## Leveraging Advanced Manufacturing to Address Challenges in the Automotive Memory Market

### SWTW 2018

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# Agenda

Micron Overview

Industry 4.0

### Automotive Market Requirements and Trends

Memory Test Challenges for Automotive Products



## Driven Collaborative Innovative

### Who We Are

- 40 years strong
- Headquartered in Boise, Idaho, USA
- FY17 net sales of \$20.3B
- World's 3rd largest memory company
- #226 on 2016 Fortune 500
- Over 20,000 patents
- Industry's broadest portfolio of memory and storage technologies
- Trusted advisor to the compute, consumer, networking, storage, embedded and mobile markets



# End Market Driven Business Model



## Compute & Networking

Relentless dedication to providing the memory technology and packaging solutions for Networking, Cloud Server, Enterprise, Graphics, and Client markets.

### Mobile

Deep understanding of the mobile computing architecture coupled with leading edge memory solutions.

### **Embedded**

Application specific expertise and a broad range of reliable, high value memory solutions concentrated on the Automotive, Industrial, Consumer & Connected Home markets.

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### Storage

Advanced storage solutions to meet a wide spectrum of customer needs—from low-density, cost-effective embedded storage, to client and performance-class SSDs.



# **Expansive Product Offering**

DRAM	DRAM Modules	NAND Flash	Managed NAND	NOR Flash	Multichip Packages
<ul> <li>DDR</li> <li>DDR2</li> <li>DDR3</li> <li>DDR4</li> <li>GDDR55</li> <li>GDDR5X</li> <li>LPDRAM</li> <li>RLDRAM®</li> </ul>	<ul> <li>FDDIMM</li> <li>LRDIMM</li> <li>Mini-DIMM</li> <li>NVDIMM</li> <li>RDIMM</li> <li>SODIMM</li> <li>SORDIMM</li> <li>UDIMM</li> <li>VLP Mini-DIMM</li> <li>VLP RDIMM</li> <li>VLP UDIMM</li> </ul>	<ul> <li>3D NAND</li> <li>Enterprise NAND</li> <li>Serial NAND</li> <li>Serial NAND</li> <li>TLC, MLC, SLC</li> <li>Storage</li> <li>Client SSD</li> <li>Enterprise PCle N SSD</li> <li>Enterprise SAS S</li> <li>Enterprise SATA S</li> <li>Industrial microS</li> </ul>	<ul> <li>eMMC</li> <li>Embedded USB</li> <li>UFS</li> <li>Adva</li> <li>Hybrid</li> <li>Persista</li> <li>NV</li> <li>SD</li> <li>SSD</li> <li>Migh Persista</li> <li>D Cards</li> </ul>	<ul> <li>Parallel NOR</li> <li>Serial NOR</li> <li>Xccela<sup>™</sup> Flash</li> </ul> nced Solutions Memory Cube ent Memory /DIMM XPoint <sup>™</sup> erformance ting	<ul> <li>eMMC-Based MCP</li> <li>NAND-Based MCP</li> <li>NOR-Based MCP</li> </ul>

Software

## **Global Manufacturing Scale**





# Micron Foundation

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Each year the Micron Foundation donates an estimated \$5 million across our major site communities, all over the world.



# Enabling Advanced Manufacturing in today's Industry 4.0



### **Unprecedented Data Growth Driving System Evolution**

Networking **Cloud / Big Data Internet of Things** 27.1 billion networked Global IP traffic grows Data center storage installed at a CAGR of 24% from capacity to grow ~5X to 1.8 ZB devices by 2021 between 2015 and 2020 2016 to 2020

> Mobile / Client Global mobile data traffic to rise ~7X between 2016 and 2021

Enterprise

Exploding demand for inmemory database solutions Automotive 98 percent of cars will be connected to the internet by 2020



## Advanced Manufacturing powered by Big Data

Visualization Technology

- Dashboards
- Remote Control
   Management
- Mobile devices

#### **Advanced Planning**

- Connectivity
- Modelling
- Optimization
- Scheduling
- Forecasting

#### **Advanced Platform**

- Sensors in Fab/Facility (IoT)
- Real Time Process Control
- Autonomous robots



#### **Big Data Analytics**

- Artificial Intelligence
- Machine / Deep Learning
- Predictive Analytics
- Graph Analytics

