IoT Technologies for Industry 4.0

Tzi-cker Chiueh

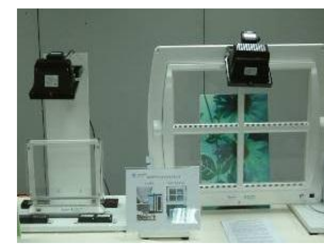
Information and Communications Research Laboratories, ITRI

Industrial Technology Research Institute









Total Staffs: 5,772

Ph.D.：1,371

Master：3,135

Bachelor ：1,266

Alumni：22,755

Total Patents

20,477

Startups & Spinoffs

244

Industry Services

Provided Services：14,373

Transferred Technologies：681

ITRI
Industrial Technology Research Institute

Organization Chart

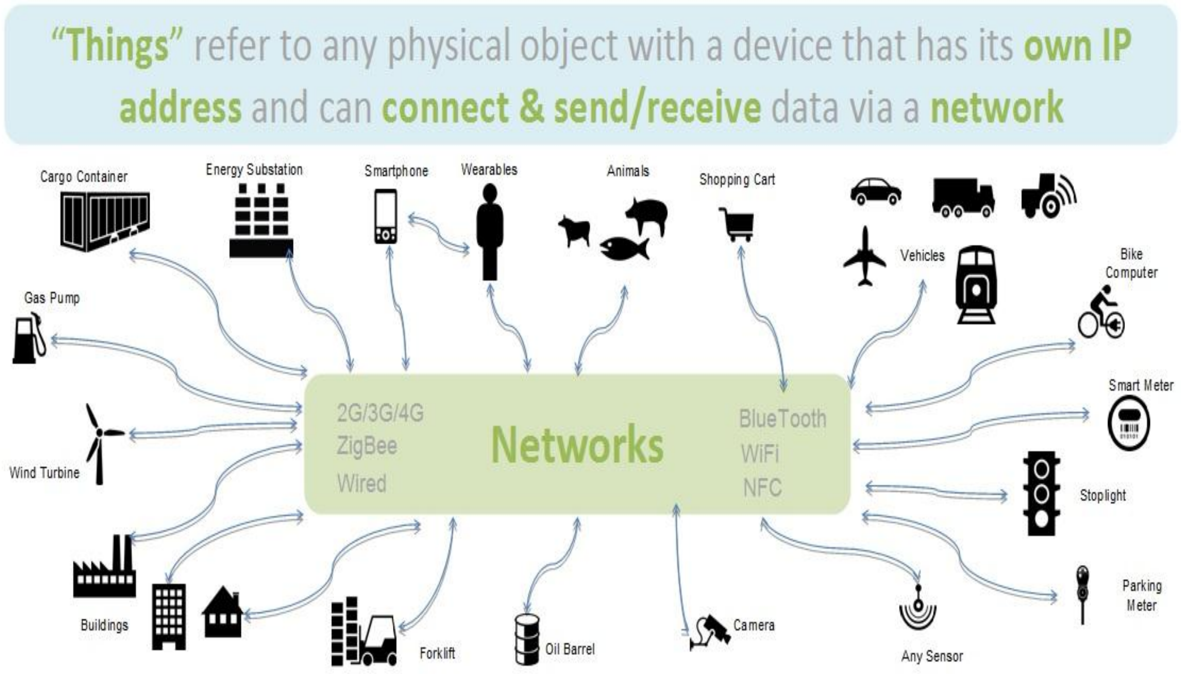
ITRI

- Industrial Technology Investment Corporation
- ITRI College
- Technology Transfer Center
- Commercialization and Industry Service Center
- ITRI International Center
- Office of Strategy and R&D Planning
- Office of Marketing Communications
- Administrative Service Center
- Accounting Resource Center
- Information Service Center
- Human Resources Office

- Biomedical Technology and Device Research Laboratories
- Green Energy and Environment Research Laboratories
- Material and Chemical Research Laboratories
- Mechanical and Systems Research Laboratories
- **Information and Communications Research Laboratories**
- Electronics and Optoelectronics Research Laboratories
- Center for Measurement Standards
- Display Technology Center
- Service Systems Technology Center
- **Cloud Computing Center for Mobile Applications**
- Industrial Economics and Knowledge Center
- Knowledge-based Economy and Competitiveness Center
- Computational Intelligence Technology Center

IoT in a Nutshell

- Design pattern
  - Sense
  - Collect
  - Analyze
  - React
- Common practice in communication and computer systems design
  - Feedback control
  - Data-driven
  - Smart X



Example: Intelligent Building

- Collect occupancy, weather, temperature and air quality
- Reconfigure heating, ventilation, air conditioning and lighting to minimize energy consumption

