

Enabling 21st Century Manufacturing through Digital Thread and Connected Factory

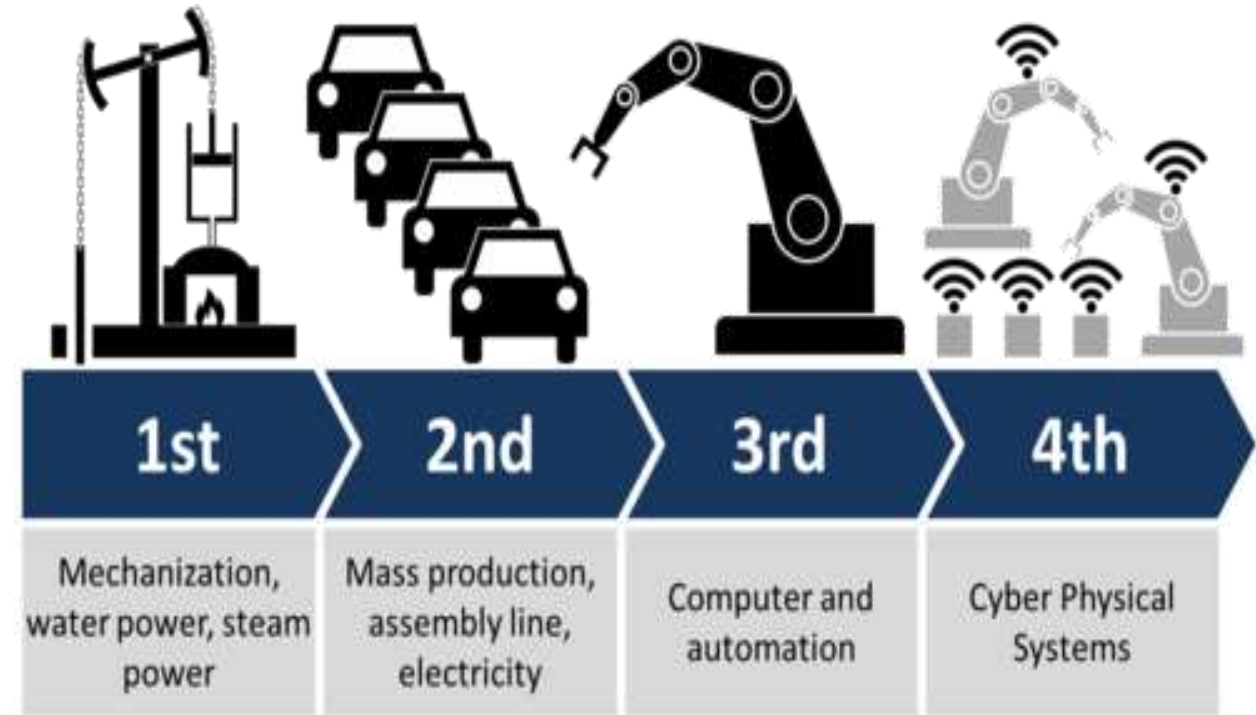
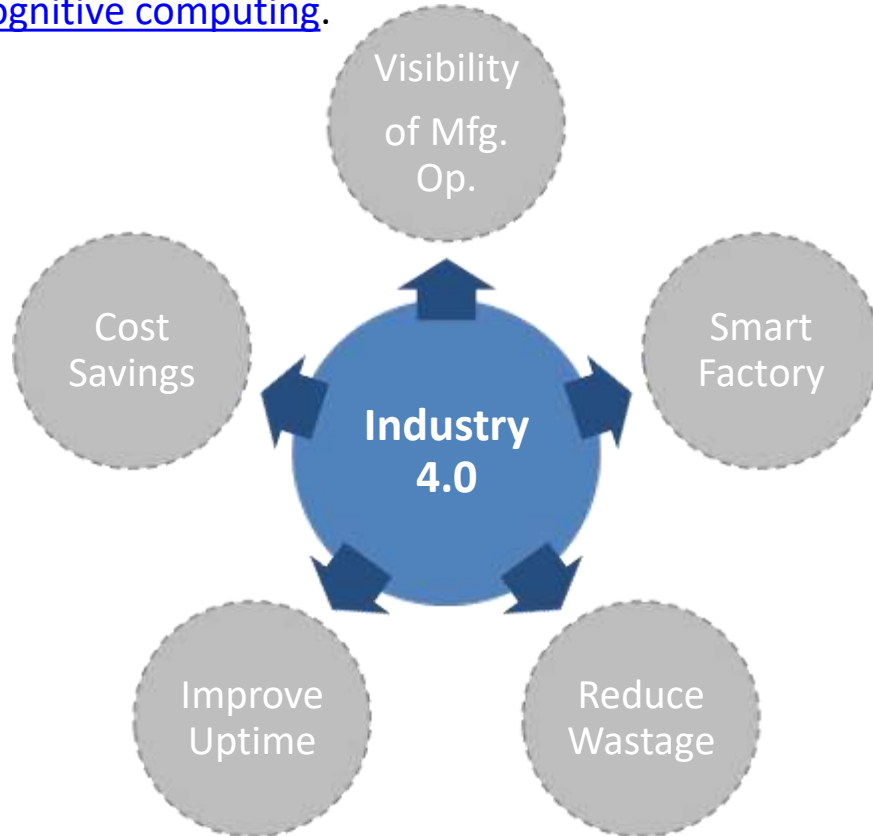
Presented by:

Shantanu Rai

Global Director – Digital Manufacturing and Industry 4.0, HCL Technologies

Definitions

Industry 4.0 is the current trend of [automation](#) and data exchange in manufacturing technologies. It includes [cyber-physical systems](#), the [Internet of things](#), [cloud computing](#)^{[1][2][3][4]} and [cognitive computing](#).



Industry4.0 | Smart Factory or Connected Factory | Digital Manufacturing

Connected Factory as the instantiation of Industry 4.0

HCL Positioned in Winner's Circle & No.1 IOP in HfS Blueprint Guide: Industry 4.0 Services



Pareekh Jain



Tanmoy Mondal

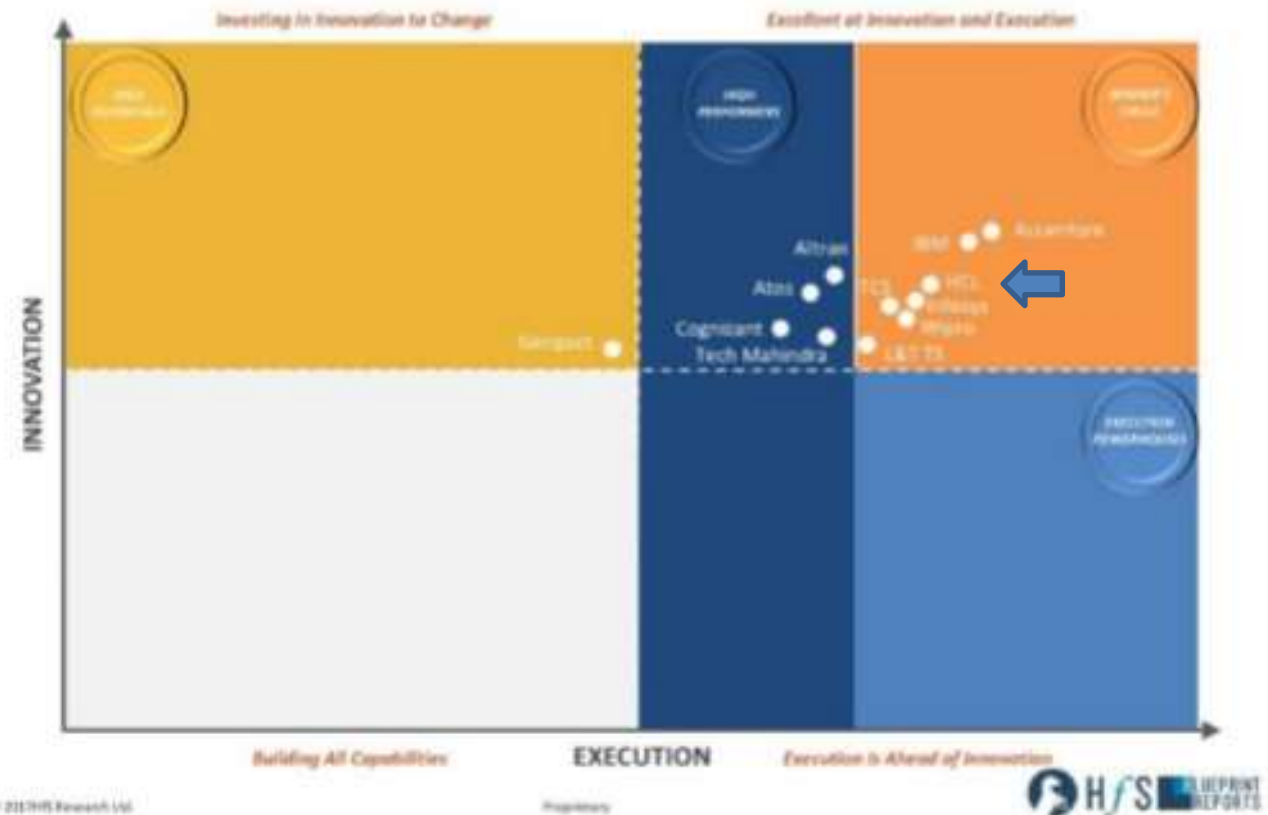
HfS Blueprint Guide: Industry 4.0 Services

