# MEMS Sensor Testing Challenges and Requirements

**Nigel Beddoe**

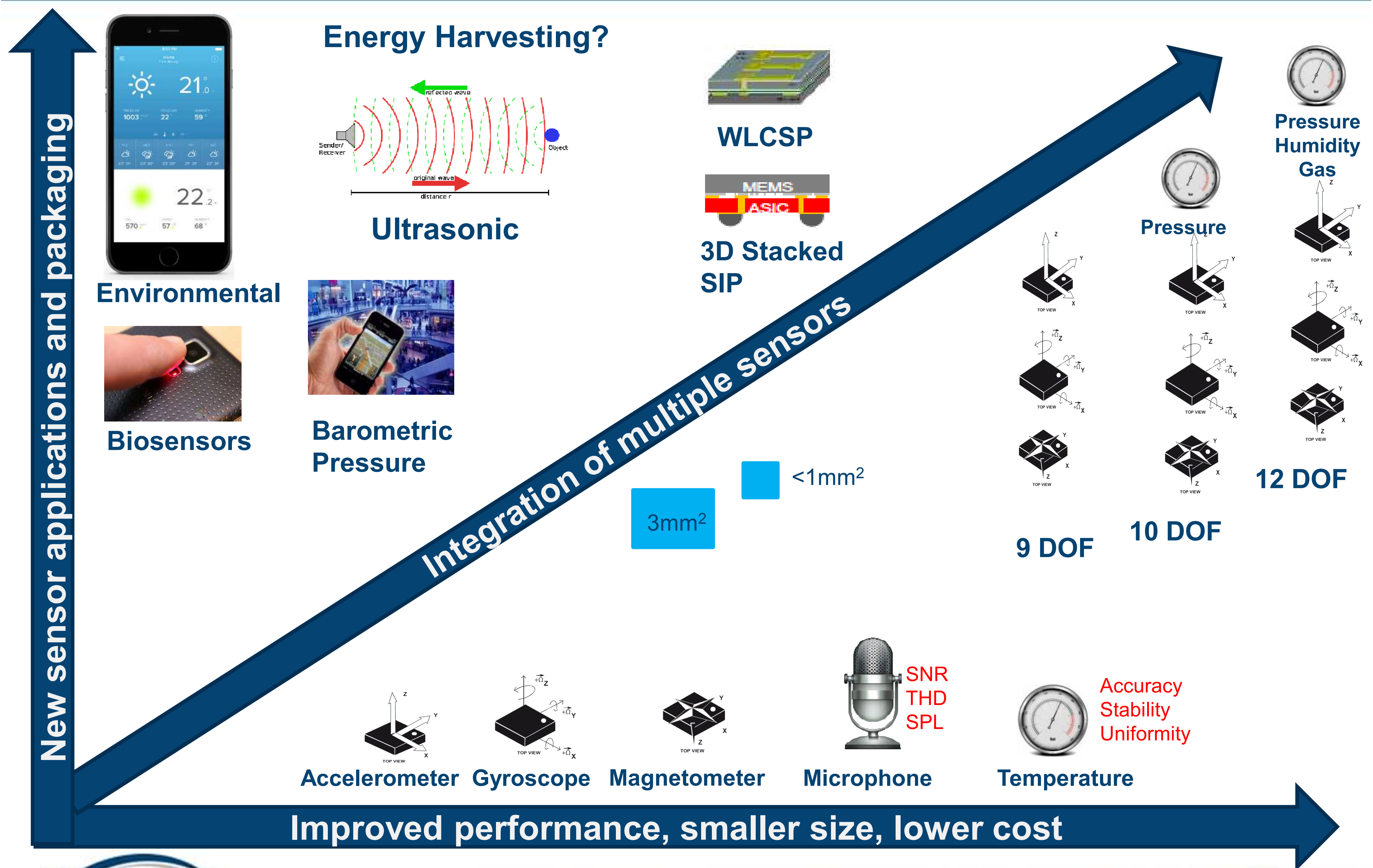
**Xcerra Global Business Development**

# Agenda

- Sensor Trends and Market Drivers
- Sensor Testing Challenges
- Sensor Testing Requirements
- Sensor Test Cell for High Volume Manufacturing

accelerometer gyroscope compass magnet pressure humidity gas temperature microphone optic oscillator