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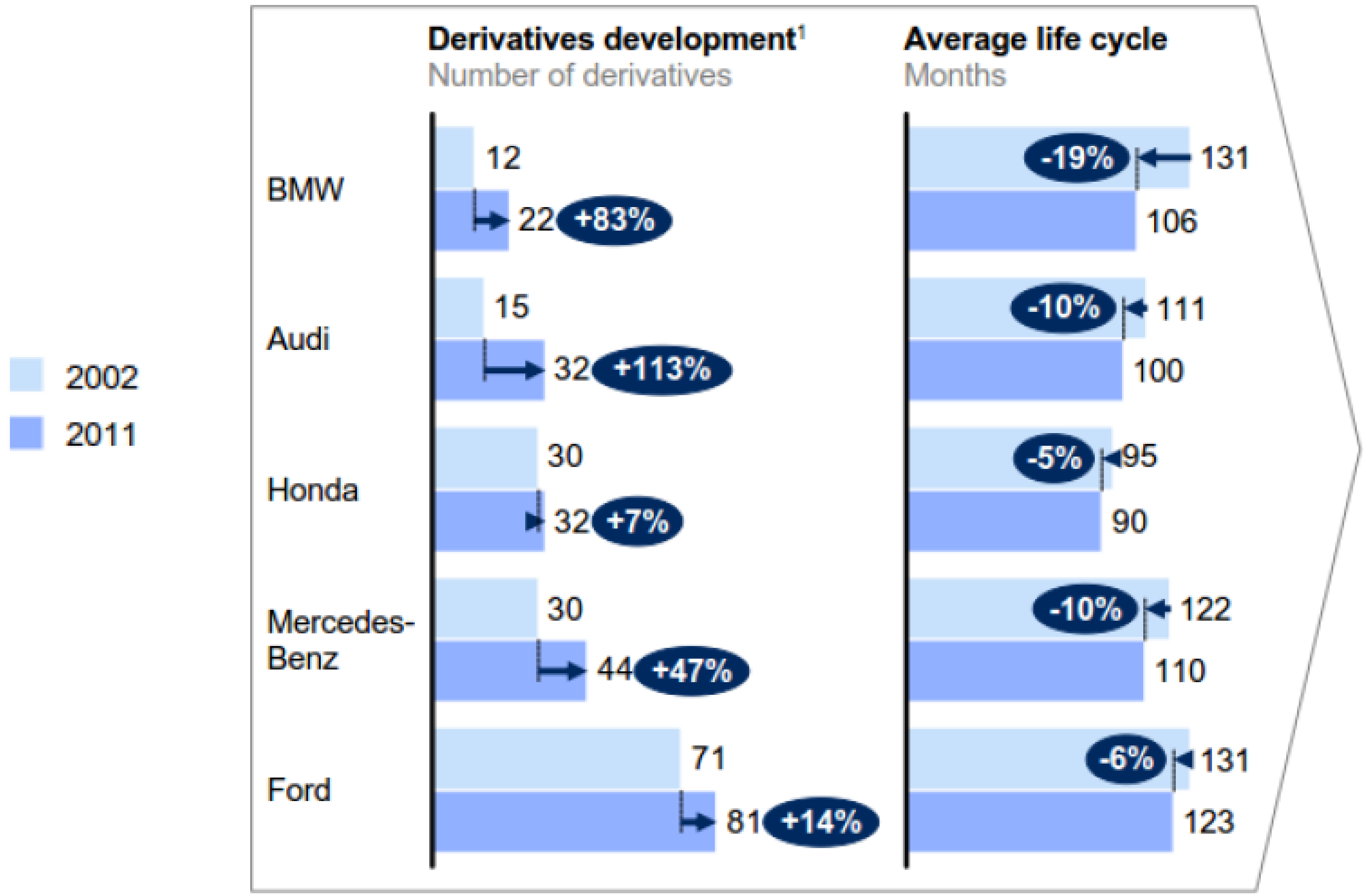
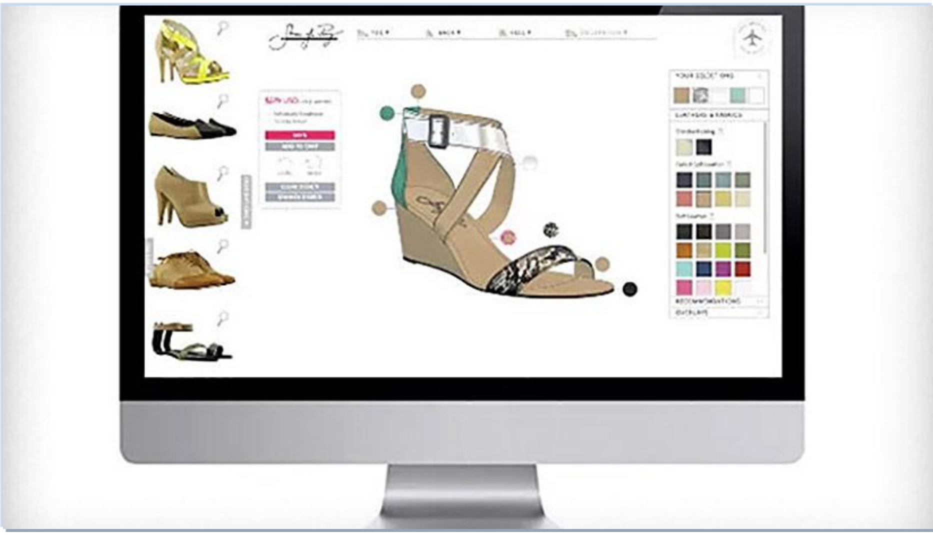
Diversification of Product Lines

