INTEL’S POV ON DIGITAL TRANSFORMATION IN MANUFACTURING

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Intel at a glance:

• > 105,000 people globally
• > $55B in revenue
• > $12B in R&D (averages >20% of revenue)
• 2,784 patents in 2016 (#6 globally)
• Ranked #14 on Interbrand’s 2016 Best Global Brand list
A SINGLE WAFER

Real-time analytics against large, complex and changing datasets is challenging. Our focused approach results in increased yield and faster throughput time.

• Intel sorts 1000’s of wafers per day containing roughly 1 GB of data
  • Intel collects over 5B sensor data-points per day per factory and it’s growing
  • Each MFG DC manages over than 1 PB of data
  • Response to defects must be immediate

Challenges

• Time series analysis is complex
• Real-time processing of data to manage the manufacturing line is not trivial
BUSINESS CHALLENGES FACING LEAN OPERATIONS

- Raw-material price volatility
- Customer demands
- Aging workforce
- Increased compliance
- Complex supply chains

- High cost of unscheduled maintenance
- Added processes to overcome deficiencies
- High cost of general maintenance
- Lack of accurate, timely, actionable data
- Increased time and cost to forecast and do analytics

Risk to product quality and ability to fill orders on time, on budget
3 PHASES OF IoT

CONNECTED

SMART

AUTONOMOUS
CONNECT THE UNCONNECTED
MOVE THE DATA

Production Equipment

Network Infrastructure

Data Center / Cloud

One Direction
INTEGRATE OT, SENSOR AND IT SYSTEMS TO ENABLE ADVANCED ANALYTICS AND MACHINE LEARNING

REDUCE
- Risk Exposure
- Failures
- Downtime
- Maintenance Costs

OPTIMIZE
- Asset Availability
- Asset Life
- Workforce Productivity
- Operational Performance

IMPROVE
- Product Quality
- Customer Satisfaction
- Safety and Compliance
- Employee Productivity
## INTEL’S AUTOMATED AND OPTIMIZED FACTORIES ANALYZE OVER 1 PB OF DATA DAILY

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<thead>
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*Other names and brands may be claimed as the property of others.*
Transitioning Fixed Function to Software-Defined Automation

From Rigid Industrial Automation & Control Systems

- Innovation restricted to process & supervisory layers
- Tightly-integrated HW/SW, limits flexibility & change
- Proprietary, lock-in devices & networks → expensive O&M
- 100’s of per device control loops leads to single points of failure, unmanageable wiring
- Bolted on security

To Software-defined Automation & Control Systems

- Open (HW/SW) architecture
- Real-time computing and networking
- Modern SW methods of innovation, application hosting, lower O&M
- Real-time data management & analytics for integrated business and process control
- Embedded security
Internet of Things Group

Data Warehouse

Machine Learning

Shaper DB

Machine parameters

New Sensors

IoT data acquisition

Quality Measurement

New Sensors
SMART AND CONNECTED THINGS

MOVE THE DATA TO THE COMPUTE...

Worker

Facilities

Network Infrastructure

Data Center / Cloud

Bi-Directional

Industrial

Smart & Connected
SOFTWARE-DEFINED AUTONOMOUS WORLD
MOVE THE COMPUTE TO THE DATA

Virtualized, Reconfigurable, Software-Defined, Autonomous
Monitor, Maintain & Optimize Operations from End to End

**Data Collection**
- Sensors
- Actuators
- Meters
- Legacy Systems
- Smart Machines
- Human/Machine Interfaces

**Data Aggregation & Actions**
- Sensor Data
- Real-time Data From Instrumented Assets
- Gateway
- Corrective Action
- Updates to Model

**Data Scoring, Analytics & Model Updates**
- On-Premise Industrial PC
- Data Center
- Hybrid Cloud/On Premise
- Analytics
- Security End to End

**Business Intelligence Result Sharing**
- IT Oversight
- Management Dashboards
- Business Intelligence
- Corrective Action
- Updates to Model
- On-Premise Industrial PC

**Internet of Things Group**

**Intel® IoT Platform Enables Integration, Interoperability & Flexibility**
Fault Detection
By having a known mathematical relationship between sensor data and metrology, extremely accurate fault detection and classification is achieved.

Tool Matching
Sources of tool mismatch that are driving the metrology can be determined.

Classification for Process Diagnostics
The source of the variation in the process chamber can be determined and quantified. For example, Post PM instability, 1st wafer effect will be understood.