Published : April 2017



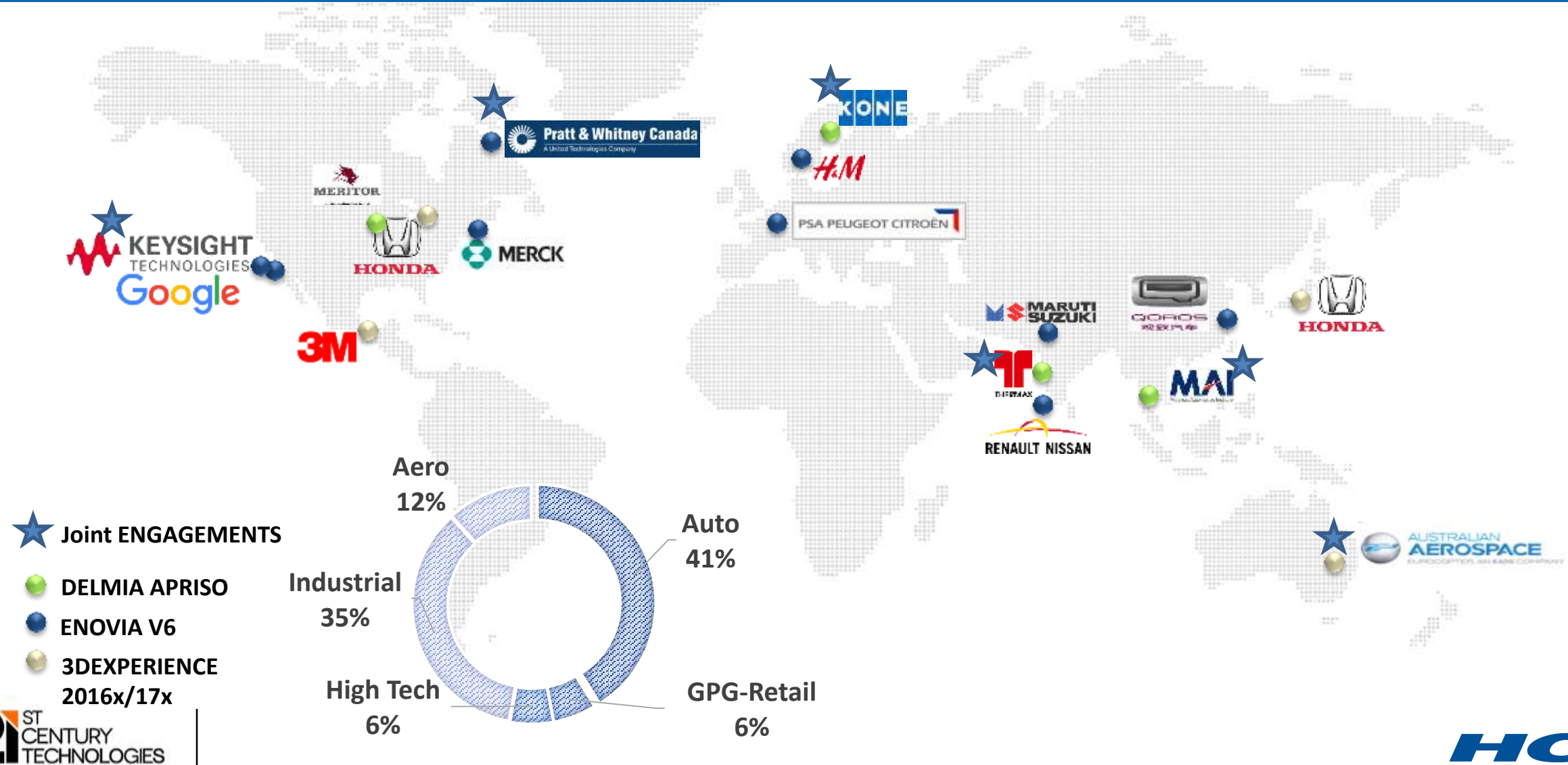
Highlights of the Report

- HCL has not only been placed in the Winner's Circle but also rated ahead of all IOP's including TCS, Infosys, Wipro, Cognizant, Tech M and L&T TS.
- HCL has made vertical-focused Industry 4.0 solutions offerings a strategic priority. HCL is also focusing on retrofit solutions for brownfield customer segments
- HCL has a strong vision for Industry 4.0 and is making significant investments in developing its capabilities
- HCL has developed a focused acquisition strategy to augment its existing Industry 4.0 offerings and is leveraging its acquisitions for Industry 4.0, such as Geometric for digital manufacturing, Volvo IT for Automotive Industry 4.0, etc