#### Intelligence

- Innovation
- Knowledge sharing across organization
- Scalable solution across enterprise

#### Partnership

- Supplier Engagement and Collaboration to innovate self diagnostic equipment
- Transparency of tool data



### **Big Data Fast Facts in Micron**



### **Advanced Manufacturing Applications**



### **Remote Operation Center (ROC)**





### **Quality: Sensor Based Fault Detection (IoT)**

Pressure and Temperature Sensor	Detect facility equipment failure
Acoustics Sensor	Detect scratches, arcing, mechanical failure
Vibration Sensor	Detect pump and robot failure
Image, Video Sensor	Detect defects and 'hotspots'





## **Quality: Predictive Maintenance**



#### Identify degradation signal from tool

Monitor trend and predict remaining useful life

Prevent quality issues before it happens

Alert on dashboards / Send email notifications / Trigger preventive maintenance schedule

### **Yield: Deep Learning**

#### **POWERFUL ANAYLYTICS TO MEET THE DEMAND OF UNCERTAINTY**

- Recognize image with deep learning
- Classify defect
- Diagnose source of defect from tool / process





### Partnership with Suppliers to engineer the future of Manufacturing



# Automotive Market Requirements and Trends



## **The Next Big Trend**

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DRAM is the oxygen that feeds the A.I. and VR/AR bonfire, and data from NAND storage the fuel.

- Bill Joy, founder of Sun Microsystems

A.I. + Autonomous Driving

Mobile + Social Media Era



Source: DRAM and NAND revenue for 2000 – 2016 sourced from WSTS. DRAM and NAND revenue for 2017 – 2021 sourced from Micron FSG A1-18 forecasts.



### **Levels of Autonomy**

#### Human

#### Machine

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http://www.sae.org/misc/pdfs/automated\_driving.pdf

### **Solutions Enabling Autonomous Driving**



### **Automotive Memory Growth**



### **Automotive Memory Requirements**

## Quality and Reliability

IATF 16949 2016 Automotive Certification

### Zero Defect Target Approach

Dedicated Automotive Screenings Temperature Ranges from -40C to +150C

Screenings vary depending on process & products families



## Memory Test Challenges to Support Automotive Products



## **Memory Test Complexity**



- Since SWTW 2013...
  - DRAM 1TD wafer test is mainstream
  - -40C to 150C automotive temperature requirements
  - Reduced probe pad size and pitch
  - Higher die-per-wafer, higher parallelism = greater power and thermal management overhead



### Full Wafer Contact Challenge at Extreme Temperatures

#### **Full-Wafer Scrub Mark Placement**



- Probe card coefficient of thermal expansion (CTE) must be tuned to match wafer over test temperature range
- Extended automotive temperature products often require separate probe cards for cold & hot testing

### Wafer Test Thermal Challenges

- Higher wattage prober chucks are needed for memory wafer test
- Higher DPW, Higher Parallelism = Higher Wattage



**Prober Chuck A** 

**Prober Chuck B** 

Capable

Micron

**Die-Per-Wafer & Parallelism** 

### **ATE Handler Thermal Challenges**

- Convection (chamber based) handlers cannot meet thermal requirements today
- Need innovative hybrid convection / conduction solution



## **High Frequency Test**

- High frequency test solutions needed for Graphics DRAM and High Performance Near Memory pushing 14Gb/s to 20Gb/s
- Memory probe cards limited to ~3Gb/s to 4Gb/s
- Traditional pogo test sockets cannot support >4Gb/s; pressure conductive rubber sockets or new technology needed



## **High Frequency Wafer Test**

 Probe card capability limited due to interconnects, signal line length, impedance mismatch, etc.

 High frequency probe card cost is prohibitive



## Multi-Chip Package (MCP) Test Complexity

- MCP complexity is Increasing
- Wafer level test coverage added to increase overall package yield



### Wafer Test vs Package Test Cost

- Wafer Test Cost can be higher than package
- Higher yields for multi die packages has greater impact on overall Cost





### **Automotive Quality Approach**

- Tighter Process controls and additional Test Coverage
- Continuous Improvement throughout the manufacturing process





### **Big Data Application for Automotive**



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