Factory of the Future Technologies and Approaches Applied to Solve Today's Power Density Challenges

To: APEC 2021 Conference

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Agenda

- **Factory of the Future** Electronics Manufacturing Industry Context
  - definition, expectations, integration levels, opportunity vs. current state, implementation and ROI delivery focus

- Applied examples – Solving Today's Power Density Challenges
  a) **Creating reliable hardware designs** with digital thread and CAD simulation
  b) **Enabling higher placement densities** with back-end manufacturing automation
  c) **Achieving high quality levels, yields, and throughput** with data analytics

- Key Messages & Call to Action

Definition & Expectations

Industry 4.0, Ind4.0, Industrie 4.0,
Smart Manufacturing, Smart Factory
Factory of the Future (F2)

F2 = Modernization

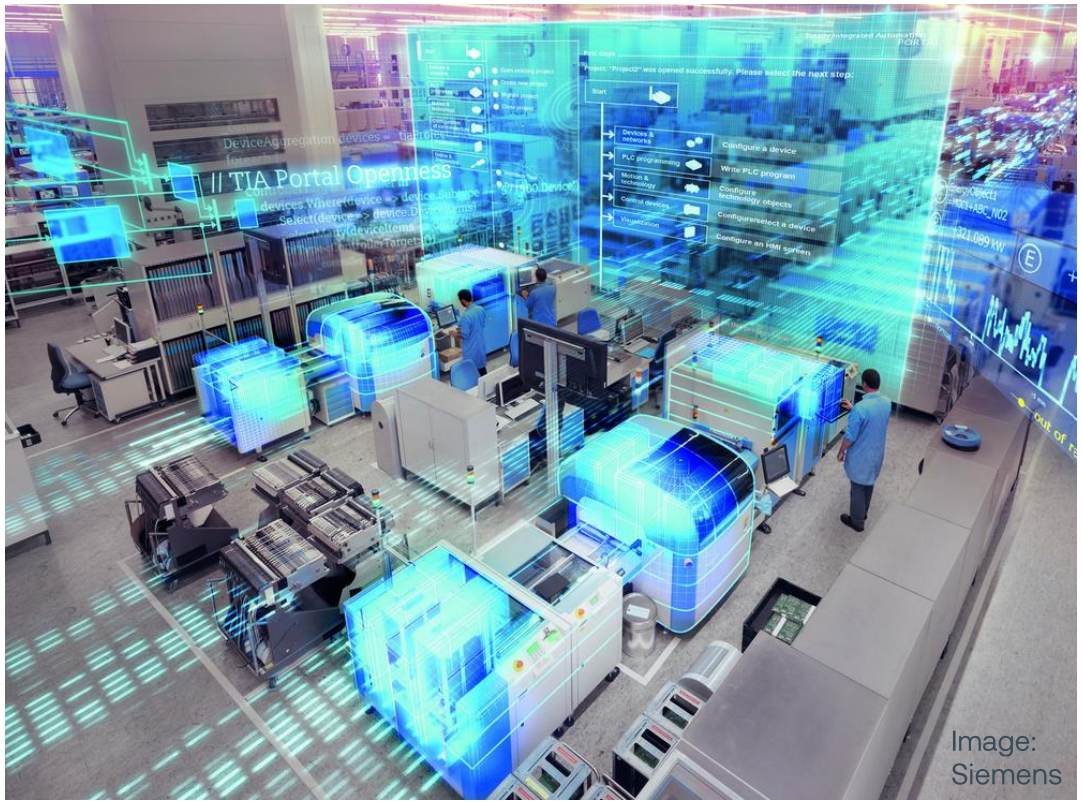
Industry-wide transformation

Includes:
(a) Highly skilled people – new roles, skills, focus
(b) New technologies – AI, data analytics, IT/OT networks
(c) Conventional technologies – PCB, components, PCBA
(d) Foundational engineering/operations – QMS, SPC, SCM
'good old-fashioned engineering'

Trusted, global, horizontal supply chain
***Industry coordination of F2 implementation needed**

Impacts E2E operations: Design – PCB – Components – Assembly/Test – Mechanicals – Final System Build

Expect moderate/slow steady F2 adoption → 2,5,10 yrs
Reason: CapEx and skills intensive

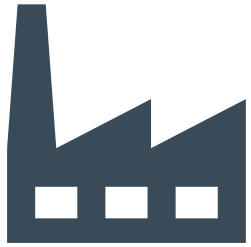


"Linking people, objects and systems creates dynamic, real-time optimised, self-organising and inter-enterprise value creation networks which can be optimised according to various criteria such as costs, availability and resource usage"

(Plattform Industrie 4.0 2015, p. 3)

Modernization Integration Levels

1



Individual Factory/Company

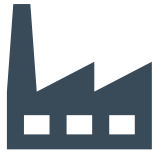
OEM, PCB, EMS, Components, Mechanicals

*Current adoption level across industry

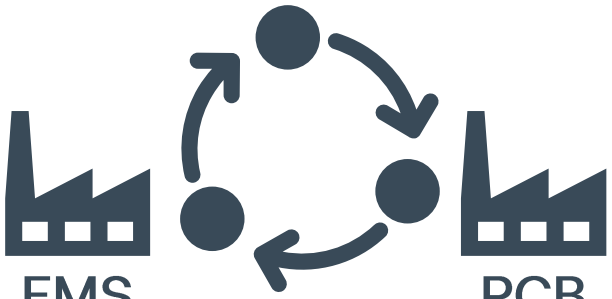
Individual company view
New technologies & processes
Productivity, efficiency, ROI

2013 - 2020

2



OEM



EMS PCB

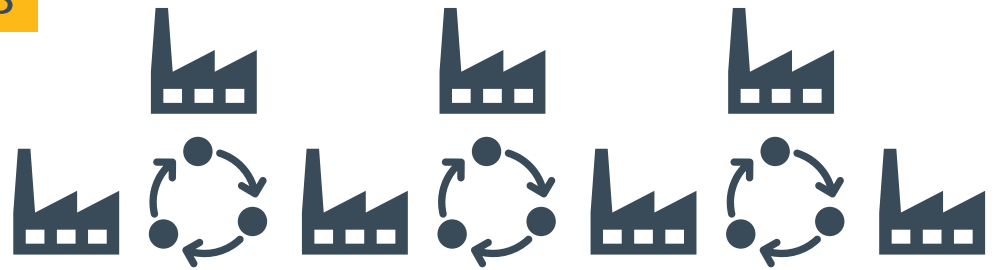
OEM Product Supply Chains

New product introductions using trusted supply chain partners

OEM-defined ecosystems
Faster cycle times, quality/reliability
Data driven supplier management

2025

3



Electronics Manufacturing Industry

Common Supply-base servicing multiple OEMs/markets
Regional & Global Supply Chains
Various Markets (Aerospace, Automotive, Consumer)
Big and small companies (Tier 1 – Tier 5)

*Not many are thinking about or addressing this

Industry-wide view & transformation
Modernized infrastructure for industry benefit
Industry leadership needed

