

INTEL'S POV ON DIGITAL TRANSFORMATION IN MANUFACTURING

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ABOUT INTEL

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

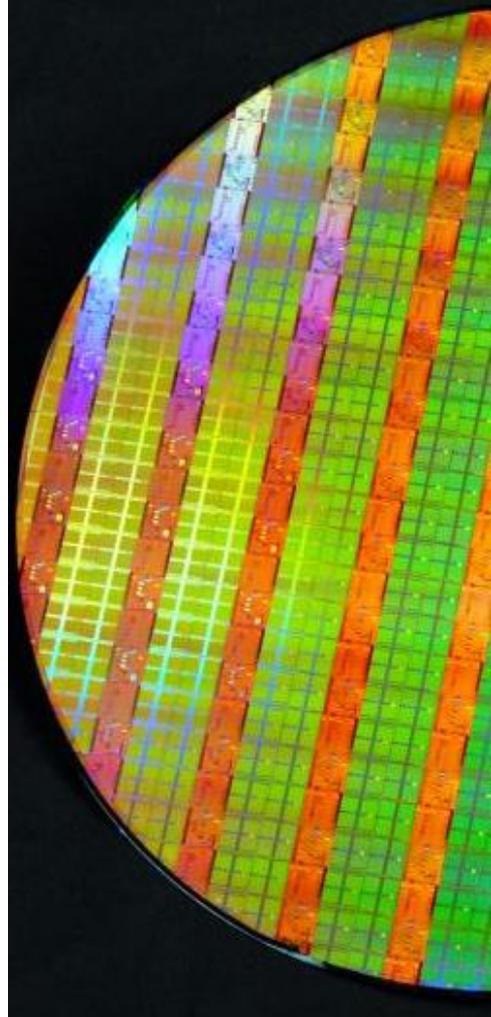
A SINGLE WAFER

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

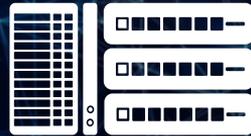
CONNECT THE UNCONNECTED

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

Data Collection

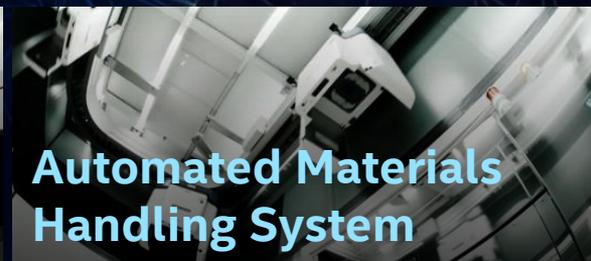
Data Aggregation & Actions

Data Scoring, Analytics & Model Updates

Business Intelligence Result Sharing



Factory Floor



Automated Materials Handling System



Data Center

- 2,000+ thick clients (all Intel® x86 64-bit desktop platforms)
- 1,000–2,000 production semiconductor tools
- 200,000+ feet of Ethernet cable
- 100+ access switches and WAP

- Robotic delivery and storage systems
- 150+ high speed interbay robotic delivery vehicles
- Covers 400k sq ft of cleanroom space
- 5+ miles of vehicle track on the ceiling; 200+ overhead robotic delivery vehicles

- 600+ servers (all Intel x86 64-bit)
- 200+ routers, switches, firewalls
- MS Windows* and Linux* OS
- 150,000+ feet of fiber
- 200+ routers, switches, firewalls

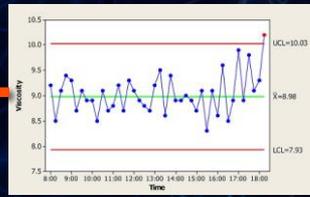


Security End to End

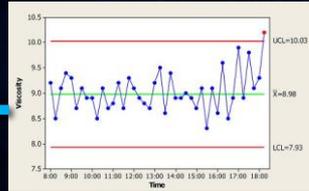
*Other names and brands may be claimed as the property of others.