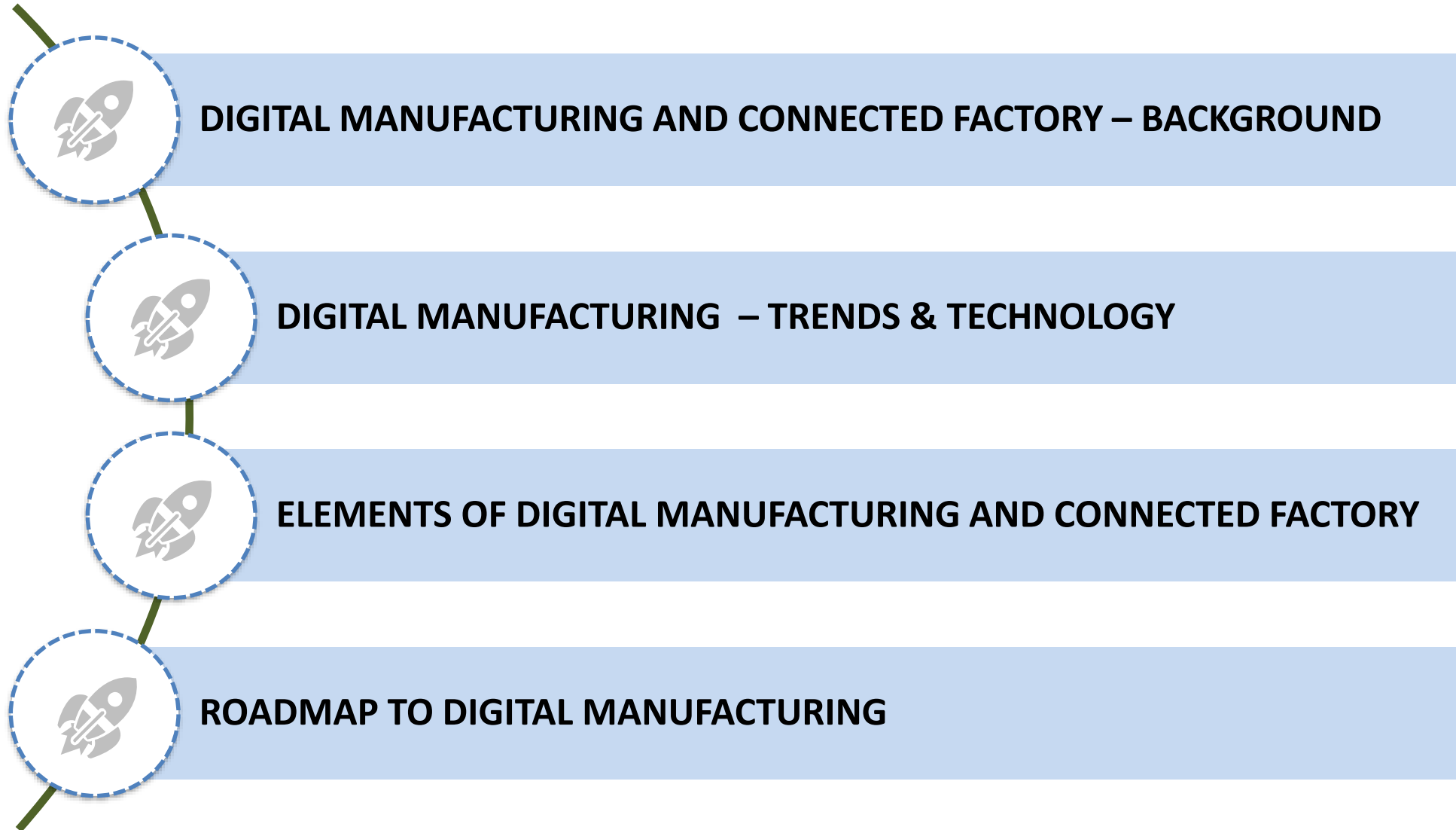


HCL Engagements around DS Platforms

15+ Ongoing engagements over the world



Contents





Background

DIGITAL MANUFACTURING AND CONNECTED FACTORY

Industry 4.0: Disruption on the Horizon



- Considered to be driving the Fourth Industrial Revolution; based on the application of digital technologies / “digitalization” in the supply chain and manufacturing
- Underlying technology drivers include AI, Robotics, IoT, 3D Printing and others. These technologies are rapidly becoming mainstream
- Potential business value is expected to be significant -
- innovation, customer experience, product quality, productivity, efficiency
- Talent and skill will be a key factor of production going forward
- Expect to see more transparency and consumer engagement in the way companies design, develop, manufacture and sell products

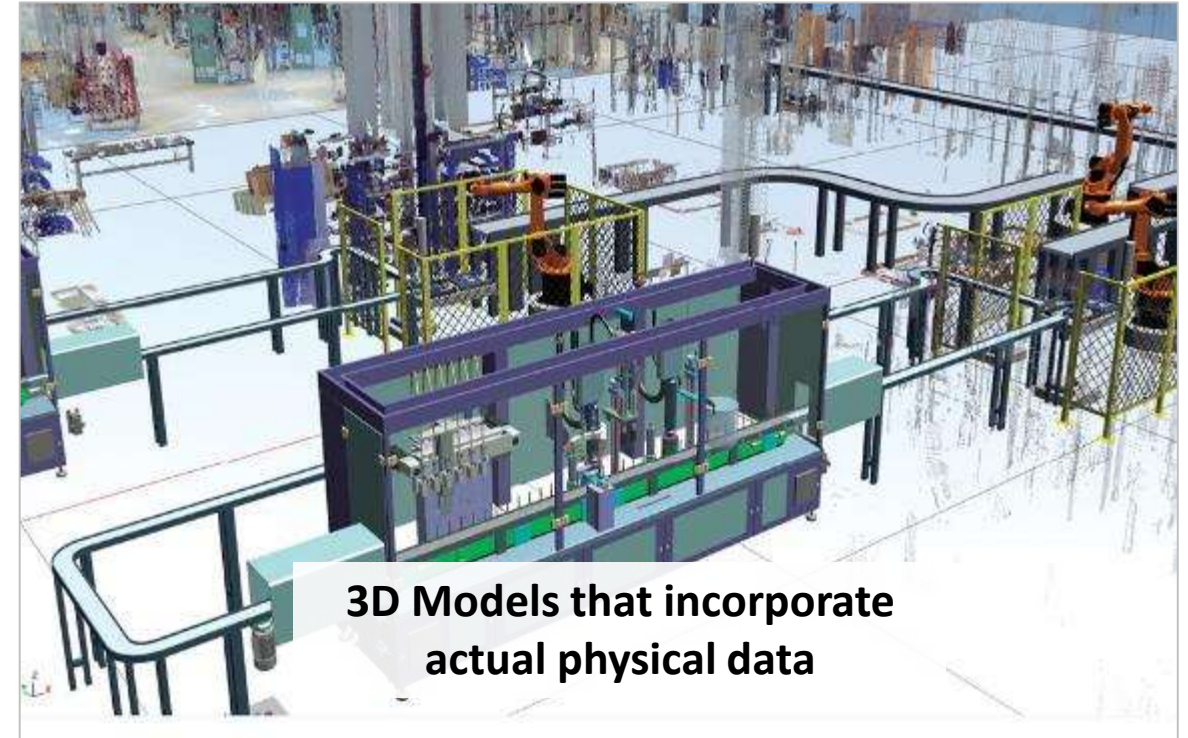
Fundamental Components of Industry 4.0

DIGITAL THREAD



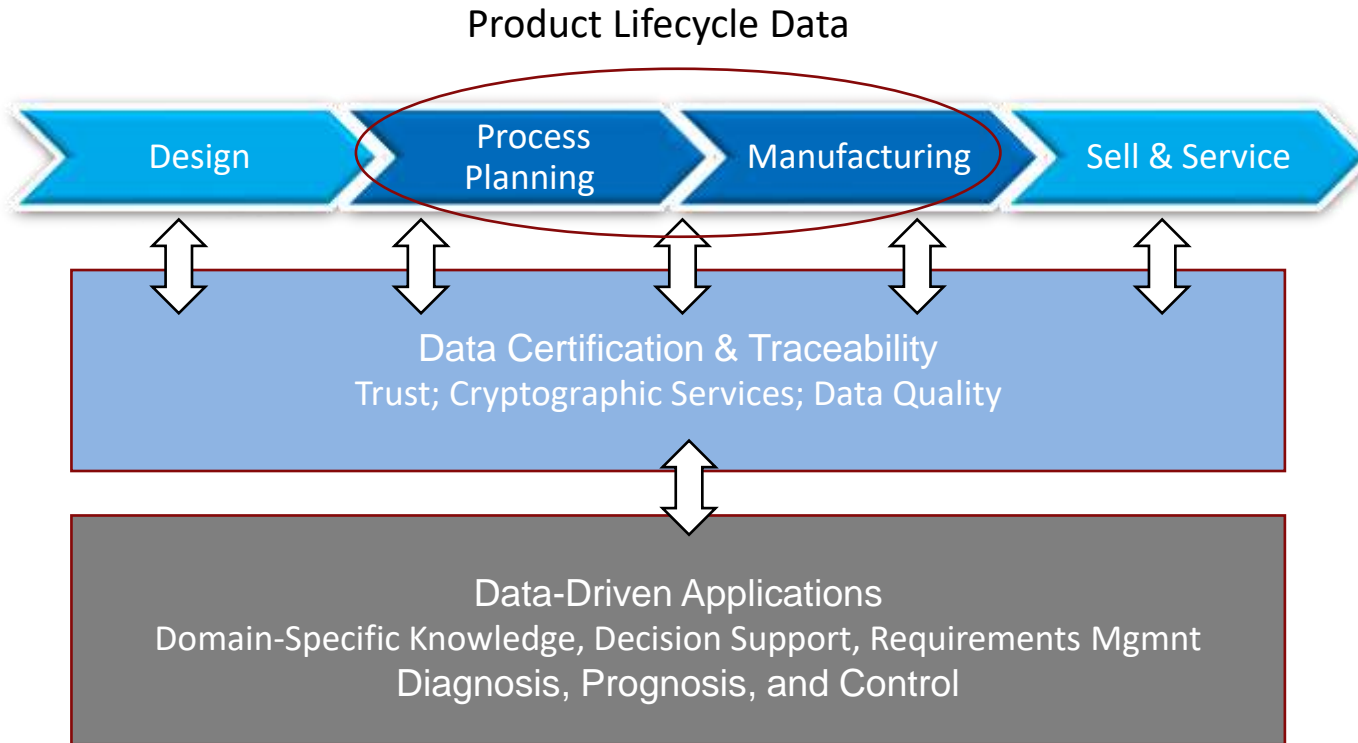
Sharing of information (using standards) throughout all stages of the product lifecycle, including design, manufacturing, supply chain, and aftermarket support.

DIGITAL MANUFACTURING



Digital Model of a particular asset or system, encompassing design specifications, engineering models and as-built and operational (in-use) data. Used for improving the loop between design, manufacture and customer-use.

