Smart Factory at Fuyong

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Abstract

The highly-automated and connection-driven methods in Electronics Manufacturing is a more and more important topic in the industry today. Advances in modern manufacturing technologies make factories smarter, safer and more environmentally sustainable. *Get Manufacturing Functions* connected with Real Time Information Systems to enable a predictive approach in all functions to serve Higher Reliability and HMLV (high-mix low-volume) services solutions.

In this paper, we will share our experience with a current project called "Smart Factory"[1], especially for Phase I of the project. Our objective is that Get Manufacturing Functions connected with real time information systems enable predictive approaches in all functions to serve Higher Reliability and High-Mix Low-Volume (HMLV) services solutions.

Through establishment of a KOI (Key Operation Indicator) structure with visualization eDashboard, we have realized the alarming abnormalities in real time and failure analysis mining from top symptoms to bottom root cause with processes correlation.

Collecting the parameters of machine and process data in real time automatically makes the connection between machines and processes to get higher efficiency for quality and production monitoring and control. Color coding for different level abnormalities gives visualization control. The real time data captured from machines and process is loaded into a central factory SPC (Statistical Process Control) system that makes predictions for taking action before failures. Real time data was sent to mobile phones to improve communication between operators and machines which has increased production efficiency.

We have seen significant achievements for the Phase I: Average yield (Final Pass Yield) increased from 99.1 % to 99.44%, NDF (No Defect Found) decreased from 2% to 0.9%, and also have SPC to be more predictive. Prevention is always better than detection [2].

Keywords: SMART Factory, Connection, Real Time, Predictive, Traceability, Automation, Standardization, Control Tower, Dashboard, Cloud, LEAN, KOI (Key Operation Indicator), 5C (Connect Elements), Higher Reliability, HMLV (High Mix Low Volume), NDF (No Defect Found), Yield, Defects, MES (Manufacturing Execution System), CSER (Corporate Social and Environmental Responsibility), Operation, Supplier Chain, Printer, SMT (Surface Mounting Technology), Wave (Wave Soldering), SPI (Solder Past Inspection), AOI (Automatic Optical Inspection), ICT (In-line Circuit Test).

Introduction

The "Smart Factory" project has been ongoing for more than six months. In March 2015, management set a high goal for our factory's future: achieve Smart Factory. "Develop the company site to be a SMART factory with High-Mix Low-Volume (HMLV) service with flexibility, quality, consistency, cost effectiveness and profitability, creating value that increases customer competitiveness for win-win solutions."

A Smart Factory Implement Team was setup to start the Smart Factory journey. In this paper, experiences will be shared on this journey.

The SMART FACTORY with HMLV Services Solutions has a visualization control tower with the company site cloud which links to Smart Office, Smart Operation, Smart Supply Chain, and External Cloud which are shown in Figure 1.

Figure 1. SMART FACTORY with HMLV Services Solutions

The objective was to get Manufacturing Functions connected with real time information system to enable a predictive approach in all functions to serve higher reliability and high-mix low-volume services solutions.
What does **SMART** stand for? Below are our definitions.

- **S**trategy with Standardization
- **M**anufacturing with LEAN to optimize and remove WASTE
- **A**utomation in Software and Hardware solutions
- **R**eal Time Data control limits monitoring and triggering
- **T**otal Quality Management with SPC to enable predictive approach

The past six months, the Smart Factory approach has been called the *5C Get Connect Elements*.

- **C**onnection (Sensors and Networks),
- **C**loud (Computing data on demand)
- **C**ontent / Context (Correlation)
- **C**ommunity (Corporate Social and Environmental Responsibility and Partnership Collaboration)
- **C**ustomization (HMLV)

The intelligent machine to machine or process to process setup has to provide self-optimization, self-configuration, self-diagnosis, self-learning and ability to connect with a real time information system to provide self-awareness and triggering capabilities.

The Smart Operations has a Technical Architecture and Operation Architecture that is shown in Figure 2.
The team studied the current status of the environment, process, data collection and analysis as well as yields to develop the Technical Architecture and Operation Architecture for the project.

Physical Device Layer, Connection Layer, Data Acquisition Layer, Data Storage Layer, Algorithm Layer, and Control Tower Layer are for the Technical Architecture which are shown with a blue color; and Decision Layer, Operation Layer, Execution Layer, and Service Layer are for Operation Architecture are shown with a yellow color. All of these layers are connected in real time.

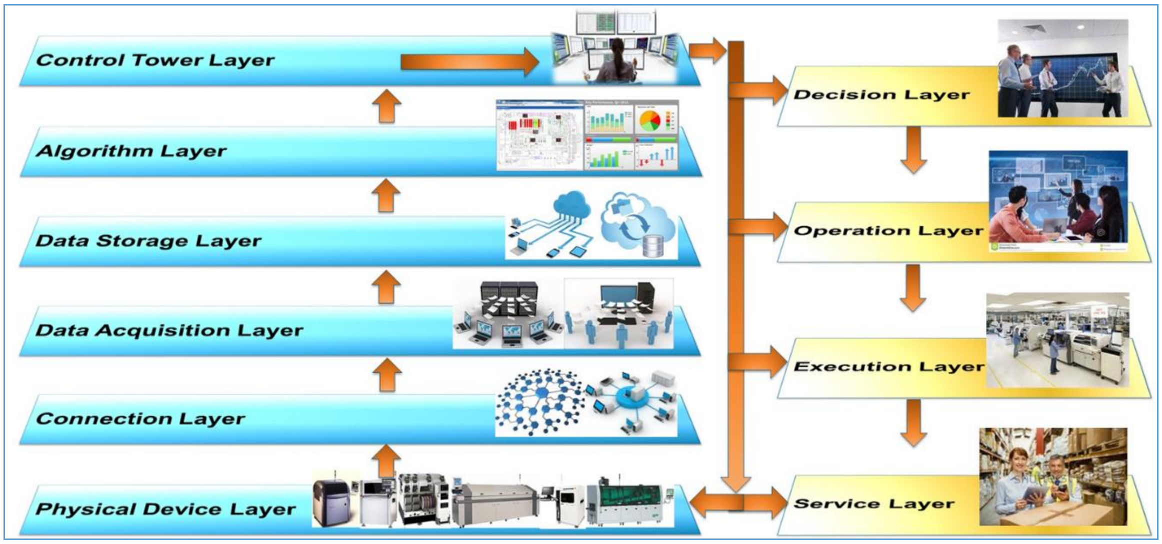

Figure 2. Smart Operations - Technical Architecture and Operation Architectures

Practices and Achievements

Smart office, Smart Supply Chain, External Cloud and Smart Operations, and the Smart Operations require good Technical and Operation Architecture. The Cross Function Interconnections include: Machine to Machine, System to System, Machine to System, Machine to People, and System to People. In this paper, we will only share practices and achievements for Smart Operations in five sections: SMT – Connection and Real Time, SMT – 1 Head Count 1 Line, Wave-Standardization and Systemization, ICT, and SMT – eDashboard which are shown in Figures 3 to 7 for each section.

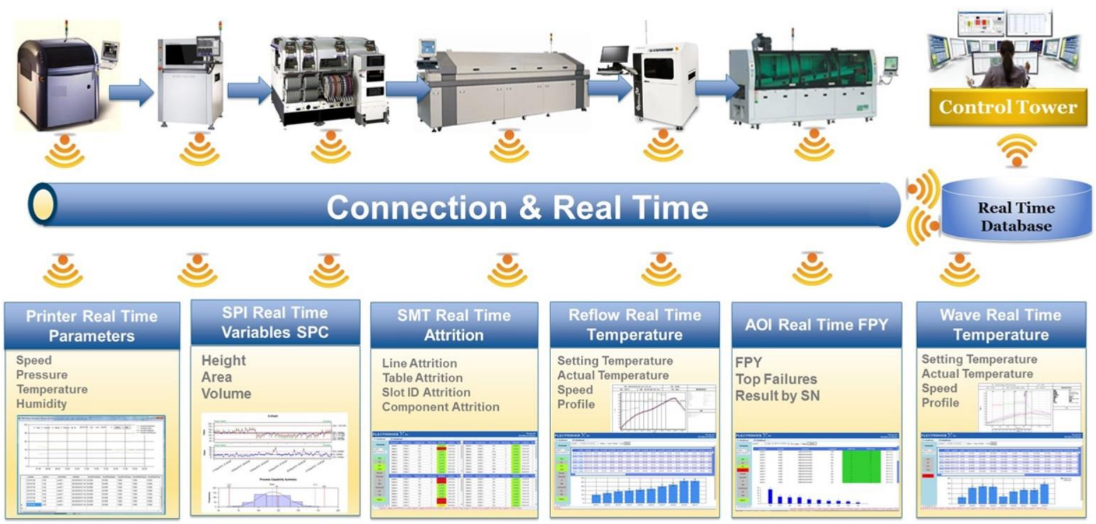

Figure 3. SMT – Connection and Real Time

First, we focus on the data system and work for the data connection and real time database, The expectations for the database should be: connected data allowing automation, connected data allowing efficiency, and connected data allowing lower cost. Figure 3 is our brief description of SMT – Connection and Real Time that listed the main machines and key measurement data items. All data should be connected and real time to the control tower by company site cloud.

There are five Phases for the Smart Factory project plan. The project currently is at Phase I.

In Phase I, the following goals will be accomplished:

- Manufacturing Environment Traceability
- Scatter Function to Connection
- Mobile Monitoring of Quality and Production
- MTBF– TPM.

These are the experiences gained in Phase I: Shop Floor Interconnection, especially for automatically collecting data from the test machines of SPI, AOI to ICT and Functional Test. We also focused on test data analysis, providing real time feedback to the SMT line and improving the process. The interconnection between machines, people and machine, people to people, optimization of human and their optimization for technical and management personnel.