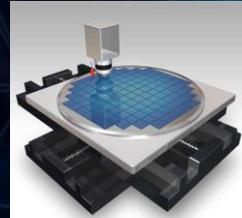
Data Warehouse



Machine parameters

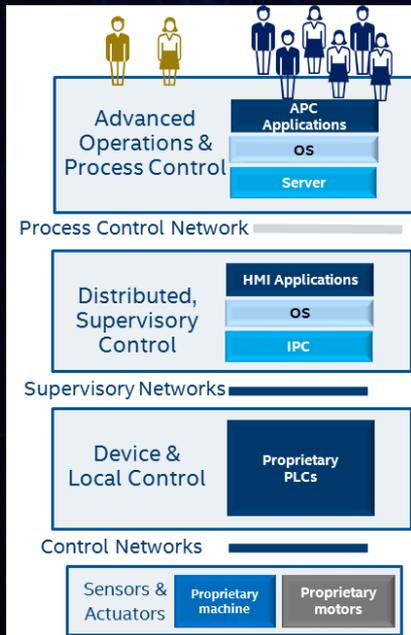


Quality Measurement



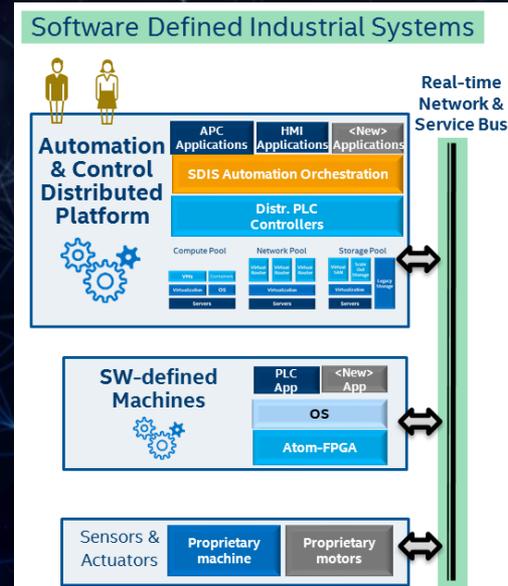
TRANSITIONING FIXED FUNCTION TO SOFTWARE-DEFINED AUTOMATION

From Rigid Industrial Automation & Control Systems

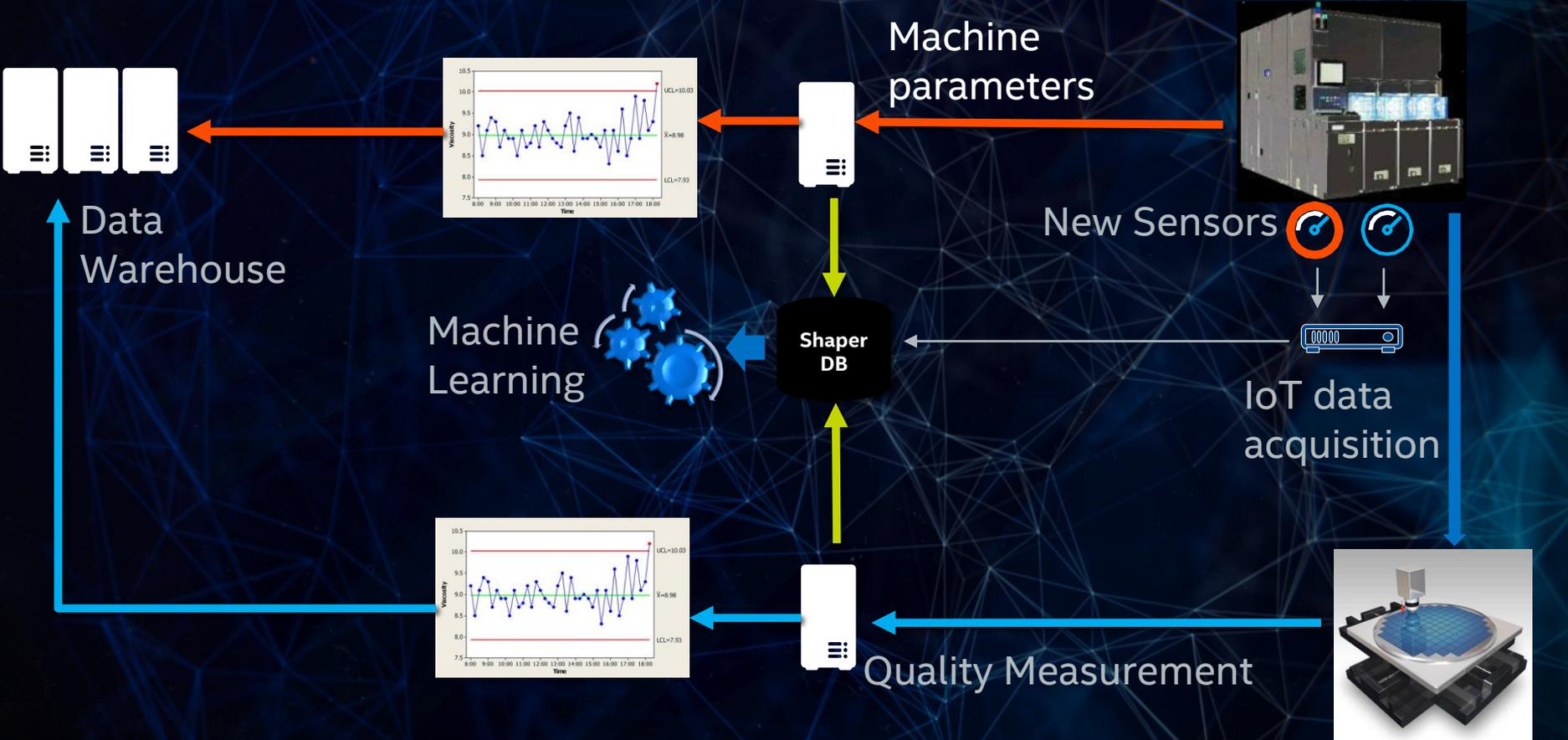


- Innovation restricted to process & supervisory layers
- Tightly-integrated HW/SW, limits flexibility & change
- Proprietary, lock-in devices & networks → expensive O&M
- 100's of per device control loops leads to single points of failure, unmanageable wiring
- Bolted on security

