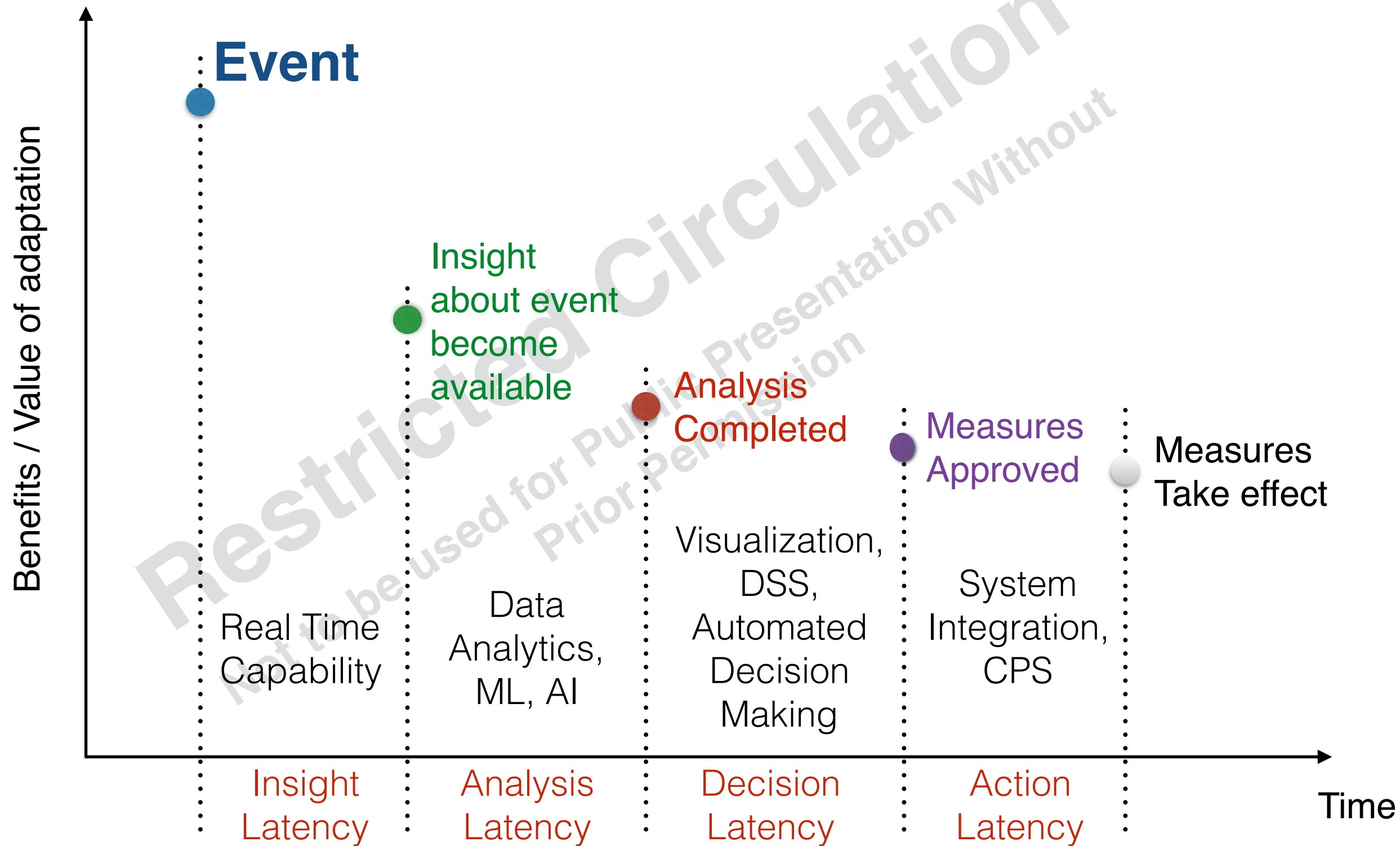
The **significance** of Smart Manufacturing lies in the role of **information processing** in enabling **rapid** organisational **adaptation** processes.

The **faster** an organisation can **adapt** to an event that causes a change in its circumstances,

Greater the **benefits** of the **adaptation**.



Corporate Adaptation Processes



Source: based on Hackathom 2002; Muehlen/Shapiro 2010



Smart Manufacturing

Smart Manufacturing is about manufacturing “**with intelligence**” at **each step** along the “**Design - Make - Use**” continuum

Smart manufacturing will **transform** how products are:



It will **transform** the **operations**, **processes**, and **energy footprint** of factories

and the **management** of manufacturing **supply chains**.



Levels of Smart Manufacturing

Decision Making

Make **optimised**, **real-time** **decisions** on production **levels**, **locations**, **options** etc. based on **corporate intelligence** created by **Smart Manufacturing enterprise**

Data Analytics

Applying DA to broad manufacturing **intelligence** to **optimise processes** and to iteratively design **smart products**

Digital Thread

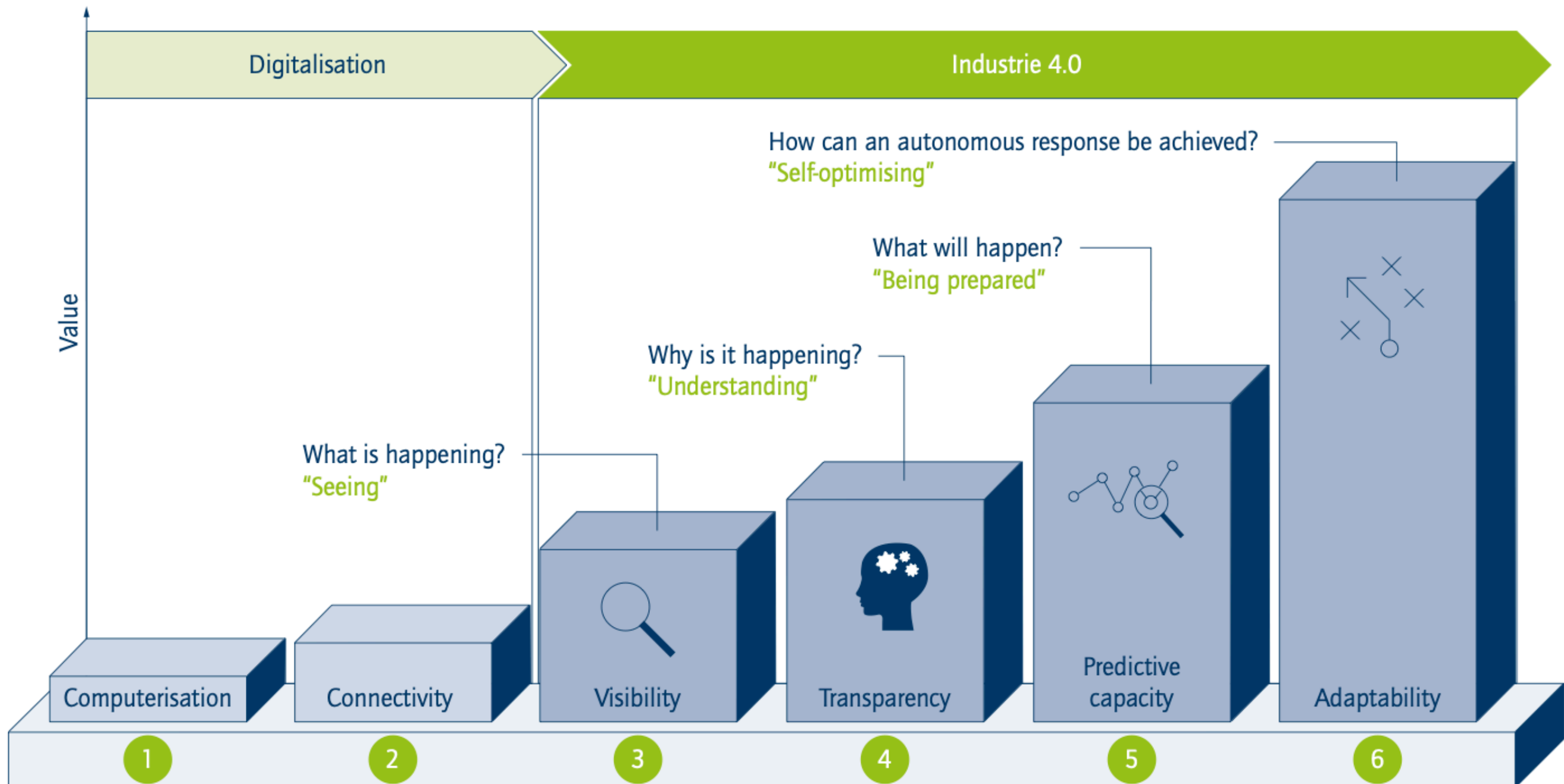
Consolidates **information streams** from individual machines across **factory floor** by linking multiple process-chains together

Intelligent Machines

Production **equipments** equipped with **sensors** integrated into **IIoT**
(*information stream*)



Stages in Smart Manufacturing Development Path



(source: RWTH Aachen University)



1: Computerisation

- Different **information technologies** are used in **isolation** from each other within the company.
- Computers are primarily used to perform **repetitive tasks** more efficiently
- Still possible to find many machines **without** a **digital** interface
- One example for the computerisation stage would be a **CNC milling machine.**

CAD data detailing actions still often has to be transferred to the milling machine manually – in other words, the **machine is not connected.**

- Semi-automated quality assurance is carried out at a test station, but the recorded data is not associated with the corresponding work order



2: Connectivity

- The **isolated** deployment of **information technology** is replaced by **connected** components.
- Widely used business applications are all connected to each other and mirror the company's core business processes
- Parts of the operational technology (OT) systems provide connectivity and interoperability, but **full integration** of the IT and OT layers has **not yet** occurred
- Connectivity means **seamless information exchange** between design, production, maintenance and service.



3: Visibility

What is happening?

- **Sensors** enable processes to be captured from **beginning** to **end** with large numbers of **data points**.
- This makes it possible to keep an up-to-date **digital model** of **factories** (company's **digital shadow**) at all times.
- Producing a digital shadow is a **major challenge** for many companies.
 - data is often held in decentralised silos,
 - very little data collected,
 - data captured is only visible to a limited number of people



3: Visibility

What is happening?

- In order to achieve the goal of an **agile learning enterprise**, comprehensive **data capture** right across the company is **essential** for the provision of **relevant data about the operation** throughout the business.

Real-time KPIs
and dashboards

Rapidly determine the
delivery date variance

Production planning
can be adjusted

Inform customers
and suppliers

- The **combination** of existing data sources with **sensors** on the shop floor can deliver significant benefits.
- Integrating **PLM**, **ERP** and **MES** systems provides a comprehensive picture that creates **visibility** regarding the **status quo**.



4: Transparency

Why is it happening?