Components of Industry 4.0: Digital Thread and Digital Manufacturing



Source: Thomas Hedberg, NIST



STEP Standards

MTConnect

QIF

Key Challenge Today:

- Islands of excellence (e.g. Manufacturing, Quality, Suppliers, etc)
- Integration and information sharing across the Product Lifecycle is very difficult (lack of standards, customization, etc)
- No feedback from Customer and Services back to Product Design
- **Result:** High costs of development and manufacturing. High Cost of Quality. Low Customer Sat

Digital Thread:

- Interconnected and linked data across the entire product lifecycle

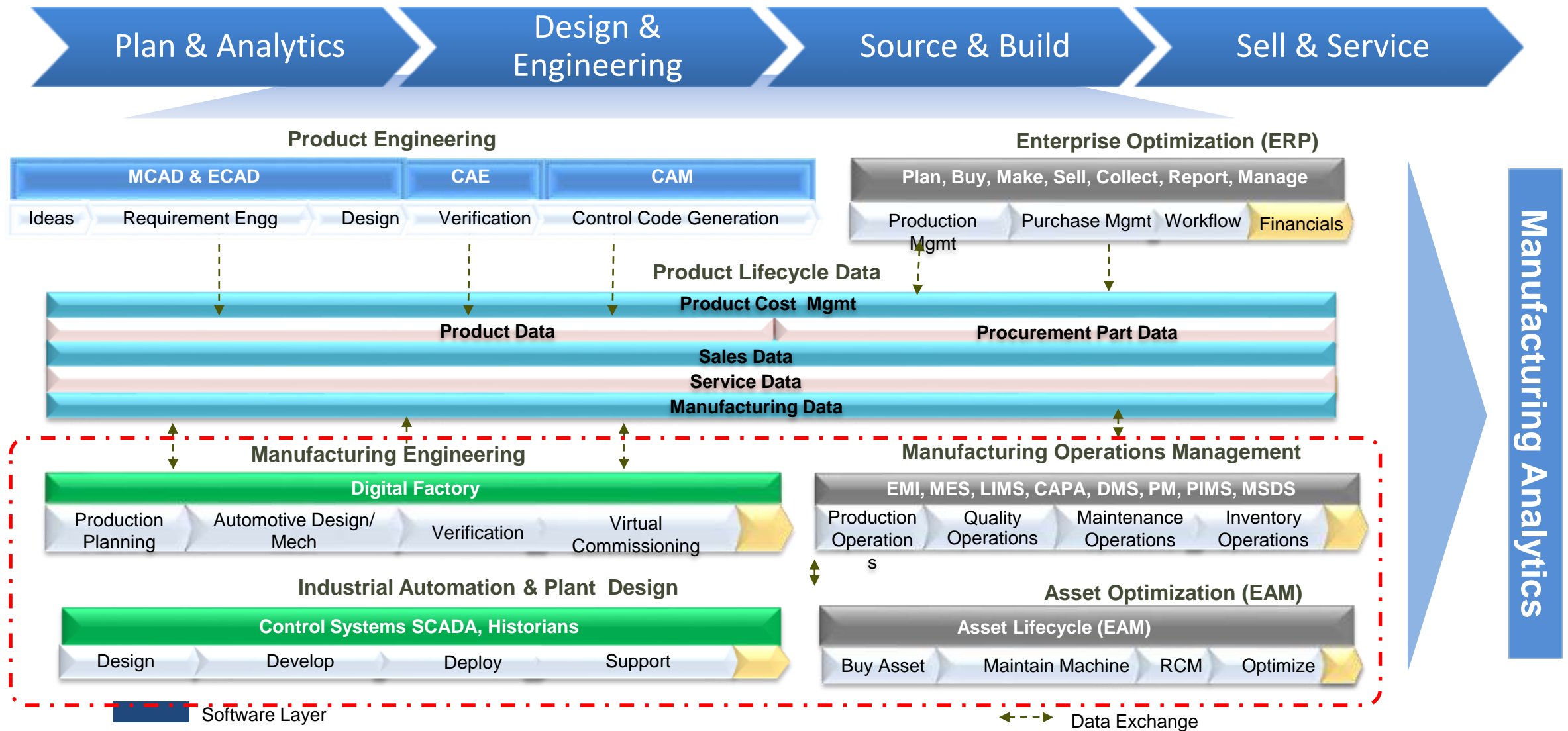
Digital Manufacturing / Smart Manufacturing / Connected Factory is a subset of the Digital fabric



Trends and Technology

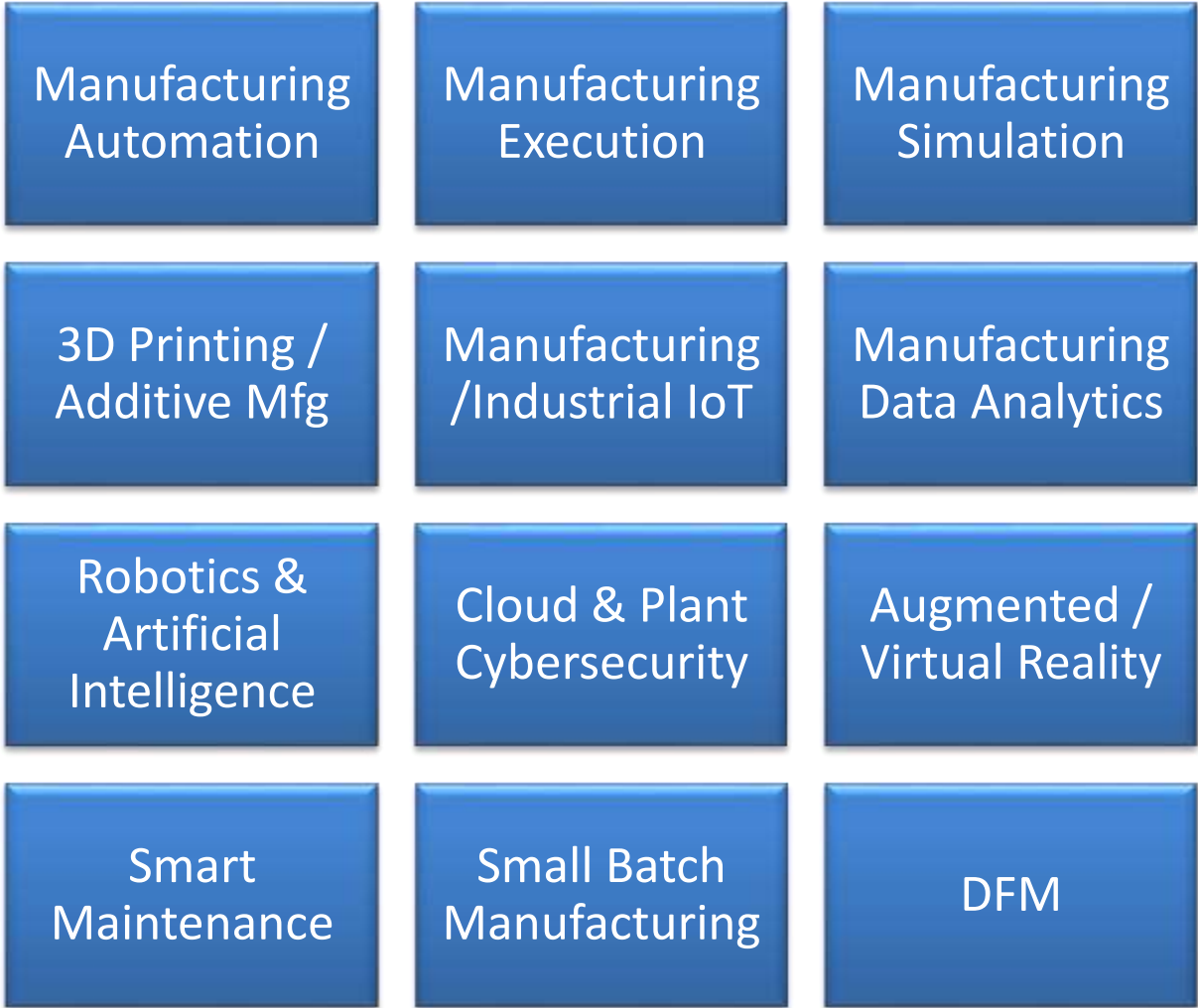
DIGITAL MANUFACTURING AND CONNECTED FACTORY

Reference Architecture for a Connected Factory



Manufacturing Analytics

Elements of Digital Manufacturing and Connected Factory



L4 ERP/ PLM

Enterprise Applications

L3 MES/ QMS

Plant Applications

L2 HMI/ SCADA

Control Systems

L1 I/O Sensors Drives

Instrumentation



System Hierarchy as defined in ISA-95 standard



Elements

DIGITAL MANUFACTURING AND CONNECTED FACTORY

Connected Factory : Manufacturing Execution Areas with APRISO - 1

Functional Capability

Benefits

Order Management

1. Transfer Production Orders from SAP to MOM for micro level planning of production schedule (shift planning)
2. Update Operation Completion, Quantities, Inventory Update, Order Status to SAP
3. Adhoc scheduling