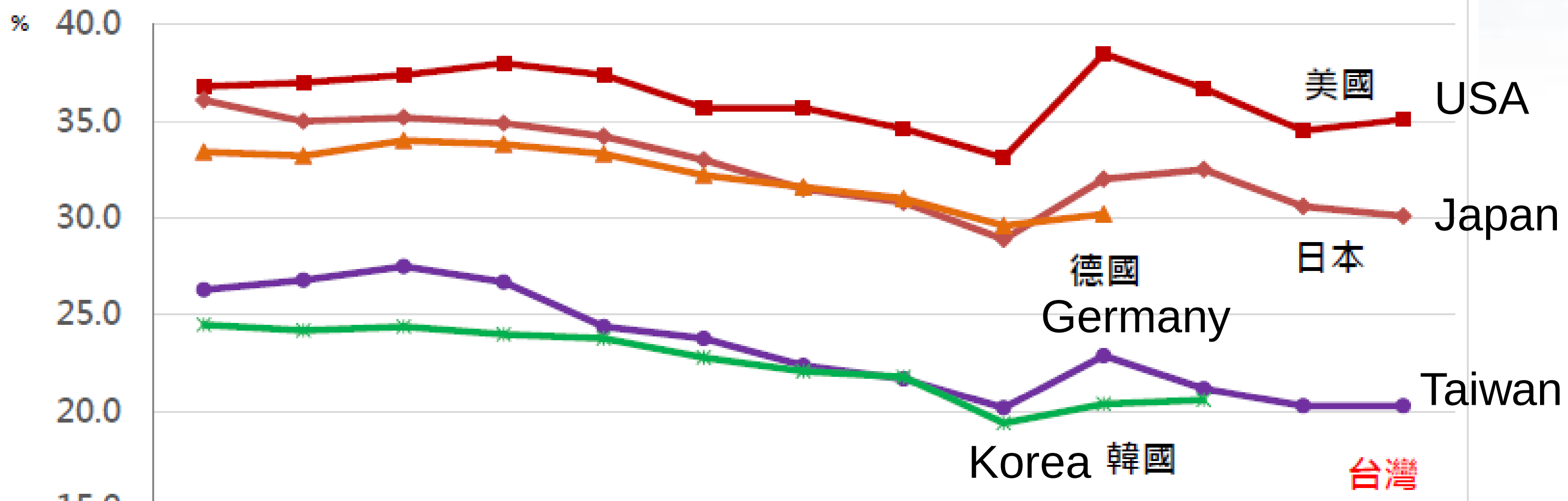


Source: McKinsey Global Institute, 2012

Mass Customization



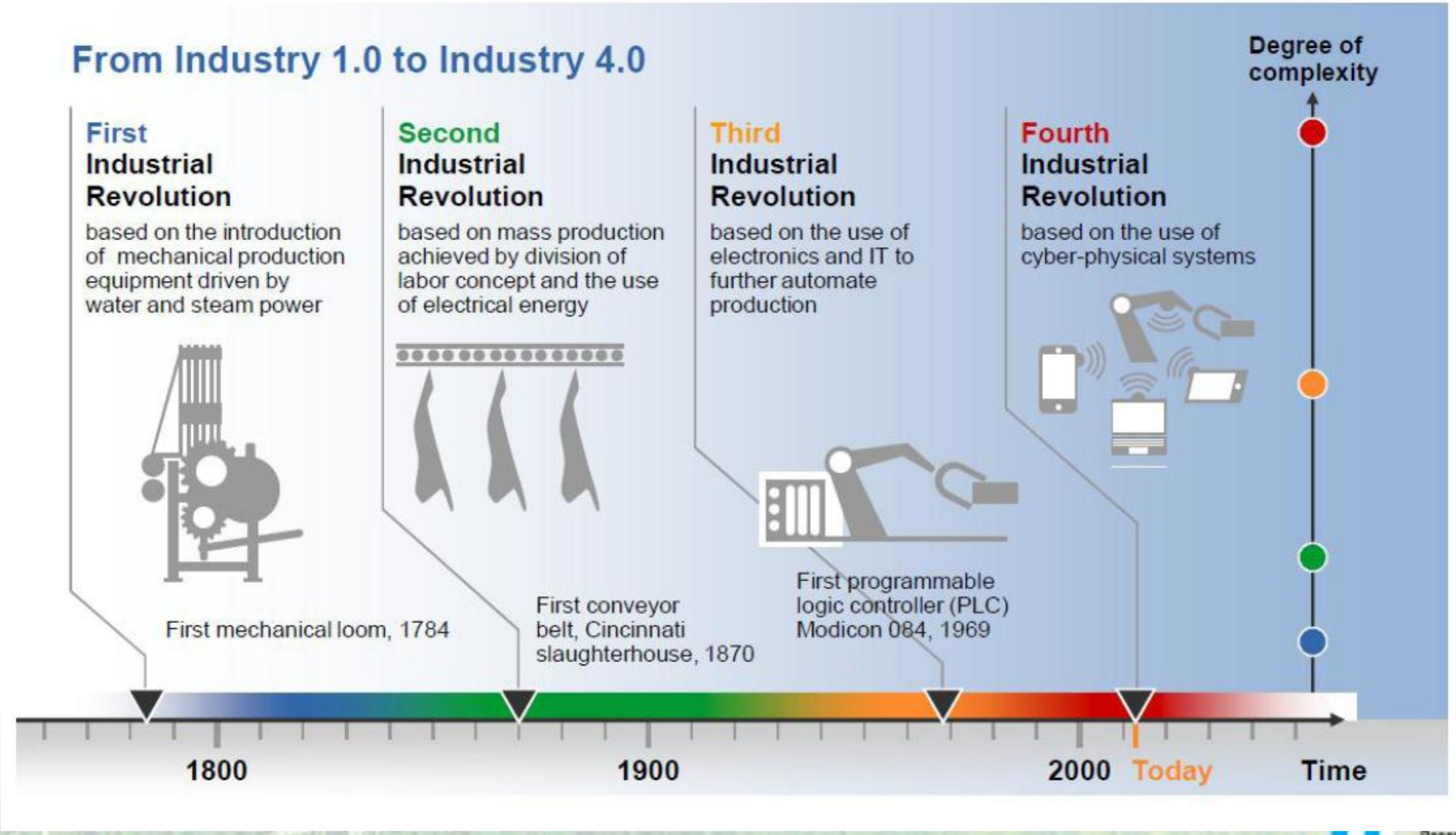
Percentage of Economic Value Added



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
美國	36.8	37.0	37.4	38.0	37.4	35.7	35.7	34.6	33.1	38.5	36.7	34.5	35.1
日本	36.1	35.0	35.2	34.9	34.2	33.0	31.5	30.8	28.9	32.0	32.5	30.6	30.1
德國	33.4	33.2	34.0	33.8	33.3	32.2	31.6	31.0	29.6	30.2			
台灣	26.3	26.8	27.5	26.7	24.4	23.8	22.4	21.7	20.2	22.9	21.2	20.3	20.3
韓國	24.5	24.2	24.4	24.0	23.8	22.8	22.1	21.8	19.4	20.4	20.6		

Industry 4.0

- An industrial IoT application: Use of sensor values for work pieces and manufacturing equipment for real-time manufacturing process optimization



Siemens's Smart Plant in Amberg

- 950 production lines using 1.6B component combinations coming from 250 suppliers
- 24 hours turn around time with an error rate < 10 ppm
- 7 times improvement in productivity in 20 years

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Key Building Blocks of Industry 4.0

- Sensors for manufacturing equipment and work pieces
  - Work piece: Error between "should be" and "turn out to be"
    - Example: All-optical instrumentation (AOI), but other sensors are needed, e.g., how to measure how tightly a screw is twisted
  - Manufacturing equipment: health status and operation condition
- Sensor data communication, collection and storage
  - Heterogeneous sensors, PLCs, and manufacturing equipment
  - Unified information model: SECS/GEM, MT Connect, OPC UA
- Data analysis and feedback control
  - Model-based: Cyber physical system (CPS) model
  - Statistics-based: Big data analytics, machine learning and AI

Industrial IoT Platform as a Service

- SMEs account for 97% of Taiwan's manufacturing industry.
  - The majority of them use 20 or fewer machining tools.
- Cannot afford programmers to build IIoT applications
- Even if they can afford the cost, it is difficult to recruit qualified programmers.
- How IIoT PaaS helps?
  - Reduce the development effort of IIoT SaaS
  - Reduce the operational support overhead of running IIoT services