- The next stage is for the company to **understand** why something is happening and use this understanding to **produce knowledge** by means of **root cause analyses**
- In order to **identify** and **interpret** interactions in the digital shadow, the captured **data** must be **analysed** by applying **engineering knowledge**.
- New technologies that support the **analysis** of **large** volumes of **data**
- Recorded parameters are **searched** for mutual **events** and **dependencies** that are then **aggregated** to produce complex events reflecting the condition of the machine or equipment.



5: Predictive Capacity

What will happen?

- Once it has reached this stage, the company is **able** to **simulate** different **future scenarios** and identify the most likely ones.
- Companies are able to **anticipate future developments** so that they can take decisions and **implement** the appropriate **measures** in good time.
- A company's **predictive capacity** is heavily **dependent** on the groundwork that it has **previously** undertaken.
- A properly constructed **digital shadow** combined with a **knowledge** of the relevant **interactions** will help to ensure correct **forecasts** and the right **recommendations**.



6: Adaptability

Achieving Autonomous Response

- Predictive capacity is a fundamental requirement for **automated actions** and **automated decision** making.
- **Continuous adaptation** allows a company to **delegate** certain decisions to **IT systems** so that it can **adapt** to a **changing** business environment as **quickly** as possible.
- The degree of adaptability depends on the complexity of the decisions and the cost-benefit ratio
- Important to **carefully assess** the **risks** of automating approvals and acknowledgements for customers and suppliers.
- The **goal** of adaptability has been **achieved** when a company is able to **use the data** from the digital shadow to **make decisions**



Smart Sensors

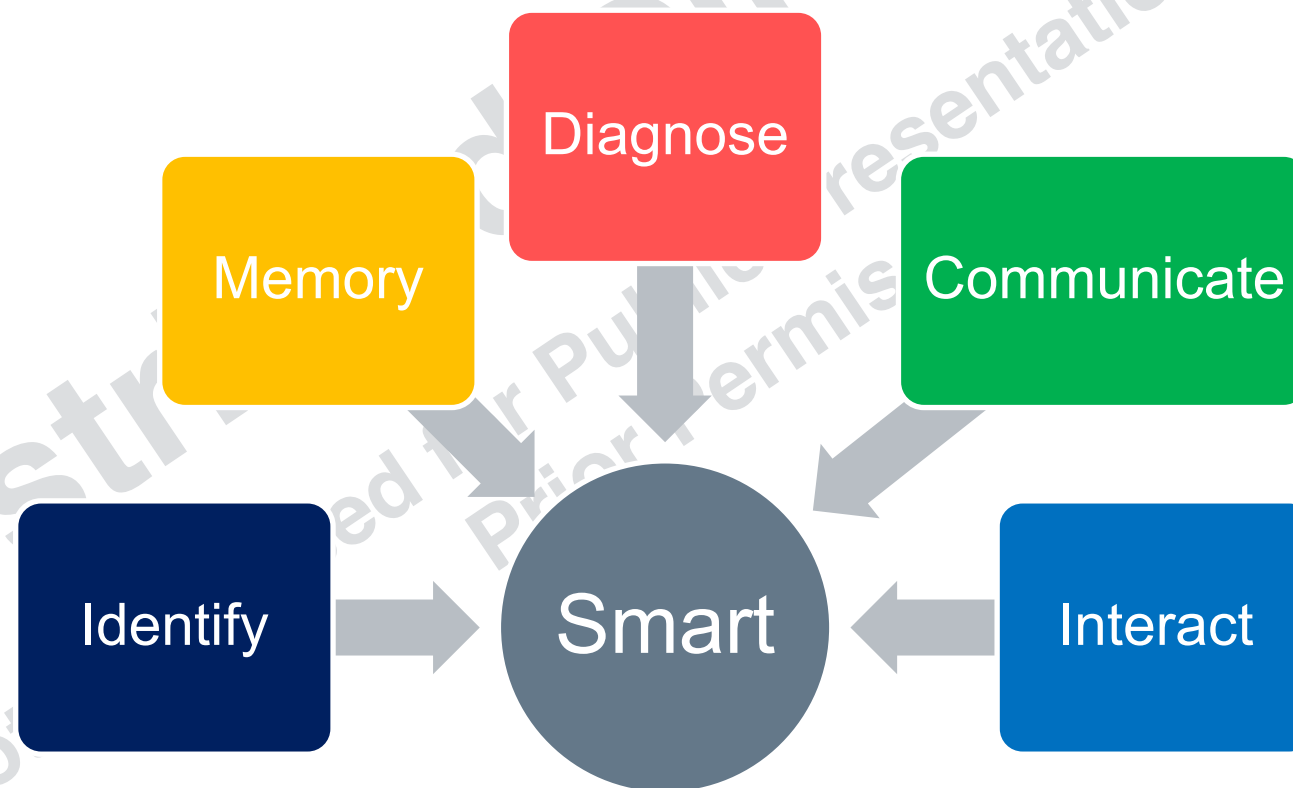
Dr. Sunil Jha, Professor
Department of Mechanical Engineering,
IIT Delhi, Hauz Khas, New Delhi - 110016
suniljha@mech.iitd.ac.in

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What are Smart Sensors?

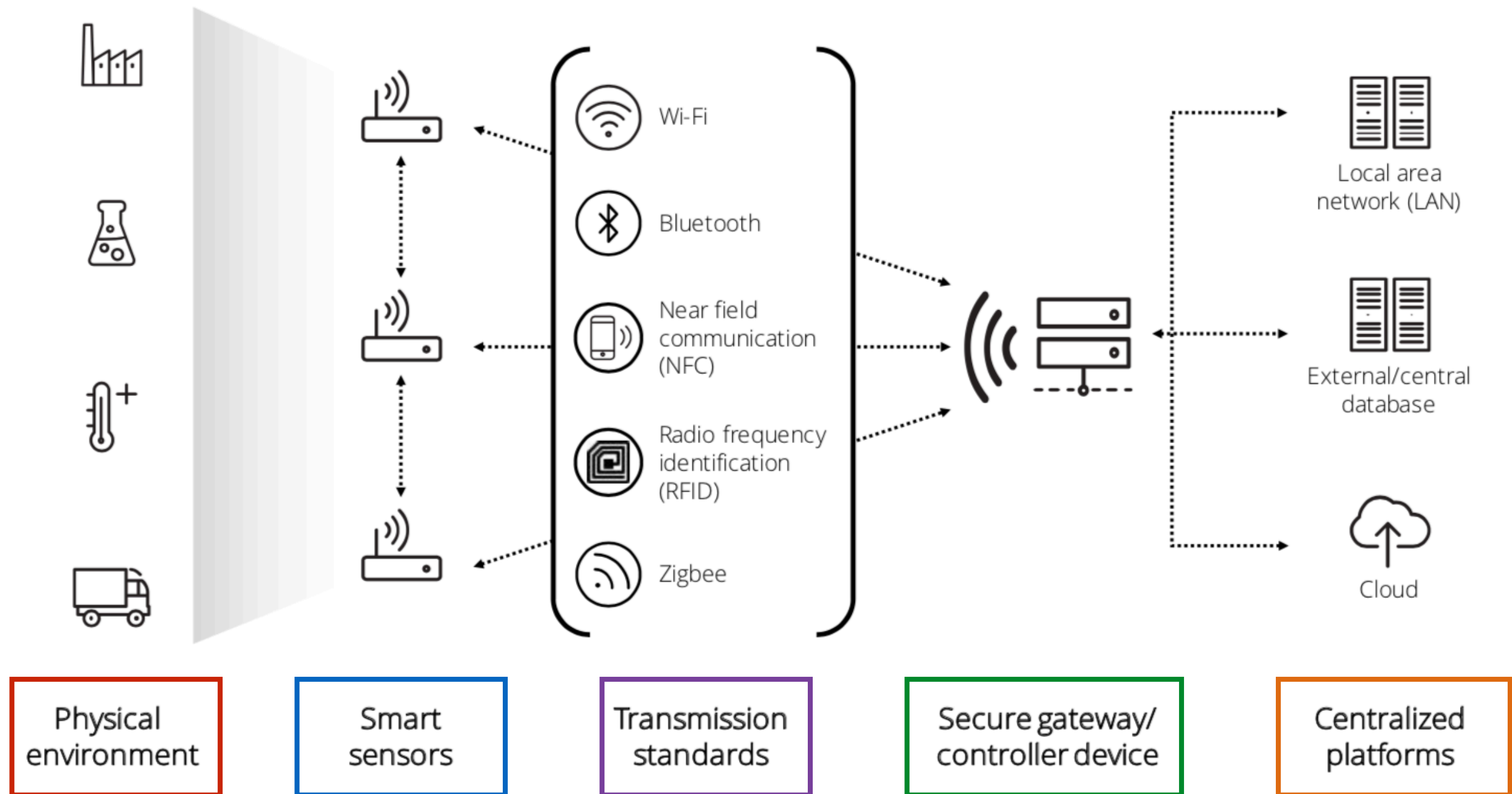
Smart sensors are **advanced platforms** with onboard **technologies** such as **microprocessors**, **storage**, **diagnostics**, and **connectivity** tools that **transform traditional feedback signals into true digital insights**.



These **smart sensors** can provide the **timely** and **valuable data** to power **analytical insights** that can in turn drive **improvements** in **cost**, **performance**, or **customer experience**.



Smart Sensor Ecosystem



Smart Sensors

Need of smart sensors

Smart sensors transform the **physical world** into **digital insights** that are used to create **new value**.

By arming managers with **real-time information** about their **inventory**, **machinery**, and **purchased materials**,

Smart sensors create **visibility** across the supply chain and fuel **analytics** that can be used to understand and anticipate **demand**, **optimize sourcing**, and drive **high-value** manufacturing **decisions**.



Smart Sensor

Recent Developments

Computing Capabilities

Enabling **data processing** and **analysis** at or **near** the **source** (“edge computing”) and **reducing** the **amount** of **data** that moves between the **device** and **platform**.

Compact

MEMS technology allowed for more **compact**, higher functioning smart sensors by effectively incorporating **microelectronic** functions in **minimal space**

Connectivity

New **wireless** technologies are offering connectivity solutions that are more **scalable** and **tailored**

Low-power wide area networks (**LoPWAN**), for example, have **reduced cost**, **power consumption**, and **range** issues for smart sensor usage.



Smart Sensor Recent Developments

Recent Developments

Analytics Tools

Extracting **insights** from sensor-created data is getting **easier** as **analytics** tools continue to improve.

Big Data

Handling and storing large, complex data sets is becoming more **manageable** through **Big data platforms**.

Real Time Processing

Tools enable **processing** and **analysis** of data on a **real-time** or a near-real-time basis, driving **timely decision making** and **action**.

New Algorithms

Algorithms continue to advance, expanding the **capability** to **predict** and **prescribe** courses of **action**.