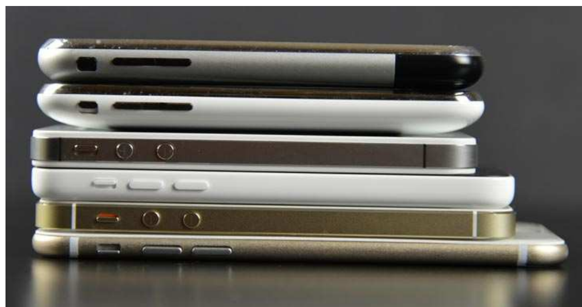
# Sensors Trends



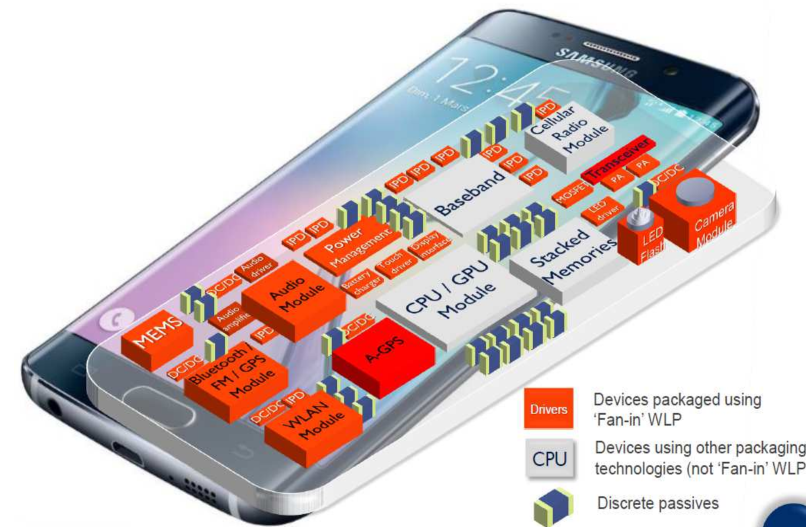
# Sensor Trends WLCSP

- Wafer Level Package (Fan-In) unit count is growing at a CAGR of 9% between 2014 and 2019.
- Demand for WLCSP driven mainly by mobility customers due to low cost and smaller form factor (<50mm$^2$)
  - **Sensors**, Connectivity, PMIC, Touch Controller, Camera, Transceiver/PA,…….
- Automotive and Internet of Things markets expected to grow MEMS WLCSP

Fan-in Wafer Level Packaging Market and Technology Trends Report, Yole Development May 2015

