SEVENTEENTH ANNUAL

BiTS™

Burn-in & Test Strategies Workshop

March 6 - 9, 2016

Hilton Phoenix / Mesa Hotel
Mesa, Arizona

Archive- Session 1

Presentation / Copyright Notice

2

Session 1

Ila Pal
Session Chair

BiTS Workshop 2016 Schedule

Frontiers Day

Monday March 7 - 10:30 am

Marketplace Report & Thing One, Thing Two, and Test Them We Do

"Marketplace Report"

Ira Feldman - Feldman Engineering Corp.

"How Internet Of Things Will Change Back End Processing"

Mike Frazier & Laurie Wright - Xcerra Corporation

"Serialized Programming Solutions for IoT Secure Elements"

Robert Howell - Exatron

"Internet of Things Testing Challenges"

Anthony Lum - Advantest

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Internet of Things Testing Challenges

Anthony Lum & Dave Armstrong
Advantest

2016 BiTS Workshop
March 6 - 9, 2016

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IoT is Creating Many Challenges for Test

Device Size	Device Type
Small Size Devices	Smart Sensors Personal Sensors Medical Sensors
Medium Size Device	Cell phones Automotive devices APUs / GPUs/ MPUs
Large Size Device	Communications infrastructure components Server devices FPGAs

Internet of Things Testing Challenges

2

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Small Size IoT Devices

GoPro Hero4
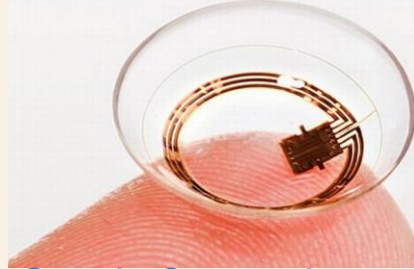
Google Contact Lens
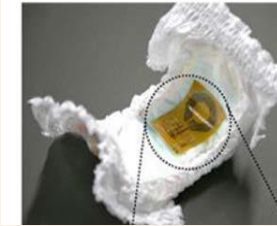
Wireless Diaper (University of Tokyo)

Wireless Tire Pressure Sensor

Low Cost Testing is Critical to This Class of Device

Sensors/year

100,000,00

10,000,00

1,000,00

100,000,000,000

10,000,000,000

1,000,000,000

100,000,000

10,000,000

	"Abundance"
△	QCOM Swarm Lab, UCB
◆	Bosch
■	Hewlett-Packard
●	Intel
■	TI Internet devices
—	Yole MEMS Forecast, 2012
—	TSensors Bryzek's Vision
—	10 year slope
—	Mobile Sensors Explosion

56%/√

21%/√

222%/√

2007   2012   2017   2022   2027   2032   2037
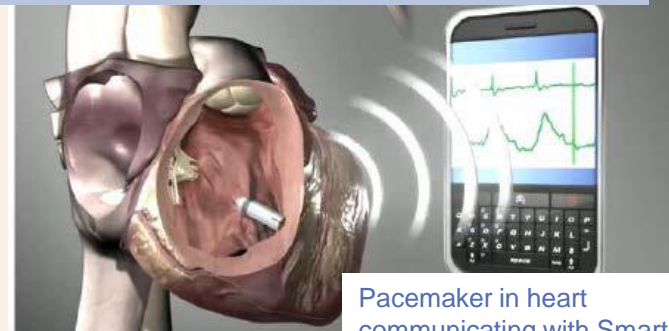
Pacemaker in heart communicating with Smartphone.

http://www.tsensorssummit.org

Internet of Things Testing Challenges

3

Sensor Testing

Creative solutions are needed to test the various sensors on the industry's roadmap.   There is a very long list of anticipated sensors:

- Accelerometer
- Magnetometer
- Gyroscope
- Ambient
- Light
- Pressure
- Touch
- Fingerprint
- Health
- Environmental
- UV & RGB
- Humidity
- Microphone
- Radiation

- Temperature
- Conductivity
- Camera/Optical
- Micro-Speakers
- eNose

- pH
- Humidity
- Galvanic Skin Response
- Blood chemistry / DNA

Accelerometers and gyroscope testing requires elaborate fixtures.

(courtesy of Multi-Test)

Internet of Things Testing Challenges

4

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Low Cost Testing

There are two solutions to the cost of test question:

1. Higher site counts on existing ATE
   + Most effective for small pin-count devices.
   + Supports the testing of very complex devices.
   + Often times leverages existing hardware.
   + May require "massive multi-site testing" to be cost effective