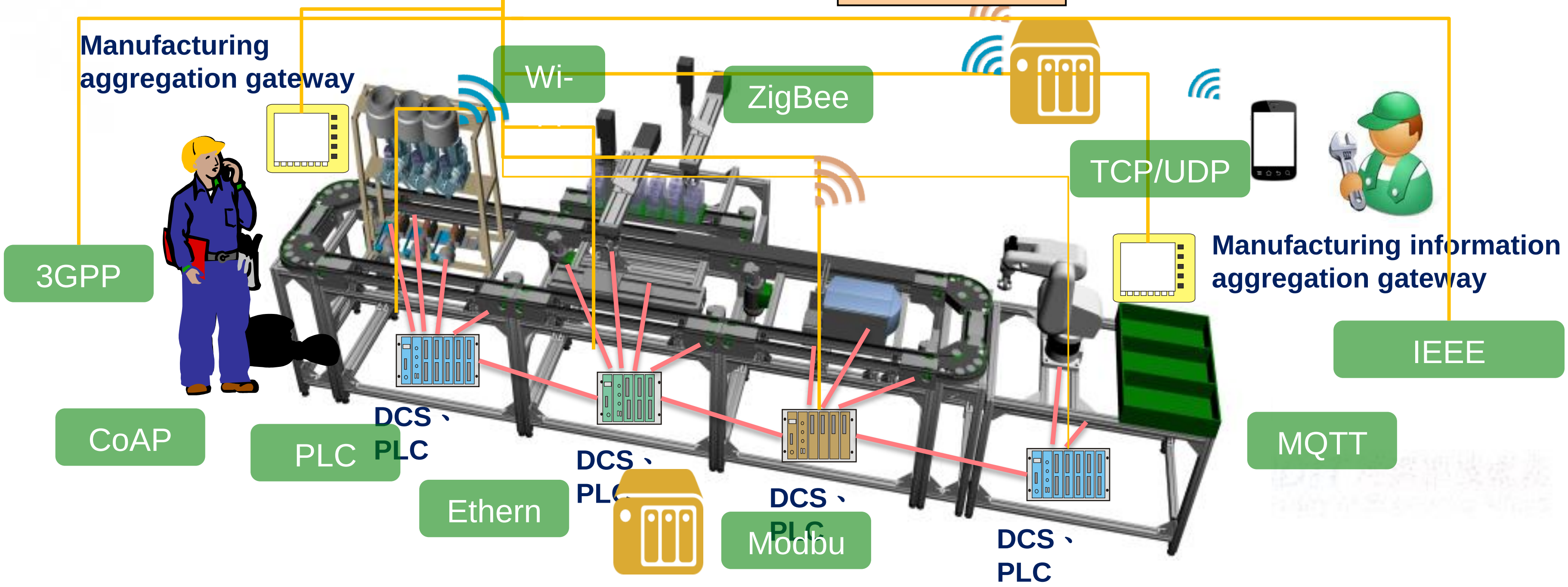
Heterogeneous Networks and Protocols

Network

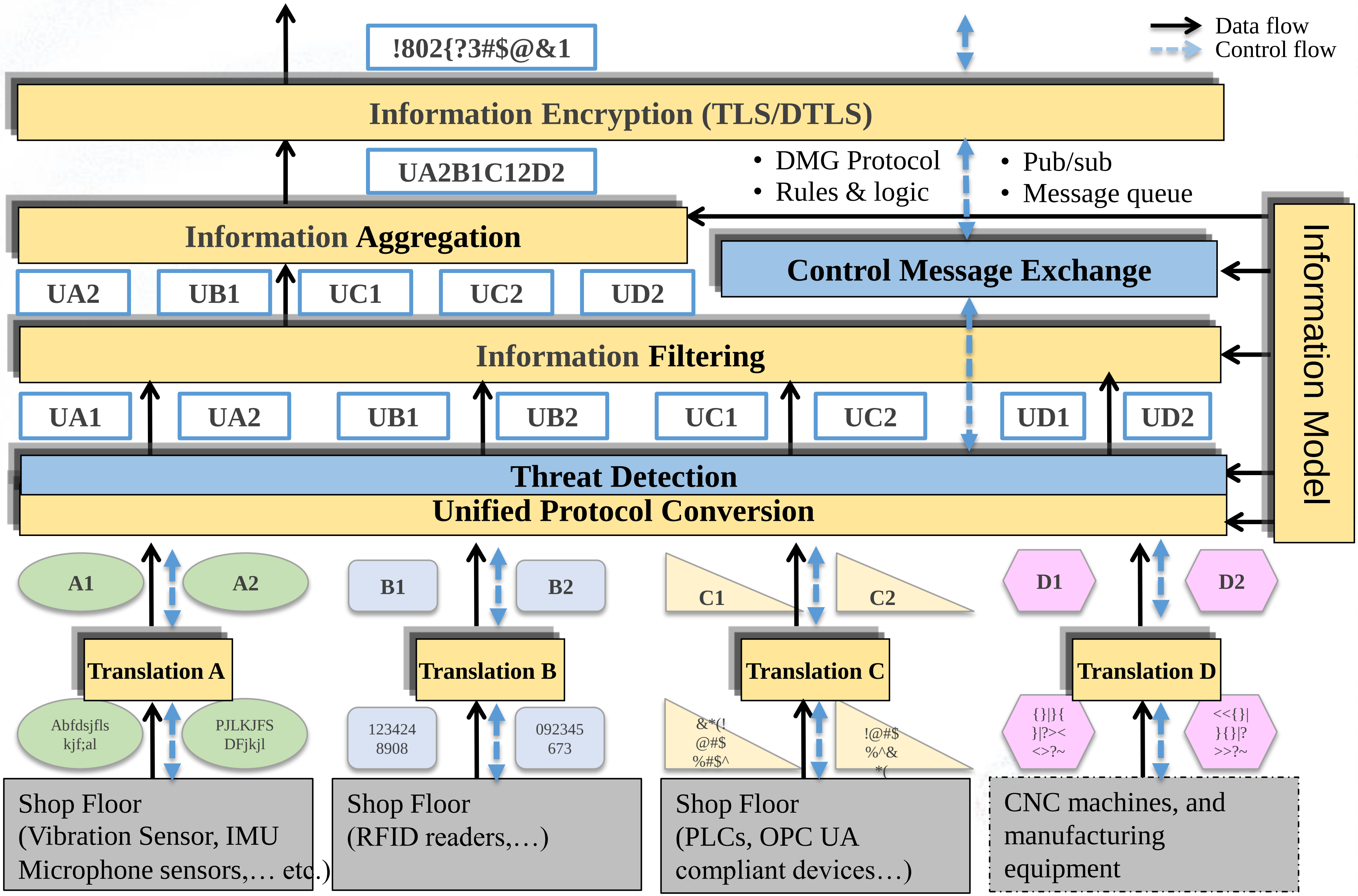
- MODBUS、CAN BUS、CANopen、Profibus-DP
- EtherCAT、C.C.Link