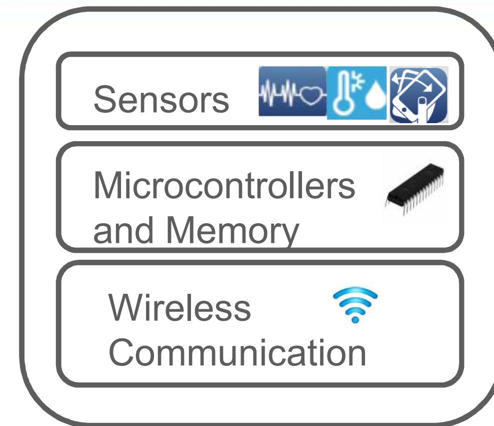


Evolution of the iPhone

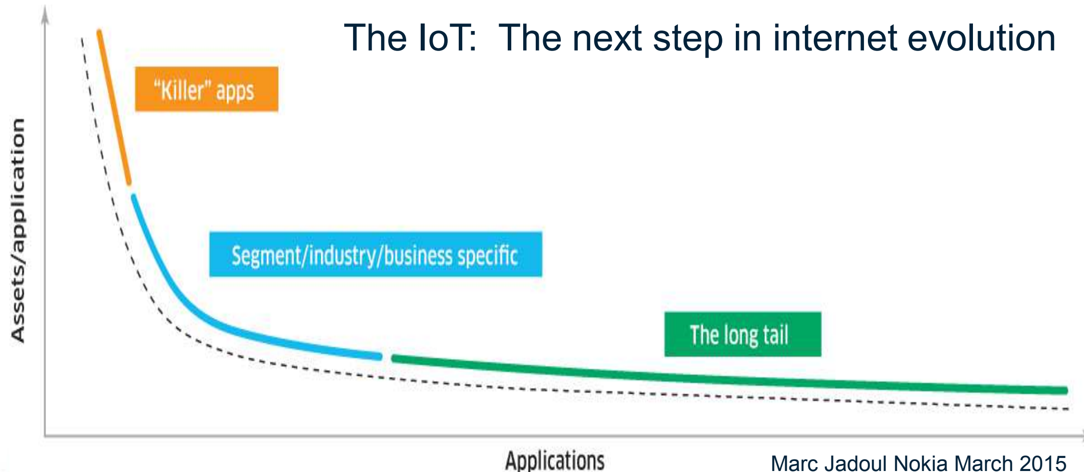


# Sensor Trends Internet of Things

- The number of IoT connected devices is expected to grow to 30 – 50B devices by 2020.**
- Wide variety of sensors needed to cover the long tail of applications in every market segment.
- IoT will drive higher levels of integration of sensors, microcontrollers and RF in new innovative packaging (SiP, 3D,…).




**Connected Smart Things**




Marc Jadoul Nokia March 2015

**The "Thing" that senses our world**

Sources: **: (Cisco, Gartner)
Images from Nest, Philips, Ftibit, iCon

# Sensor Testing Challenges

- Stringent technical specifications
  - New sensors require higher performance and better accuracy
  - High performance sensors for competitive advantage and higher ASP

- High volume production and low Cost of Test
  - Billions of sensors shipped every year
  - High parallelism and UPH
  - Faster time to market

- Higher levels of integration
  - Multiple sensors integrated with demanding test challenges

- New technologies and applications
  - Innovative and smaller packaging (WLCSP, SiP, 3D, Embedded)
  - New sensor applications
  - Sensors for all markets (consumer, automotive, medical, industrial…)

# Sensor Testing for High Volume Manufacturing (HVM)

- Custom bench top engineering lab systems struggle to meet HVM requirements.
  - SITRI has the Xcerra solution which not only meets the engineering R&D requirements but is also capable of HVM production.

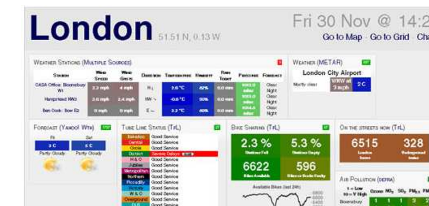
- HVM requires fully automated test cell that output millions of different sensor devices per month for low Cost of Test.

- Testing high accuracy specification sensor devices can be challenging in HVM.
  - High accuracy stimulus with high parallelism
  - Temperature accuracy and uniformity for large number of devices
  - Stable test conditions (low drift during test)
  - Isolation of test from environment (temperature/humidity, noise and vibration of test floor)
  - SNR requirements for Microphones
  - Achieving highest first pass yield

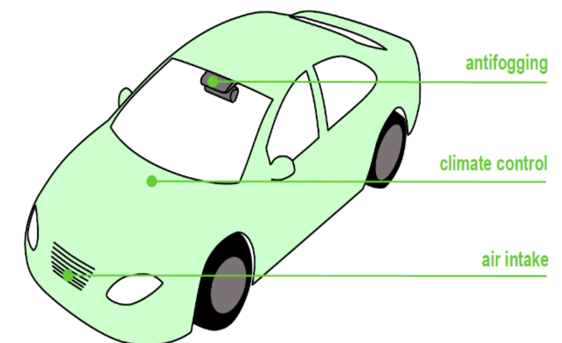
# Environmental Sensors

- ❑ Growth of environmental sensors driven by smart devices
- ❑ Combination of pressure, temperature, humidity and gas in the same package
- ❑ Ideal Gas Law PV=nRT, model to predict the behavior of gas
  - ❑ Pressure related to temperature.
  - ❑ Humidity related to pressure and temperature.
- ❑ HVM test cell needs advanced temperature capability to meet stringent test requirements
  - ❑ Temperature Accuracy ±1°C
  - ❑ Temperature Uniformity ± 0.5°C
- ❑ Need stable test environment before start of test
  - ❑ Fast pressure switching time