2. Lower cost testing hardware
   + Lower tester costs but possibly higher handler costs.
   + Easier test programming costs – looks and feels like a bench instrument.
   + Easier and lower cost fixturing.
   + Most effective when volumes don't justify a multi-site ATE solution.
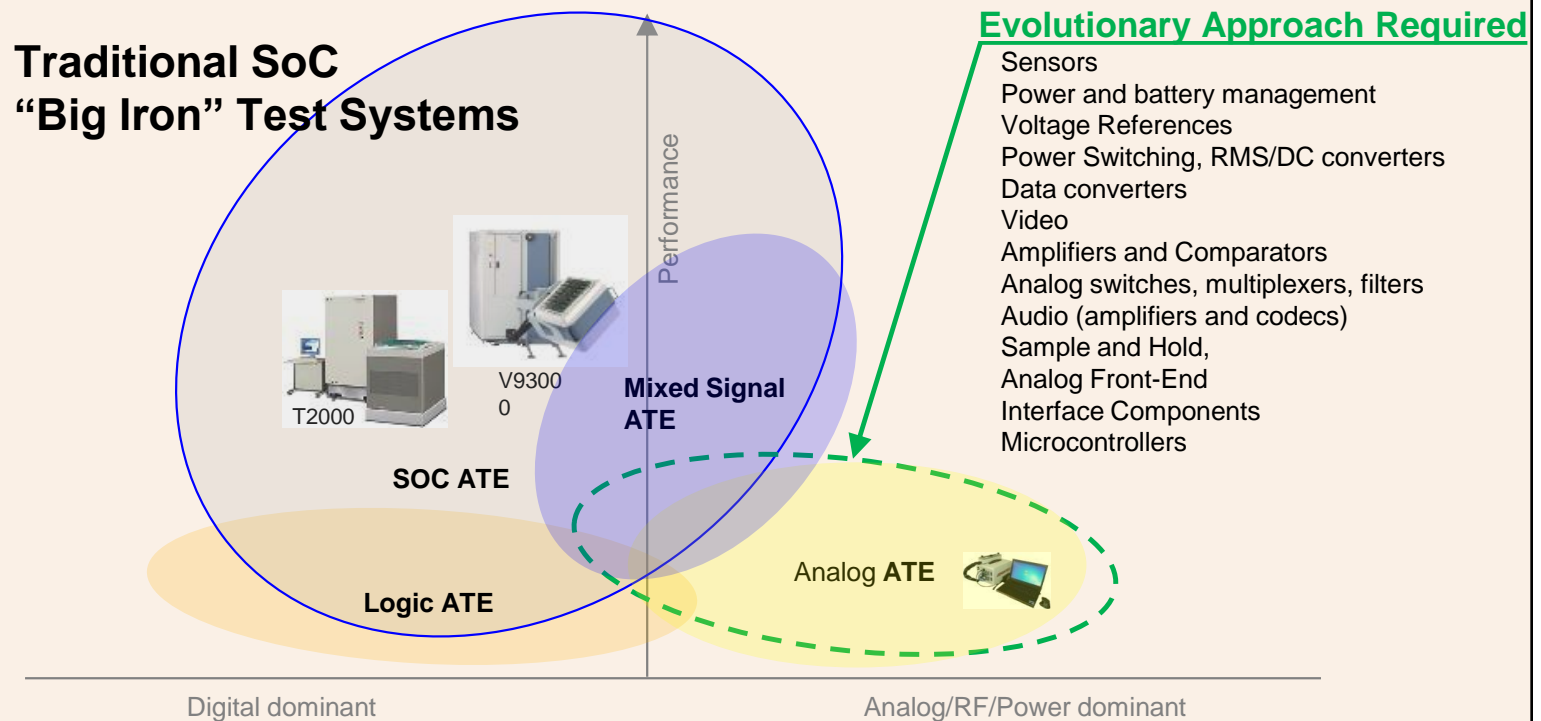
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High Site Count ATE

Small IoT device testing requires new levels of multi-site testing.   This in turn requires new levels of multi-site efficiency.

– Multi-site testing is moving is pushing to higher site counts.

– Multi-site efficiencies (MSE) needs to be > 99.5% in order to support this trend cost effectively.

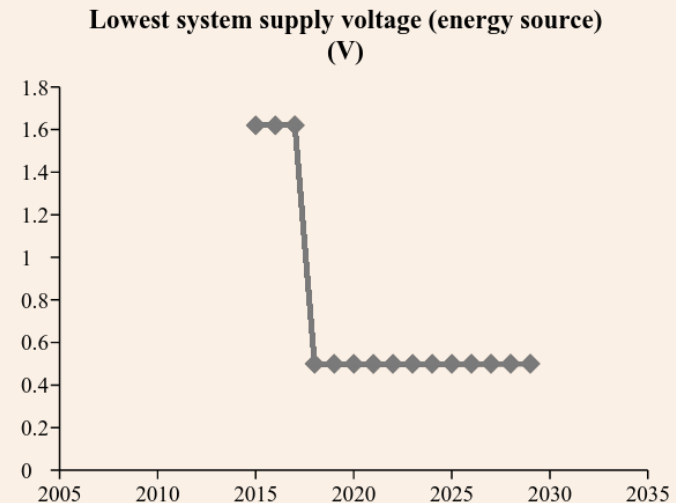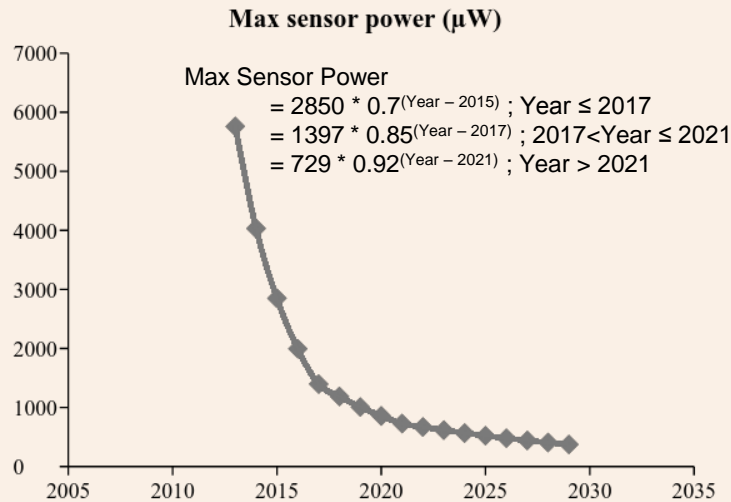Internet of Things Testing Challenges