There have been significant achievements in Phase I of the Shop Floor Interconnection Project, especially for flexible, reusable, deployed solutions providing many benefits across final assembly, testing and packaging operations at the platform connection. In this session, we have completed some machine connection, overall process mapping, data automatic feedback to SMT process machine and process improvement based on testing data.

Figure 4 shows several examples to reduce head count as a result of the Smart Factory project. The goal is to have one operator for one SMT line.

Figure 4. SMT – 1 Head Count 1 Line

Figure 5 illustrates the standardization and systemization for the wave machine. Solder dross systemization and wave solder dross reduction are also implemented.

Figure 5. Wave-Standardization and Systemization

Figure 6 lists standardization and connection and systemization for ICT. There is robot automation at ICT which has allowed us to reduce head count by 10. ICT also links to the MES database. This allows a $96k annual savings.

Figure 6. ICT

Figure 7 shows the SMT – eDashboard. With data/results in the system, we can have detailed information for not only board level to pad /pin level, but also for machine parameter level which is good information for SMT process improvement [3,4]. .

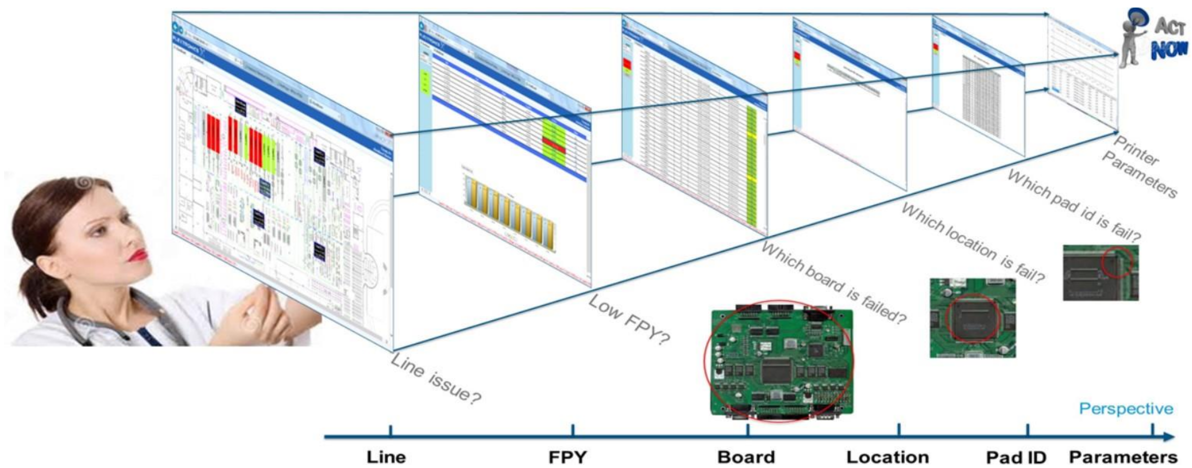

Figure 7. SMT – eDashboard

There are several examples of achievement in process improvement.

First we have improved Machine Parameters Collection Architecture The older machine data was not previously collected as shown on the left side of Figure 8 with red color.

The previous data parser directly accessed a controlling PC via a shared folder. This network solution was very unstable, and machine raw data was always missed for collection to SPC system.

The right side of Figure 8 shows the new Machine Raw Data Collection Network Solution.

The new collection method for raw data is now complete. The new implementation is as follows:

1. Uses a raw data center file server.

2. Software developed that uses the task scheduler on each PC to automatically upload data to the server. Thus, our parser server is able to parse data from the server.

Figure 8. Machine Raw Data Collection Network Solution

This is another example for the connection of the Smart Factory. Previously the production printer machine was isolated with parameters only available locally on the printer. It was not able to be connected to the database centralized control and for remote monitoring to correlate failures. Software has been developed to collect and upload measured parameters to the database. Key parameters (Speed, pressure, temperature, humidity….) are now monitored helping engineers to shorten the FA time.

Figure 9 shows before and after) the connection of the printer to the database to collect parameters for monitoring.

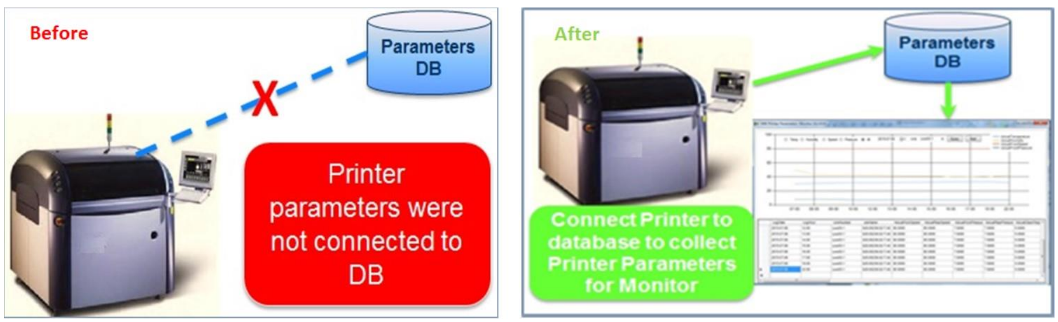

Figure 9. Production Printer Parameter Monitoring

Figure 10 shows the Solder Paste Inspection (SPI) Test Data Link to Database (MES).

Prior to this link, SPI data was only available on the SPI system making it difficult to get the test result by serial number by Location and Pad ID. Quality issue root causes were difficult to be identified with the disconnected test data.

A SPI test data parser has been developed to link to MES data with product serial number by the following:

1. Allow scanning of the product barcode to correlate test results with product serial numbers.

2. Parsing of test logs to upload to the MES database. This allows traceability back to the original point of failure.

SPI test results by serial number are uploaded to the MES database where they are correlated with First Pass Yield, Units per Hour and Defects per Hour as shown on the right side of Figure 10.

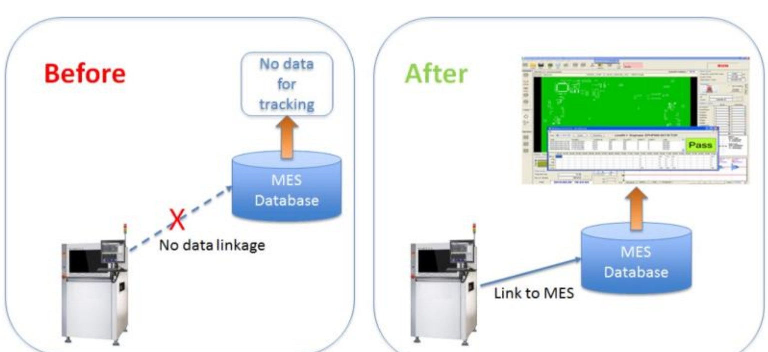

Figure 10. SPI Test Data Link to MES

Table 1. Quality and Productivity Achievements from April to July of 2015

Name	Item	Baseline	April	May	June	July
Quality	AOI Defect (Bot)	9	6	6	5	5
	AOI Defect (Top)	9	9	8	5	5
	AOI NDF (Bot)	118	95	76	54	46
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	H/L Defect	41	35	28	22	-
	ICT Defect	15	12	9	8	-
	FT Defect	8	7	7	6	-
	RTY	80.7%	85.0%	88.1%	90.3%	90.5%
Productivity	SMT UPH (Bot)	235	-	240	-	238
	SMT UPH (Top)	255	-	-	-	262
	ICT UPH	190	-	208	-	-
	Manual paper report	47	-	40	-	-
	H/C Optimization	QA 1/3	-	1/3	1/4	1/4
		ME 1/2	-	½	1/2	1/2
	(Headcount / Lines)	Prod 2/1	-	2/1	3/2	3/2
	Missing Scanning	140	-	100	40	24

Significant accomplishments have been made in Phase I of the Shop Floor Interconnection project, providing flexible, reusable, deployed solutions having many benefits across final assembly, testing and packaging operations at Platform Connection.

Now, we have machine connection, defect overall process mapping, data automatic feedback to SMT process machine and process improvements based on testing data. Units per hour have increased from 200 to 250 in a short time, and productivity has been improved.

SPC data and analysis have given predictability to the process. Achievements in quality and productivity from April to July of 2015 for Phase I of the project are listed in Table 1 showing the LEAN tools applied: 5W, Fishbone, and value added identification.

Average yield (Final Pass Yield) increased from 99.1 % to 99.44% in the last 3 months.

Figure 11 shows the main SPC data and results from the SMT line. With SPC data/results monitoring, assembly yields are improved significantly.

Taking action predictively with SPC as shown in Figure 12, the FPY (first pass yield) of SPI increased from 98 to 99 percent, AOI from 99.2 to 99.7 percent and ICT from 96 to 98 percent in a short time.