1. Synchronization of MOM & ERP at all times
2. Real Time visibility of status of Customer Orders



Production Tracking & Visibility

1. In-process tracking of Production Orders
2. Workstation wise tracking of current and next operation
3. Details of parts consumed at each workstation
4. Display work instructions for operator at each workstation

1. Reduce lost hours due to non-availability of material
2. Improve quality by process standardization



Material Management

1. Real-time material consumption with replenishment strategy based on Inventory Levels
2. Synchronization with ERP
3. Order / Serial No wise kit preparation and allocation
4. Finished Goods management – Quality & Dispatch

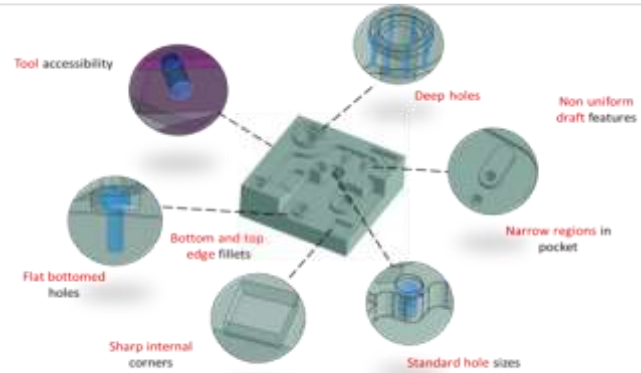
1. Ensure material availability at store
2. Inventory optimization



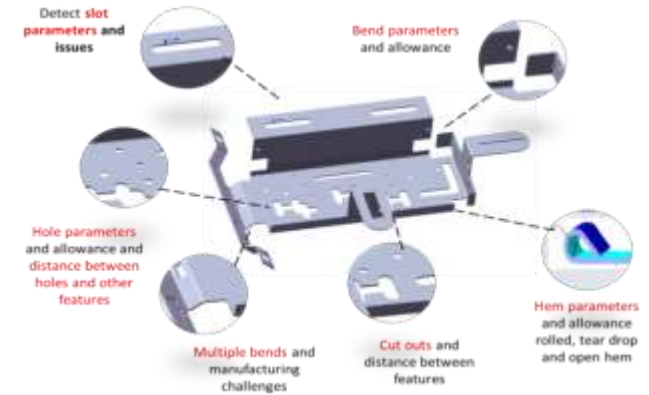
Design for Manufacturability - DFMPPro



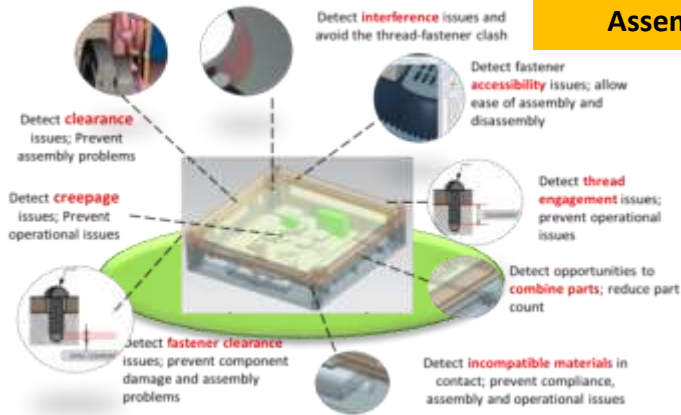
Injection Molding



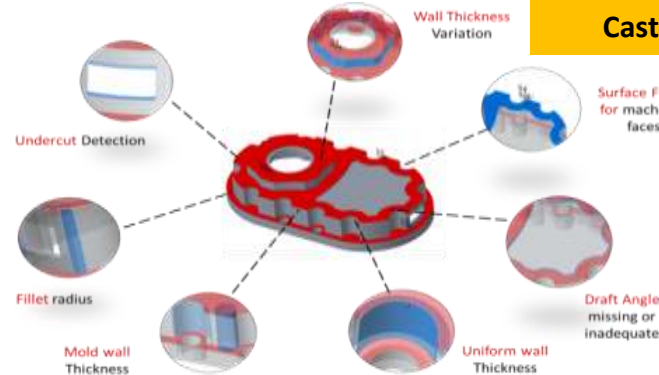
Machining



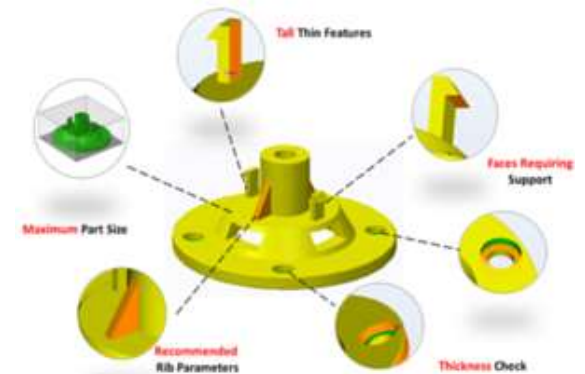
Sheet Metal



Assembly



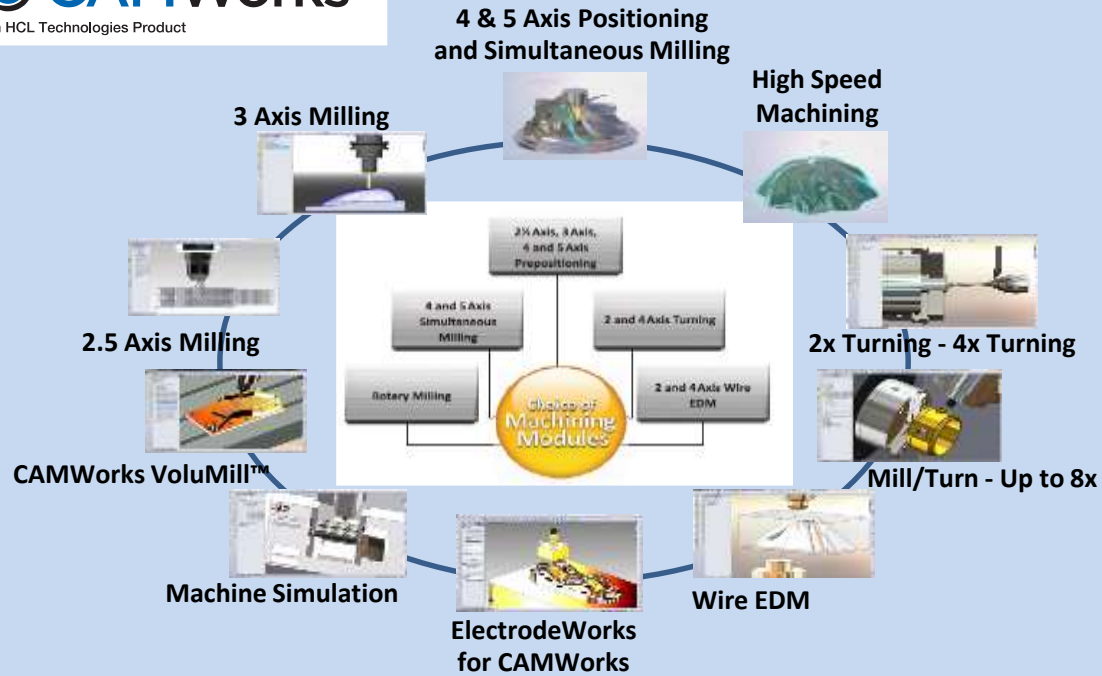
Casting



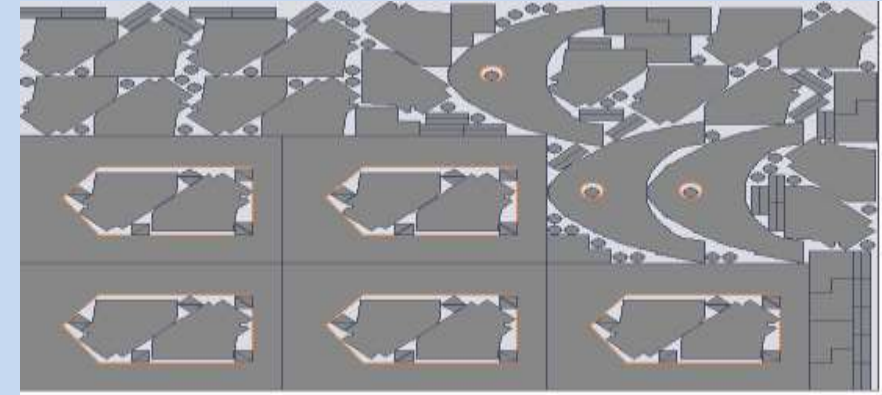
Additive Manufacturing

- Reduction in **re-work** by 10-20% ,improve **throughput** by 8-12%, reduce **product cost** by 3% -6%
- DFMPPro will help to improve productivity of the design process by capturing downstream requirements early thus reducing design rework, review time and leading to better quality.
- Provides global best practices and a framework to capture knowledge within organization