2030

Complexity, coordination, industry standardization needs increase

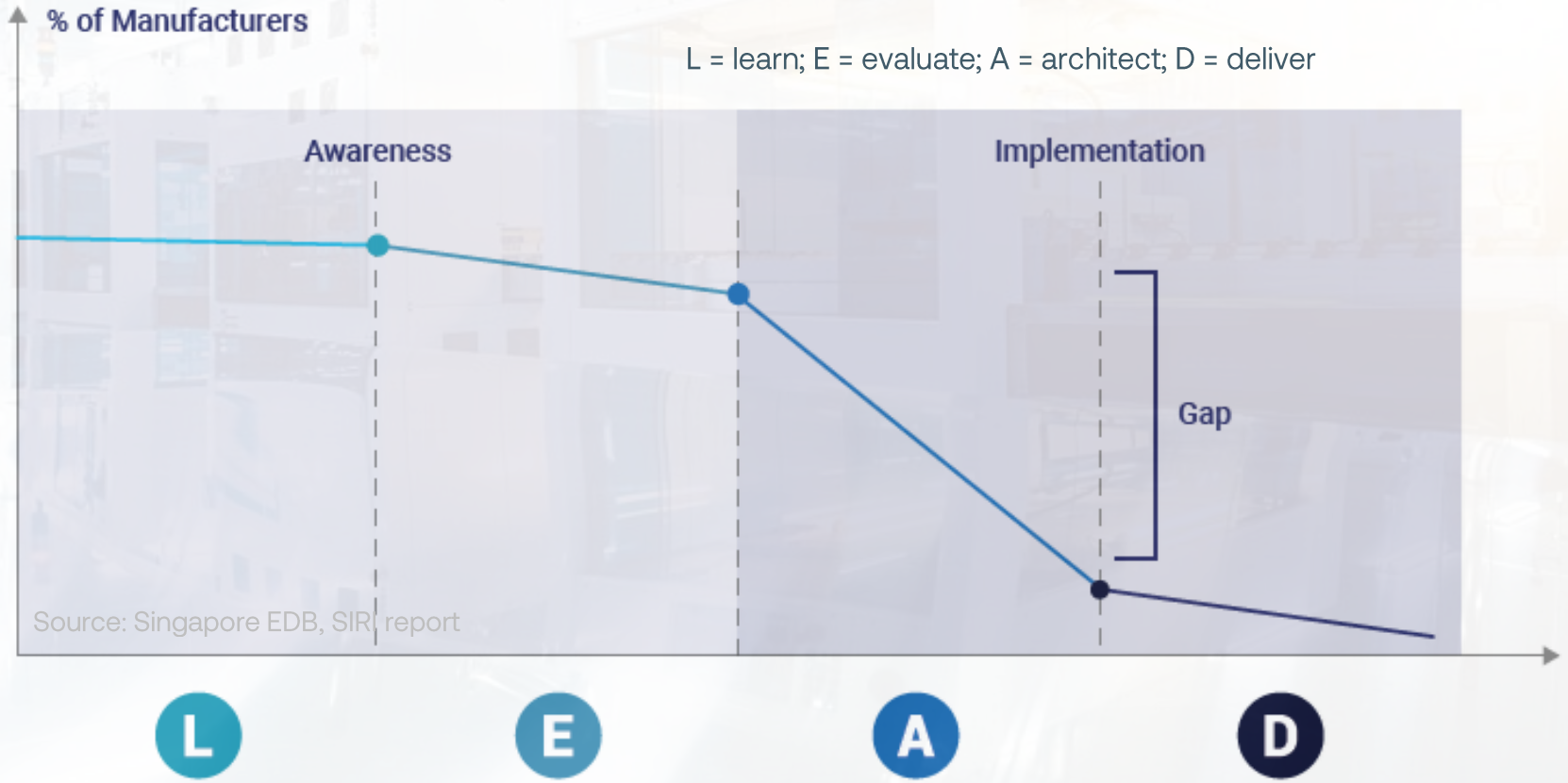
Factory of the Future – Opportunity

- Sustainability / Circular Economy
- Energy Usage / Carbon Footprint
- Profits / Costs
- Perfect 1st Pass Designs
- Fastest NPI Cycle Times
- Supply Chain Excellence
- Resiliency, Disruptions
- Agile, Predictive
- Flexibility

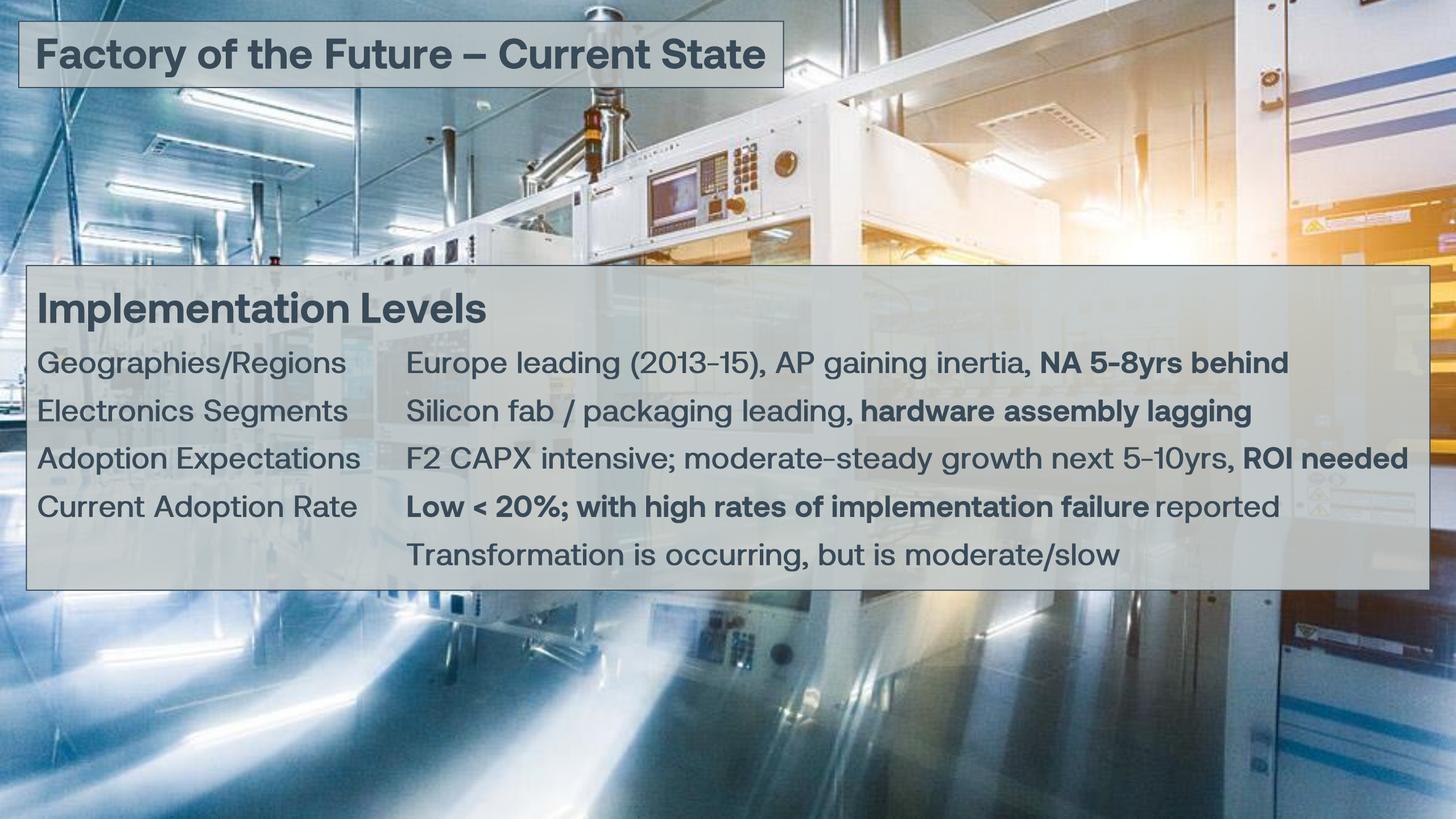
- Availability, Utilization
- Efficiency
- Productivity
- Optimized Capacity
- Faster, Deeper Insights
- Quality / Reliability
- Yields, Scrap
- Build to Order
- Perfect Fulfillment