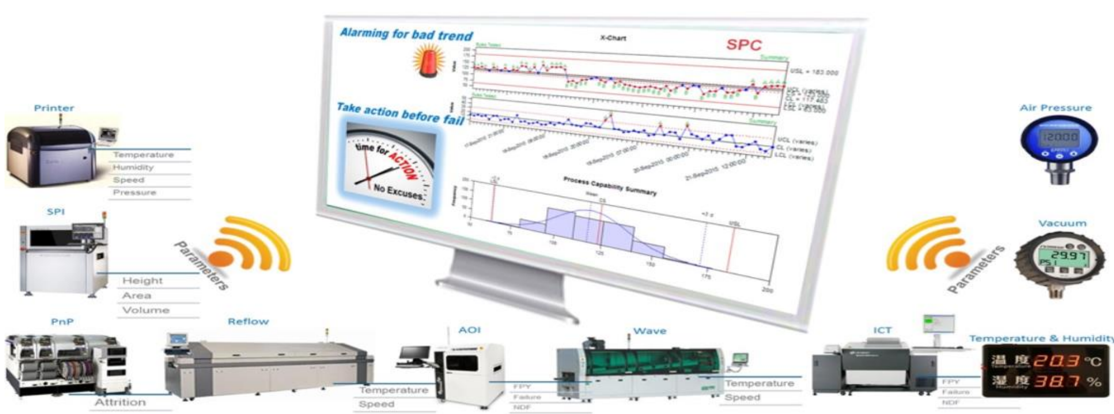

Figure 11. SPC – Predictive

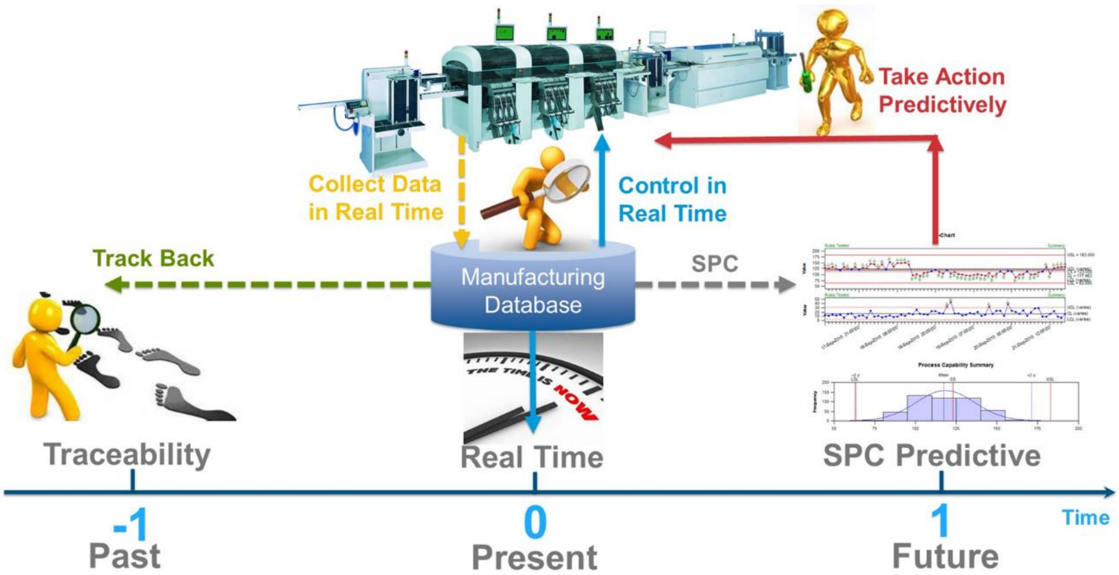

Figure 12. SMT – Predictive

In the past six months, good progress has been made in the manufacturing environment traceability as shown in Figure 13. Traceability has been implemented for main machine parameters of Printer, Solder Paste Inspection, Pick and Place, Reflow, AOI, Wave Solder and ICT for each board. There is good correlation information to analyze processes for defect root cause with this information and process actions.

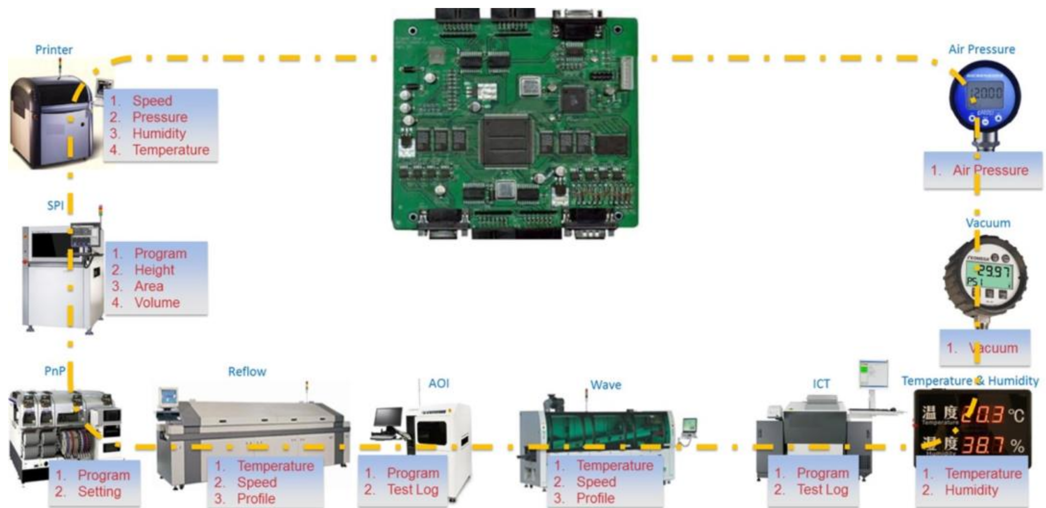

Figure 13. Manufacturing Environment Traceability

Conclusions

There are five smart levels for the Smart Factory:

- Shop Floor Interconnection
- Supply Chain Interconnection
- Front Office Interconnection
- Back Office Interconnection
- Control Tower.

The Control Tower is through the whole Smart phases. Each phase connection result will be put into the Control Tower for more smart control to the whole factory. Figure 14 is the company road map for the Smart Factory.

Our conclusion for the Smart Factory is as below:

1. Standardization is the basic for Smart.
2. Only standardization can make connection.
3. Smart Factory start from connection.
4. Smart Factory is driven by connected data.
5. Smart Factory's key approach is predictive.
6. Software first, Hardware second.
7. Data automation first, Hardware automation second.

It is nice to see what practices and achievement we have today; however there are still many challenges on the way. The company is confident on working together to make a good Smart Factory in the SMT field soon.

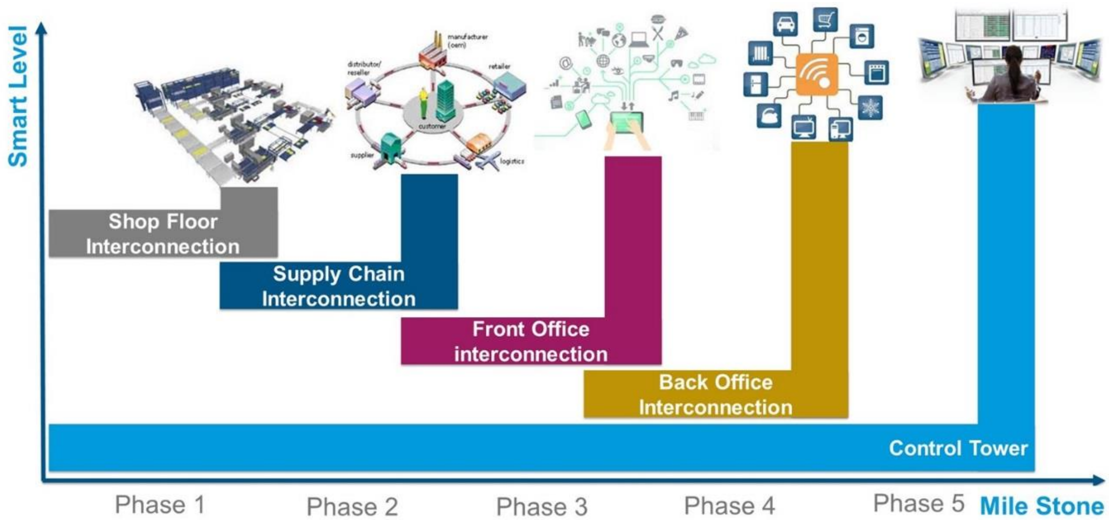

Figure 14. Roadmap – SMART Factory

Acknowledgements

The authors would like to thank the engineering and production teams of the company site, company AEG (Advanced Engineering Group), our customers and vendors for their strong support for this successful project. Special thanks also go to Dr. Zhen (Jane) Feng for her strong support; also to Mr. LC Tai and Mr. Hill Zhang, for their many contributions during this Smart factory journey.

References

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[2] R. Rowland, "What is Quality?" SMT magazine, December, 2001.

[3] Alejandro Castellanos, Zhen (Jane) Feng, Ph. D., David Geiger, Murad Kurwa, "Head in Pillow X-ray Inspection", SMT magazine, May, 2014.

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Agenda

- Background
- Objectives
- Practices & Achievements
- Conclusions

Company Site Brief

Shenzhen Factory in China

Headcount: 3000

Background – SMART FACTORY

In Mar. 2015, our management set a high goal for our factory's future: achieve Smart Factory.

"Develop company site to be a SMART factory with High-Mix Low-Volume service with flexible, quality consistency, cost effectiveness and profitable, creating value that increases customer competitiveness for win-win solutions. "

So we setup a smart factory implement team to start our Smart Factory journey. Below we will present to all of you our practices we have experienced in this journey.

SMART FACTORY With HMLV Service Solutions

Objective – SMART FACTORY

Get Manufacturing Functions **connected** with **Real time** information system to enable **predictive** approach in all functions to serve Higher Reliability and High-Mix Low-Volume services solutions.

S.M.A.R.T.