To Software-defined Automation & Control Systems

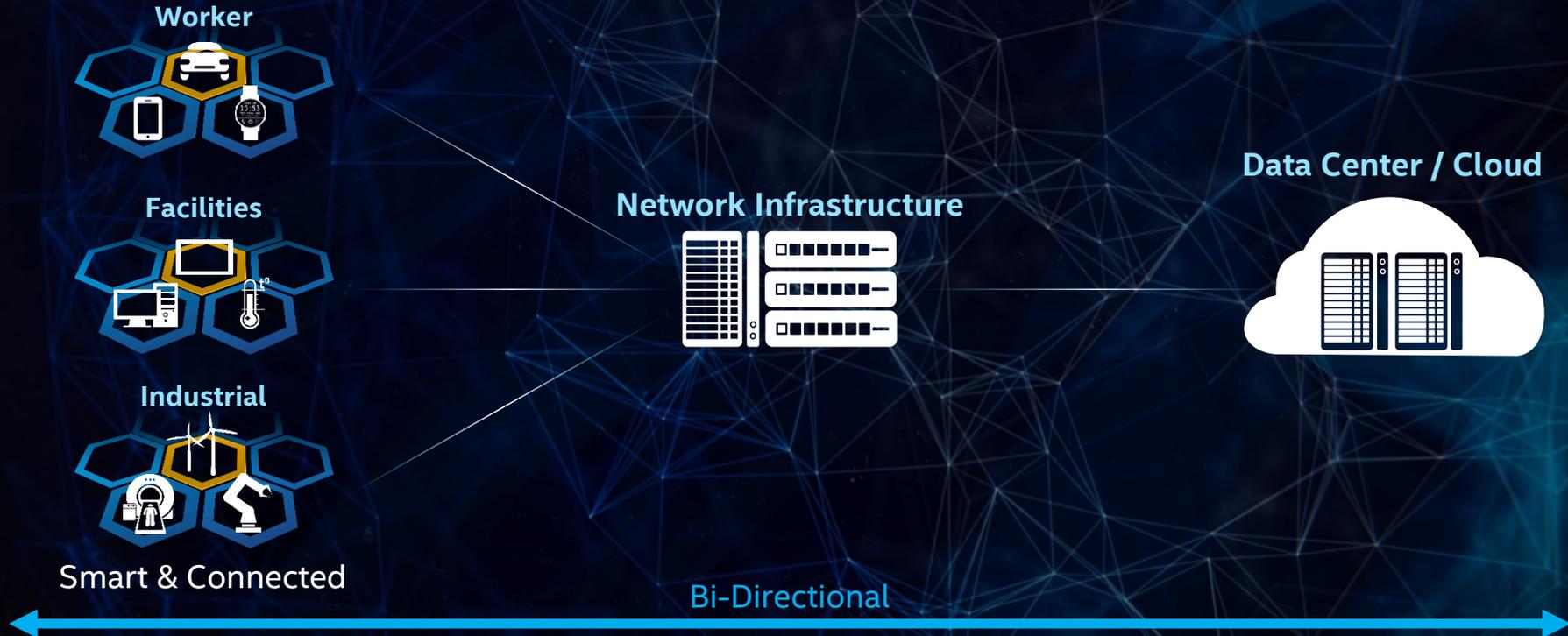


- Open (HW/SW) architecture
- Real-time computing and networking
- Modern SW methods of innovation, application hosting, lower O&M