Protocol

- SECS/GEM: 支援SEMI E42、E53、E58、E84、E87、E90、E109、E116、E142通訊協定
- OPC-UA, MT Connect

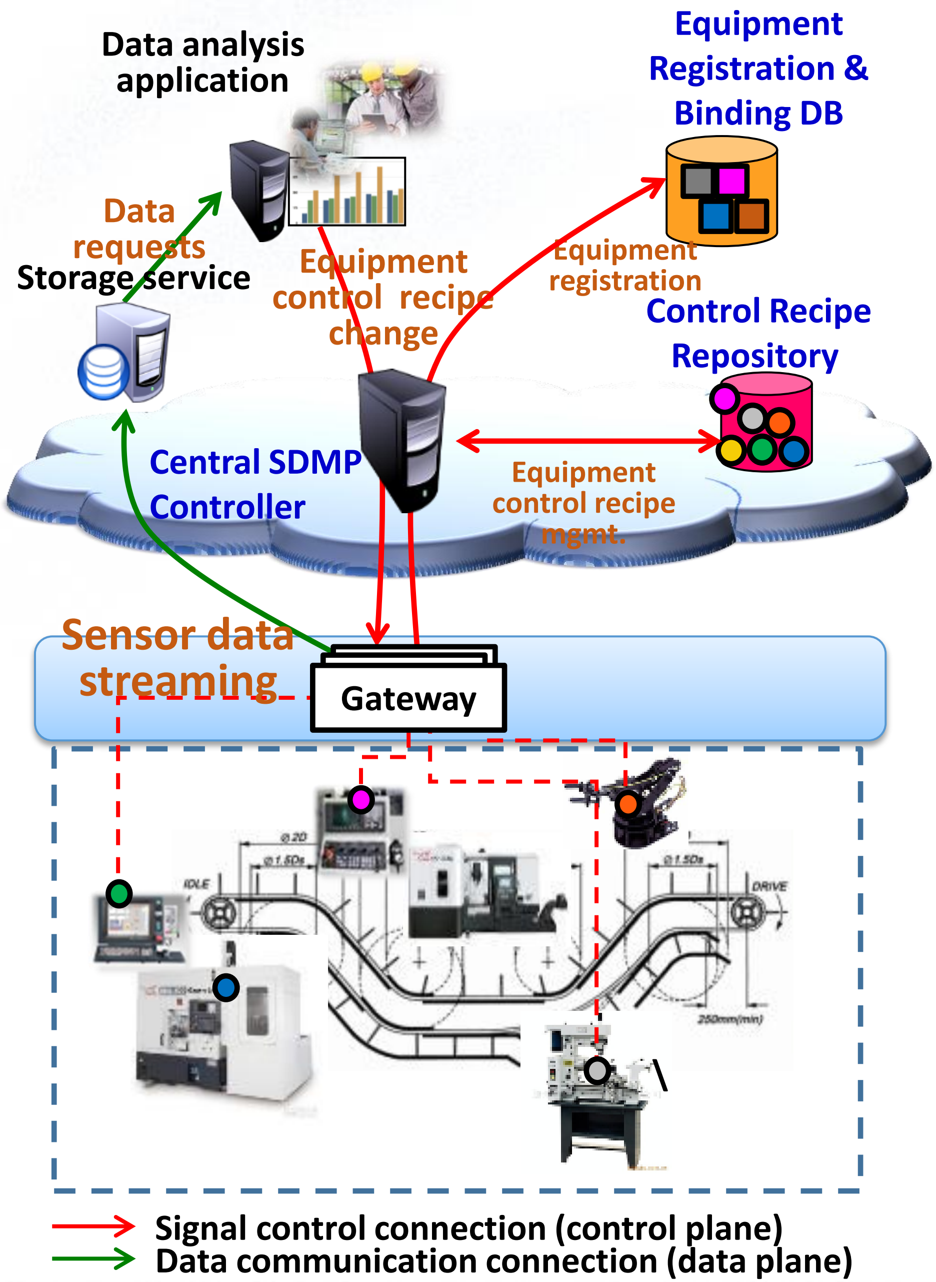


Shopfloor Data Communication



Industrial IoT PaaS

Software Defined Manufacturing Process



- Trend: Large-variety-small-volume manufacturing
- **Manufacturing process = equipment + recipe**
- **Recipe = configuration parameters + control programs**
  - G-code for machining tools and control program for robots
- A central SDMP controller
  - Maintenance of recipe repository, including version control
  - Manufacturing equipment discovery
  - Consistent and reliable uploading and downloading of machine recipes
  - Unification of machine-specific provisioning APIs
  - Security via strict lock-down

Visualization Support

- Goal: Provides manufacturing engineers an easy way to comprehend and analyze the sensor data and their derived results
- Offers a set of built-in visualization primitives that allow users to visualize data in various ways without writing code

Manufacturing Event Analysis

- Unified identification for part lots, products and equipment
- For every manufacturing object
  - Sequence of manufacturing steps it goes through
  - Quality check result after each manufacturing step
- For every manufacturing step: its parameters and health status
- Basic event data analysis
  - Application-independent, newer data only, on the fly
    - Trending, basic aggregate statistics, drastic increase/decrease, etc.
  - Designed to impose minimum performance overhead: built-in
- Deep event data analysis
  - Application-dependent, new/old data, in the background
    - Feature extraction, correlation, clustering, classification, etc.
  - User-specific customization needed

Development of an IIoT System

- Deploy sensors throughout the manufacturing process
- Measure sensor values and transport them to the backend service via a high-level sensor network communication library
- Design sensor database schema and their indexes
- Configure rules for data cleaning/filtering, data summarization, basic data analysis, and anomaly detection
- Write code for Big Data-based or CPS-based analysis against stored sensor data collected by IoT PaaS
- Write a smartphone app to visualize, hopefully in real time, raw sensor data, senor data summary, and sensor data analysis results
- Test the IOT devices and service
- Augment the resulting SaaS with logs so that it is operation-ready