- **Strategy with Standardization**

-**Manufacturing with LEAN to optimize and remove WASTE**

-**Automation in Software and Hardware solutions**

-**Real Time Data control limits monitoring and triggering**

-**Total Quality Management with SPC to enable predictive approach.**

Approach – SMART FACTORY

Get Connect Elements – 5C

- Connection (Sensors and Networks),

-Cloud (Computing data on demand)

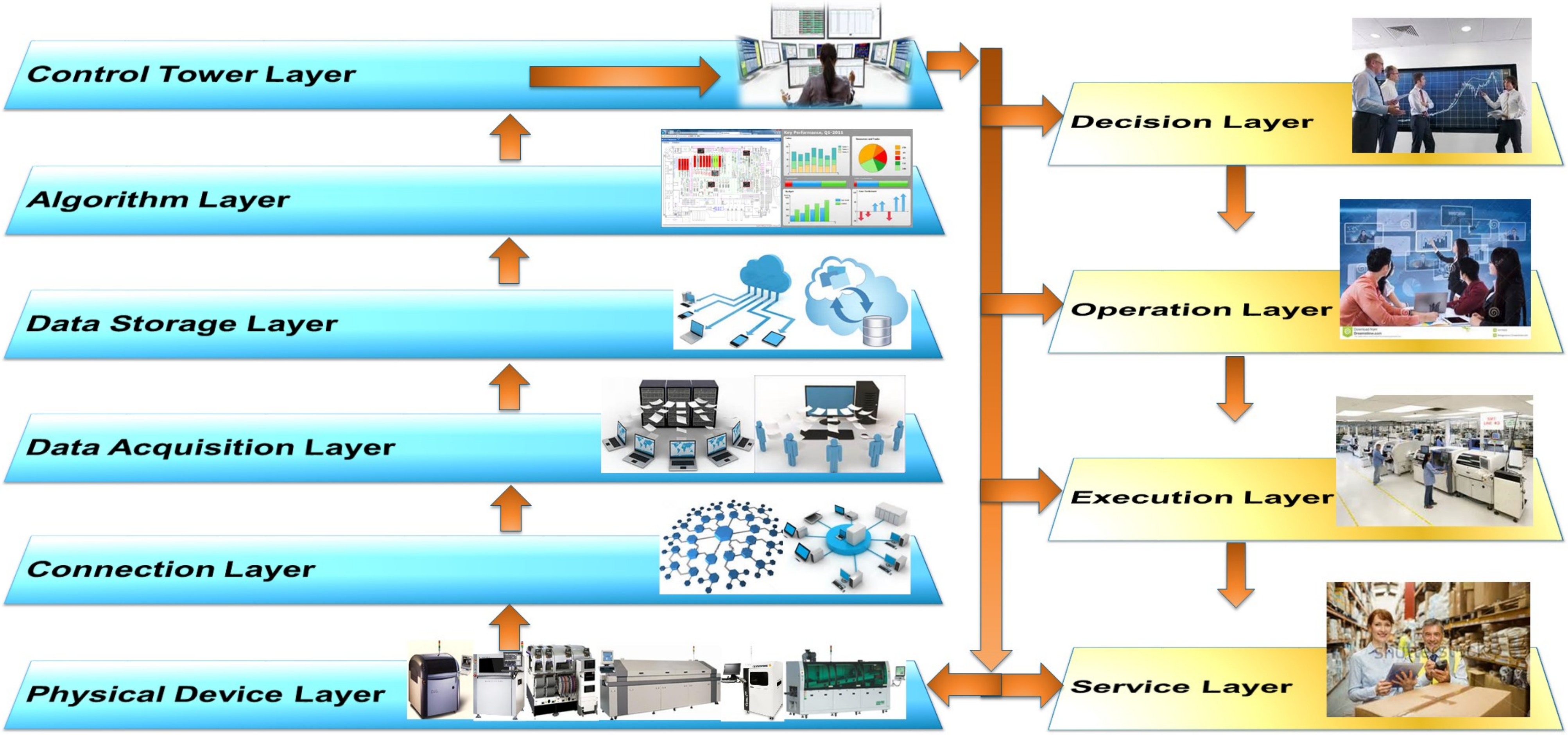
-Content/Context (Correlation)

-Community (CSER & Partnership Collaboration)

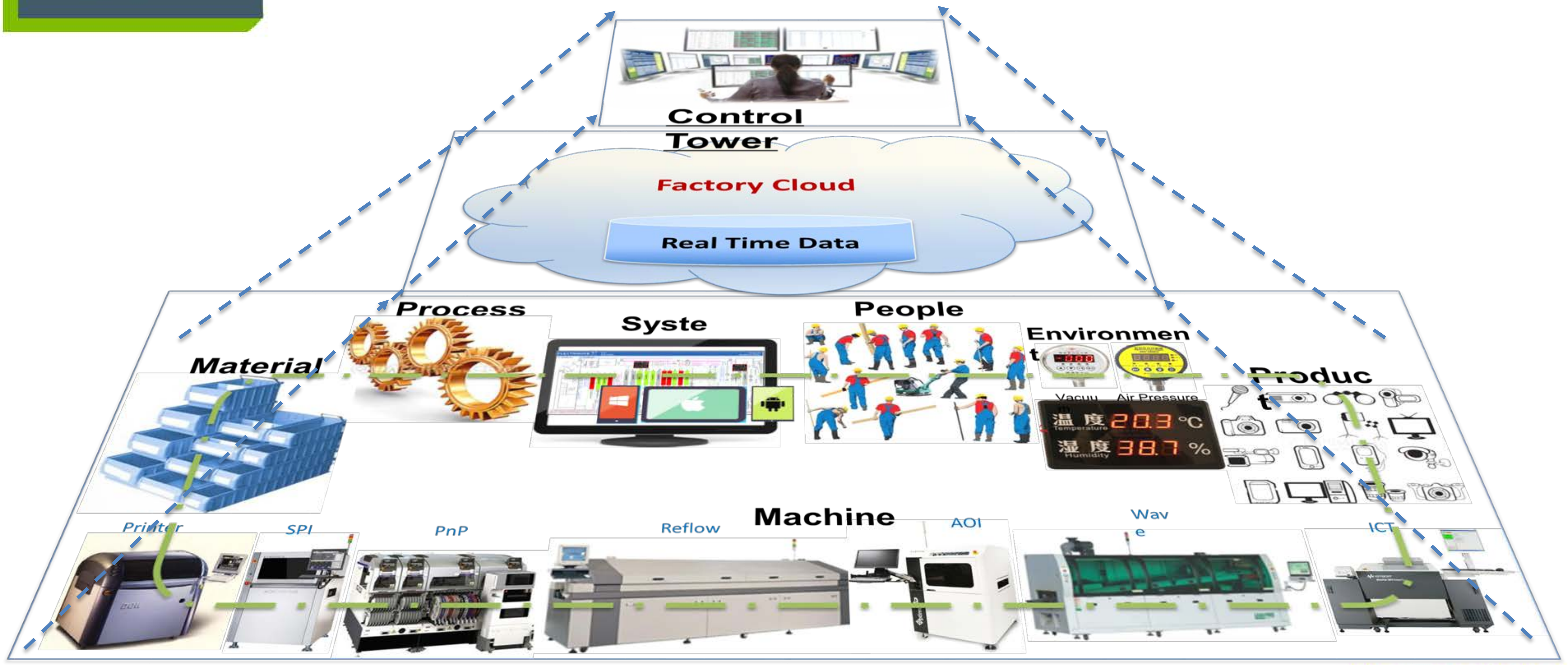
-Customization (High-Mix Low-Volume)

The intelligent Machine to Machine or Process to Process setup has to equip with self-optimization, self-configuration , self-diagnosis , self-learning and ability in connecting with Real time information system to provide self-aware and triggering capabilities.

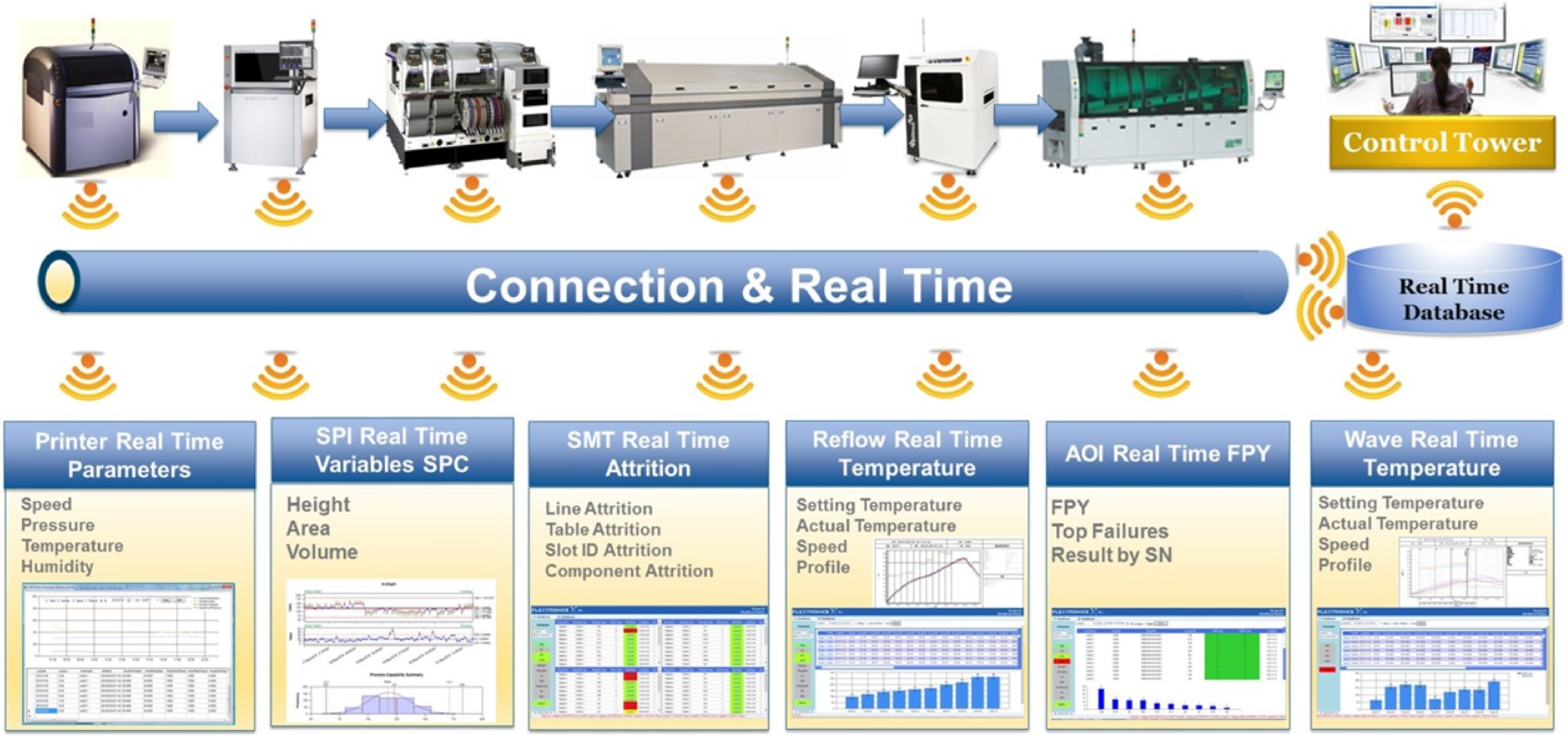
Smart Operations
Technical Architecture & Operation Architecture



Cross Function Interconnection



Smart Operations
SMT – Connection & Real Time



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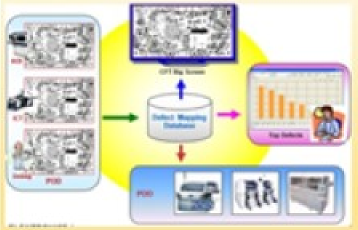
Smart Operations
SMT – 1 HC 1 Line

Key elements for 1 HC 1 line

eDashboard

Defect Mapping

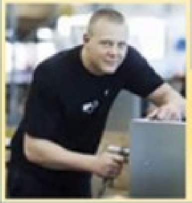


Splicing Reminding with Phone

AOI Remote Control

Super Operator Special Man

Super operator for machine and material both.