Design for Manufacturability



- The Complete CAM Solution Seamless Integrated within Creo/CATIA/SolidWorks /SolidEdge/Standalone
- Advanced 3D Feature Based Machining (FBM) with Automatic Feature Recognition (AFR)
- Knowledge Based Machining (KBM) with Full Model and Toolpath Associativity and Machine Simulation
- High Performance Toolpaths (HSM & VoluMill)



- Fast, flexible and easy-to-integrate true shape nesting libraries designed to maximize raw material utilization
- One of the most successful technologies developed from scratch by Geometric
- In production since 1994 with over 100 OEM customers all around the world
- Robust & Customizable, one of the fastest nesting products commercially available in the world.
- Reduces material wastage
- Improves Productivity by reducing manufacturing time
- Reduces manufacturing costs by generating optimized layouts

Connected Factory : Manufacturing Execution Areas with APRISO - 2

	Functional Capability	Benefits
Quality Management	<ol style="list-style-type: none">1. In-process Quality Assurance & Inspection through<ul style="list-style-type: none">▪ Display Quality checklist to the operator at the workstation▪ Ability to capture inspection data linked to part serial number / customer order2. Raise non-conformance and track closure3. Defect tracking & re-work management	<ol style="list-style-type: none">1. Quality records are managed with traceability to serial number, defect source and operator2. Integrated Change Control
Time & Labour Management	<ol style="list-style-type: none">1. Skill-wise allocation of resources to operations2. Efforts tracking operator-wise3. Job-wise tracking of machine hours	<ol style="list-style-type: none">1. Reduce defects by allocation of skilled resource to the job2. Process cost visibility3. Operator evaluation
Error Proofing & Genealogy	<ol style="list-style-type: none">1. Error proofing of critical parts using bar-code2. Capture genealogy for serial and lot based items3. Operator Vs Work Order traceability4. Production Log Management	<ol style="list-style-type: none">1. Full traceability of parts – defects – workstation - operator2. Operator evaluation



Connected Factory : Manufacturing Analytics

Enterprise Interoperability & Business Visibility

Supply/demand match

Yield & Quality
prediction

Real time data

Root cause & defect
detection

Informed Decisions

Asset Management

Predictive maintenance

OEE & RUL

Track & Trace

Inventory Management

New Service models

Operational Effectiveness

Increased Productivity

Reduced Waste

Enhanced Safety

Better resource
utilization

Profitability & Cost savings

Enables more timely product manufacturing and shipment, reduced rate of product rejection, faster product repair turnaround, and enhanced production throughput

Manufacturing Analytics – Lost Time and OEE Analytics

Use Case Description

Manufacturing productivity depends upon many factors, including Lost Time (due to setup / changeovers, unplanned line downtime, etc) and Overall Equipment Effectiveness (OEE). Analytics on data from manufacturing operations systems are critical to understanding reasons for low productivity and identifying improvement opportunities



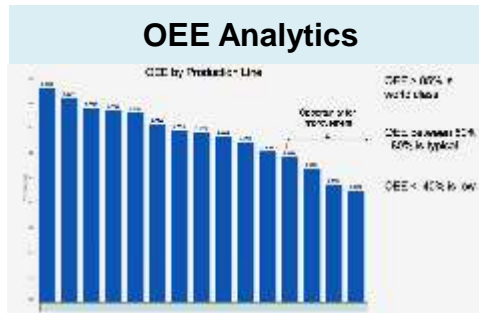
Manufacturing Plant

Lost Time Analysis

1 Data Ingestion

Data collected from production operations systems

OEE Analytics



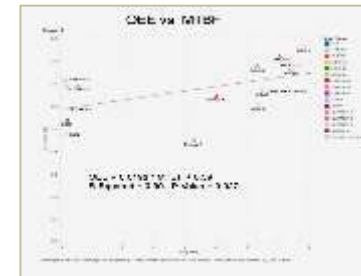
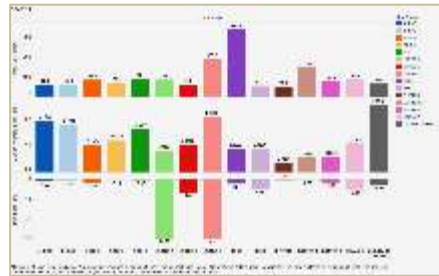
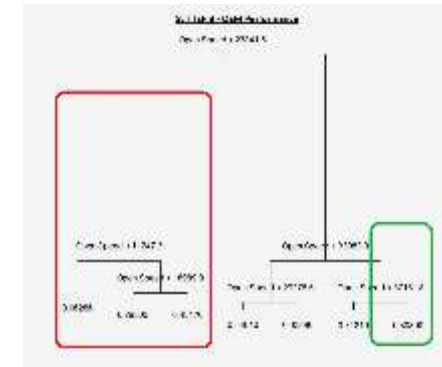
Lost Time Dashboard

2 Exploratory Data Analytics

OEE Dashboard



3 Predictive Modeling



Manufacturing Analytics : Prediction of Supplier Performance

Using data provided

Granularity

- Primary prediction requirement solely based on material order, expected delivery date, actual delivery date
- Difference in expected and actual gives percentage deviation

Extensibility

- Additional correlations and granularity can be achieved by making use of filters such as per vendor, per plant, per buyer

Forecasting using

- Regressions
- Moving Averages
- Exponential Smoothing
- ARIMA

Illustrative View – Sample data and Prediction

MaterialID	Sum of OutstandQty	Count of OutstandQty 2
4953992	242	43
4950022	1189	41
3072234-01	3475	40
3072287-01	1850	36
3085891-01	751	30
4950881	918	29
7000669H02	251	29
ST3023-04	38800	29
4950565	363	28
4950017	1276	25
4950079	416	24

Vendor	Buyer	MaterialNumber	Plant	OutstandQty	StatDate	Compliance
100063	H18	4953992	61	1	26-06-2017	100%
100063	H18	4953992	61	1	04-07-2017	50%
100063	H18	4953992	61	1	10-07-2017	100%
100063	H18	4953992	61	1	13-07-2017	100%
100063	H18	4953992	61	1	18-07-2017	75%
100063	H18	4953992	61	1	21-07-2017	50%
100063	H18	4953992	61	1	25-07-2017	75%
100063	H18	4953992	61	1	28-07-2017	75%
100063	H18	4953992	61	1	02-08-2017	50%
100063	H18	4953992	61	1	14-08-2017	100%
100063	H18	4953992	61	1	17-08-2017	0%

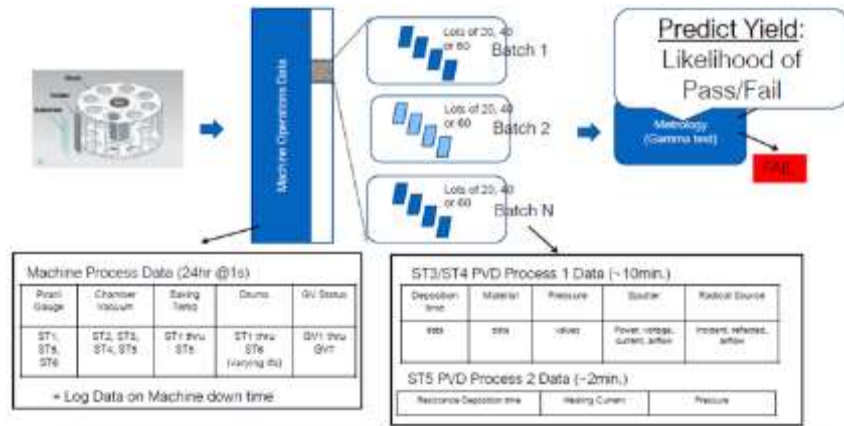


Manufacturing Analytics: Predict Quality Deviations & Root Cause Analysis

Use Case Description

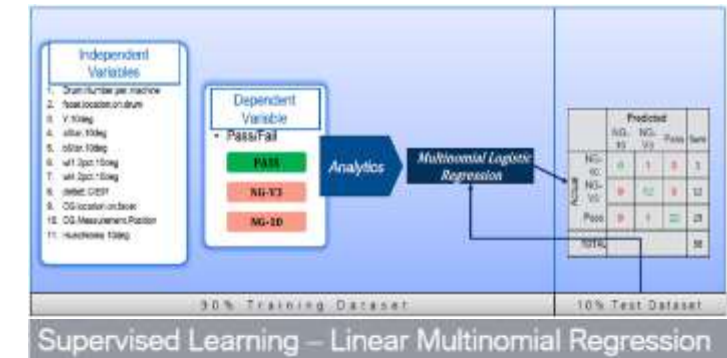
Pain Point: Lack of visibility of Quality Deviations and Production Shortfalls impacting delivery commitments

Solution: Machine learning based predictions of quality and output. Data driven approach to identify hidden patterns and relationships that impact quality/production outcomes



- 1 Acquire machine data and process parameters from IoT enabled devices & equipment

2 Data exploration and feature elimination. Correlation Analysis of state variables to Outcomes (Pass or Fail) through supervised learning.