Factory of the Future – Current State

THE GAP FROM AWARENESS TO IMPLEMENTATION



Factory of the Future – Current State



Implementation Levels

Geographies/Regions	Europe leading (2013-15), AP gaining inertia, **NA 5-8yrs behind**
Electronics Segments	Silicon fab / packaging leading, **hardware assembly lagging**
Adoption Expectations	F2 CAPX intensive; moderate-steady growth next 5-10yrs, **ROI needed**
Current Adoption Rate	**Low < 20%; with high rates of implementation failure** reported
	Transformation is occurring, but is moderate/slow

Focus: Implement ROI Driven Solutions

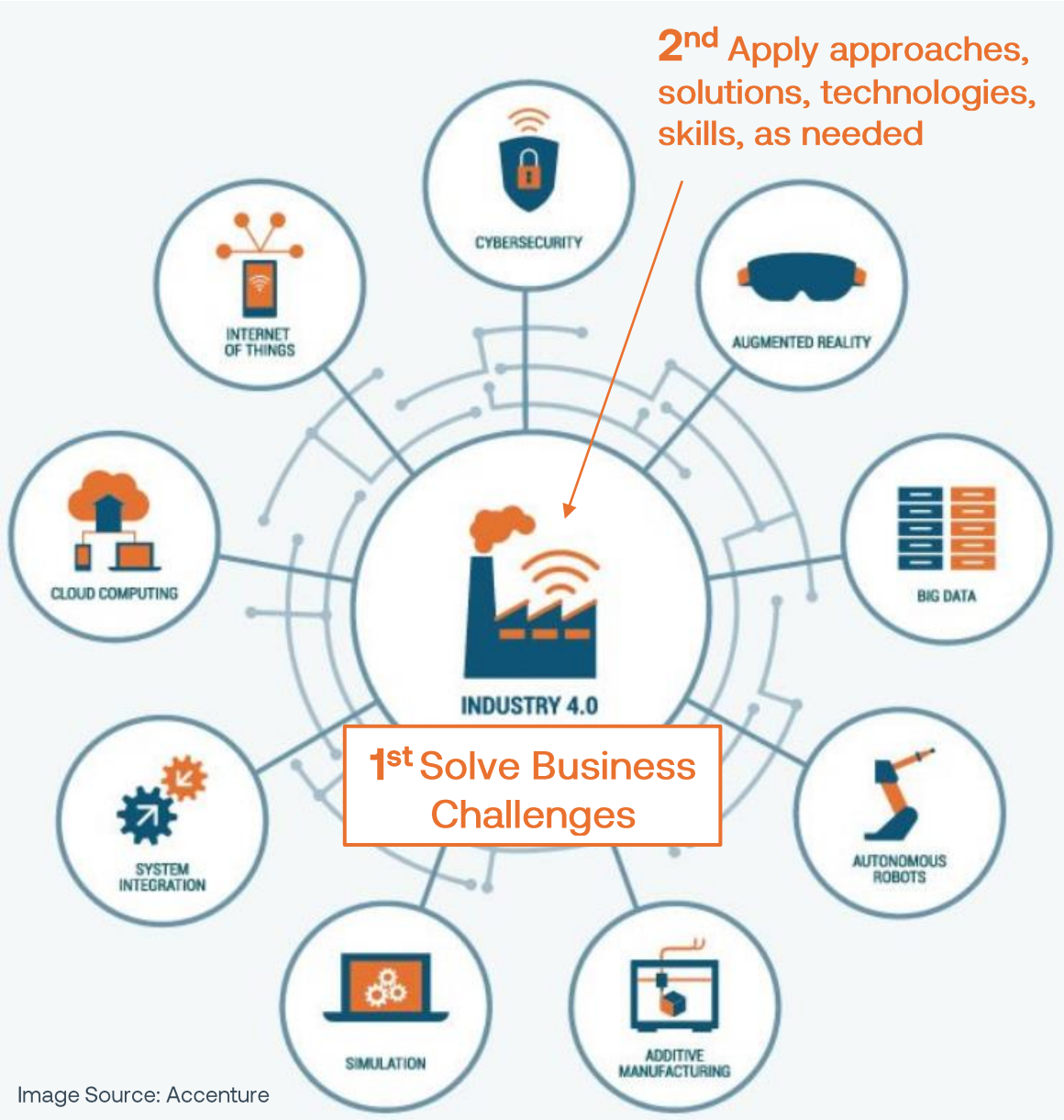


Image Source: Accenture

Factory of the Future Disruptive Technology Stack

- Common design data format - Digital Product Model Exchange (DPMX)
- Common equipment data protocol - Connected Factory Exchange (CFX)
- Data Analytics/Predictive Analytics, Big Data/Business Intelligence (BI)
- 3D Printing/Additive Manufacturing in Electronics
- Artificial Intelligence (AI) / Machine Learning
- AI-Enabled Inspection
- Automation
- Industrial Networks (IT/OT Convergence)
- CAD, 3D Design
- Robotics/Cloud Robotics/ Cobots
- Simulation and Modeling
- AI Human Presence Detection
- Cybersecurity
- Industrial Internet of Things (IIoT)
- Smart Sensor/Actuator Technologies
- Cloud Computing
- Augmented Reality/Virtual Reality
- Digital Twin/Digital Thread
- Digital Transformation of Operations and Supply Chain
- Systems Integration
- Cyber-Physical Production Systems (CPPSs)
- Blockchain / Digital Supply Chain