Special man only for abnormality

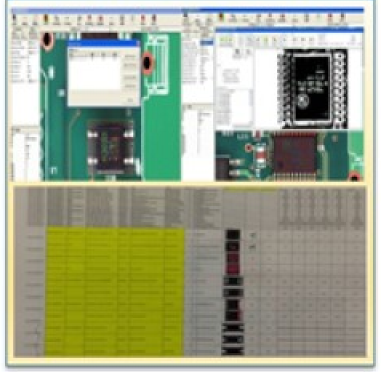
Basic for 1 HC 1 Line

1. SPI>99%, AOI>98%,
2. Standardize and simplify operator applications.
3. Critical parameters for SPC to real time trigger and control limits driving.
4. Super Operator.
5. Single defect stop line.

Stencil AOI Inspection

Printer Autonomation

AVL Library for AOI NDF Reduction



eFAB - First Article Building

eProfile

eTPM

APEX EXPO IPC 2016

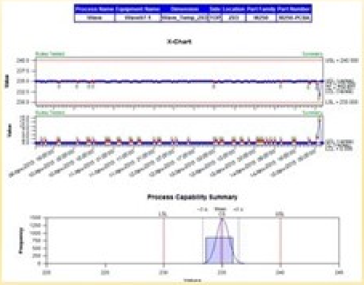
Smart Operations
Wave –Standardization & Systemization

Wave Real Time Temperature

Temperature
Speed
Profile

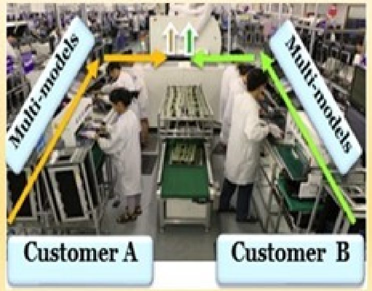
Wave Temperature to SPC

Temperature SPC by Zone



Wave Multi-Models

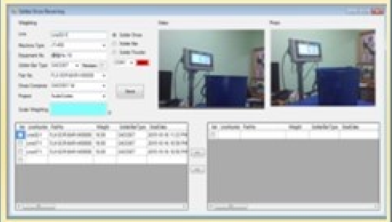
Reduced 3 sets Wave
Optimized 1 HC



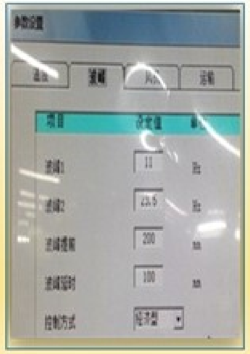
Standardization & Connection & Systemization

Solder Dross Systemized

Weighting value auto capturing.
Photo taking.

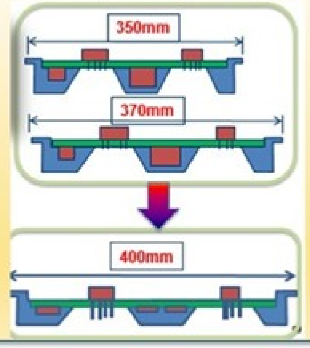


N2 Consumption Auto Control



Wave Pallet Standardization

Reduced to 3 types pallet



Solder Bar Standardization

Reduced Solder Bar types from 6 to 3.