Industrial IoT

Dr. Sunil Jha, Professor
Department of Mechanical Engineering,
IIT Delhi, Hauz Khas, New Delhi - 110016
suniljha@mech.iitd.ac.in



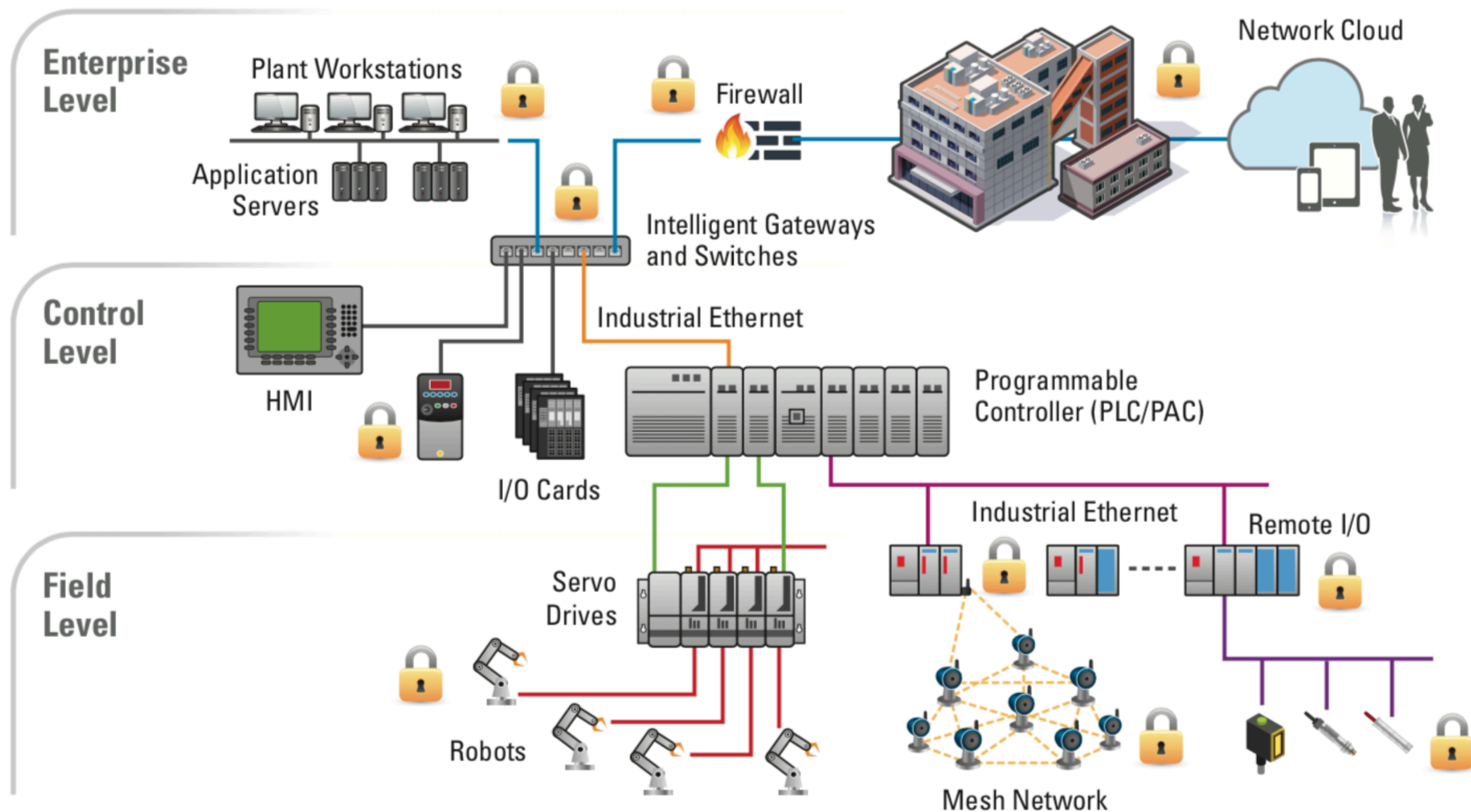


Why IIoT ?

- Ensuring **reliability** and **quality** of the product or process
- Improving **efficiency** of the manufacturing processes and adding **predictive maintenance**
- Introducing **products** faster with more **intelligent asset management**
- **Connecting** interdependent **multi-located** manufacturing facilities

White Paper on “Smart Factory Connectivity for the Industrial IoT”, Ashish Pathak, Industrial Automation Segment, Renesas Electronics America Inc.
February, 2017

Smart Factory Connectivity for IIoT



White Paper on "Smart Factory Connectivity for the Industrial IoT", Ashish Pathak, Industrial Automation Segment, Renesas Electronics America Inc. February, 2017

IIoT for Condition Monitoring

Reactive

Fix it When it
Breaks

Preventive

Schedule
Maintenance

Predictive

Maintain it Before
it Breaks

Condition Monitoring Enables



12-18%

Increase in Productivity



8-12%

IIoT Key Ingredients

People

- How are they identified?
- How do they interact with the data (near real-time)?
- How do they consume the data (notifications, trends, alerts)?

Devices

- What are they?
- How do they communicate with systems?
- How are they managed?

Data

- What happens with data flowing in?
- What happens when data needs to flow out?
- How can data converted into business value (Monetization)?

What qualifies as complete IOT use case?

Uniquely
identifiable and
connected things

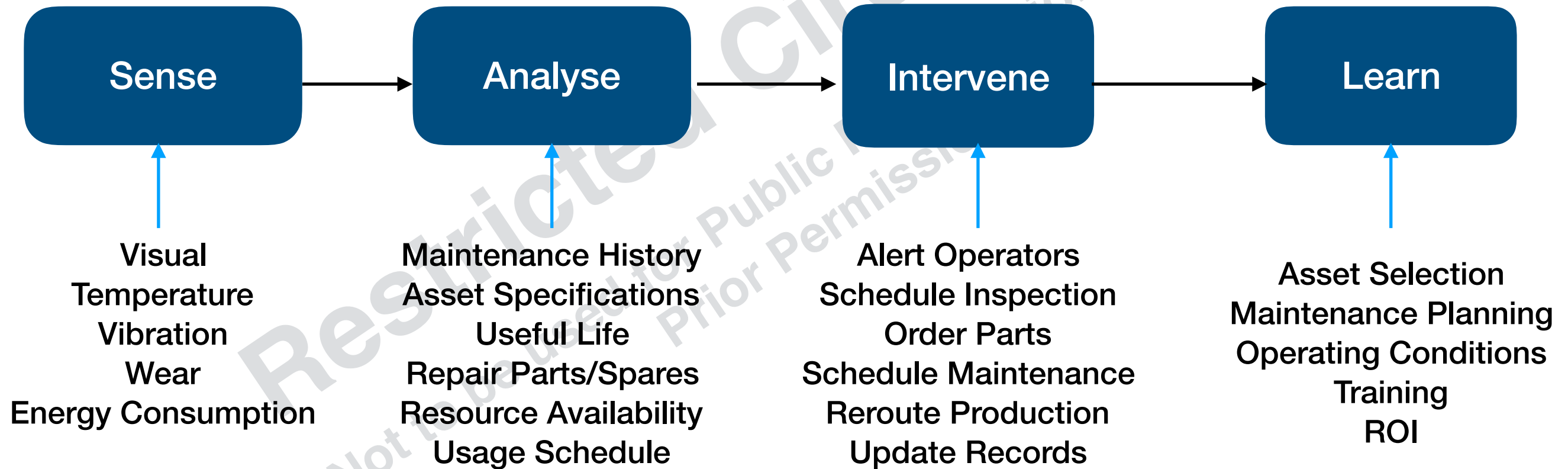
Data capture,
contextualization
and storage

Analytics triggering
automated
responses

Measurement and
reporting of relative
changes in
performance

Return on Assets

Use Case Theme



IIoT Survey

Source: www.infor.com

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Prior Permission

IIoT Survey

Priority

How important is IIoT in your business?

A. Top Priority

C. Top Five

B. Top Three

B. Not a Priority

IIoT Survey

Business Impact

Indicate the impact you anticipate IoT will have on your business?

A. Major

C. Minimal

B. Moderate

B. None

IIoT Survey

Benefits

Where do you anticipate the biggest benefits of IIoT in your business (select 3)?

A. Machine & Equipment Utilization

B. Productivity

C. Insight & decision Making

D. Visibility & Traceability throughout Supply Chain

E. Plant Floor Automation

F. New Revenue Streams

G. Product Quality

H. Safety & Security

I. No benefits anticipated from IIoT in our business

J. New Services

IIoT Survey

Urgency

What would be your **top concerns** if your business were **not** to implement an IIoT strategy in the **next 3 yrs**?

A. Competitor will gain productivity & cost advantage

B. We might not catch up innovative services / product

C. May become harder to stay Compliant

D. May not be able to support customers & suppliers

E. Employee productivity will fall

F. Harder to attract new customers

G. Harder to attract / retain skilled employee

H. No Concerns

IIoT Survey

Readiness

How ready is your business to Capitalize on the opportunity of IIoT?