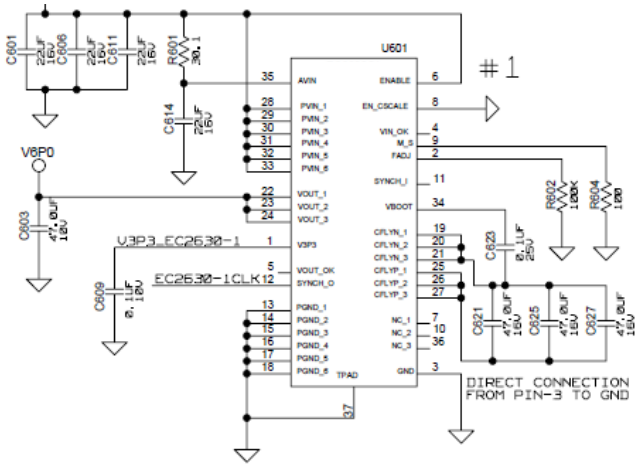
3 Examples – Innovative Manufacturing Solutions

Solving Today’s Power Density Challenges

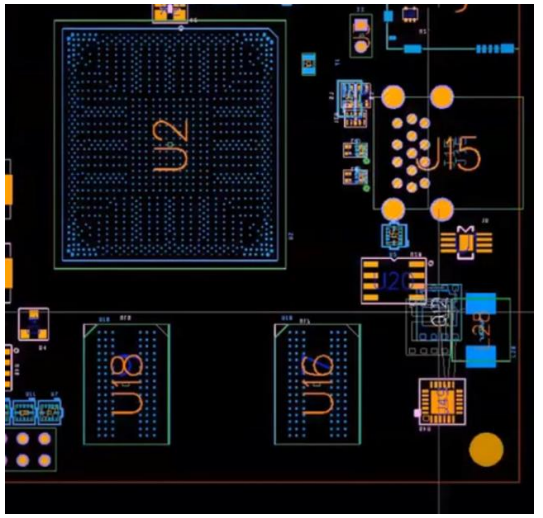
→ **Enable miniaturization | higher density | highest quality & reliability**

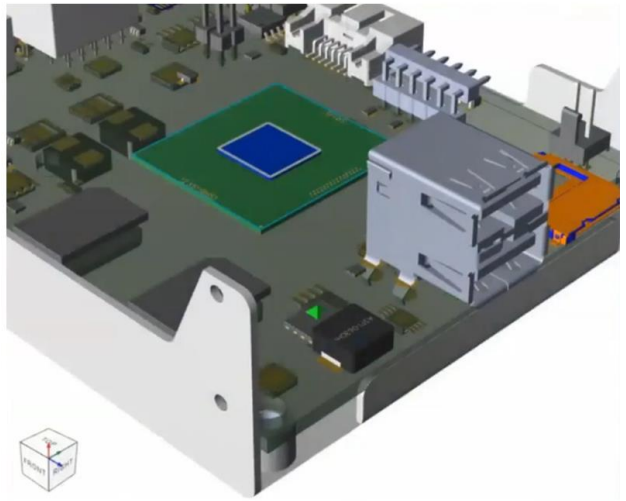
Applying Factory of the Future approaches, technologies, thinking

Challenge #1: Create reliable hardware designs – Digital Thread



Layer	Cu Thick. (mils)	Cu Foil wt (oz)	DK	Lam. Thick. (mils)
1	1.40	0.5 oz	3.23	2.26
2	1.40	0.5 oz	3.25	3.71
3	1.30	0.5 oz	3.44	2.96
4	1.20	1 oz	3.66	4.00
5	0.60	0.5 oz	3.34	3.23
6	1.20	1 oz	3.45	3.50
7	2.40	2 oz	3.23	3.82
8	2.40	2 oz	3.45	3.50
9	1.20	1 oz	3.34	3.21
10	0.60	0.5 oz	3.66	4.00
11	1.20	1 oz	3.44	2.96
12	1.30	0.5 oz	3.25	3.70
13	1.40	0.5 oz	3.23	2.26
14	1.40	0.5 oz		





Logic, schematics, engineering drawings

PCB stack ups, drill charts

ECAD Electrical 2D physical design, BoM

MCAD 3D mechanical design

Need – Standardized model-based design data flow – design, procurement, manufacturing, field application

Challenge #1: Create reliable hardware designs – Digital Thread

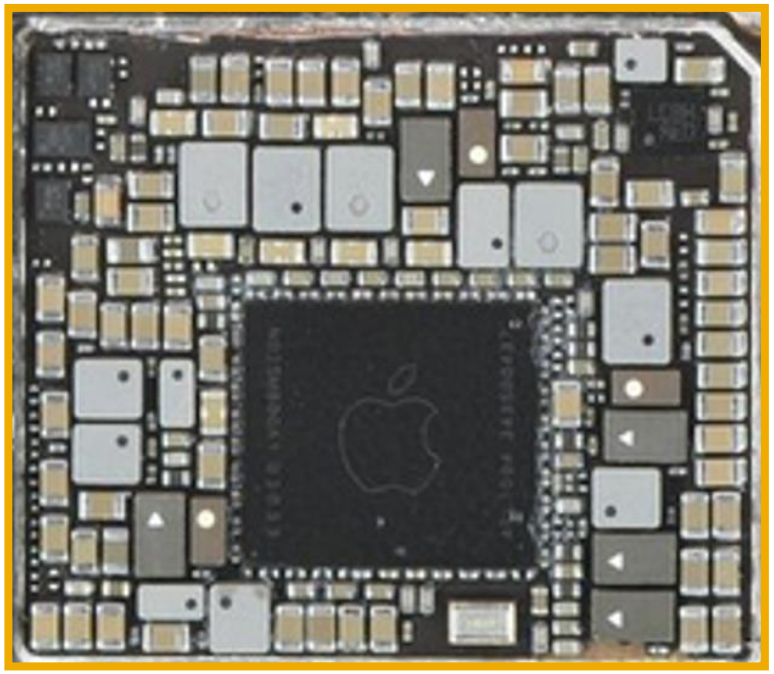
Issue: Ensuring high quality/reliability electro-mechanical designs with faster NPI cycles