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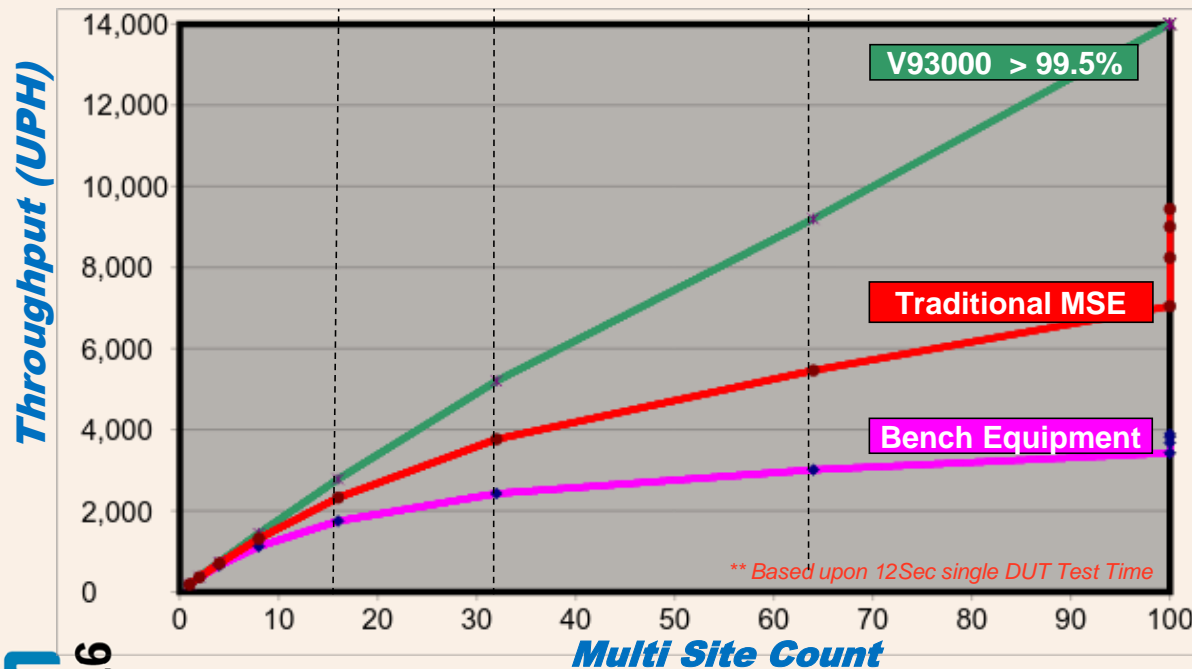
Lower Cost Test Hardware

Need for a low-cost highly-capable test system as an evolutionary step for the industry. Example: EVA (Evolutionary Analog Test) modular test system

Traditional SoC "Big Iron" Test Systems

Performance

V93000

T2000

SOC ATE

Mixed Signal ATE

Logic ATE

Analog **ATE**

Digital dominant

Analog/RF/Power dominant

Evolutionary Approach Required

Sensors
Power and battery management
Voltage References
Power Switching, RMS/DC converters
Data converters
Video
Amplifiers and Comparators
Analog switches, multiplexers, filters
Audio (amplifiers and codecs)
Sample and Hold,
Analog Front-End
Interface Components
Microcontrollers

Internet of Things Testing Challenges

7

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Long Term Trends for Small Sensors

• Sensor supply voltages are expected to scale down significantly in the future. This will result in test challenges with lower voltages and noise levels.

• Energy harvesting will also complicate device testing when they no longer require external power.

Max sensor power (µW)

Max Sensor Power
$$= 2850 * 0.7^{(Year - 2015)} \; ; \; Year \le 2017$$
$$= 1397 * 0.85^{(Year - 2017)} \; ; \; 2017 < Year \le 2021$$
$$= 729 * 0.92^{(Year - 2021)} \; ; \; Year > 2021$$

Lowest system supply voltage (energy source) (V)