A. Hardware & Software in place, fully equipped

C. Capturing data but No Smart business systems

B. Capturing data, but Unconnected to application

D. No Smart devices / sensors deployed in the business

IIoT Survey Summary

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Customer Survey

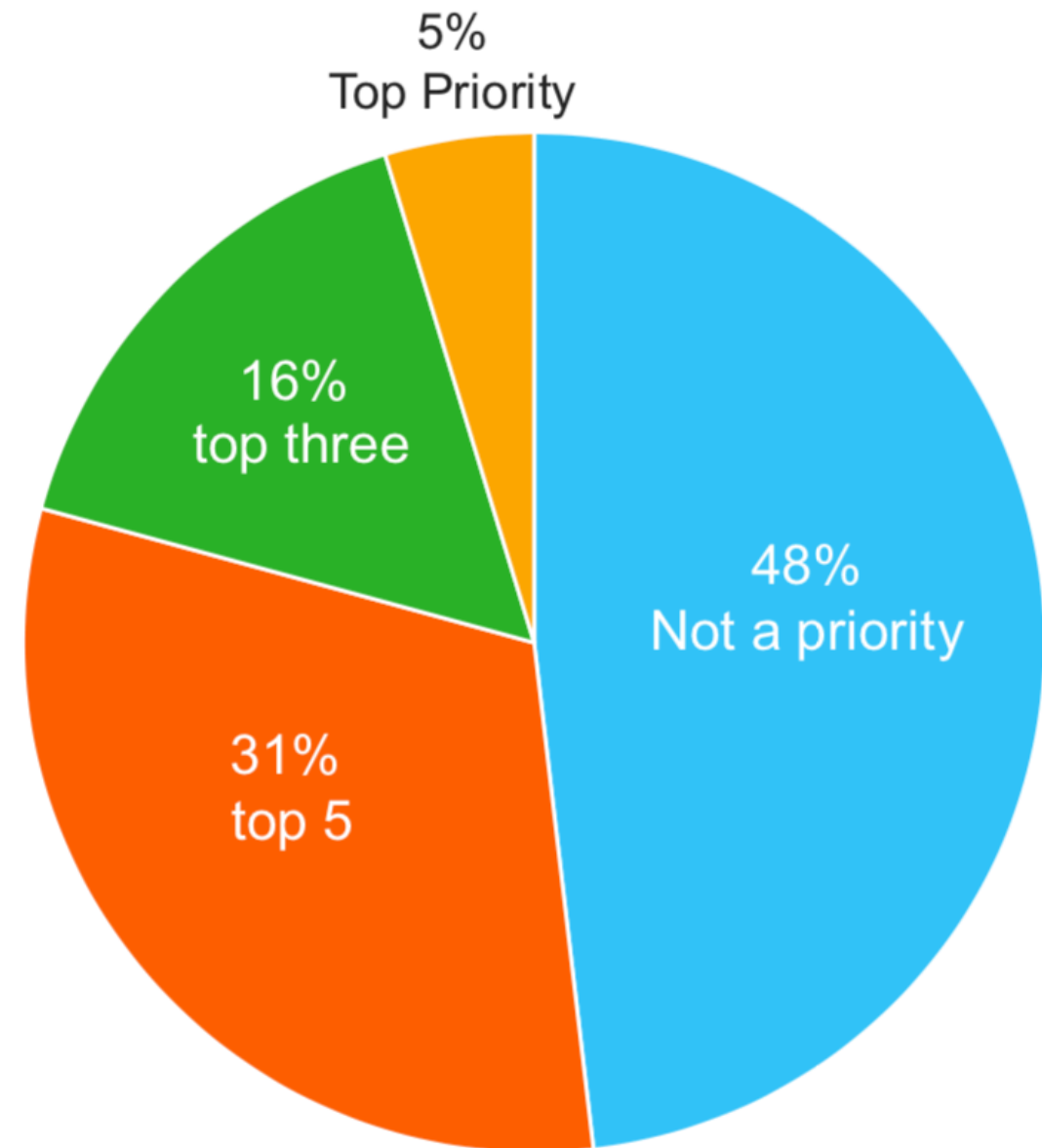
Source: www.infor.com

Priority

How important is IoT
in your business?

Over half report IoT in **Top 5** priorities

20% identifying it as a '**Top 3**'
business priority



Customer Survey

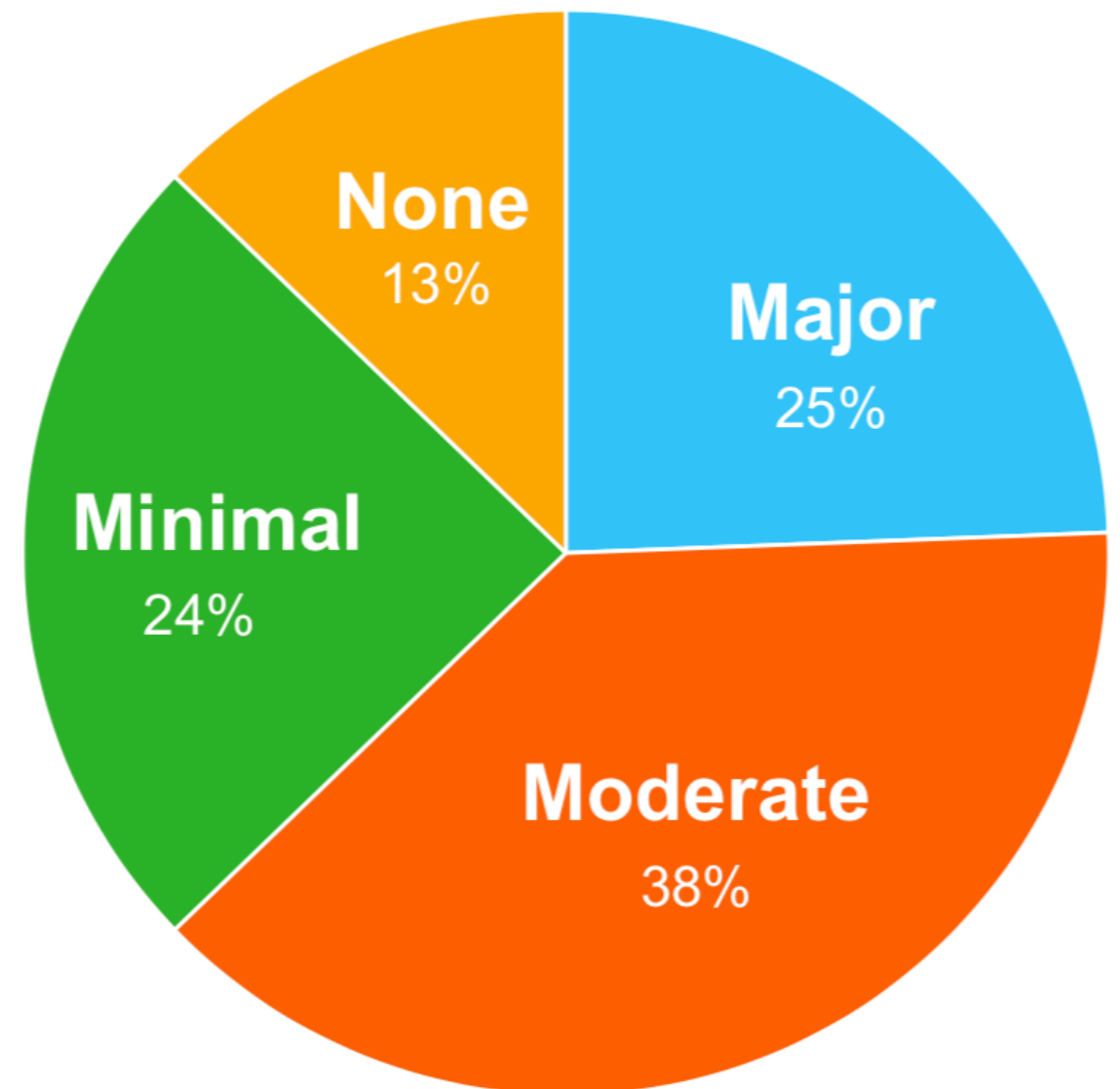
Source: www.infor.com

Business impact

Indicate the impact
you anticipate IoT will
have on your
business?

Quarter anticipate **major** impact

Only **13%** anticipate **no** impact

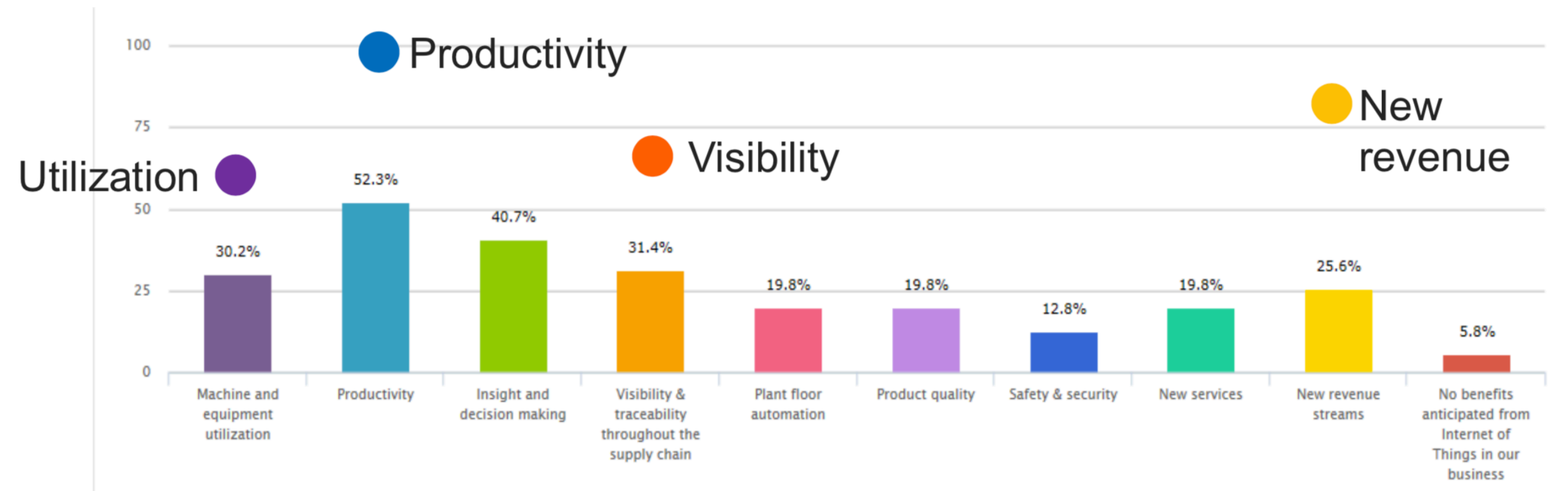


Customer Survey

Source: www.infor.com

Benefits

Where do you anticipate the biggest benefits of IoT in your business (select 3)?