- Real-time data management & analytics for integrated business and process control
- Embedded security



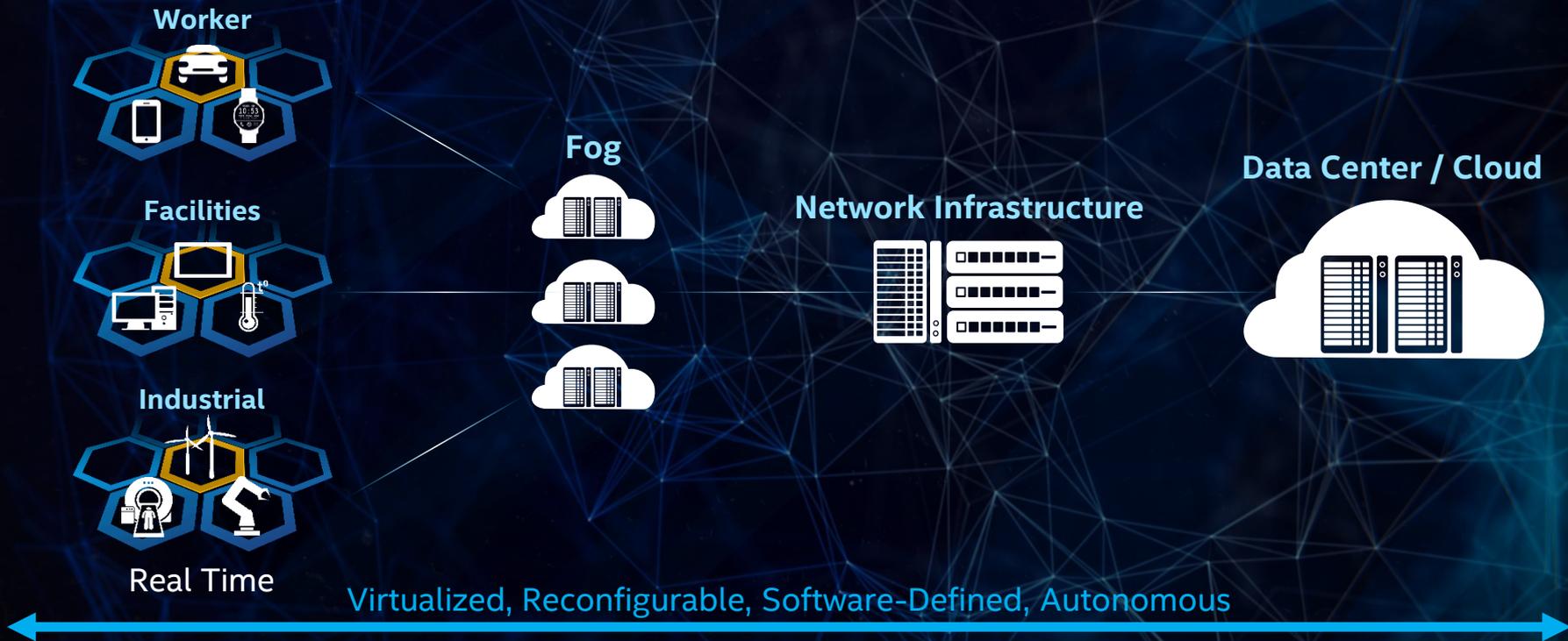
SMART AND CONNECTED THINGS

MOVE THE DATA TO THE COMPUTE...