Big Data Analysis

ITRI-MTTC   Main Menu   Hi: SaaS Developer

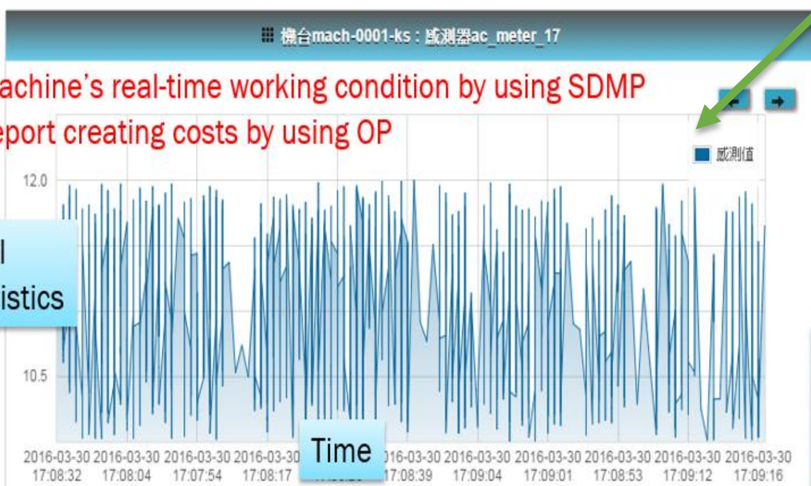
Machine Series	Item Number	Machine Status	Action
m-0001-ks	P0001	In Progress	Monitor
m-0002-ks	P0001	Complete	Predict

請設定虛擬機台的狀態:

Machine Status Selection:	In Progress	Setup

Machine Series	Item Number	Machine Condition	Action
mach-0001-ks	Virtual Element	In Progress	monitor

Update machine's real-time working condition by using SDMP
Reduce report creating costs by using OP

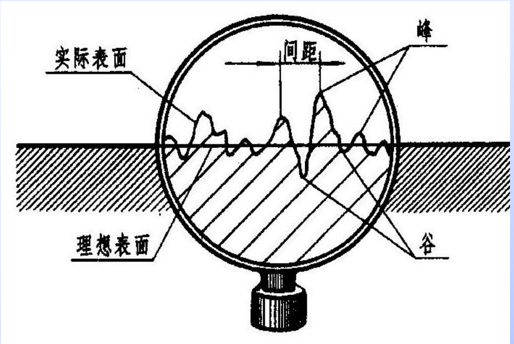


Signal Characteristics

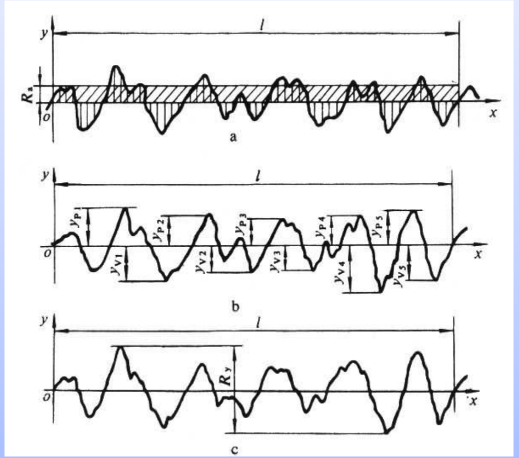
Time

Accelerometer Vibration Signal Diagram

Present the characteristics of voltage & current in sync



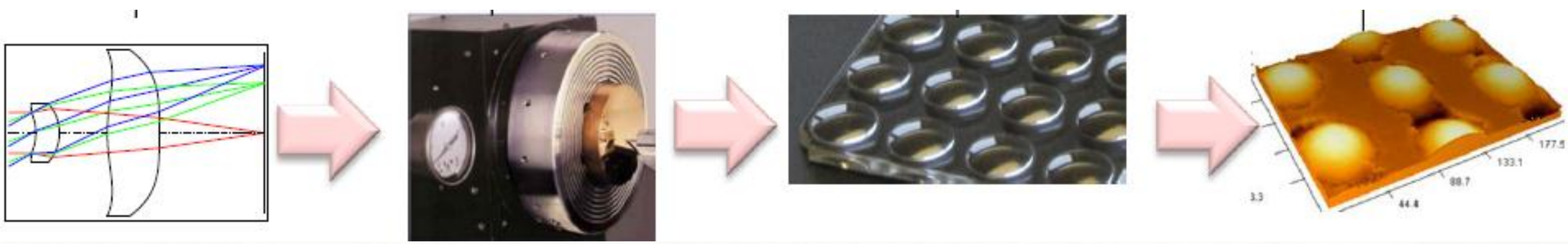
Surface Condition After Magnifying



Factors of Surface Roughness

Cyber Physical System

- CAD output ➔ CAM instructions
- Digital simulation model (cyber) of manufacturing process
- Use measured manufacturing errors (physical) to fine-tune the digital model, which is then used to control the manufacturing equipment and the work piece design in real time
- Design ➔ Mold creation ➔ Mold-based fabrication ➔ Error measurement ➔ Mold/Design change ➔....