Andrew B. Kahng ITC-2015 keynote, October 7, 2015

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Medium Size IoT Devices

Automotive Electronics

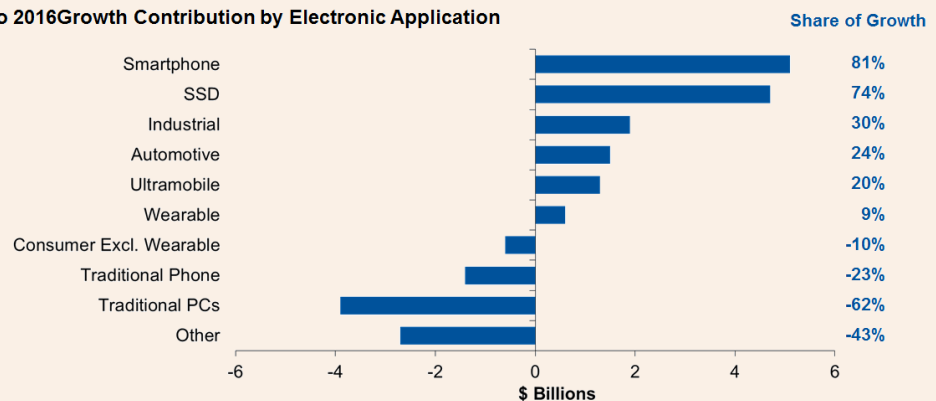### Gaming Electronics
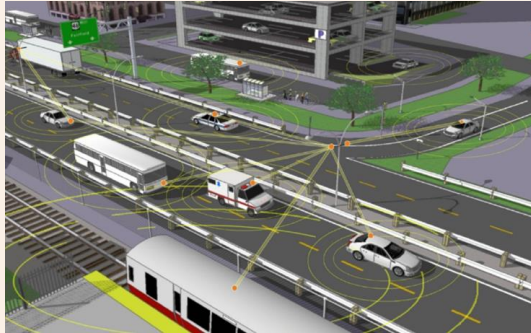
Smart Phones

[source] U.S. NHTSA, August 2014

Smartphone and Automotive testing is critical.

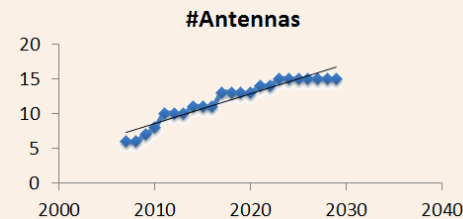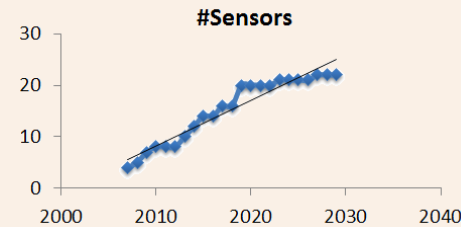**2015 to 2016 Growth Contribution by Electronic Application**

Share of Growth

Application	Share of Growth
Smartphone	81%
SSD	74%
Industrial	30%
Automotive	24%
Ultramobile	20%
Wearable	9%
Consumer Excl. Wearable	-10%
Traditional Phone	-23%
Traditional PCs	-62%
Other	-43%

$ Billions

Source: Gartner, September 2015 "Semiconductor Forecast Database, Worldwide, 3Q15 Update"

9

Internet of Things Testing Challenges

Smartphone Testing Needs

- Smartphone capabilities and complexity is expected to continue to grow. In the 2014 update the ITRS showed the trends below.

  – More Cores

  – More Sensors

  – More RF Capabilities

  – More Security Features

#AP cores

#GPU cores

$$\text{#GPU cores} = 2.0 * 1.26^{(\text{Year}-2007)}$$

#Sensors

#Antennas

* Plots from ITRS Test Roadmap 2014

Internet of Things Testing Challenges

10

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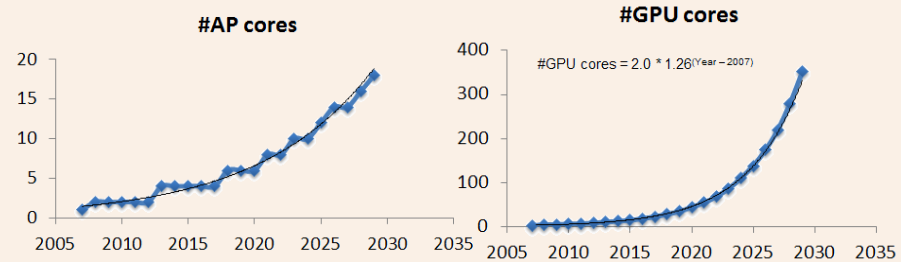
Automotive Device Types

- Four key device types are driving the automotive market:
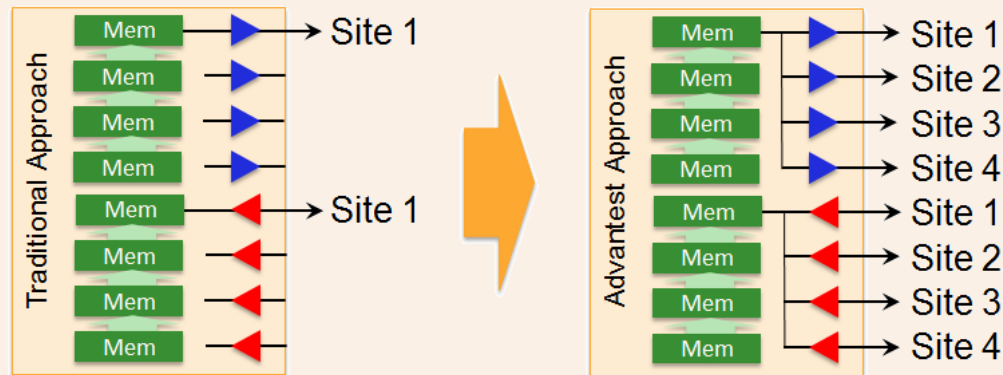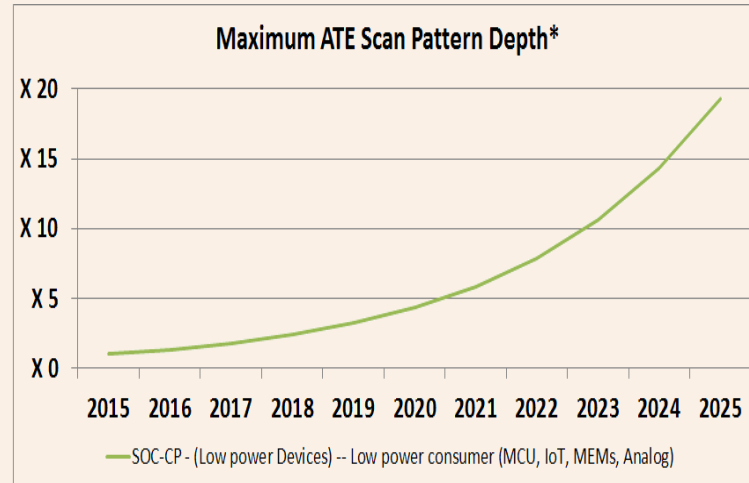
  – Autonomous Driving
    ➔ Radar
      ➔ Vision recognition
    ➔ GPS, local intelligence