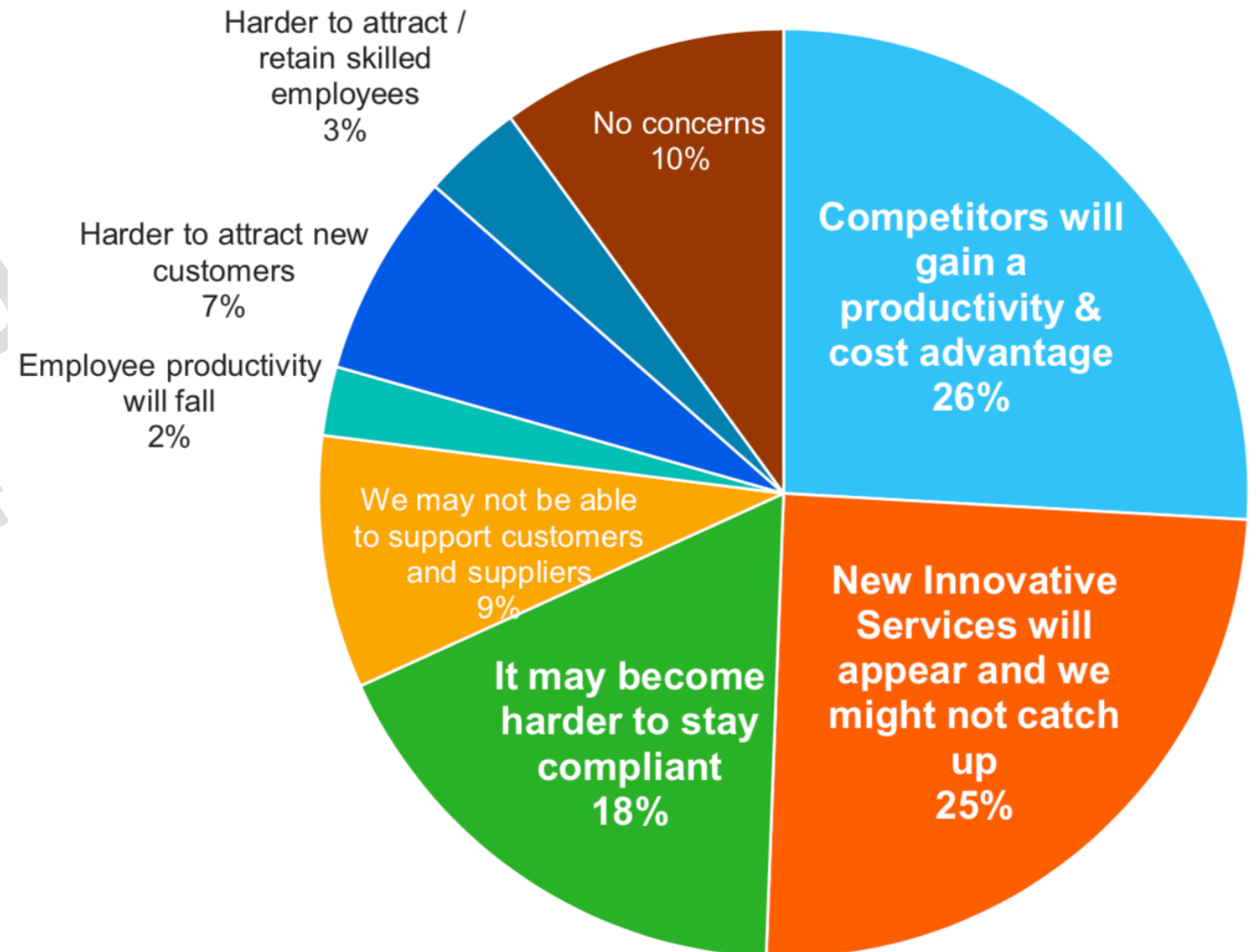
Customer Survey

Source: www.infor.com

Urgency

What would be your top concerns if your business were not to implement an IoT strategy in the next 3 years?

Productivity, Service Innovation & Compliancy major concerns of failing to adopt IoT



Customer Survey

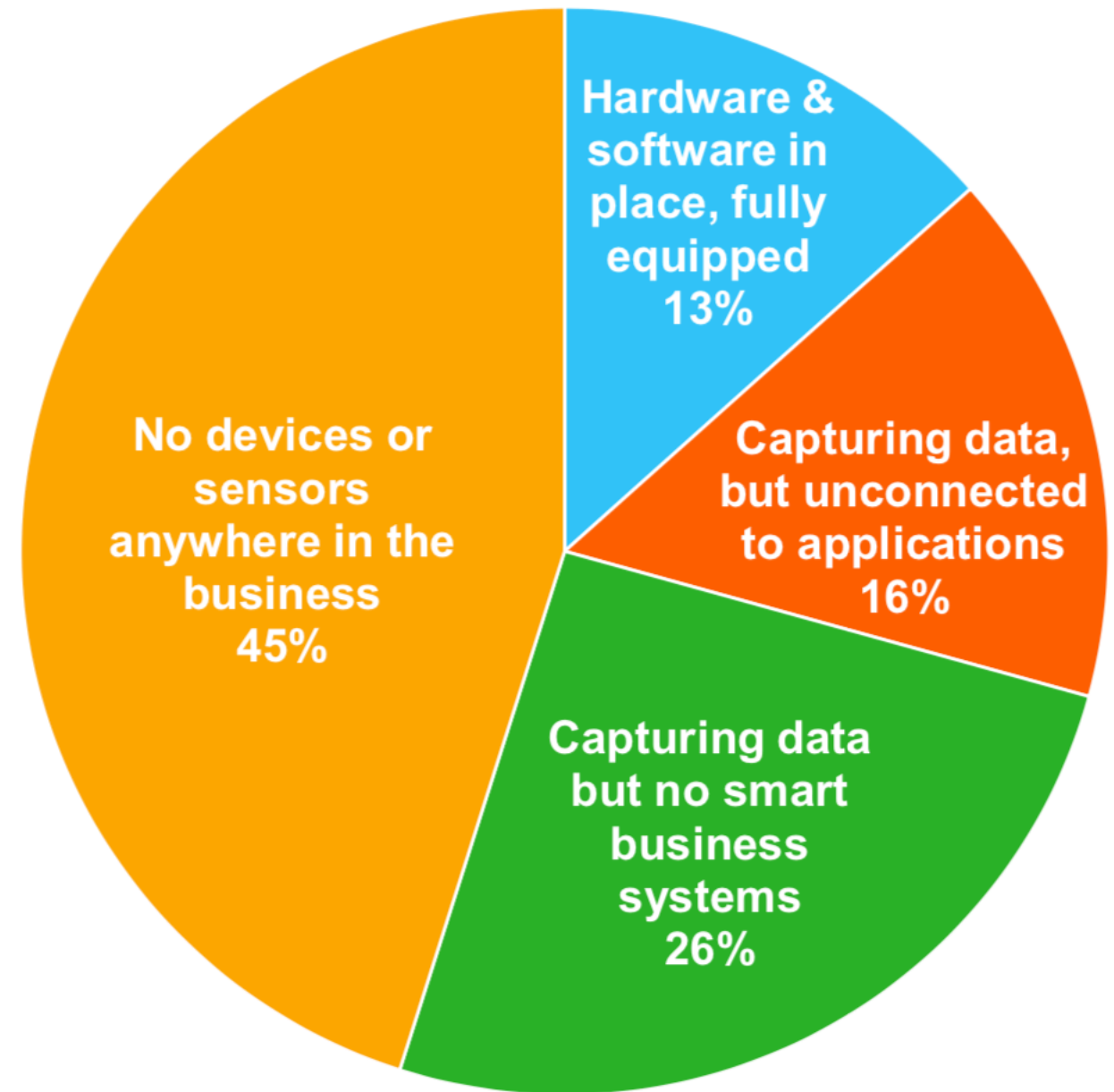
Source: www.infor.com

Readiness

How ready is your business to capitalize on the opportunity of IoT?

Only 13% fully ready to capitalize on IoT

45% report no smart devices deployed in the business

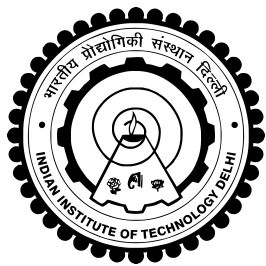


Cyber Physical System (CPS)

Dr. Sunil Jha, Professor
Department of Mechanical Engineering,
IIT Delhi, Hauz Khas, New Delhi - 110016
suniljha@mech.iitd.ac.in

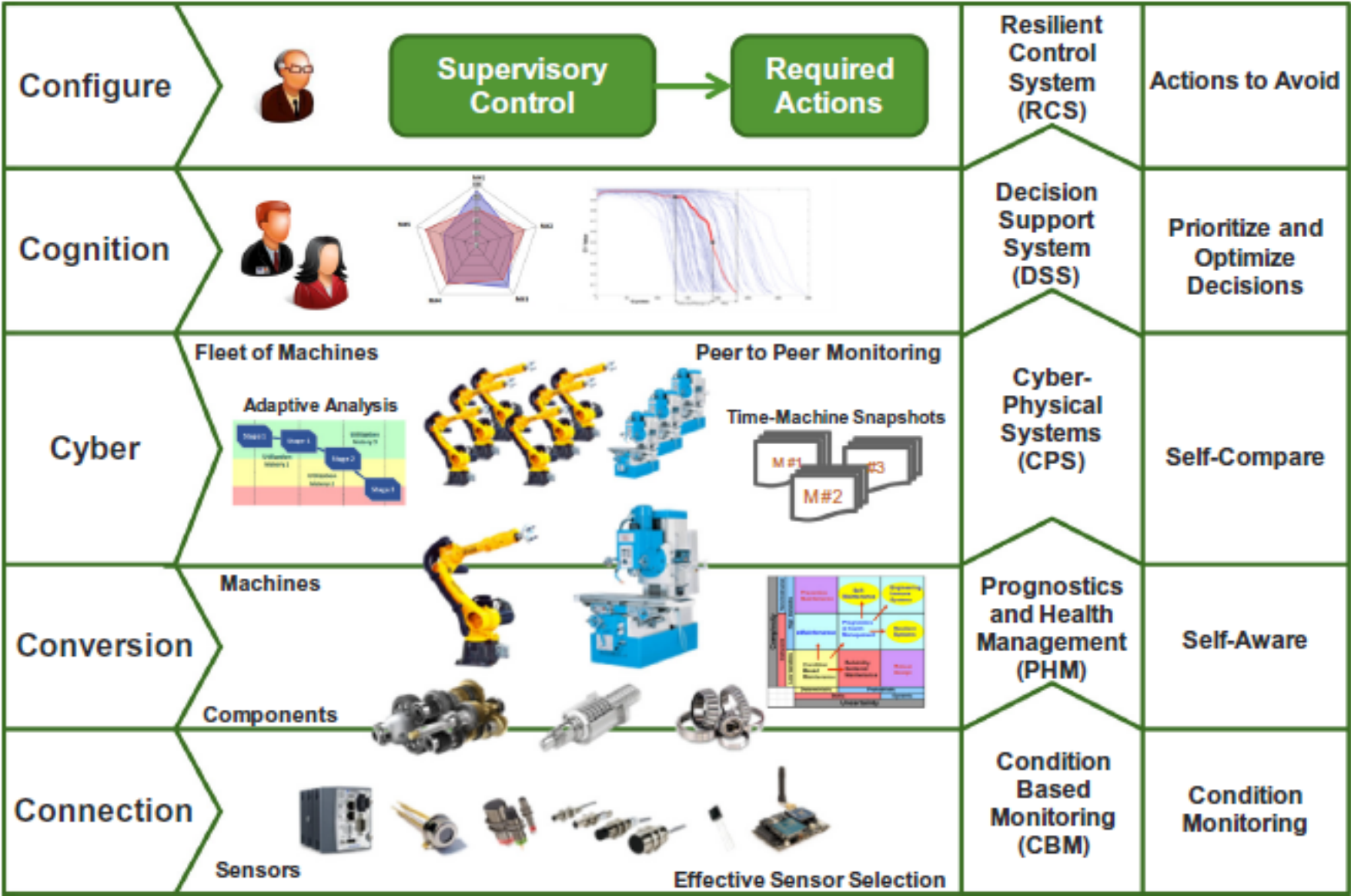
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Cyber Physical System (CPS)