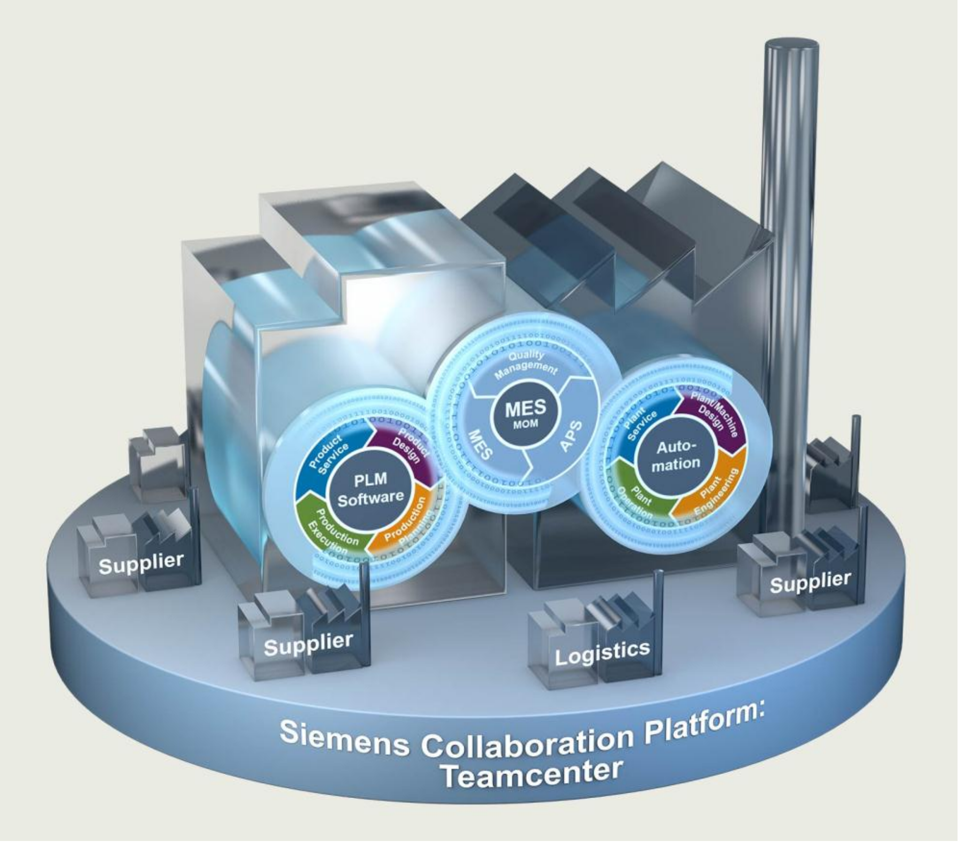


Advanced Optical Lens Design and Manufacturing

Comparison of IoT PaaS

	IBM Bluemix	GE Predix	Amazon Elastic Beanstalk	Google App Engine	Microsoft Azure IoT Services	Advantech WISE-Cloud	Siemens Cloud for Industry
PaaS	Cloud Foundry	Cloud Foundry	Amazon Elastic Beanstalk	Google App Engine	Microsoft Azure	Microsoft Azure	SAP HANA Cloud
Languages	Java, JavaScript, Python, Ruby, etc.	Java, JavaScript, Python, Ruby, etc.	Java, Node.js, PHP, Python, Ruby, and .NET web	Java, Python, PHP, Go	.NET, Node.js, PHP, Python, Java and Ruby	.NET, Node.js, PHP, Python, Java and Ruby	Java, JavaScript, Python, Ruby, etc.
Database	SQL database and NoSQL database	SQL database and NoSQL database	SQL database and NoSQL database	SQL database and NoSQL database	SQL database and NoSQL database	SQL database and NoSQL database	SQL database and NoSQL database
IDE	Visual Studio, Eclipse	Visual Studio, Eclipse	Visual Studio, Eclipse	Visual Studio, Eclipse	Visual Studio, Eclipse	Visual Studio, Eclipse	Visual Studio, Eclipse

Siemens Solution for Industry 4.0

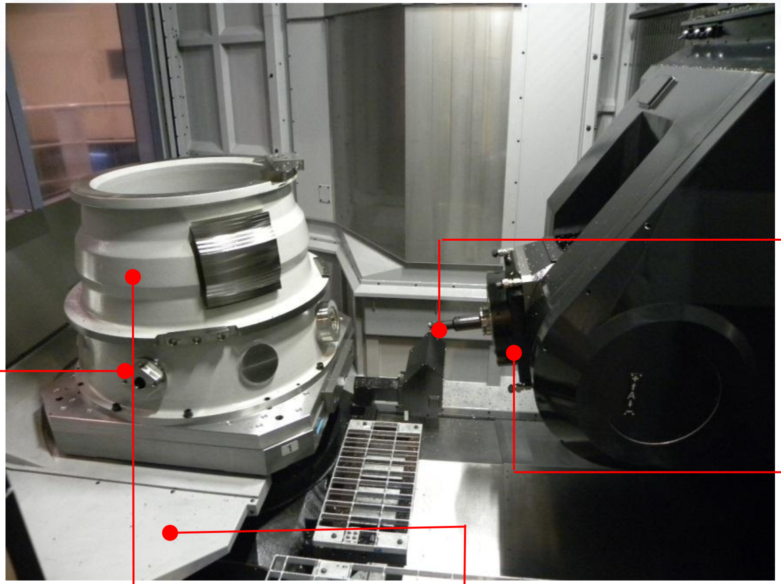


Siemens Collaboration Platform

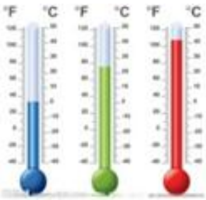
- Product Lifecycle Management (PLM)
  - Product Design
  - Production Planning
  - Production Execution
  - Product Service
- Manufacturing Execution System (MES)
  - Quality Management
  - Advance Planning and Scheduling
- Totally Integrated Automation (TIA)
  - Open System Architecture
  - Consistent Data Management
  - Industrial Communication
  - Industrial Security
  - Safety Integrated

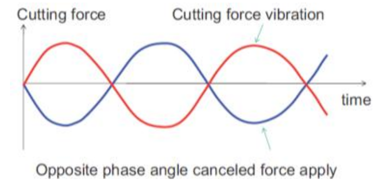
Aerospace Parts Manufacturing

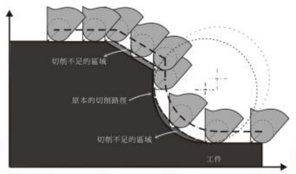
Introduction of on-line measurements



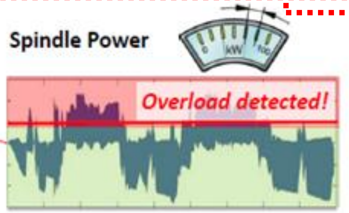
Error analysis based on measurements of sound, vibration, and temperature