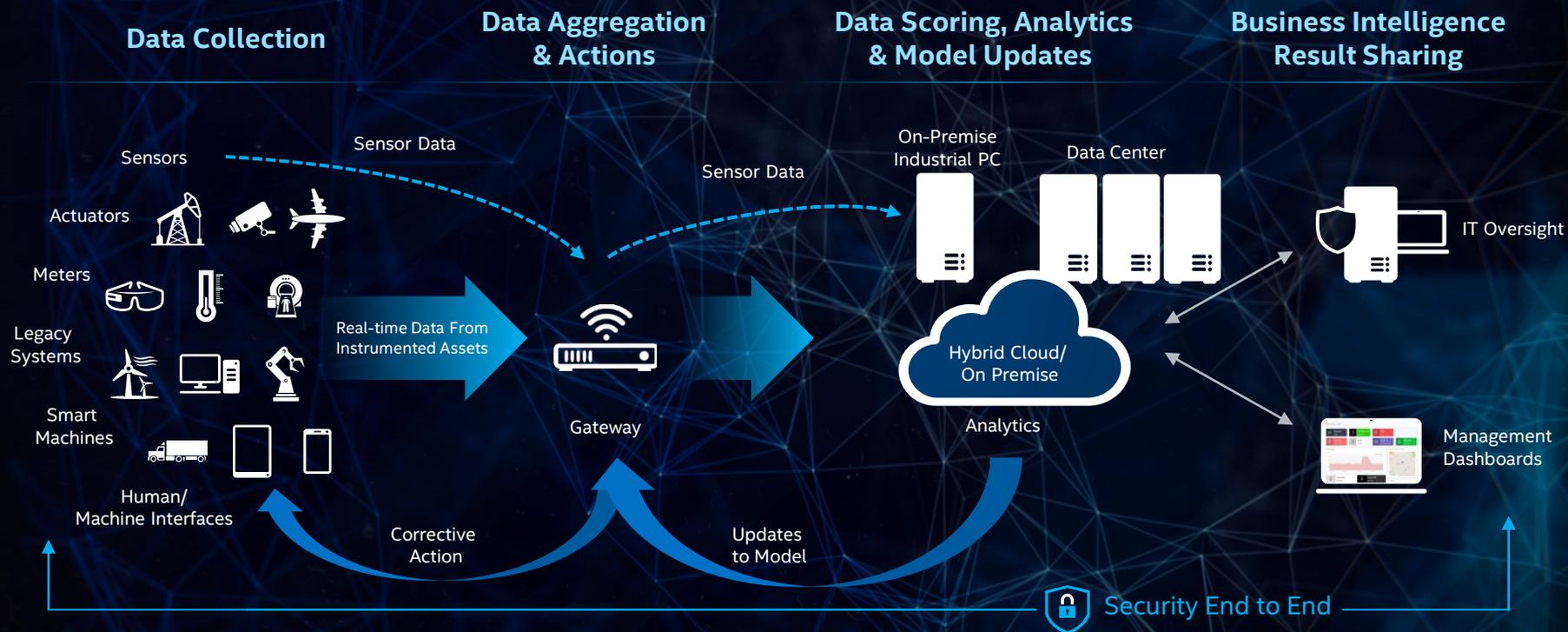
SOFTWARE-DEFINED AUTONOMOUS WORLD

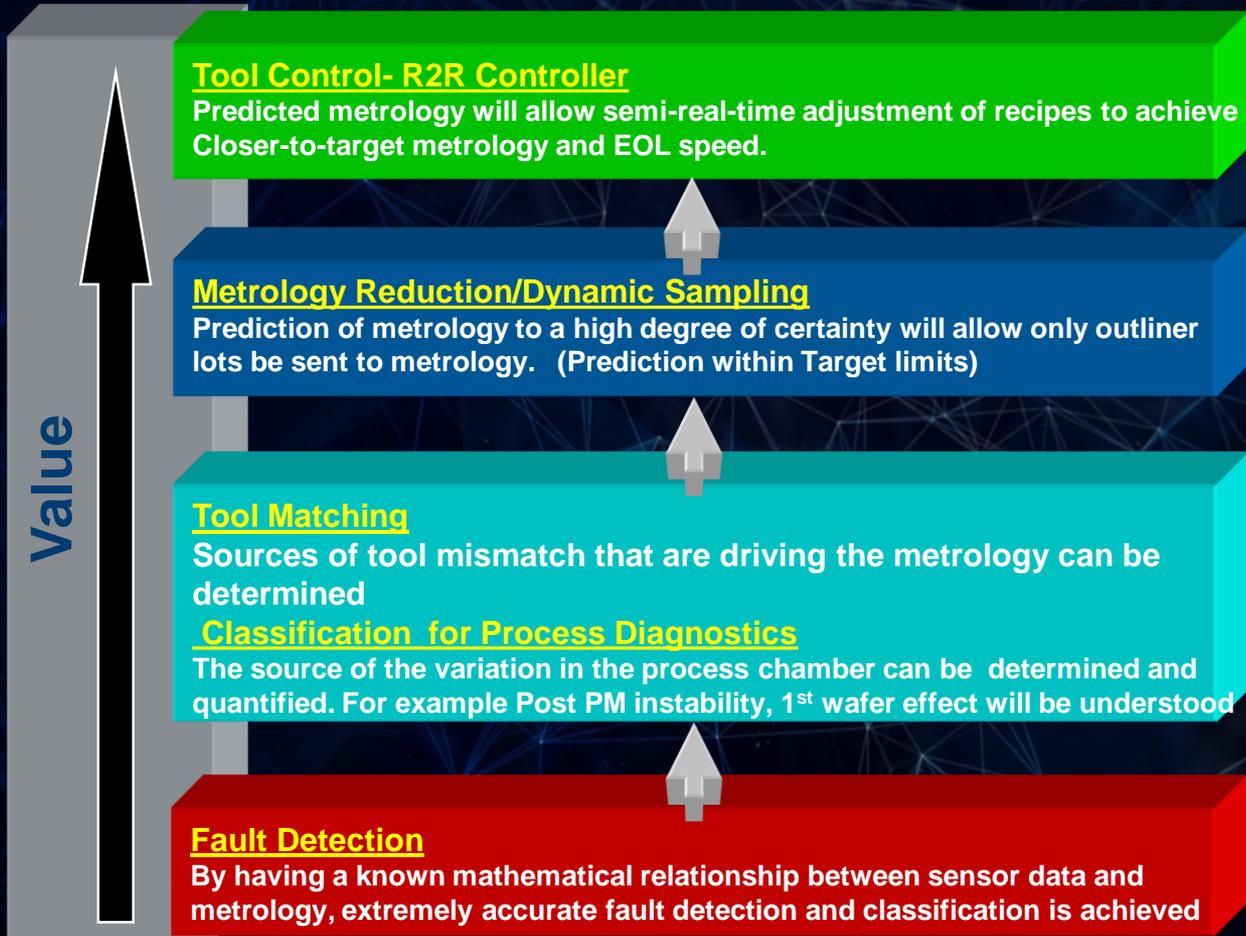
MOVE THE COMPUTE TO THE DATA



MONITOR, MAINTAIN & OPTIMIZE OPERATIONS FROM END TO END

INTEL® IOT PLATFORM ENABLES INTEGRATION, INTEROPERABILITY & FLEXIBILITY





FUN WITH NUMBERS

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 it 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-organizing, flexible production flow

Self-aware production systems

Human in the loop – enabled connected worker

Real-time & reliable compute and connectivity

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

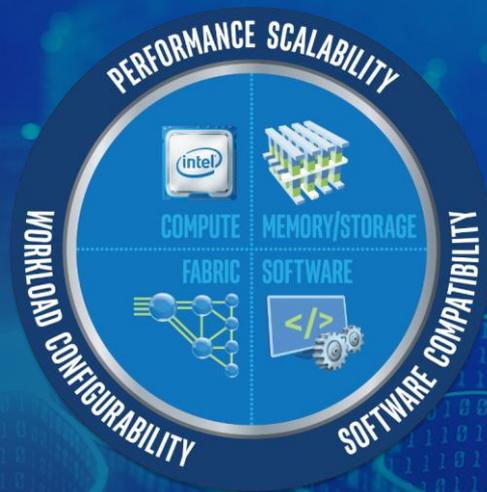


Rapid service delivery

DELIVERS 1.65X AVERAGE PERFORMANCE BOOST OVER PRIOR GENERATION¹

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

INTEL® HPC ORCHESTRATOR
SD VIS TOOLS
LUSTRE*

DEVELOPER TOOLS



* Other names and brands may be claimed as the property of others.