3 Multinomial Logistic regression to Predict Quality Shortfalls. Correlations driven remedial action to prevent undesirable outcomes

Analysis Techniques

- Correlation Analysis to identify impact of state variables and process settings on Yield outcomes
- Prediction of Quality Shortfall based on regression analysis to create a mathematical model of learning
- Trace back causes for quality deviations and anomalies associated with equipment & process settings

Benefits of Using Advanced Analytics

Ability to Predict Shortfall – Enable Manufacturing Unit to predict their ability to meet delivery commitments

Proactive Remediation – Preempt quality and output shortfalls up-front so that remedial actions may be taken preemptively

Ensure high OEE – Root cause analysis driven isolation of problem sources and recalibration of equipment, as needed.

Smart Maintenance management with Android

Customer Profile	A Japanese multinational electronics corporation		
Business Objective	To develop a MMS product for vendors and partners that provides innovative solutions through their mobility devices	Platform	Multichannel: Web & Android
Technologies Used	Web: ASP.NET, C#, MVC4, SQL Server, JQuery Android: Android SDK, Java, HTML5, JQuery Mobile, Metaio		



HCL Solution

1. Created Mobile specific layouts

2. Created native container for hybrid application

3. Used Bar Code and Bluetooth scanning for "Scan On"

4. Used AR Markers to identify the Machines

5. Used the positions of AR Marker to identify the parts and Maintenance Order History

Accomplishments

- Enhanced user Experience with various views like line view, AR view.
- Multi-lingual support for easier customization
- Maximum Code Reuse resulting the reduced cost



Roadmap Development and Next Steps

DIGITAL MANUFACTURING AND CONNECTED FACTORY

Developing a Roadmap for Digital Manufacturing and Connected Factory

Pre-Survey

Workshops

Data Consolidation

Analysis

Assessment & Roadmap

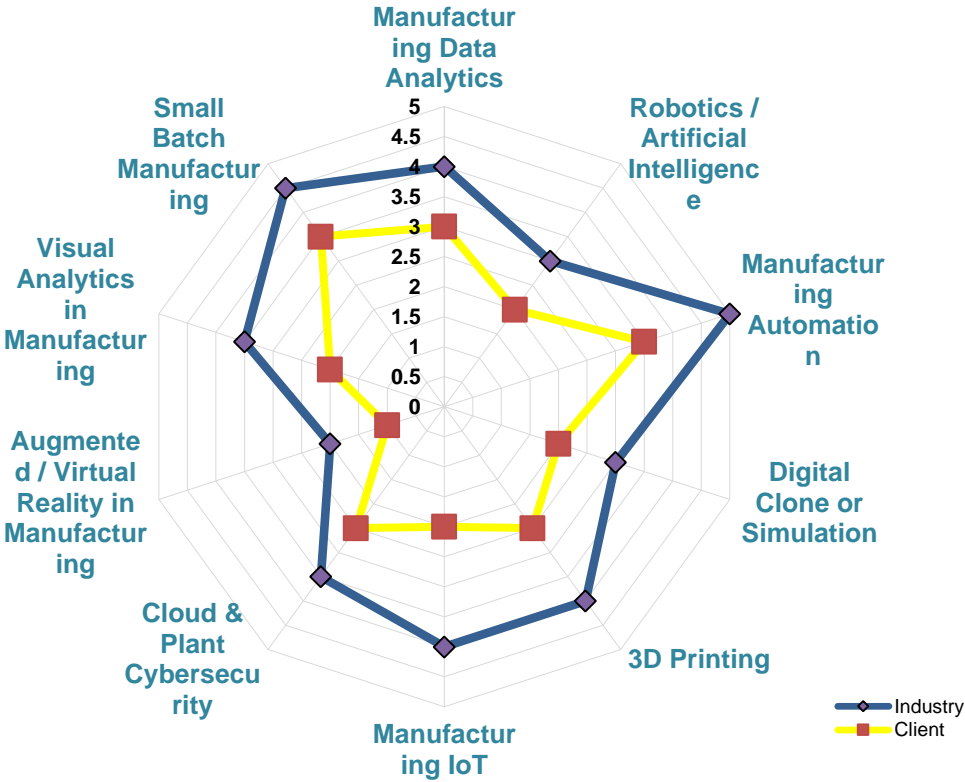
HCL has developed Industry 4.0 Assessment Framework based on Best Practices and leading / disruptive technology trends in the Industry.

The Assessment provides deeper insight into client Manufacturing IT capabilities and Readiness to adopt Industry4.0 change

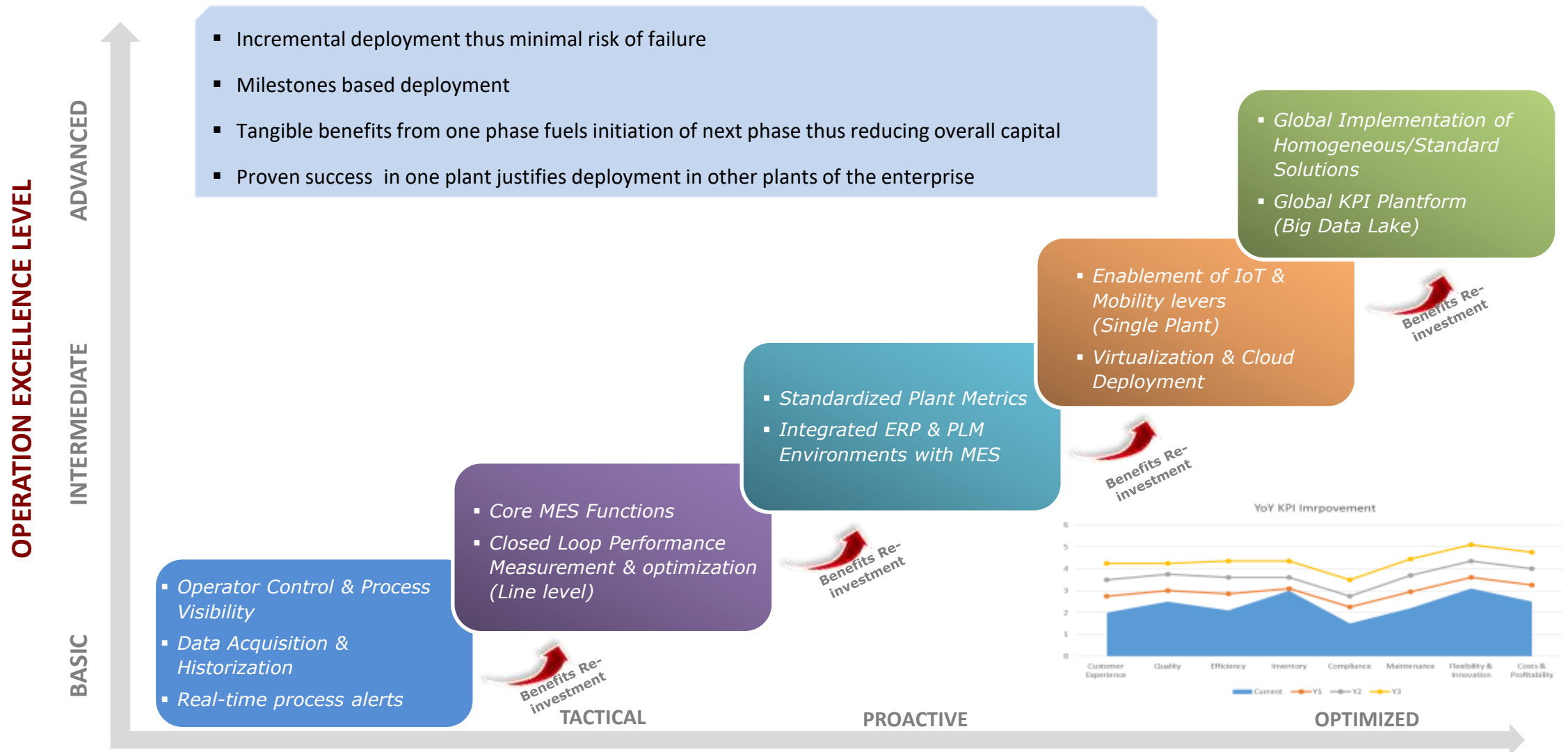
Client systems and practice are rated on a 5-point scale and compared with Industry Best Practices for improvement planning

Ten Industry Best Practices in focus for this assessment include:

1. Manufacturing Data Analytics
2. Robotics & Artificial Intelligence
3. Manufacturing Automation
4. Digital Clone or Simulation
5. 3D Printing
6. Manufacturing IoT
7. Cloud & Plant Cybersecurity
8. Augmented / Virtual Reality
9. Visual Analytics
10. Small Batch Manufacturing



Roadmap for Achieving a Connected Factory



Manufacturing Execution : Putting it together

BUSINESS PROBLEMS



Are there indications that a major component failure is likely to occur in the immediate future?