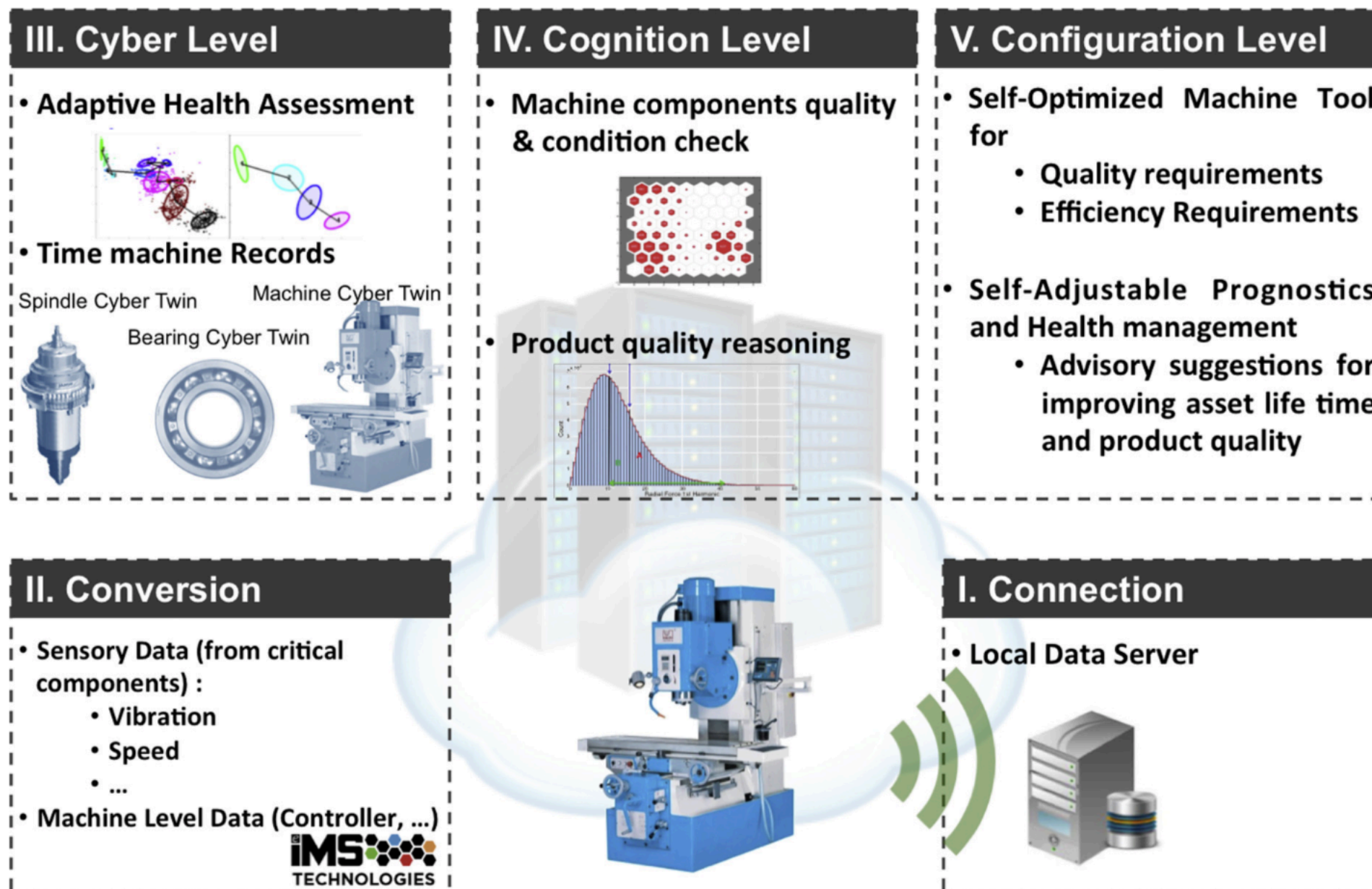
- Making **machine tools intelligent** for Smart Factory which can implement **self-aware**, **self-prediction**, **self-compare**, and **self-configure** to be more **resilient** to dynamic changing environments



J. Lee, B. Bagheri, and H. Kao, A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems, *Manufacturing Letters*, 3(2015), 18–23.

Cyber Physical System (CPS)

5C architecture for CPS as a guideline for implementation in manufacturing



J. Lee, B. Bagheri, and H. Kao, A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems, *Manufacturing Letters*, 3(2015), 18–23.

Machine Learning

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Machine Learning

Powering Predictive Maintenance

- **Maintenance** represents a **significant** part of any manufacturing operation's **expenses**.

Traditional Predictive Maintenance:

Using SCADA systems set up with **human-coded thresholds**, alert **rules** and **configurations**.

Semi-manual approach

- doesn't take into account the more complex dynamic behavioural patterns of the machinery,
- or the contextual data relating to the manufacturing process at large.



Machine Learning

Powering Predictive Maintenance

ML Approach: Machine Learning algorithms are fed

OT data (from the production floor: sensors, PLCs, historians, SCADA)

IT data (contextual data: ERP, quality, MES, etc.)

Manufacturing process information describing the synchronicity between the machines and the rate of production flow

In AI, “**training**” enables the ML algorithms to **detect anomalies** and **test correlations** while searching for **patterns** across the various **data** feeds.



Machine Learning

Powering Predictive Maintenance

The power of Machine Learning

- Capacity to **analyze** very large amounts of data in **real time**, and propose **actionable** responses to issues that may arise.
- The **health** and **behaviour** of **every asset** and system are constantly **evaluated** and component **deterioration** is identified **prior** to **malfunction**



Machine Learning

Enabling Predictive Quality Analytics

The **quality** of **output** is **crucial** and product quality deterioration can also be predicted using Machine Learning.

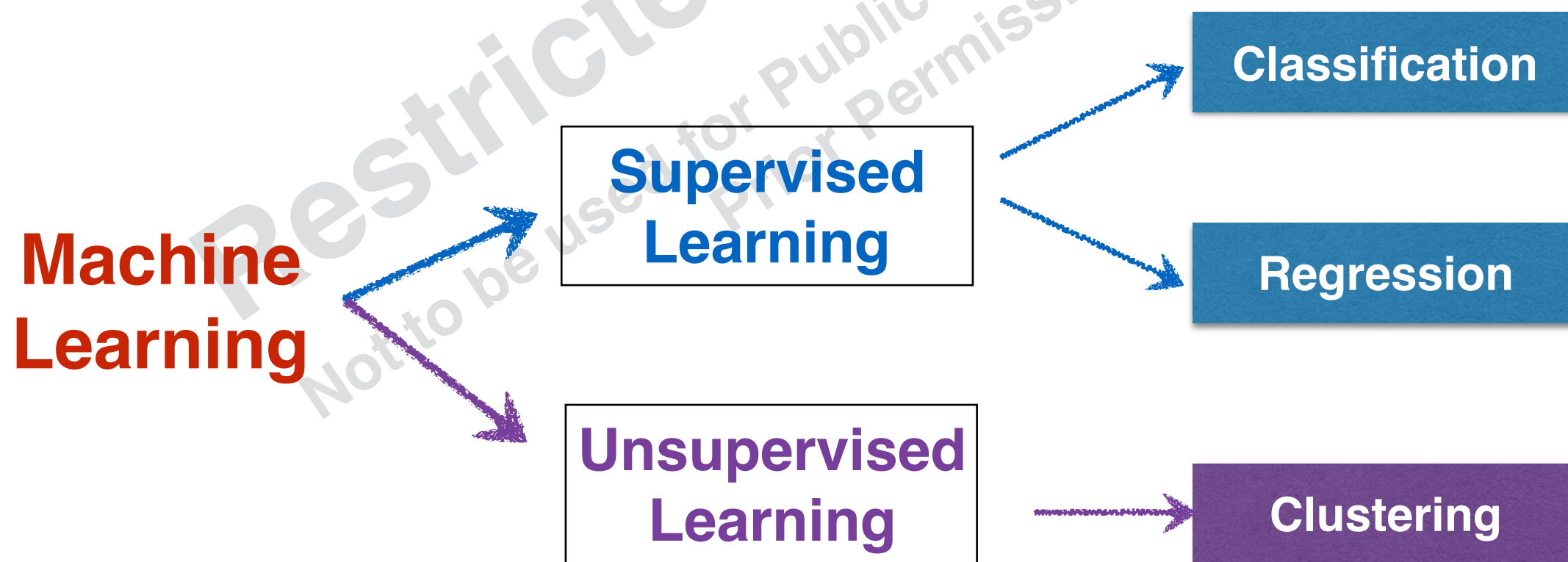
Knowing beforehand that the **quality** of products being manufactured is destined to **drop**

- prevents the wastage of raw materials
- valuable production time

Machine Learning

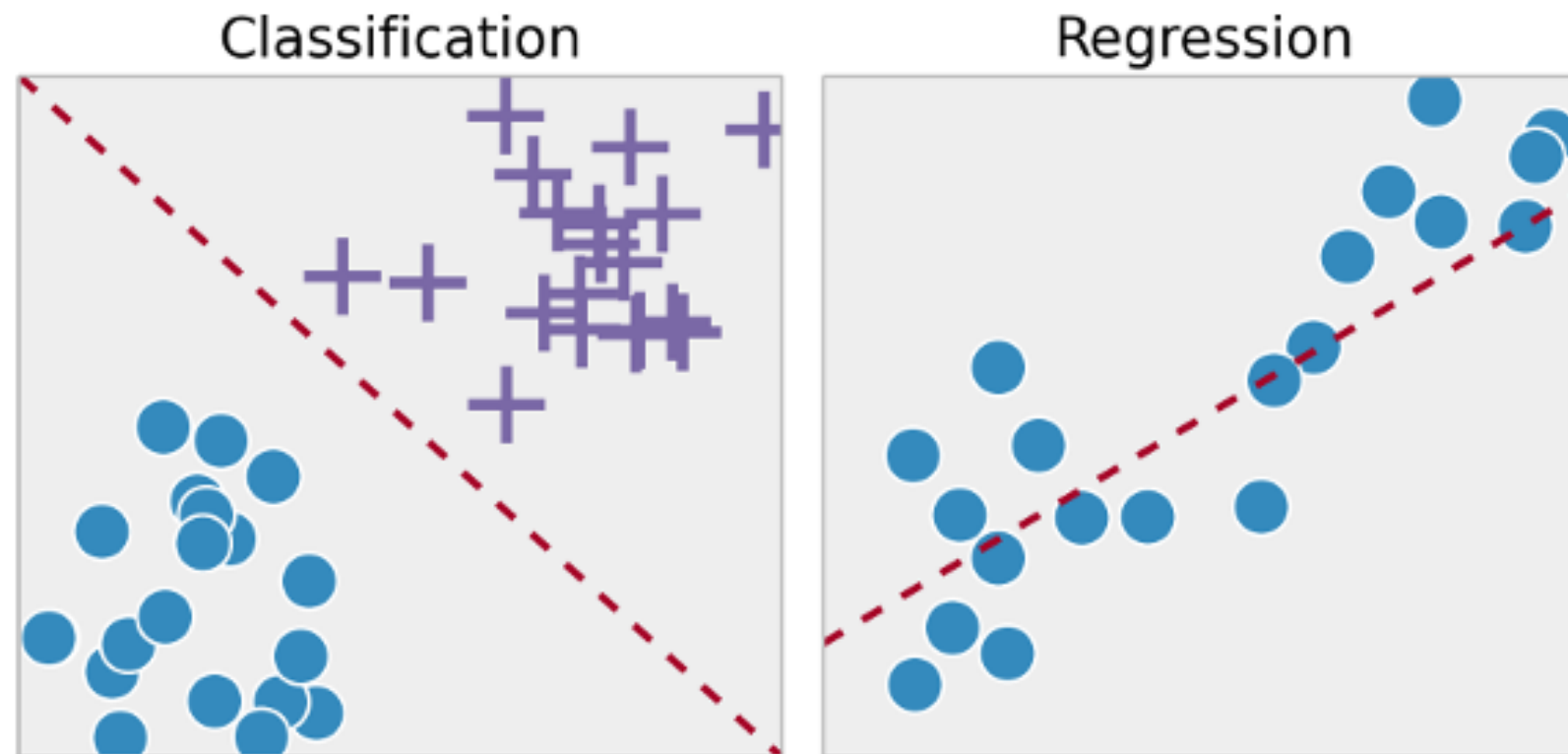
Machine learning is the process of **developing**, **testing**, and **applying predictive algorithms** to achieve the **goal** of efficient data sets.