  – Connectivity
  ➔ Ethernet communications
      ➔ Car-to-car communications

  – Infotainment
  ➔ GPS, mapping
  ➔ Video interfaces
      ➔ Stereo

  – Security
  ➔ Collision avoidance
      ➔ Security is critical for connectivity
      ➔ Vehicle & Driver status monitoring

Automotive Testing Trends
- More Scan Vectors
- More Analog
- More RF
- More Tests
- More Temperature Testing

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11

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Digital Testing Needs

- Scan depths are expected to double every three years.*

- Memory pooling provided necessary scan depths but can cost pins and limit #sites.

- Broadside scan together with memory pooling provides super deep (multi-Gb) scan on multiple sites without loosing any pins.
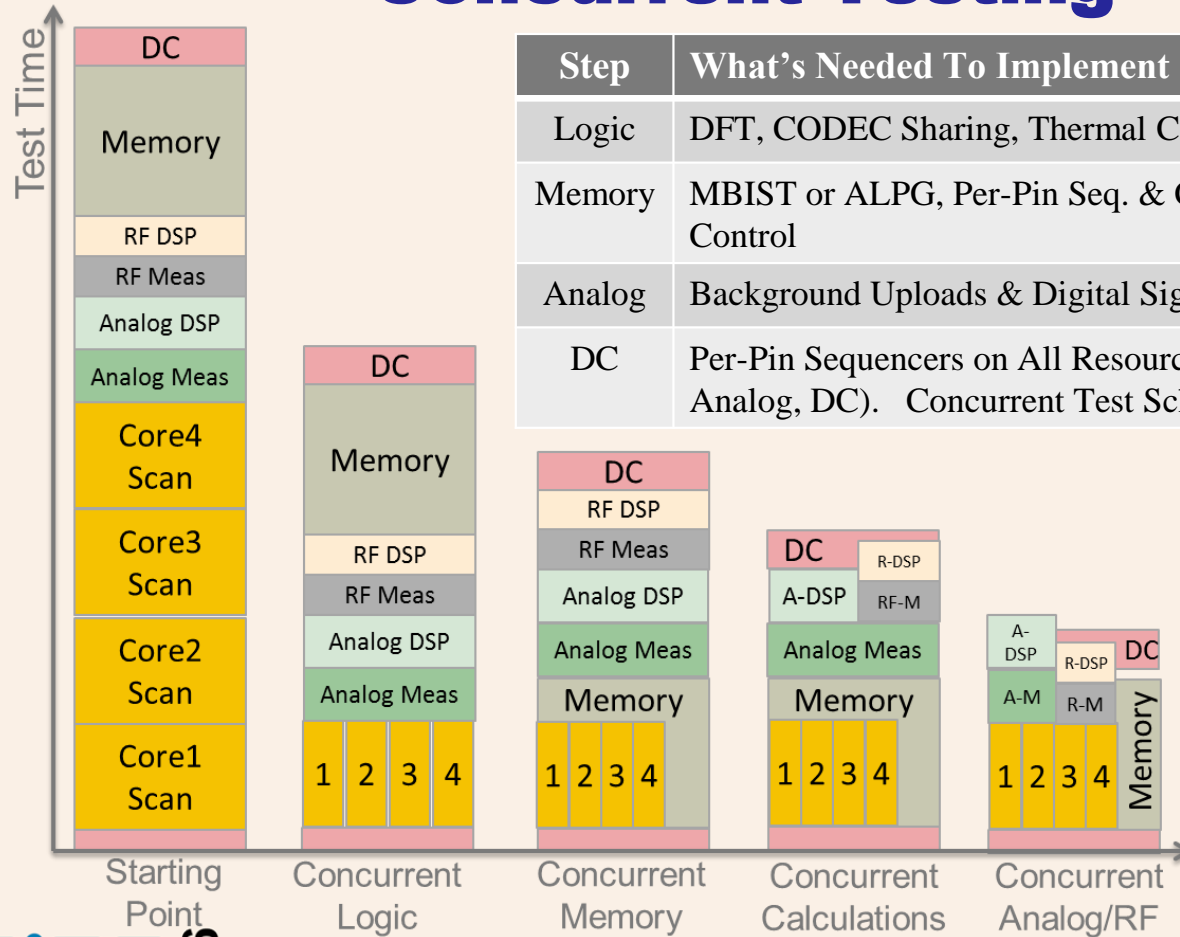
Maximum ATE Scan Pattern Depth*