How do low level failures cumulatively affect the life span of components?



What kinds of failures are likely to occur together

ANALYTICAL RESOLUTION

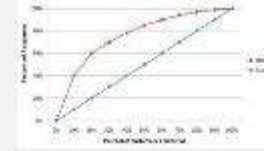
Classification model to Predict Major Component Failures

- ▶ Sensor Data
- ▶ Alarm Data
- ▶ Repair History



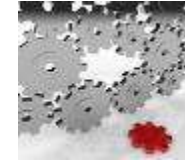
Regression models to Predict Component Life Based on Specific Machine History

- ▶ Repair History
- ▶ Events



Association Models to Identify Failures that Occur Together

- ▶ Warranty Data
- ▶ Repair History



Product health score used to predict impending failures



Understand impacts of individual low level failures, estimate component life



Identify components that have a high probability of experiencing similar failures

BUSINESS BENEFITS





Key Benefits



Improving Line Productivity

- Increased line productivity with better work process design and tools/ fixtures.
- Automation and integration of specific operations and functions
- Reduce line rejection thru better mistake proofing



Recall, Return Management Parts Traceability Multiple Models on Line

- 360 degree view of parts movement
- End to end supply chain traceability
- Flexibility to manufacturing multiple products on the same line with small setup downtime



Reduction in Rejections & line cost control & throughput

- Operations process Monitor & control at Level0 – Level1
- Predictive analytics to help control QA issues before they occur
- Line / Cell operations automation to harmonize sequencing, helps control cost & improve throughput



Best practices of plant ergonomics & capacity optimization

- Support new plant design and layout optimization thru simulation.
- Plant Asset utilization and capacity throughput optimization
- Monitoring of Plant Assets during setup phase



THANK YOU



Hirren Turakhia – Industrial Vertical Head and BU Lead Digital Manufacturing and Industry 4.0



Market Maker : 25 years of ESO/ITO Business Experience across sectors

- Forging Joint Ventures and Strategic engagements in Industry sector
- Products, Services and Solutions for HiTech / Manufacturing /Engineering Industry
- Mega Business impact with Applications, Process and Infrastructure Outsourcing engagements
- Europe's First Mega Mn IOT Project with an Industrial Major

Experience Summary :

- A pragmatic and astute business leader with extensive experience at Europe and India in leading business units , regional units and practice groups serving engineering to enterprise IT functions of various industry verticals

Proven experience in building and executing local/global business strategies, portfolios and operations, to consistently drive growth and performance goals, by business and by geography , Special focus on Digital Engineering / R&D / Digital Manufacturing / Product Life Cycle management /Industry 4.0 and IOT Led solutions

Work experience with leading multinationals : HCL, CSC, TATA,SIEMENS, ABB, Geometric (Gordrej)

Strong demand generation approaches at multiple levels : CEO, CIO, CTO, COO, CMO, R&D Heads, Plant heads and Most Recently Chief Digital Officer

Extensive multi-tier team management experience : Served customers at major industrial hubs across Europe and US leveraging global teams – Germany, Nordics, Swiss, UK and USA

Specialties: Entrepreneurial and Pioneering Spirit

Defining business strategy and solutions portfolio, identifying prospective markets & accounts in terms of regions & verticals, implementing with sales and delivery teaming , managing with multiple P&L responsibility in a global matrix organization

Shantanu Rai : Global Director – Digital Manufacturing and Industry 4.0



Shantanu is a senior business leader with over 23 years experience in PLM and Digital Manufacturing Consulting, Technology/Solution development and implementation in leading product and services organizations. He has expertise in business and technology strategy, project/ program management, process reengineering and organizational design related to Manufacturing and Industrial sectors. He has a history of successfully leading large-scale projects across a variety of industries that reduce risk, accelerate growth, and provide a measurable ROI. He is a frequent speaker at Industry forum around Digital Manufacturing and PLM areas.

Shantanu Rai is a Mechanical Engineer from IIT-Roorkee, INDIA with a minor in Mathematics and Computer Graphics.

Some of his major achievements are about bringing together Process Automation, Instrumentation, IoT into Digital Manufacturing and Connected factory.

- Implemented a Real-time Cooling Control for a Rolling Milling.
- Computer Aided Machining of Hydro Turbine blades
- Neural Network & Machine learning in Plant Cooling Applications.
- Supplier Collaboration and Integration for Aerospace supply chain.
- New Vehicle development process for multiple types of vehicles
- Production part Approval process implemented for automotive ancillaries.
- Plant Schema Design for Oil Refineries

His current research and business interest include solutions that bring together “Design, Supply Chain and Manufacturing in a Connected Factory” environment.

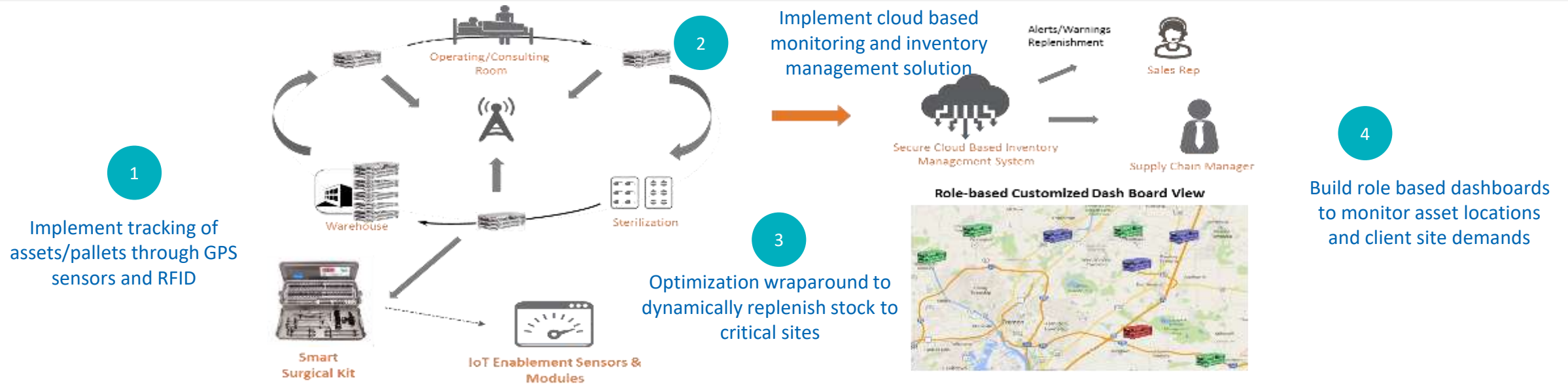
This new paradigm combines elements of Digital Thread, Industrial IoT, Micro services and Data Bus and interfaces for manufacturing stations and machining centers.

Manufacturing Analytics : Inventory Management & Dynamic Replenishment

Use Case Description

Pain Point: Excessive costs associated with overstocking of inventory. Inability to track critical assets

Solution: Provide role based access and visibility of inventory in real-time and Optimize routing.



Analysis Techniques

- A wide range of tracking devices & sensors were used to create the data ingestion layer for the IoT infrastructure
- Time histories of asset movement & site specific demands were built into the Optimization model for dynamic replenishment & optimal re-routing to critical sites
- External event predictions were made

Benefits of Using Advanced Analytics

Role based visibility – Enable role based visibility and traceability of assets in custom dashboards

Excess Inventory Cost Reduction – Predict changes in demand, leverage historical data and minimize stocking of excess inventory

Dynamic Re-routing – Optimization based dynamic replenishment of inventory to ensure supply to critical sites