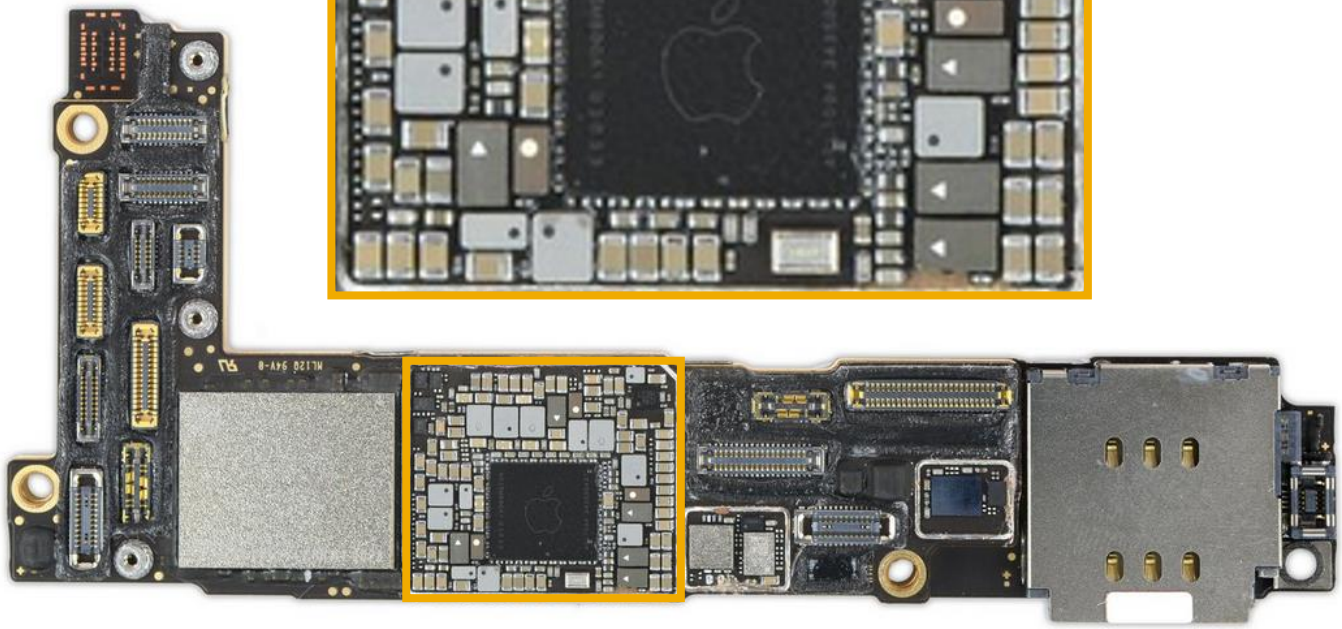
- Drivers: **rapid NPI cycles, electrical-mechanical co-design improvements, new design rules**
- Functionality, speed, bandwidth ↑
- Compute, memory, clocking frequency ↑
- Form factor, real estate ↓; HDI routing/vias usage ↑
- **Power consumption, thermal management** ↑
- Component packaging miniaturization – BTC design-multi package integration, ≤ 01005 passives
- Mechanical design complexity / **need for 3D (multi-plane) power/ground spacing checks** ↑

Innovation focus: Digital thread, CAD simulation, and Design for Excellence

- Getting it right the first time!
- **Enabling real-time dynamic changes, reduce transcription errors**, greater flexibility and productivity
- **Single digital thread:** logic → schematics → card outline → BoM → physical design → procurement → manufacturing
- **DfX, FMEA design reviews, simulation**, dynamic ECAD-MCAD integration, **new system-level standards**

Challenge #2: Enable higher placement densities – BEOL Automation





Dense electrical-mechanical integration
Complex, stacked final assembly
Bezzle, screen, battery, lenses, electronics

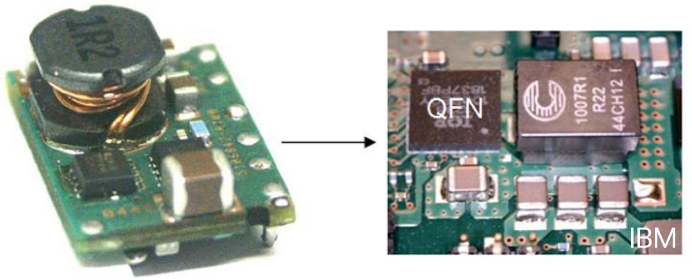
Apple iPhone 12 teardown (ifixit.com)

Miniaturization, 3D high density, power & thermal management

Challenge #2: Enable higher placement densities – BEOL Automation

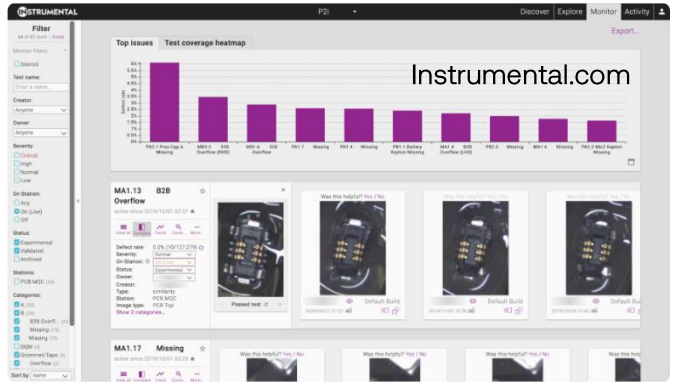
Issue: Miniaturization of electronic devices, circuit layouts, and available PCB real estate

- Driven by mobile/consumer, medical, and automotive electronic segments
- **Tighter placement** keep-out rules AND **tighter tolerances**
- Shrinking component packages (1-2mm BTCs, 01005 caps/resistors)
- On board voltage regulation ('down regs')
- Higher power devices requiring **optimal power/thermal management**



Innovation focus: Back-end of line mechanical automation

- FEOL (SMT) highly automated; **BEOL (mechanical assembly) still highly manual**
- High accuracy mechanical automation (repeatability, throughput)
- **BEOL mechanical inspection** – AI-based visual inspection – Final system quality
- **Automated BEOL assembly – SIGNIFICANT opportunities**
  - > compliant pin, manual insertion, precision screw-driving, heat sink assembly
  - > ICT/FCT handling, BTC inspection, false call reduction