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

25%

productivity increase at Daimler AG by harnessing predictive analytics & quality systems¹

30%

cost reduction for overall maintenance when switching to predictive maintenance from run-to-failure system²

35%

companies adopting Industry 4.0 expecting revenue gains of 20% over the next 5 years³

Business model transformation is the real opportunity



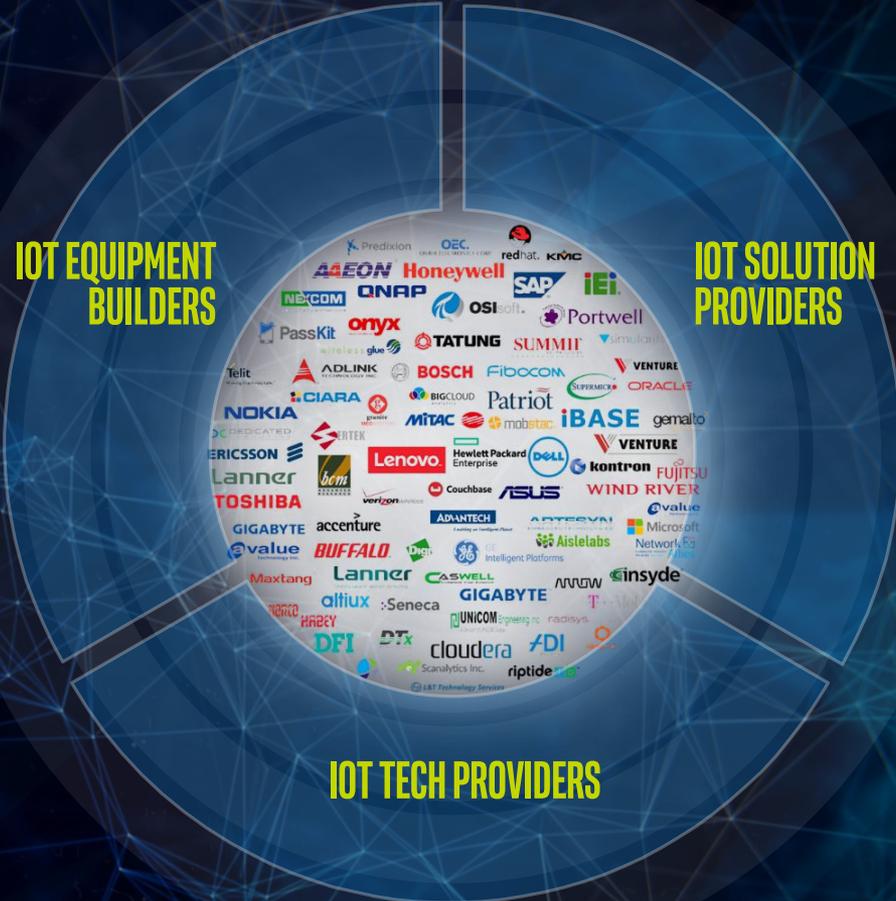
Source: 1. IBM Customer [Case Study](#); 2. http://www.wika.us/solutions_predictive_maintenance_en_us.WIKA; 3. Forbes, August 7, 2016

ECOSYSTEM PARTNERS

IOT EQUIPMENT BUILDERS

IOT SOLUTION PROVIDERS

IOT TECH PROVIDERS



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

Tags: [Internet of Things](#)



IoT Across Industries



IoT Ecosystem Connections

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](#)