Wave Solder Dross Reduction

Modified nozzle to reduce oxygenation

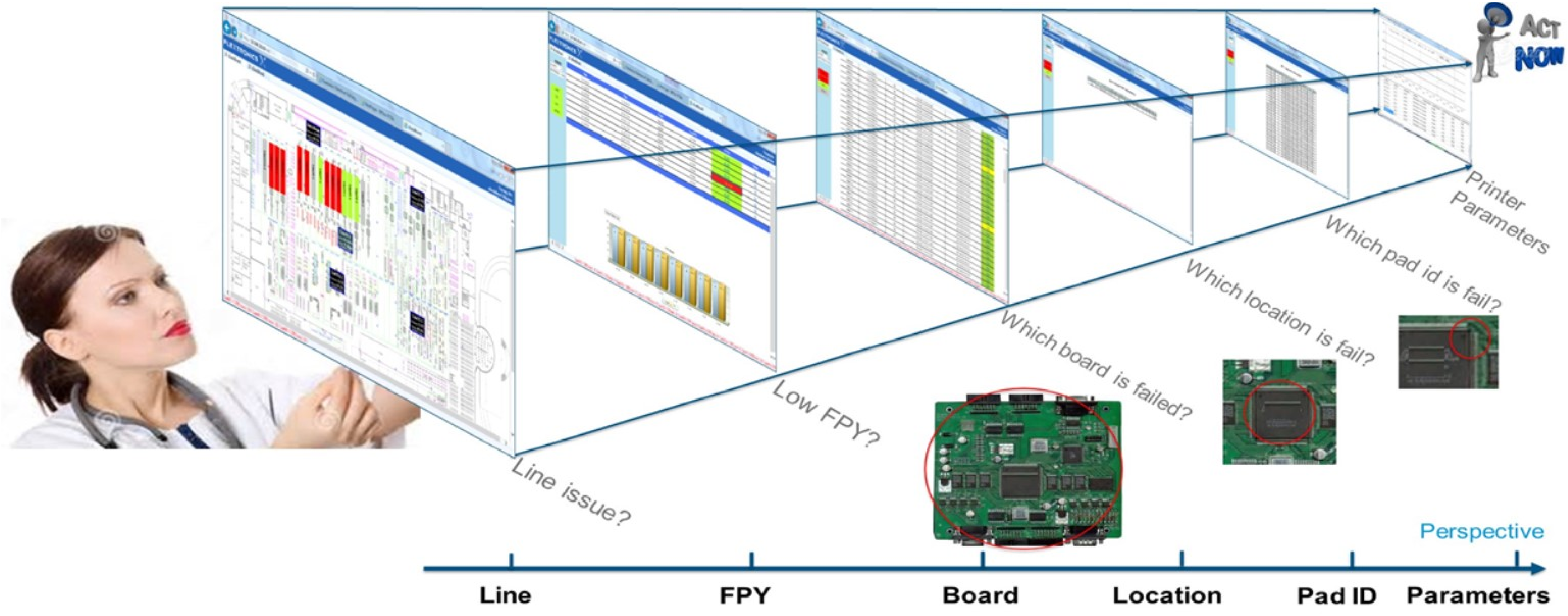
Wave Pallet Return

Space Saving

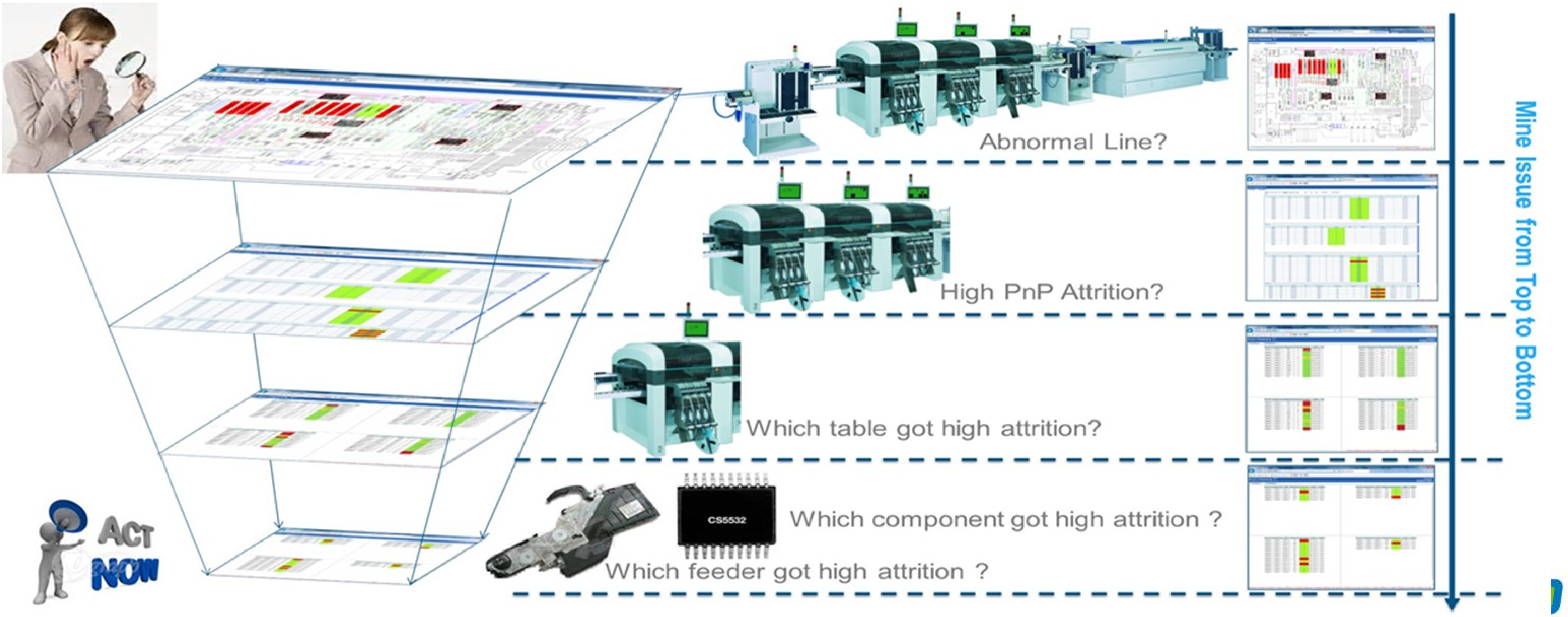
Smart Operations

ICT – Standardization & Connection & Automation

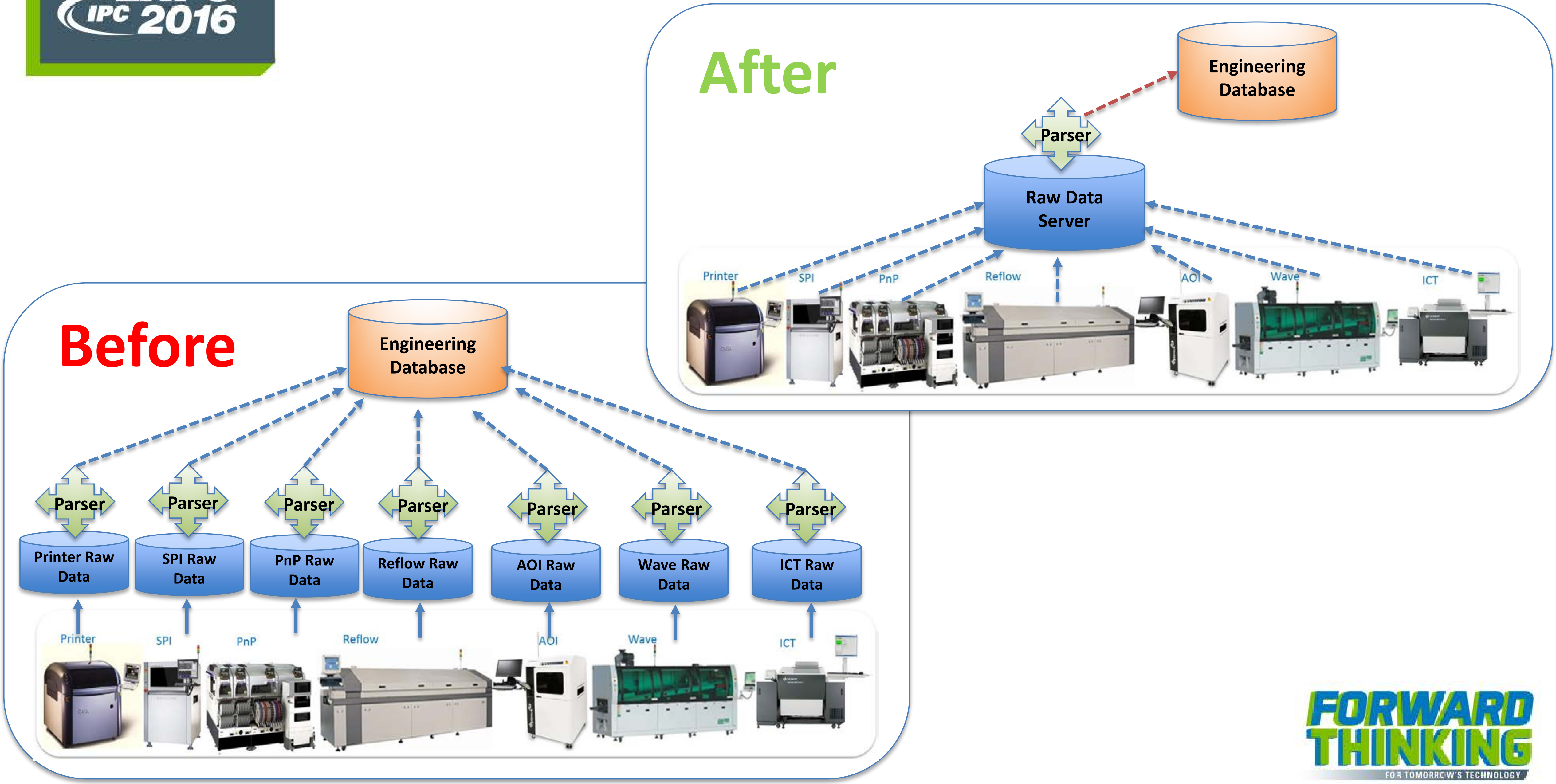
Smart Operations
SMT – eDashboard



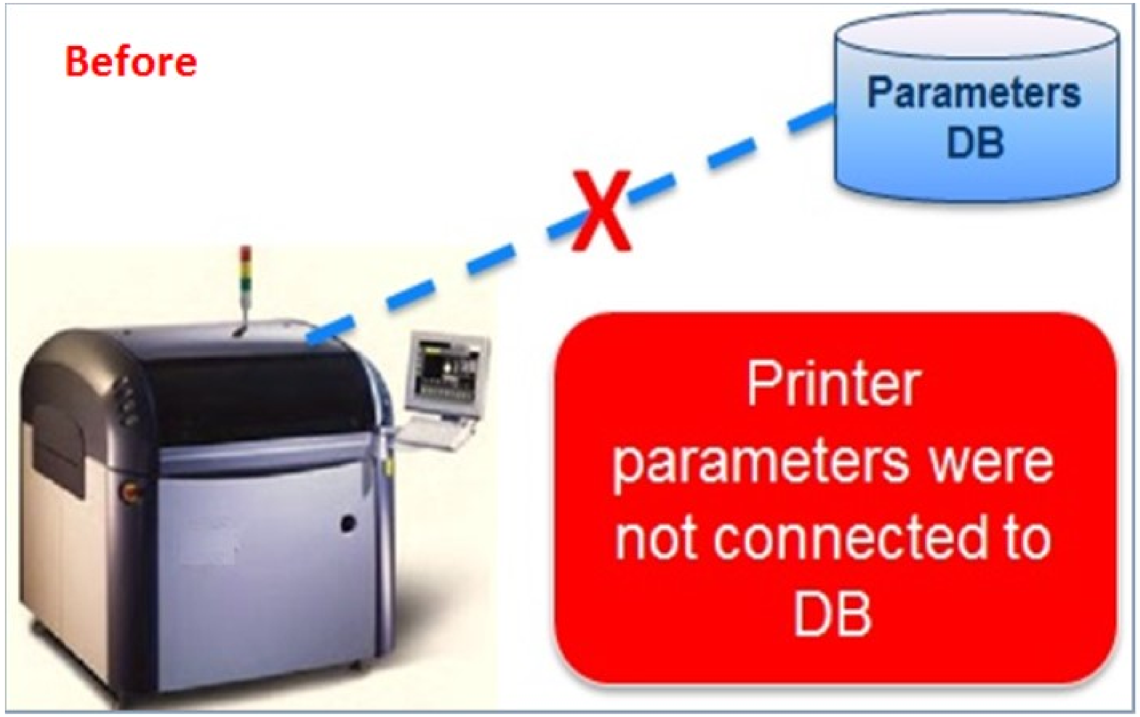
Smart Operations
SMT – eDashboard

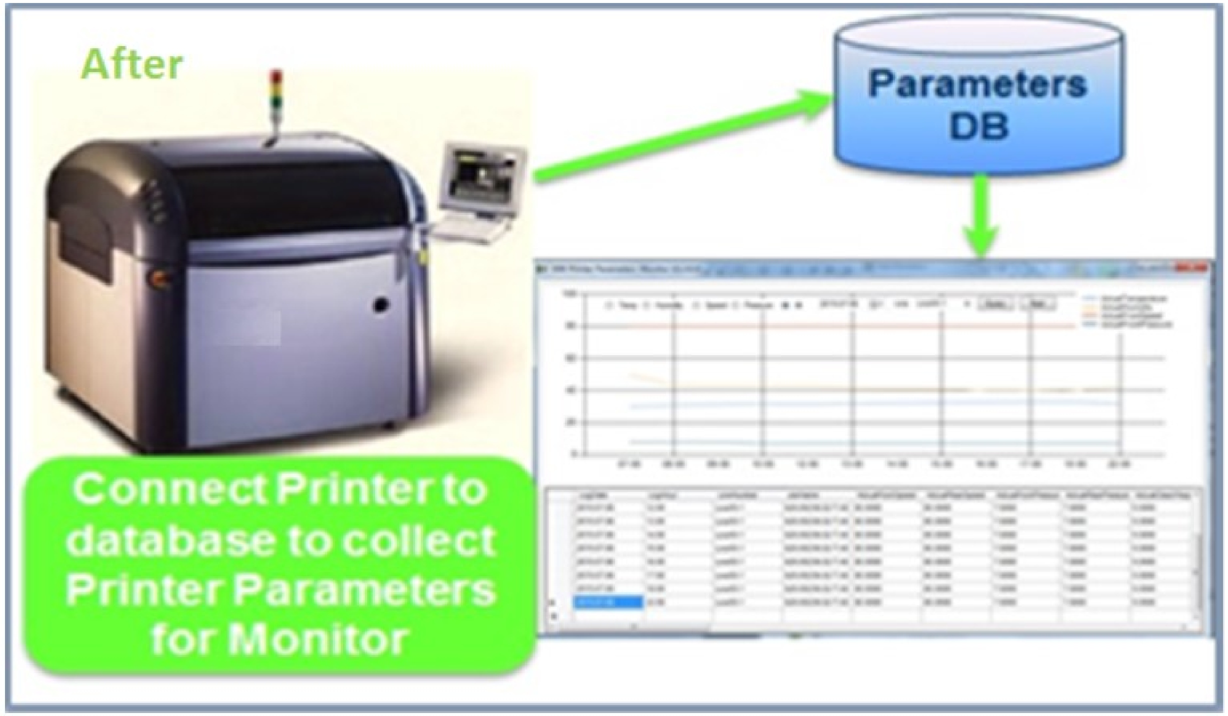


Machine Raw Data Collection Network Solution