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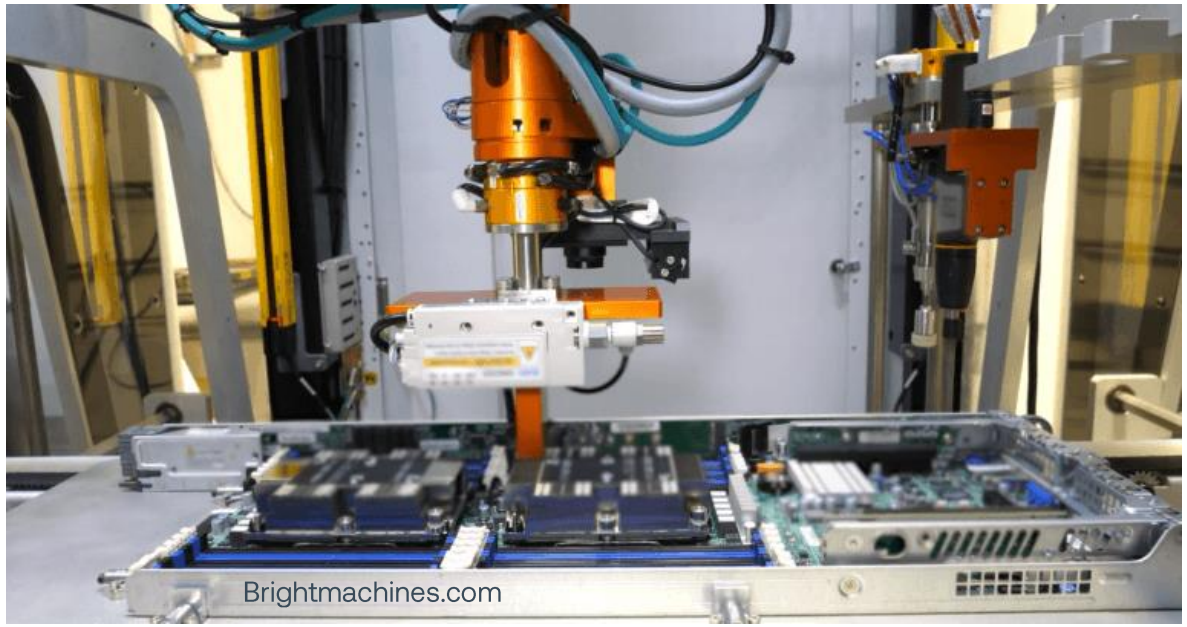
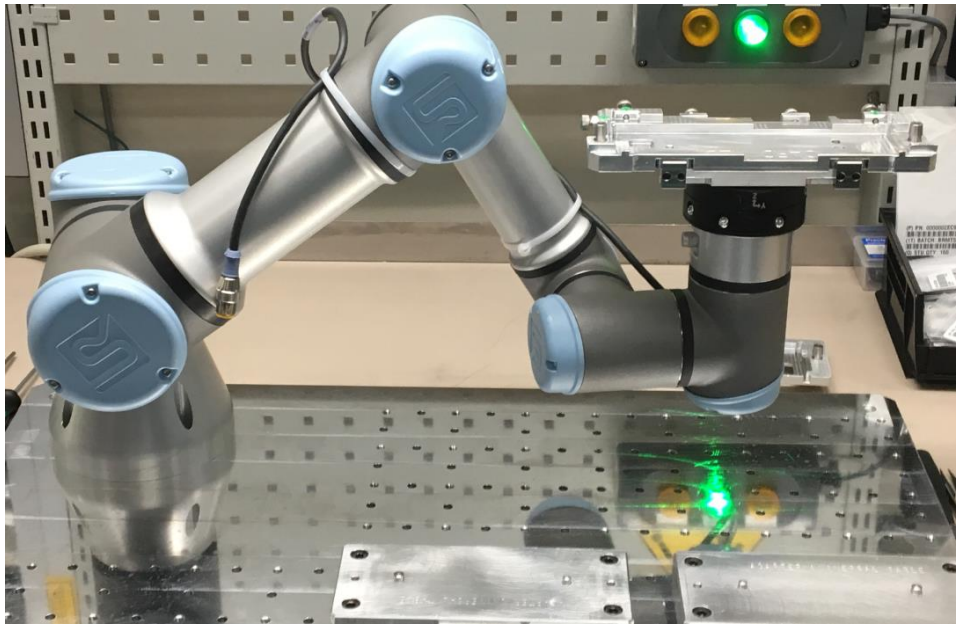
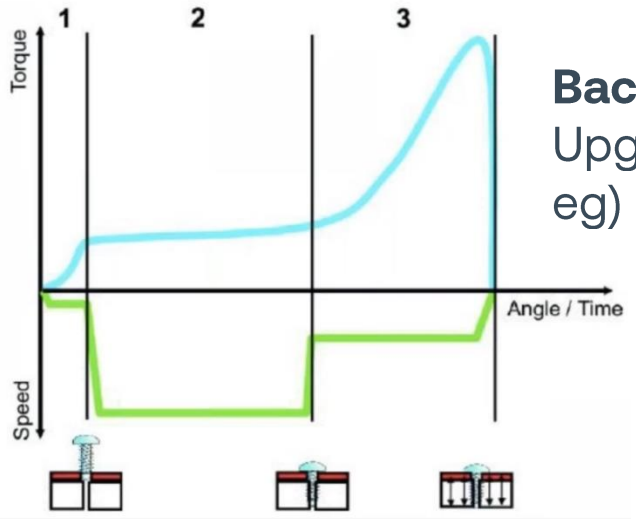
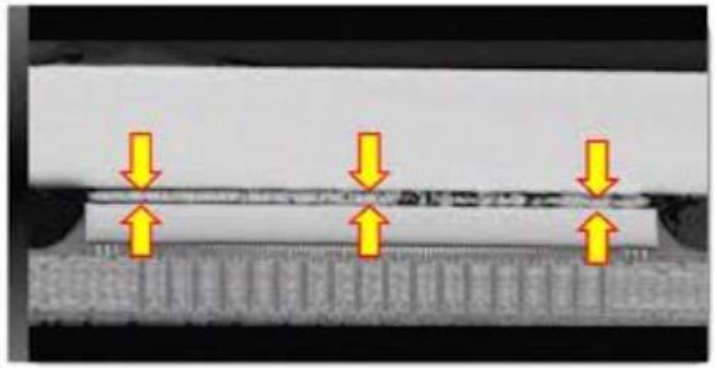






Back-End of Line Automation
Upgrade legacy manual processes
eg) controlled torque screw driving