Focus is over the application of machine learning to maximize the benefits it brings to **improve situational intelligence**, **performance**, and **reliability**



Machine Learning

Supervised Learning

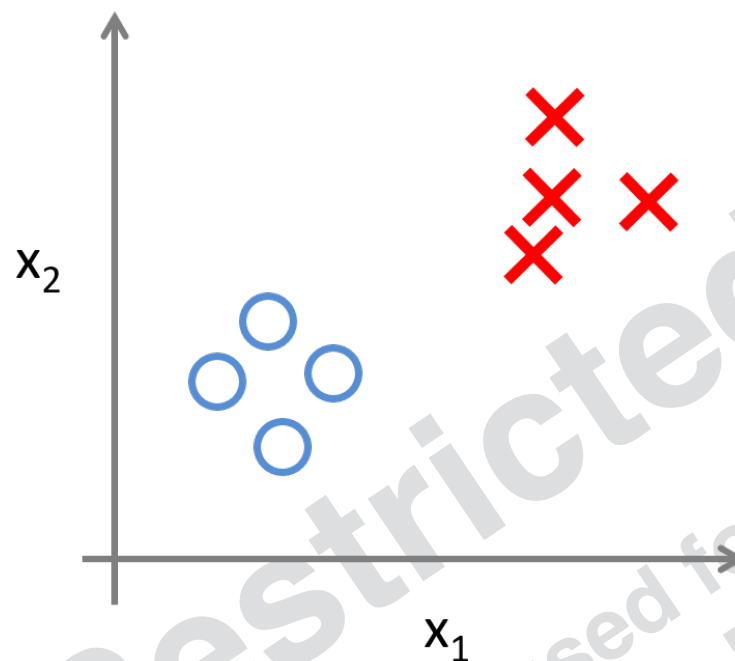


In **Manufacturing**, one of the most powerful **use cases** for Machine Learning is **Predictive Maintenance**, which can be performed using two Supervised Learning approaches: **Classification** and **Regression**.

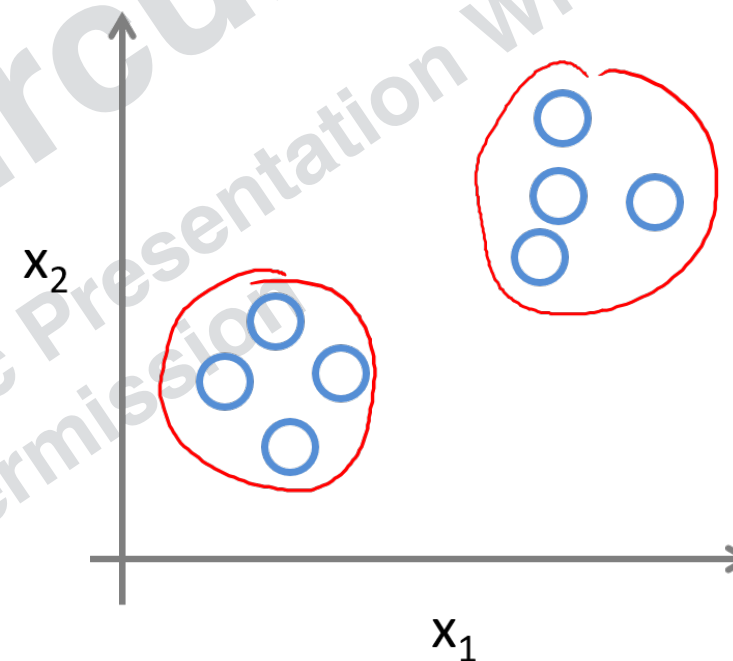
Machine Learning

Unsupervised Learning

Supervised Learning



Unsupervised Learning



Used to draw **inferences** from datasets consisting of input data **without labeled** responses

Unsupervised learning can be used to find **normal operating modes** of your assets and **detect trends** and **anomalies**



Machine Learning

Data Preparation

Machine learning is all about **data**, so understanding some key elements about the **quality** and **type** of data needed is extremely important in ensuring accurate results.

With Predictive Maintenance, for example, we're focused on **failure events**.

Therefore, it makes sense to start by **collecting historical data** about the machines' **performance** and **maintenance** records in order to form **predictions** about **future failures**.

- historical data of many years
- static information about the machine/system



Machine Learning

Data Preparation

What question do we want the **Machine Learning** model to **answer**?

Is it **possible to answer** this question using the **data** that's **available**?