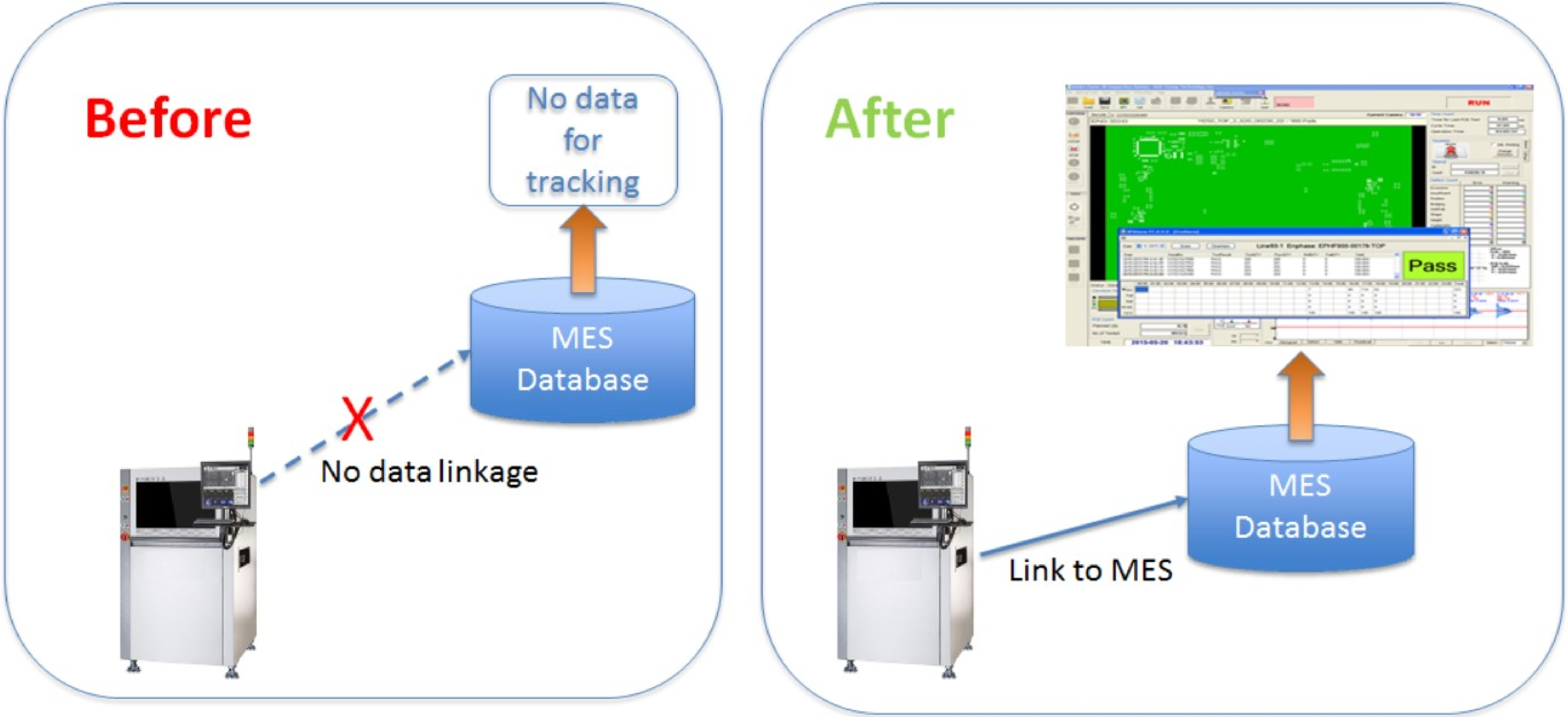


Production Printer Parameter Monitor





SPI Test Data Link to MES



Quality and Productivity of Achievements (April – July, 2015)

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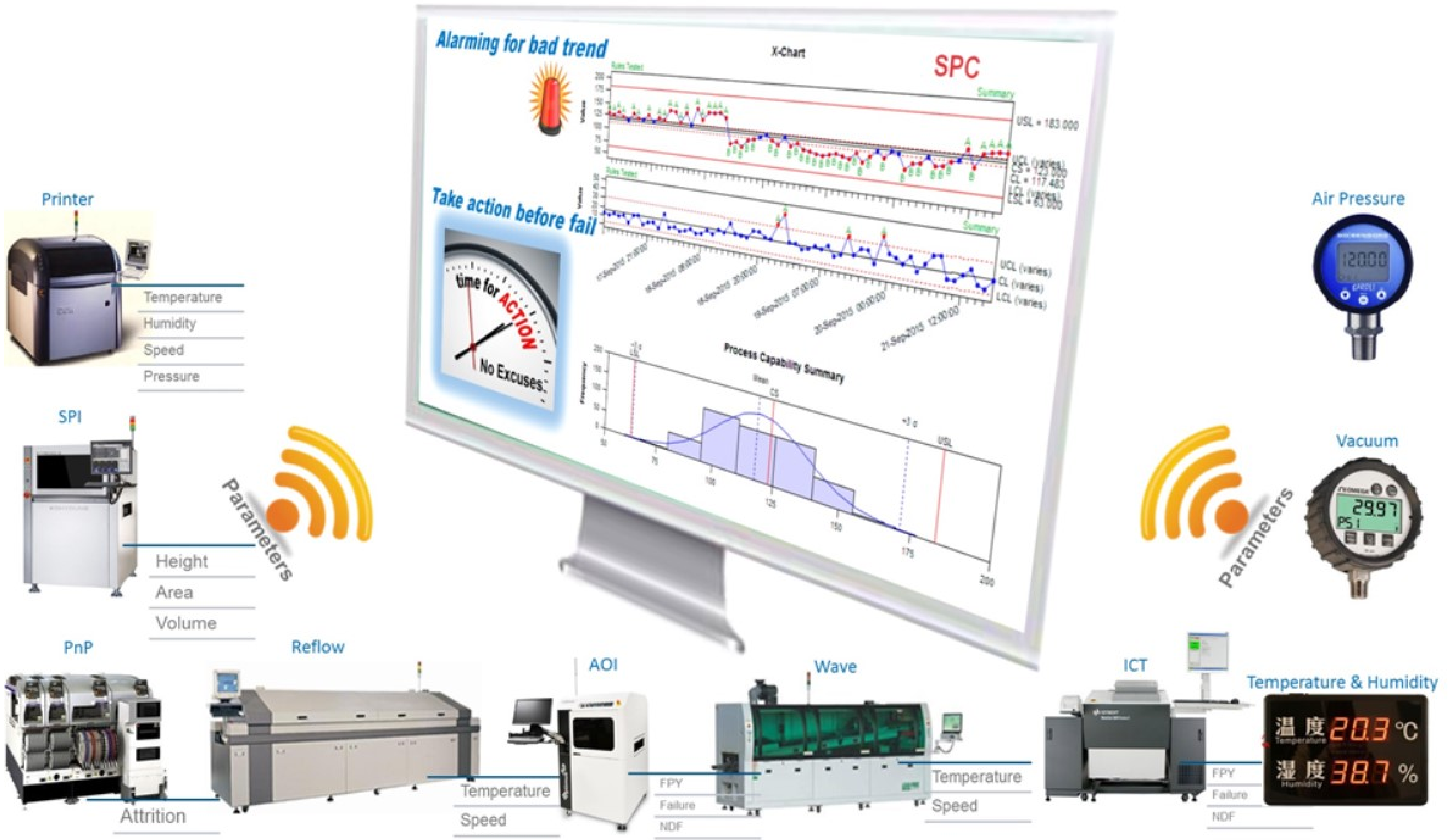
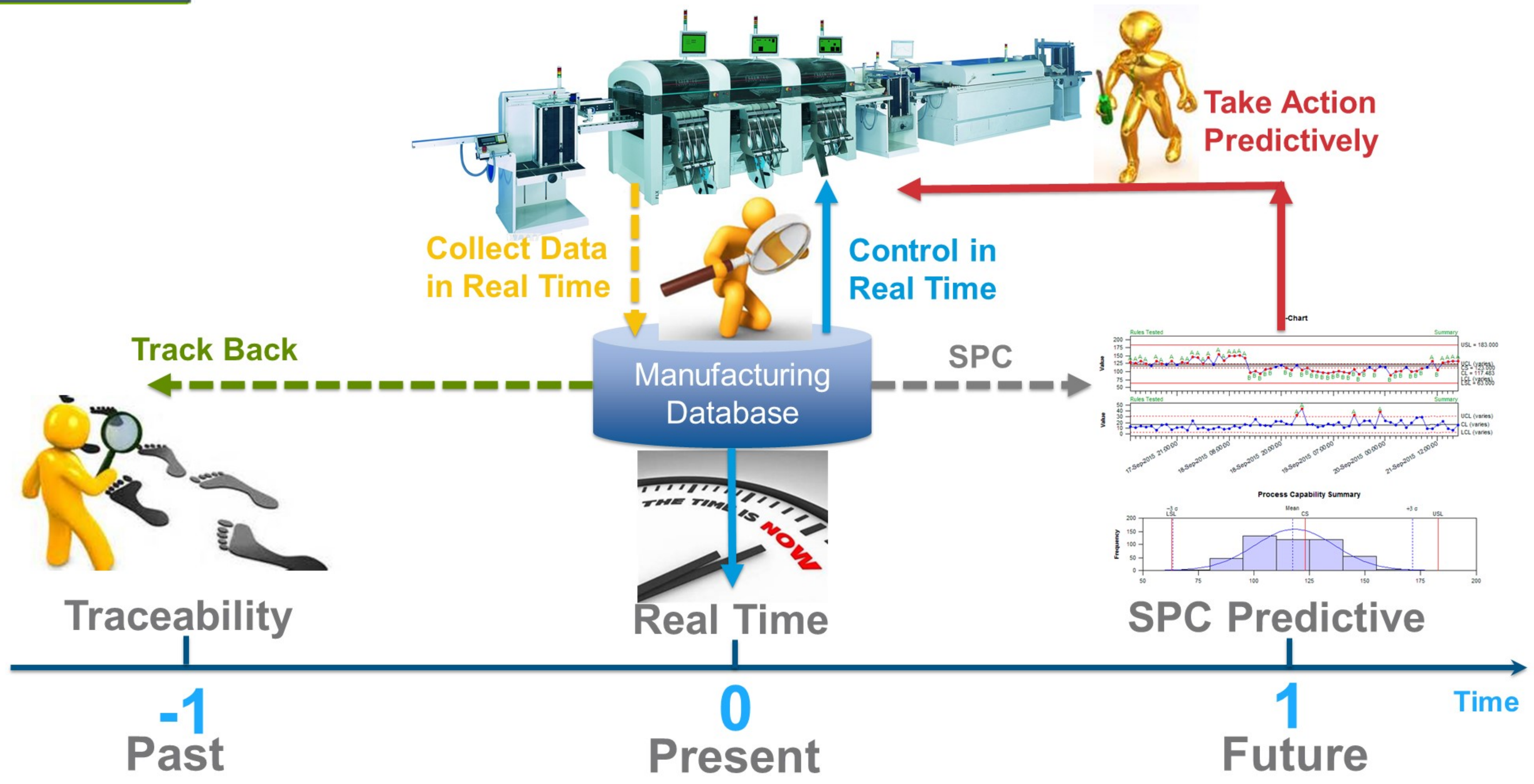
	H/C Optimization (Headcount/Line)	QA 1/3	-	QA 1/3	QA 1/4	QA 1/4
		ME 1/2	-	ME 1/2	ME 1/2	ME 1/2
		Prod 2/1	-	Prod 2/1	Prod 3/2	Prod 3/2
	Missing Scanning	140	-	100	40	24