Cobots precision alignment, applied force
eg) heatsink TIM bond-line



Challenge #3: Achieve high quality, yield, throughput – Data Analytics

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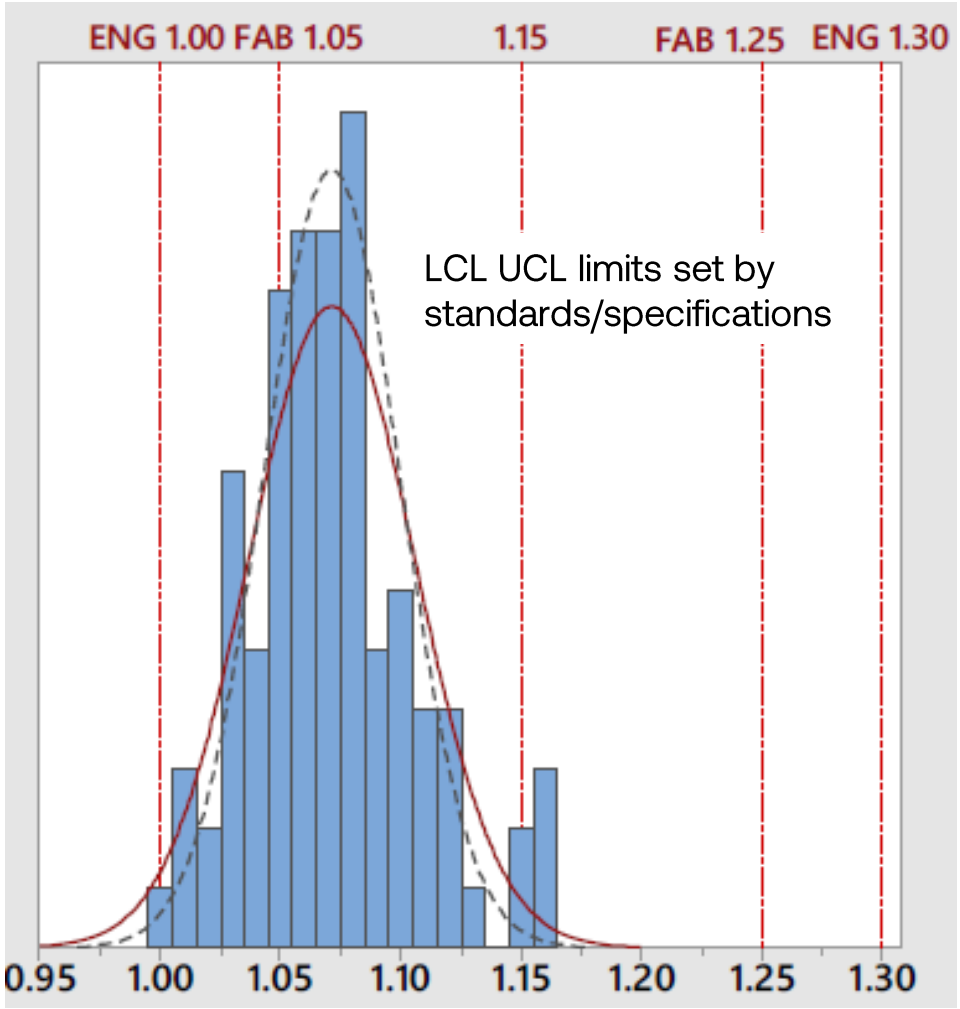
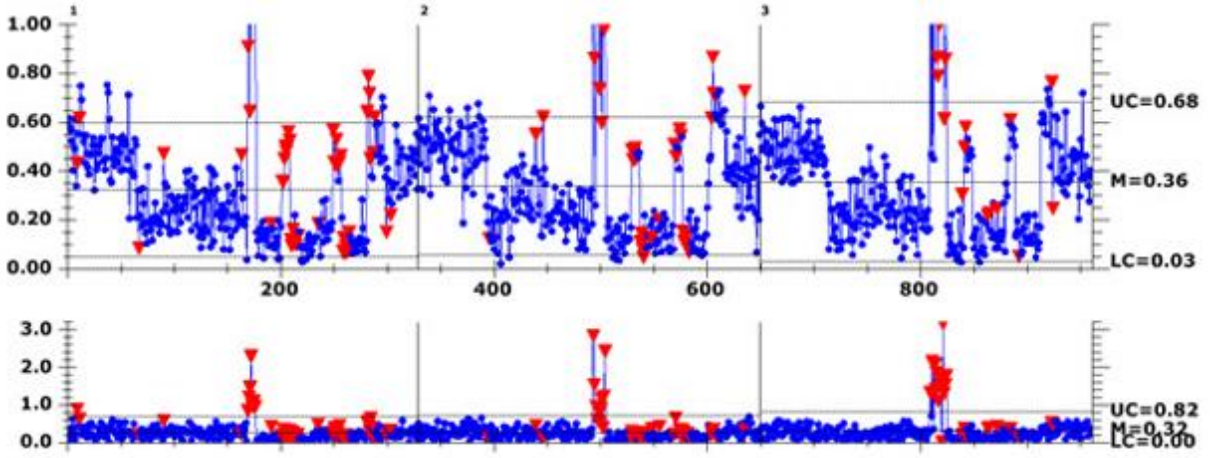
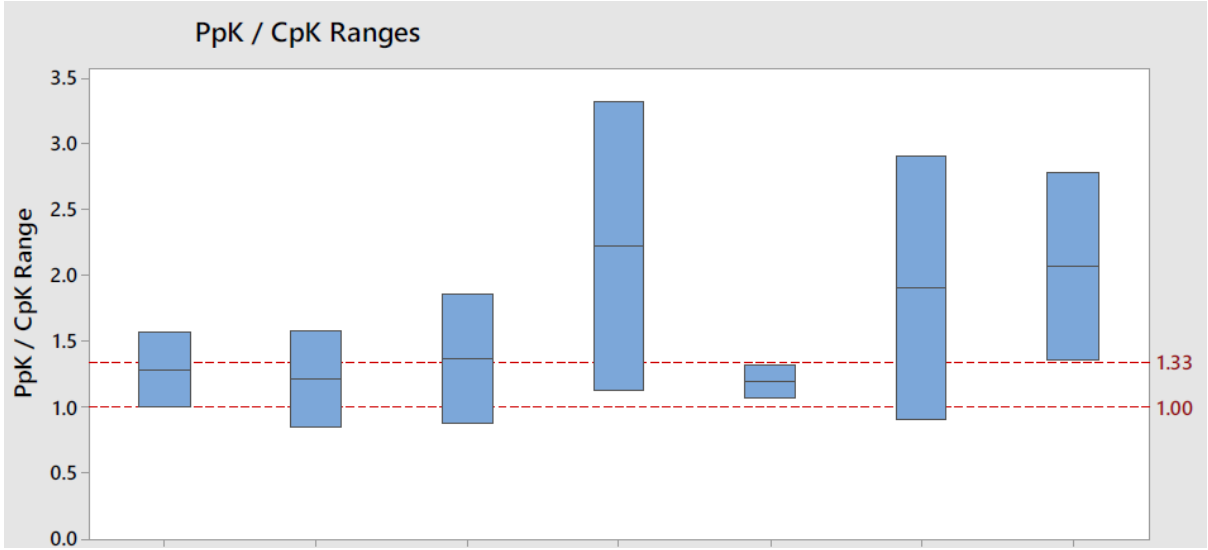
This is what engineering & operations actually needs

Data analytics starts with → Statistical Process Control, Six Sigma – Master Black Belts DMADV, DMAIC