SOC-CP - (Low power Devices) -- Low power consumer (MCU, IoT, MEMs, Analog)

Internet of Things Testing Challenges   * ITRS Test Roadmap 2015

12

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RF / Analog Testing Needs

RF

- – LTE-A & LTE Cat 10+
- – True parallel RF testing
- – Higher site counts

Analog

- – Many more power supplies per DUT
- – Floating supplies
- – Lower operating voltages drive finer precision
- – Higher site counts

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Test Time Reduction Needs Met by Concurrent Testing

Step	What's Needed To Implement
Logic	DFT, CODEC Sharing, Thermal Control
Memory	MBIST or ALPG, Per-Pin Seq. & Clock, Thermal Control
Analog	Background Uploads & Digital Signal Processing
DC	Per-Pin Sequencers on All Resources (Digital, RF Analog, DC). Concurrent Test Scheduling Software

Internet of Things Testing Challenges

Note: Conceptual example only.

14

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Device Handling Needs (Sites/Temperature)

- SOC Handling
  - More Sites (16 or more)
  - Finer pitch < 0.3 mm
  - Thinner parts < 500um
- Thermal
  - Wide temperature range (-40C to 175C)
  - Ability to handle high power (>200W)

Advantest M4871
Flexible SOC Device Handler

Key technologies:

- Fast responding high-capacity ATC
- Junction temperature feedback
- Tight integration with ATE = TestCell
- Fine pitch with Vision Alignment
- "SoftTouch" socket insertion

Pre-soak at Buffer Plate and Socket (M4871 ATC experiments)

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15

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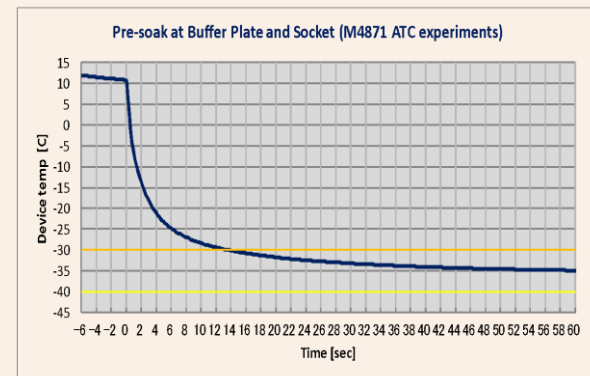
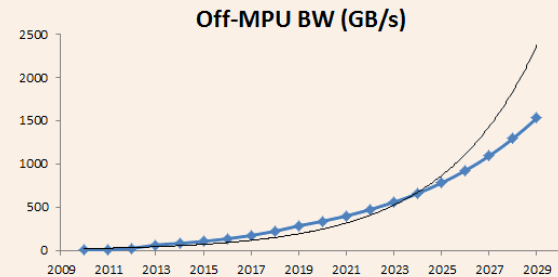# Large Size IoT Devices

Server Devices

Network Infrastructure
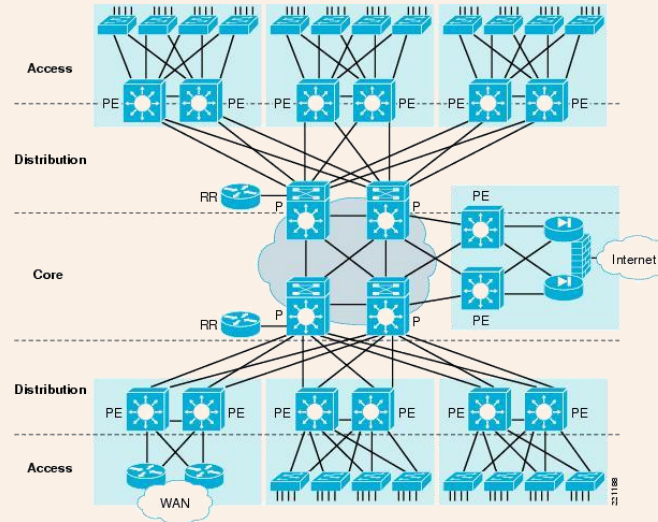
FPGAs
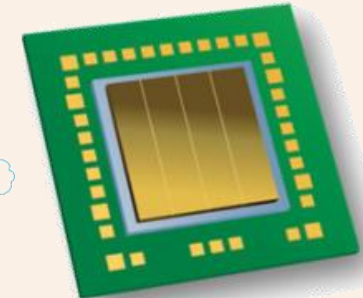
Internet traffic will exceed 88.4 Exabytes per month in 2016

This is expected to double by 2019**

1 Exabyte is 50,000 years worth of video

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16

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Large Device Product Trends

- The Need for **More Data** is driving this class of devices.

  - Interface speeds

    Higher and Higher Speeds
    Pushing the need for Optical I/O

  - Memory bandwidth

    The internet uses lots of data

  - Power constraints

   Adding more intelligence is only possible if less power is used or better thermal solutions are pursued.