Error feedback-driven cut path compensation



Spindle Torque
Forces on the Tool
Tool Deflection
Chatter Vibrations
⋮

Automated machining tool parameter tuning

Manufacturing defect monitoring

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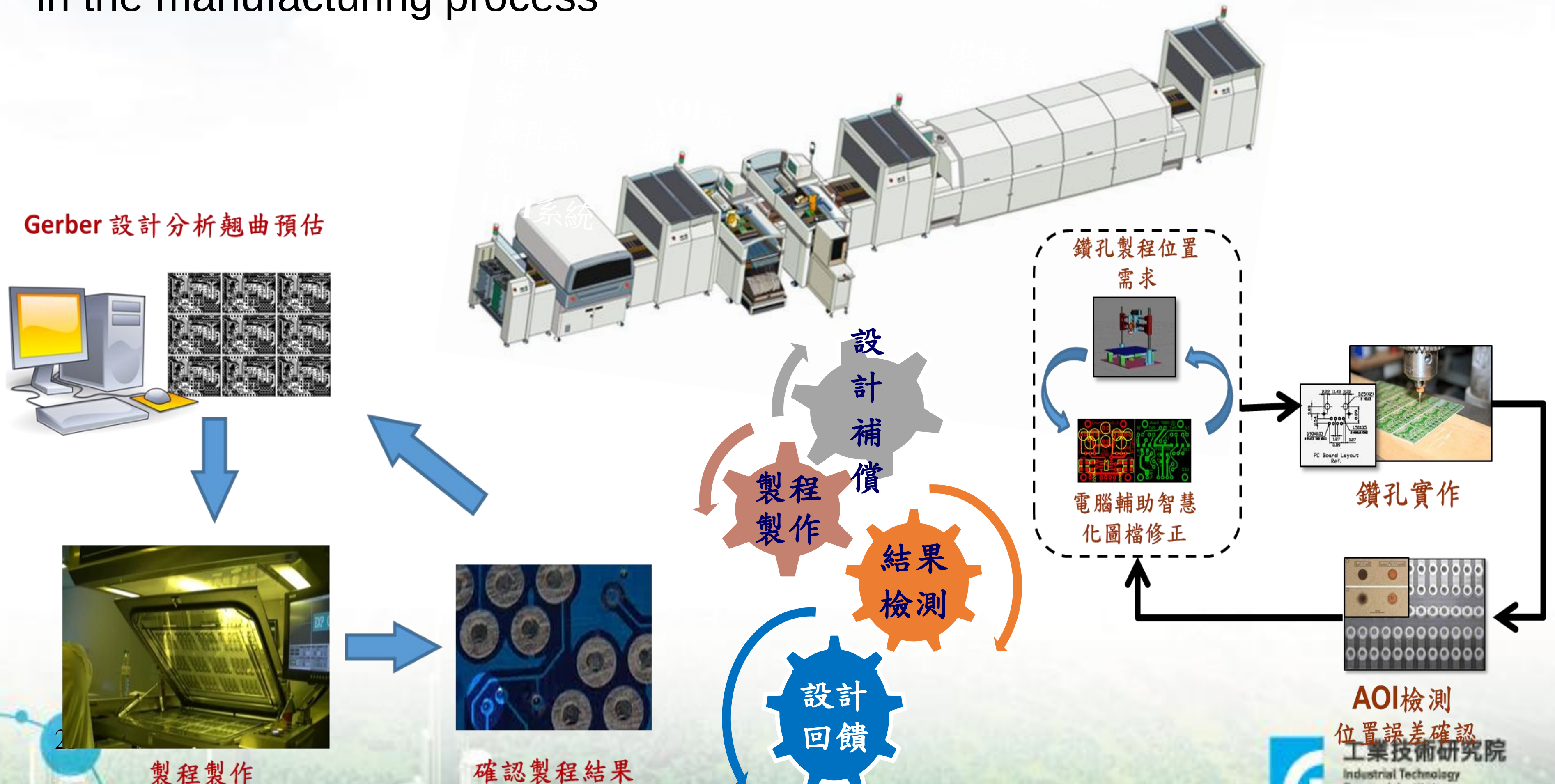
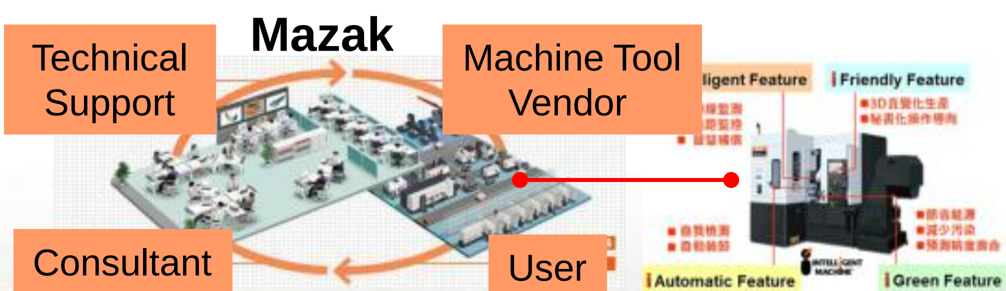
High-Precision PCB Production

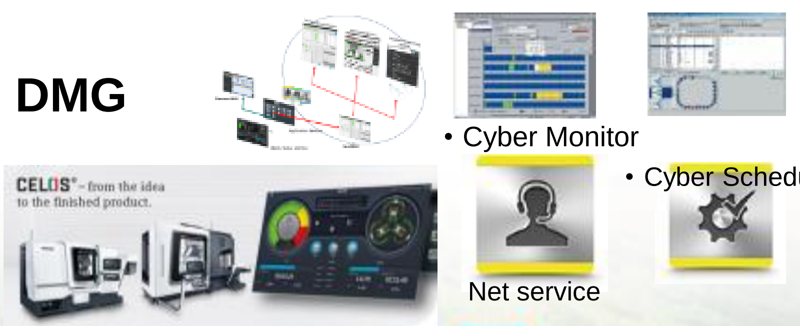
Real-time CPS-based design correction to compensate for defects measured in the manufacturing process



Remote Support for Machining Tools

- Taiwan’s machining tool industry ranks No. 4 in the world , but focuses mainly on mid-range products and below.
- Key to high-end machining tool market is effective support, including proactive equipment component replacement, real-time diagnostics and maintenance, technical consulting service, periodic software upgrade, etc.
- Mazak and DMG are two role models.





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Summary

- Industry 4.0 is an application of IoT technology to improve manufacturing efficiency and quality
  - Sense ➔ Analyze ➔ Control
- Different manufacturing domains may require different sensor data analysis expertise.
  - Statistics-based: big data, machine learning, and AI
  - Model-based: driven by cyber physical system model
- Programmers are hard to come by in the manufacturing sector, and therefore IIoT PaaS is essential to mitigate this man-power shortage problem.

Thank You!

Questions and Comments?

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