Metrology Reduction/Dynamic Sampling
Prediction of metrology to a high degree of certainty will allow only outlier lots to be sent to metrology. (Prediction within Target limits)

Tool Control - R2R Controller
Predicted metrology will allow semi-real-time adjustment of recipes to achieve closer-to-target metrology and EOL speed.
Application running on 372 chambers across 3 fabs
Total storage used is 276TB
Each chamber generates 4000 data points per second (1.488 million across all chambers). 1.5 seconds data fills a HD monitor screen.
Average number of sample points stored per chamber is 7 billion (based on 3.5m individual sample times).
Total number of sample points stored is ~3.98 trillion using 995 million DB rows
Average DB Page I/O response time is ~2ms
Each sample time consumes 10kb of DB space
Average raw to standard data conversion rate > 99.86% (.14 raw data supplied is invalid)
Edge compute activity reduces raw data acquisition by a factor of 5 from a frequency of 10Hz to 2Hz (19.9 trillion points produced by sensors in raw form)
LESSONS LEARNT

- Raw IOT data on its own is next to useless ... context creates value.
- Management of data volumes is crucial. Systems are easily overwhelmed by volumes that IOT systems create.
- Smart data association improves performance dramatically. 99% of IOT data has no relationship so why associate it in data stores.
- End to End solutions offer productivity and efficiency benefits that allow engineers to exploit data in ways that are not possible with traditional data warehousing approaches.
- Almost every IOT data source is uniquely structured. Transformation into a standardised form allows handling of the variety of IOT sources available.
- Summarisation and compression are key factors in the exploitation of IOT data.
- Service Orientated Architecture (SOA) design is well aligned to IOT environments as it is based on the exchange of data structures in a loosely coupled manner.
- Machine learning has been achieved using the models that we have developed.
  - The next challenge of Artificial Intelligence is technically possible but psychologically difficult as it requires release of control.
- Data
  - We have tons of it in different silos ... most IOT systems have it all in one heap ... finding the needle is the issue.
  - Too much focus on the miracles machine learning can do when applied to the big data.
FUTURE INDUSTRIAL SYSTEMS ARE HIGHLY FLEXIBLE AND EFFICIENT

SW-defined industrial equipment and collaborative machines

Self-aware production systems

Real-time & reliable compute and connectivity

Self-organizing, flexible production flow

Human in the loop – enabled connected worker

Embedded E2E security
Intel® Xeon® Scalable Platform

The foundation of Data Center Innovation:
Agile & Trusted Infrastructure

PERFORMANCE
Pervasive through compute, storage, and network

SECURITY
Pervasive data security with no performance overhead

AGILITY
Rapid service delivery

DELIVERS 1.65X AVERAGE PERFORMANCE BOOST OVER PRIOR GENERATION

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance Intel does not control or audit the design or implementation of third party benchmark data or Web sites referenced in this document. Intel encourages all of its customers to visit the referenced Web sites or others where similar performance benchmark data are reported and confirm whether the referenced benchmark data are accurate and reflect performance of systems available for purchase. Configuration: see backup
INTEL® SCALABLE SYSTEM FRAMEWORK

HW FOUNDATION

SW ENVIRONMENT

DEVELOPER TOOLS

INTEL® HPC ORCHESTRATOR
SD VIS TOOLS
LUSTRE*

Intel® MKL
Intel® DAAL
Intel® Parallel Studio

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CHALLENGES

TECHNICAL POV

- SECURITY AND TRUST
- INTEROPERABILITY
- INTEGRATION OF OT/IT
- ADVANCED ANALYTICS

BUSINESS POV

- SOLUTION SCALABILITY
- COST/ROI
- SECURITY AND PRIVACY
- FRAGMENTED SOLUTIONS
# IMPROVE PRODUCTIVITY AND DECREASE COSTS BY INTEGRATING PREDICTIVE MAINTENANCE AND QUALITY

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<td>25%</td>
<td>Productivity increase at Daimler AG by harnessing predictive analytics &amp; quality systems¹</td>
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<tr>
<td>30%</td>
<td>Cost reduction for overall maintenance when switching to predictive maintenance from run-to-failure system²</td>
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<td>35%</td>
<td>Companies adopting Industry 4.0 expecting revenue gains of 20% over the next 5 years³</td>
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**Business model transformation is the real opportunity**

The Internet of Things (IoT) Starts with Intel Inside®

Tags: Internet of Things

IOT INSIGHTS
Get insights from Intel CEO Brian Krzanich and Intel leaders on IoT, from real-world solutions to the latest products and technologies.

Watch the video

WWW.INTEL.COM/HPC/
WWW.INTEL.COM/IOT
WWW.INTEL.COM/IT/
STANDARDIZE THE IOT INDUSTRY

**Internet of Things Group**

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**THE FUTURE OF MANUFACTURING IS HAPPENING NOW AT INTEL**

**Big Data Delivers Year-Over-Year Gains in Uptime and Output**

**Integrated Manufacturing Line**
Data moves from the tool, sensors and OT platform to data center where analytics are run to solve business issues

**Advanced Analytics**
Solves forecasting challenges and minimizes unscheduled maintenance

**Machine Learning**
Once advanced analytics are established, models can learn from their mistake and refine algorithms automatically
THE MOTIVATION

Cost
Quality
Velocity

Moore's Law: An observation made by Intel co-founder Gordon Moore in 1965, that the number of transistors per square inch on integrated circuits had doubled every year since their invention. Moore's law predicts that this trend will continue into the foreseeable future.
## Internet of Things Group

### Security End to End

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