Off-MPU BW (GB/s)

DRAM BW (GB/s)

DRAM BW
$= 51.2 * 1.26^{(Year - 2013)}$

GFLOPS/W

GFLOPS/W
$= 0.4 * 1.43^{(Year - 2010)}$; Year < 2019
$= 14.3 * 1.15^{(Year - 2019)}$; Year ≥ 2019

* Plots from ITRS Test Roadmap 2014 & 2015

Internet of Things Testing Challenges

17

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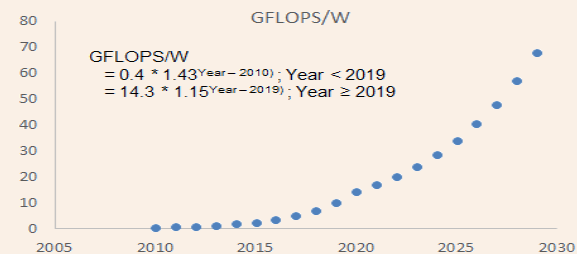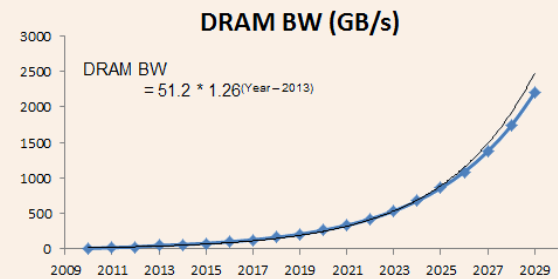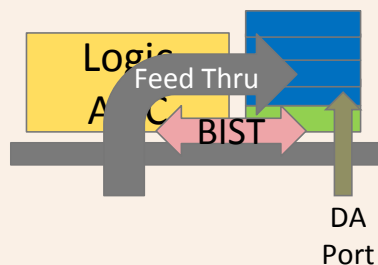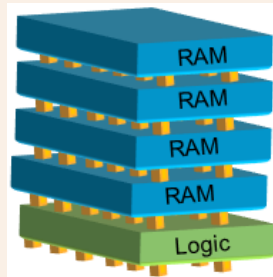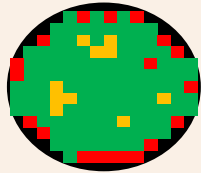
Multi-Die Packaging

- Know Good Die Testing
  - Big movement to ALL testing before expensive assembly.
  - New test incretions common.
  - Big cost savings possible.
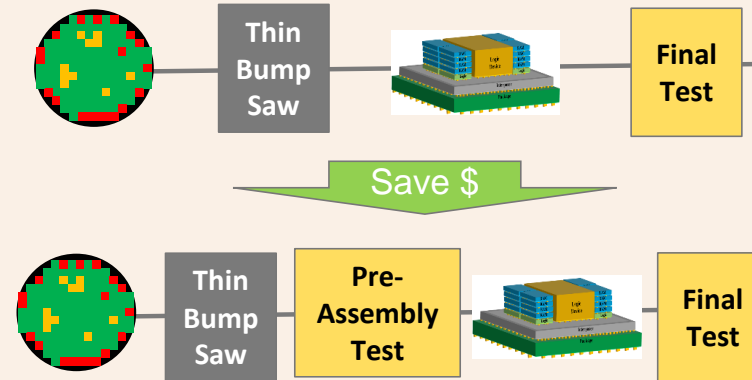
- Probe Card Cost Skyrocketing
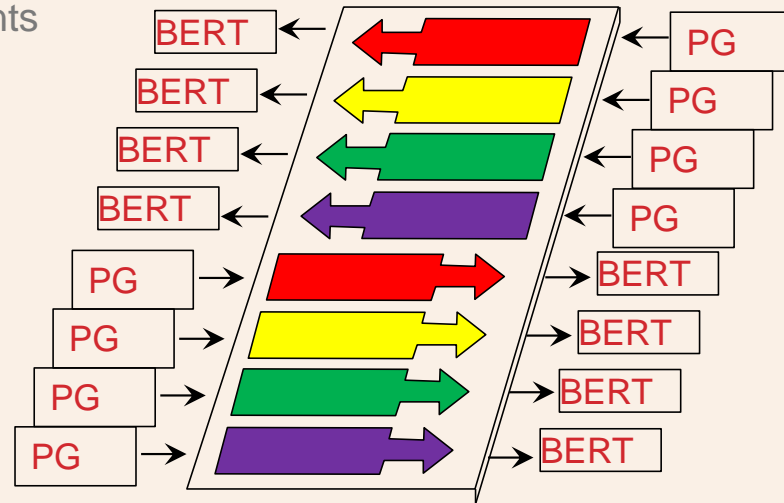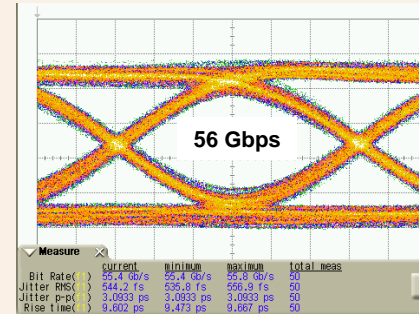 - Fine pitch probes are becoming new capital acquisitions.