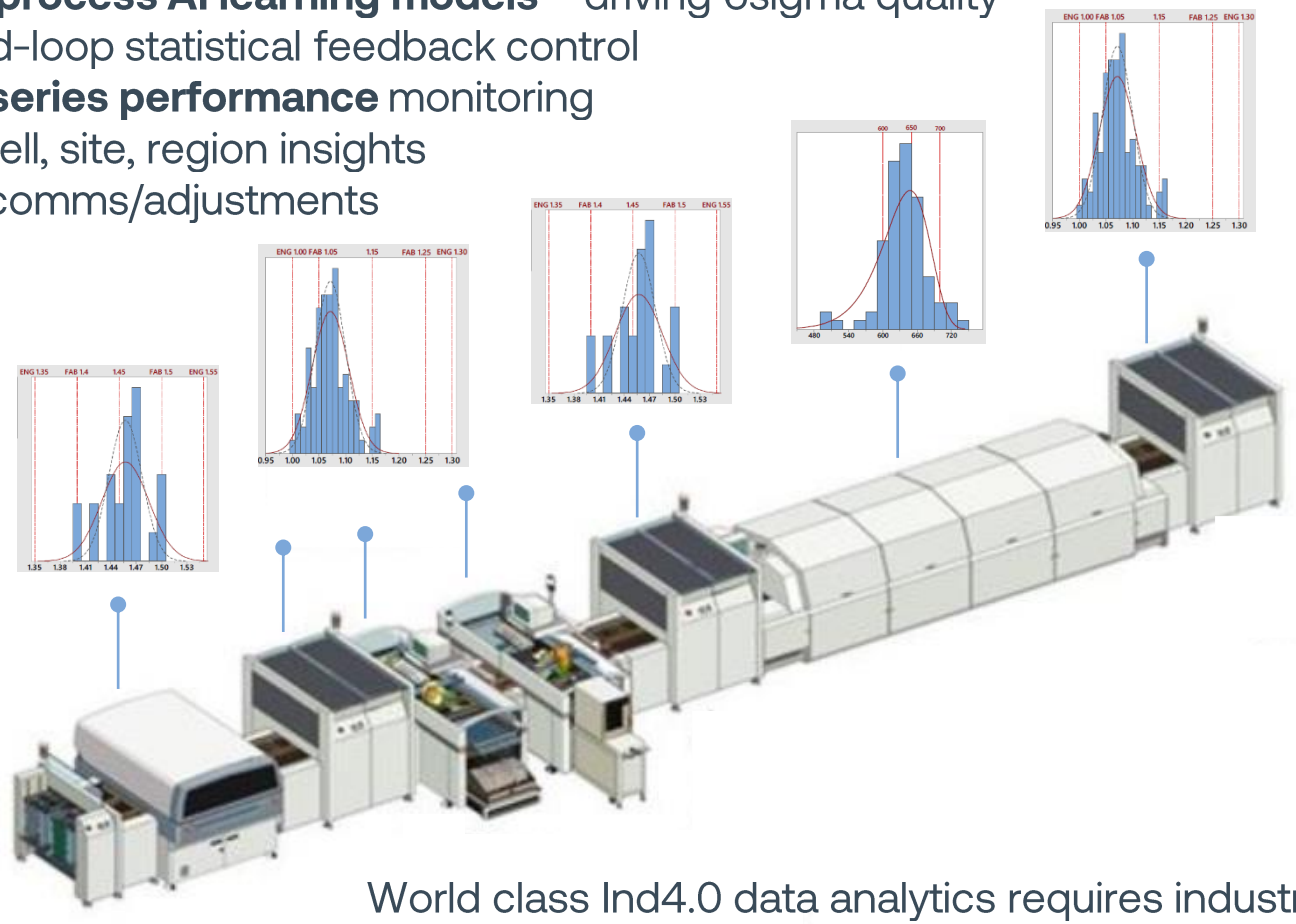


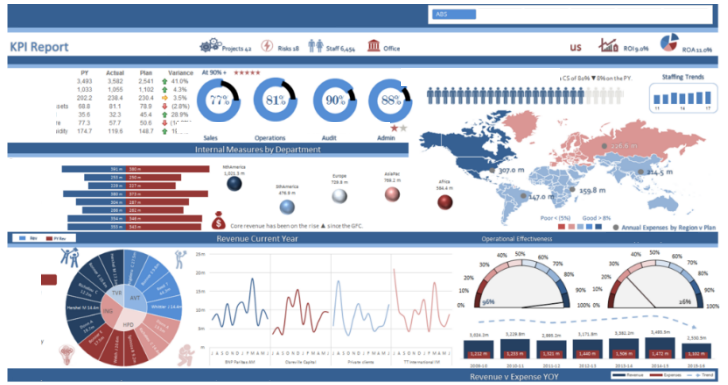


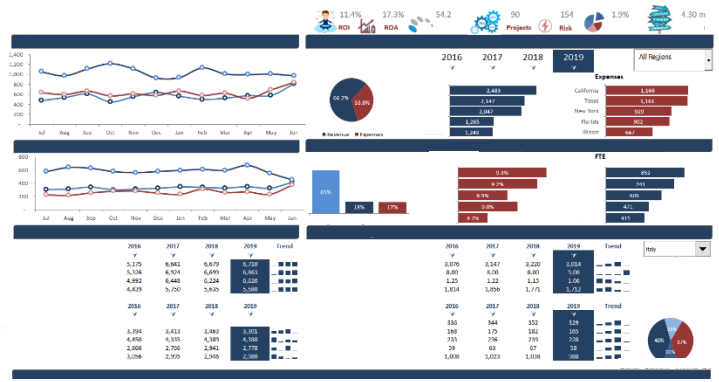
Challenge #3: Achieve high quality, yield, throughput – Data Analytics

Manufacturing line – secure, real-time, big data sets (FEOL, BEOL)

- **Individual process control**, reports, Cp, Cpk, dashboards
- **Multi-process AI learning models** – driving 6sigma quality
- Closed-loop statistical feedback control
- **Time series performance** monitoring
- Line, cell, site, region insights
- M2M comms/adjustments







World class Ind4.0 data analytics requires industry-wide,
open-source machine data communication protocol eg) IPC-2591 CFX

Challenge #3: Achieve high quality, yield, throughput – Data Analytics

Issue: Real-time data analytics and statistical process control not widely implemented

- **Semiconductor industry data usage highly sophisticated**; electronics manufacturing sector significantly lagging
- Many facilities still **very manual, data collection is messy**, too much data, don't know what to do with it
- IT/OT network integration barriers, difficulties, and security requirements
- E2E operations data analytics implementation VERY LOW → **limited by ease of data collection / various formats**
- Result: individual process **reactive batch data analysis** vs E2E process **proactive real-time continuous data analysis**

Innovation focus: Deeper Data Insights – formats, flows, collection, contextualization, analysis

- Product-level driving forces: quality, reliability, maverick lots, outliers, yields, throughput, efficiency, productivity
- Operations driving forces: line-site-region manufacturing performance, supplier management capability/performance
- **Overall data architecture** needed for operations and supply chain partners
- **How to start:** data formats, communication protocols, data mapping → apply SPC → real-time data consumption
- **Critical:** ID major quality contributors/indicators; then collect key data parameters for SPC
- Goal: **real-time 'health of line' continuous monitoring**

Key Messages and Call to Action

Key Messages

Creating reliable hardware designs with **digital thread and CAD simulation**

- **Drivers:** rapid NPI cycles, electrical-mechanical co-design improvements, new design rules
- **Enables:** high quality / reliability through improved electrical-mechanical co-design

Enabling higher placement densities with **back-end manufacturing automation**

- **Drivers:** Tighter placement keep-out rules AND tighter tolerances (power/thermal management)
- **Enables:** precision 3D mechanical assembly as product miniaturization continues

Achieving high quality levels, yields, and throughput with **data analytics**

- **Drivers:** product-level and operational performance, faster deeper insights, better decisions
- **Enables:** proactive real-time continuous data analysis, ‘health of line’ monitoring

Key Messages

Ind4.0 Factory of the Future

- It's about **harnessing multiple advanced technologies and approaches** to gain business value
- Requires: **highly skilled people**, new & conventional tech, and foundational engineering (SPC, QMS)
- North American electronics manufacturing is **5-8yrs behind European and Asian early adopters**

Advance and Modernize – Call to Action

- **Start today and be implementation focused**
- Cut through the hype and apply what matters to design, manufacturing, supply chain management
- Work beyond day to day 'fire fighting' activity; transformation requires forward thinking
- Establish transformation strategy, then **use building block approach**; 'DON'T BOIL THE OCEAN'
- ID problem → apply solution → **must solve real business issues and deliver ROI value**
- **Invest in new employee skills, systems, approaches, technology, and infrastructure**

Thank you. Questions?

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