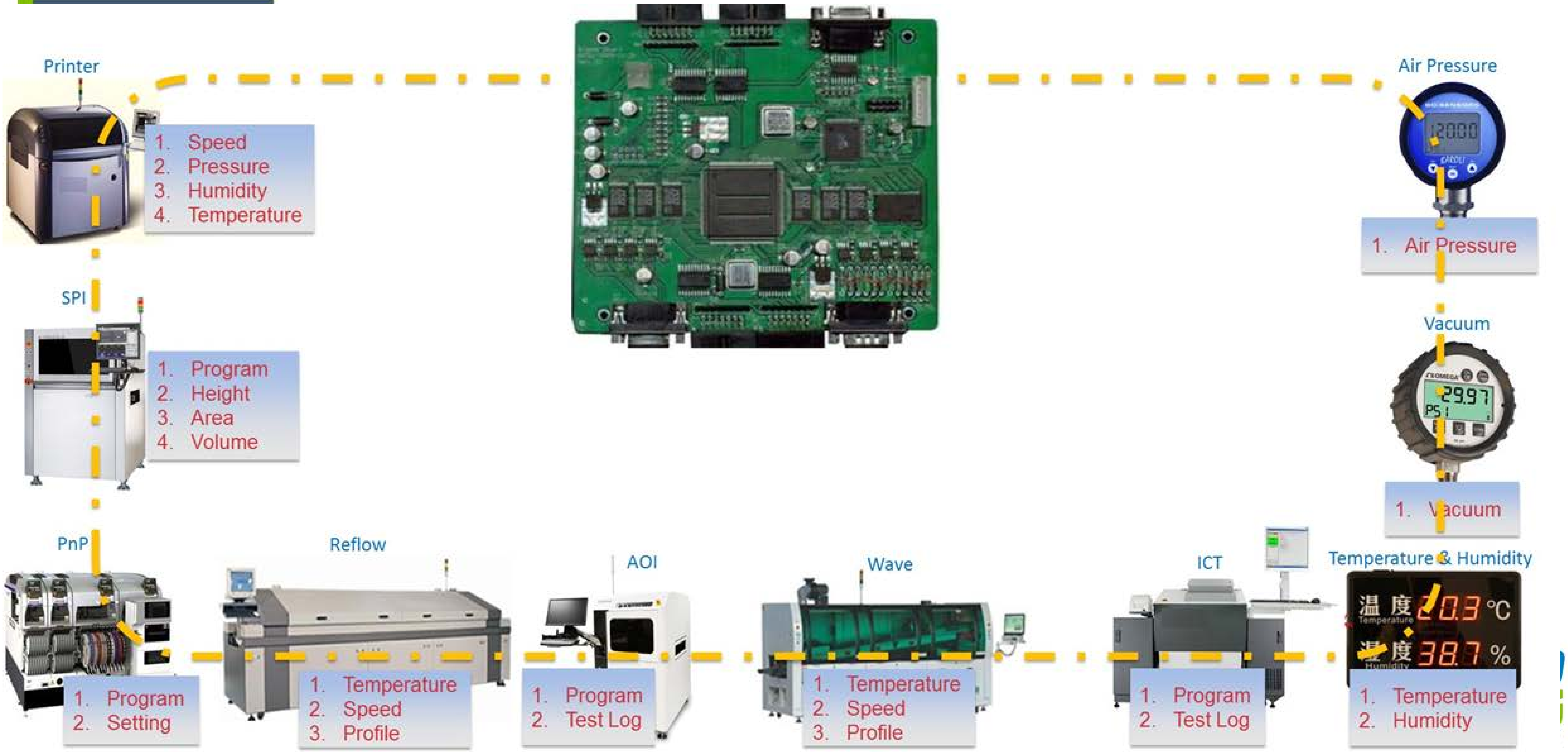
SPC – Predictive



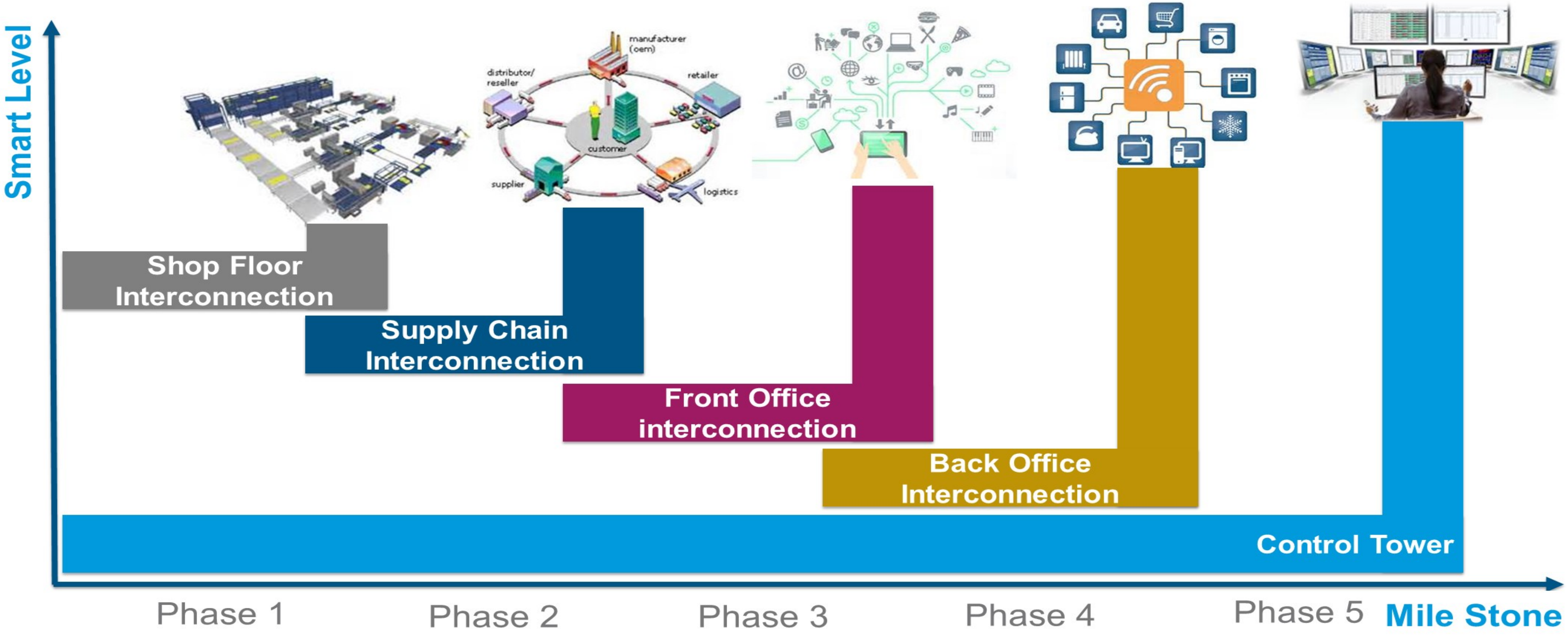
Smart Operations – SMT – Predictive



Manufacturing Environment Traceability



Roadmap – SMART FACTORY



Smart Factory – Conclusions

- Standardization is the basic of Smart.
- Only standardization can make connection.
- Smart Factory start from connection.
- Smart Factory is driven by connected data.
- Smart Factory’s key approach is predictive.
- Software first, Hardware second.
- Data automation first, Hardware automation second.

Smart Factory – Acknowledgements

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Thank you for your attending!

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