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18

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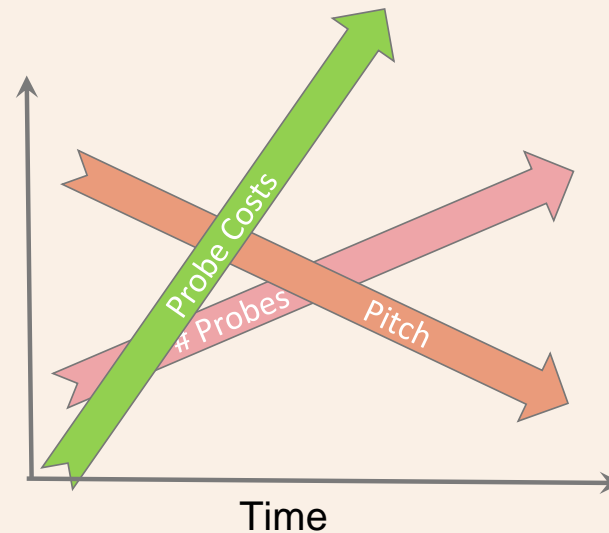
Testing the Memory in Large IoT Devices

- • Wafer memory test is mature:
  - ➢ Test times will increase with density.

- • Stacked memory test methods are being developed:
  - ➢ As speeds increase performance matching between die could be an issue.
  - ➢ Concerns for Known-Good-Stack

- • Final assembly memory test is a big concern:
  - ➢ BIST from ASIC?
  - ➢ Memory test feed through ASIC?
  - ➢ DA port testing?
  - ➢ or ???

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19

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High Speed I/O Is At The Core of the Internet

- Electrical signaling requirements are up to 50Gbps requiring specialized test solutions.

- Optical signaling test requirements are up to 100Gbps. Optical I/O and fixturing greatly complicate these test solutions.

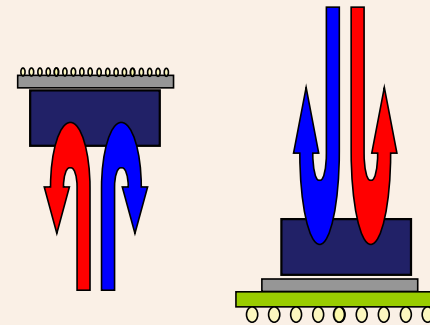- Further challenges occur when high speed I/O get integrated in 2.5D DUT.

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20

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Cooling High-Power Large IoT Devices

- Low thermal resistance is key when doing at-speed testing of large high-power devices.

t = thickness of the layer

ΔT = temperature drop
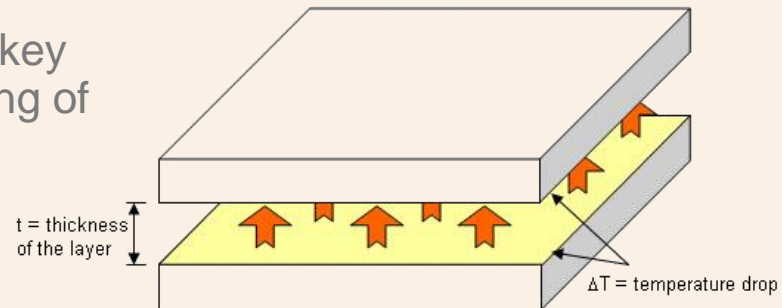
Heat power flowing through the contact area
Surface area of the contact

- Fully integrated fast responding thermal system AND fast responding power system are a MUST if you will avoid thermal run-away.
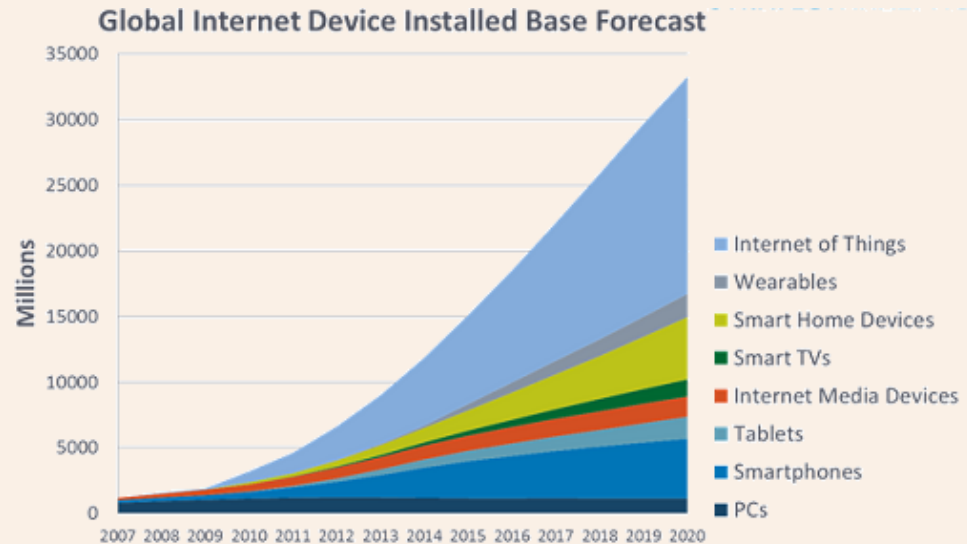

Die Testing

Package Testing

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21

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Summary

- The market growth for IoT devices looks great.

Global Internet Device Installed Base Forecast

Source: Strategy Analytics, October 2014

- IoT test challenges require IoT specific solutions. Many challenges have been solved, some remain… We're working hard on those!