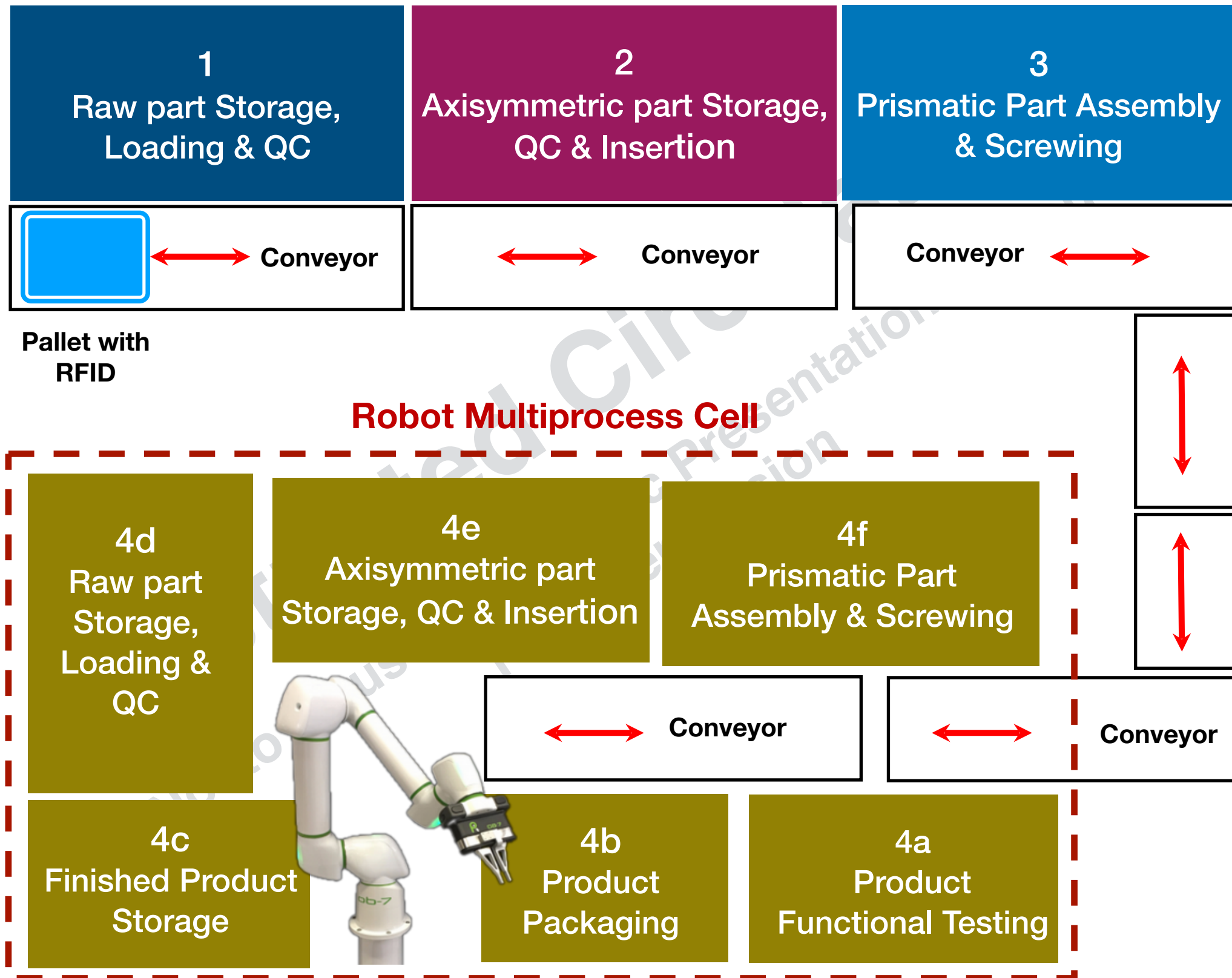
Machine Learning

Data Preparation

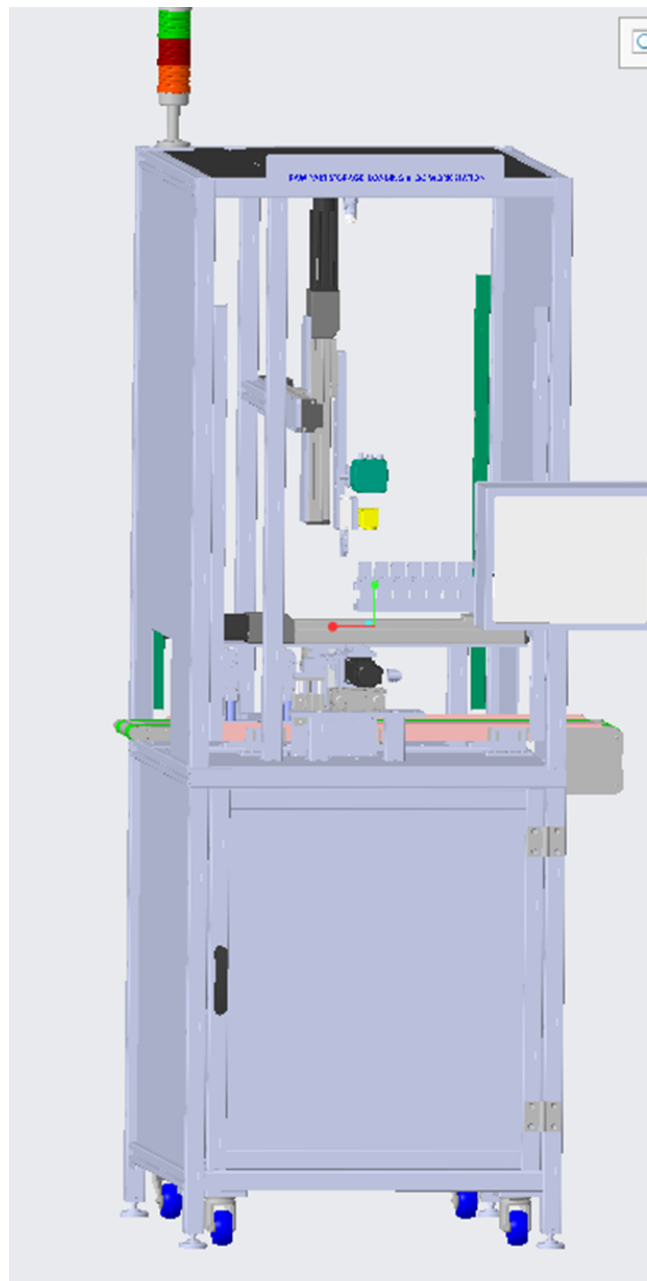
Certain **questions** should be answered to help focus on the **data** that is **most crucial** to our needs:

- What are the various **types** of **failure** that can occur with this component / machine / system?
- Which **failure events** are we interested in trying to **predict**?
- Is the **failure** a **sudden, focused event**, or is there a **slow decline** before complete malfunction?
- Which **components** are typically associated with this type of failure?
- Which **parameters** should be measured that **most signify** the state of component / machine health?
- What is the required accuracy and frequency of the measurements needed?

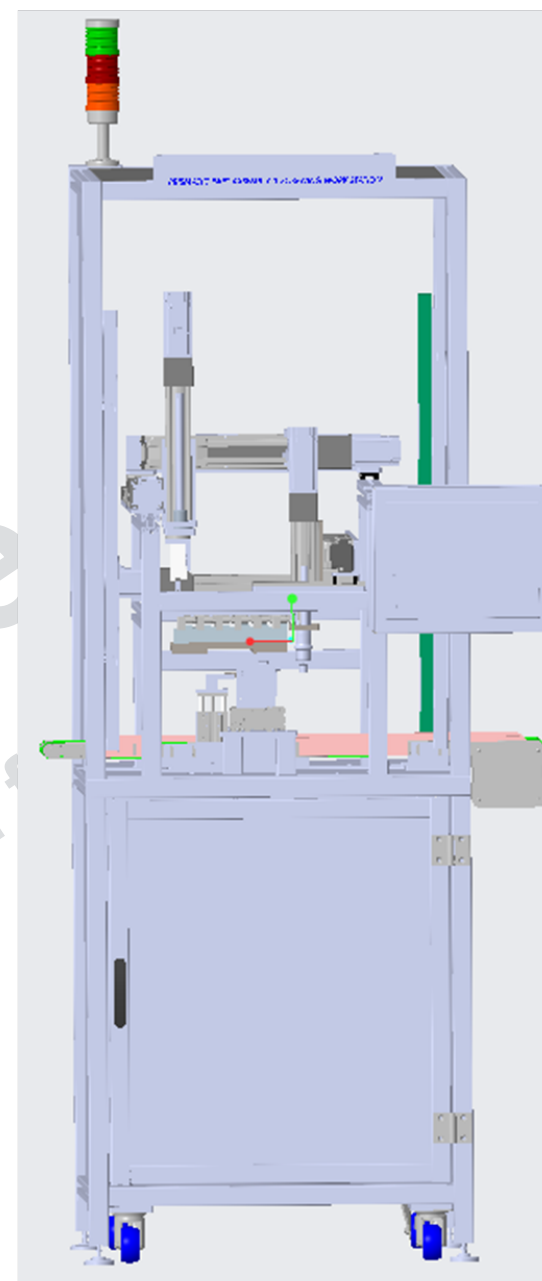
Electromechanical Component Assembly



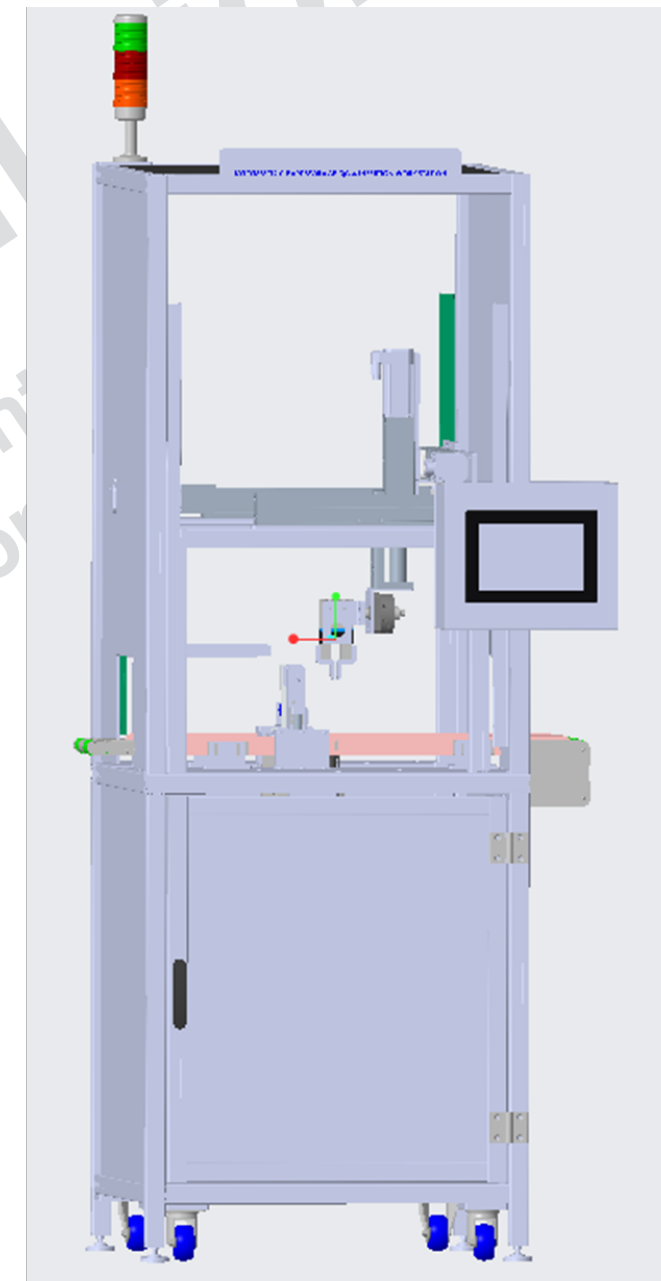
Electromechanical Component Assembly



Raw part Storage, Loading & QC



Axisymmetric part
Storage, QC &
Insertion



Prismatic Part Assembly & Screwing



Cyber Physical Lab – Modular Stations



Raw part Storage, Loading & QC

Axisymmetric part Storage,
QC & Insertion

Prismatic Part Assembly & Screwing

Digital Thread in FSM

Cyber Physical Lab

Concept & Detail Design

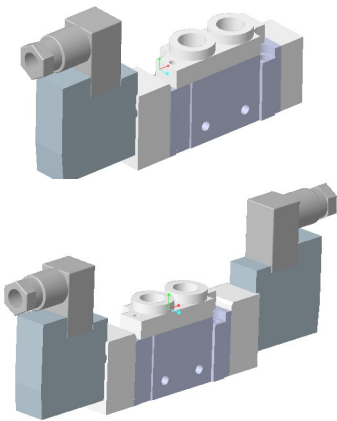
Manage Design Information

Smart Manufacturing

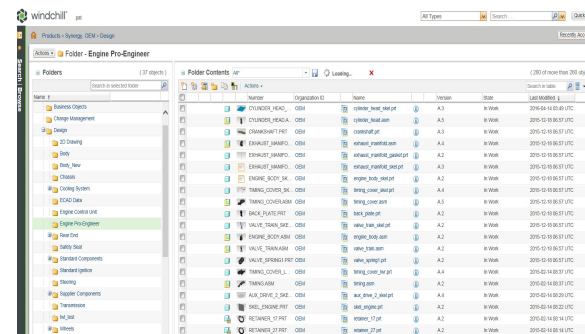
Connected Service



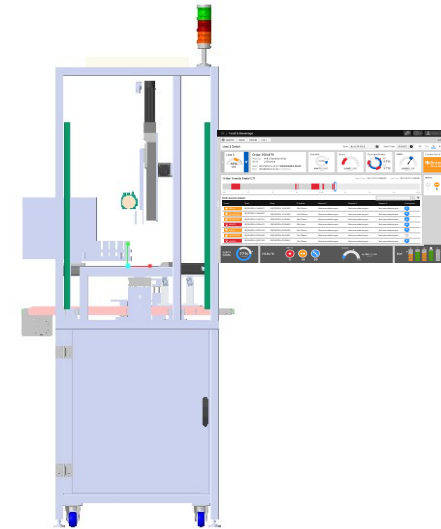
Mathcad



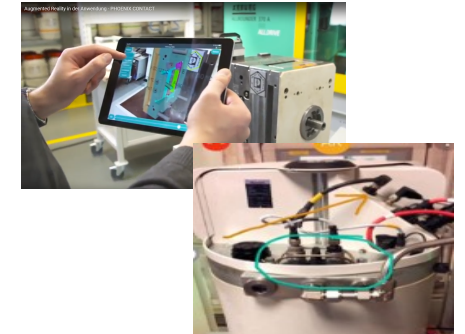
- 3D MODELING & DETAILED DESIGN
- DESIGN VALIDATION
- ENGG CALCULATION



- ENGG- BOM
- ASSOCIATIVE MFG- BOM
- COLLABORATION
- REQUIREMENTS MGMNT



- OPERATIONAL INTELLIGENCE/OEE
- REMOTE DIAGNOSTICS ANALYTICS



- PREDICTIVE SERVICE
- AR ENABLED SERVICE
- REMOTE EXPERT COLLABORATION



Thank You