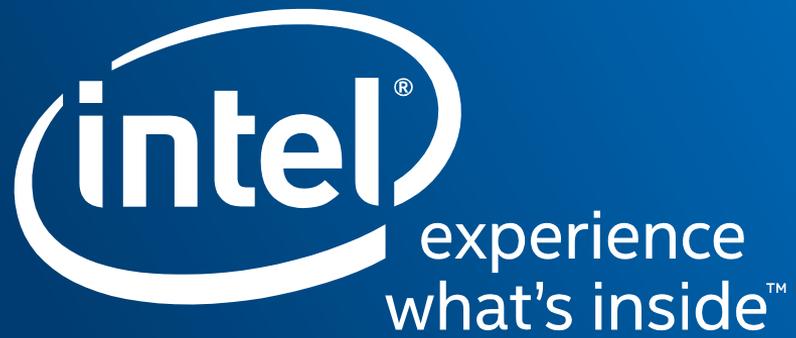


End-to-End Intel® IoT Platform



Intel® Embedded Design Center

WWW.INTEL.COM/HPC/
WWW.INTEL.COM/IOT
WWW.INTEL.COM/IT/



STANDARDIZE THE IOT INDUSTRY



194%
YOY GROWTH +

215+
MEMBERSHIP

CAICT
中国信息通信研究院
China Academy of Information and Communications Technology

SAP

Schneider
Electric

OPEN
CONNECTIVITY
FOUNDATION™

50%
YOY GROWTH +

150+
MEMBERSHIP

CAICT
中国信息通信研究院
China Academy of Information and Communications Technology

IBM

ZTE

 **Microsoft**

OpenFog™

20+
RECENTLY ANNOUNCED

intel

DELL

CISCO

ARM

PRINCETON
UNIVERSITY

 **Microsoft**

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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

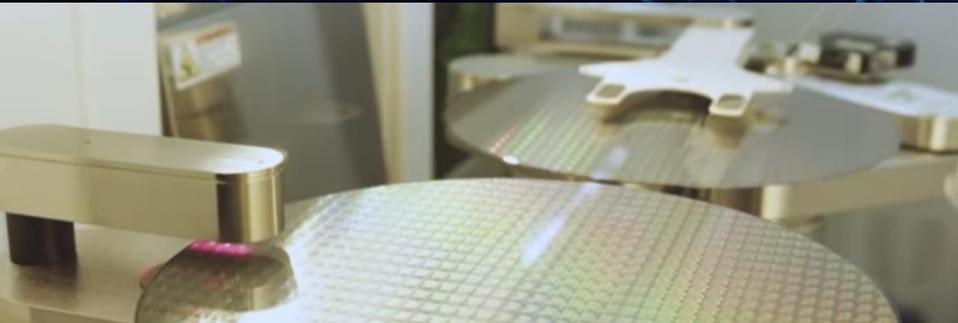
Data moves from the tool, sensors and OT platform to data center where analytics are run to solve business issues

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



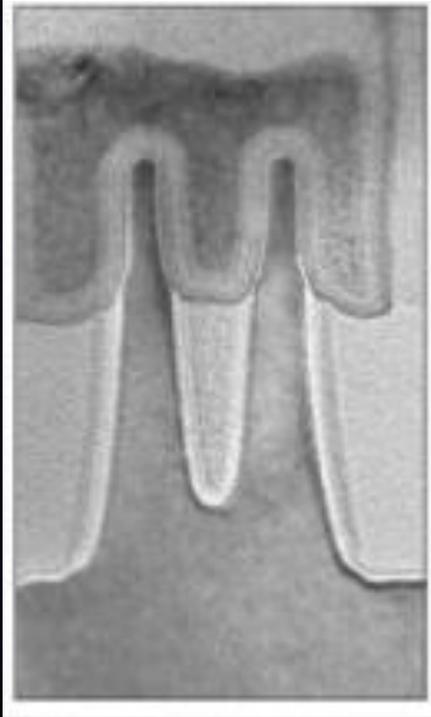
THE MOTIVATION

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.



INTEL OPERATES WORLD-CLASS, HIGHLY OPTIMIZED AND FULLY INTEGRATED FACTORIES

Data Collection

Data Aggregation & Actions

Data Scoring, Analytics & Model Updates

Business Intelligence Result Sharing



Factory Floor

- 2,000+ thick clients (all Intel® x86 64-bit desktop platforms)
- 1,000-2,000 production semiconductor tools
- 200,000+ feet of Ethernet cable
- 100+ access switches and WAP



Automated Materials Handling System

- Robotic delivery and storage systems
- 150+ high speed interbay robotic delivery vehicles
- Covers 400k sq ft of cleanroom space
- 5+ miles of vehicle track on the ceiling; 200+ overhead robotic delivery vehicles
- 200+ high-intensity power distribution panels



Data Center

- 600+ servers (all Intel x86 64-bit)
- 200+ routers, switches, firewalls
- >1PB of centralized storage
- MS Windows* and Linux* OS
- 150,000+ feet of fiber
- 200+ routers, switches, firewalls



Security End to End

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