Image by BeeWi




CITY DASHBOARD



# Temperature Performance

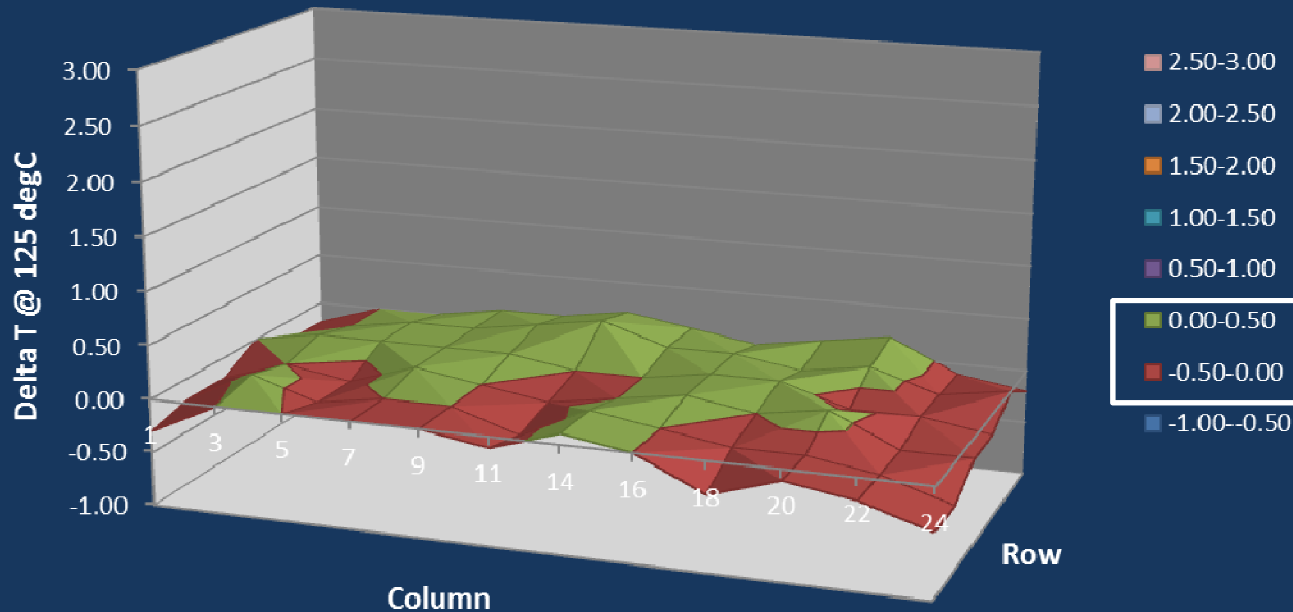



Diagram displays delta T of +/-0.5°C at 125.6°C over nest array

## Performance

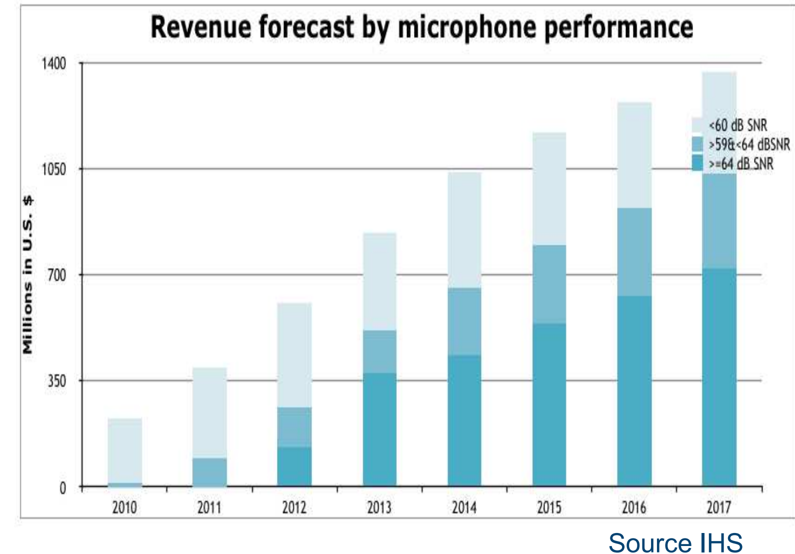
| min | 125.2 | °C |
|---|---|---|
| max | 125.9 | °C |
| mean | 125.6 | °C |

## Setup Tolerance

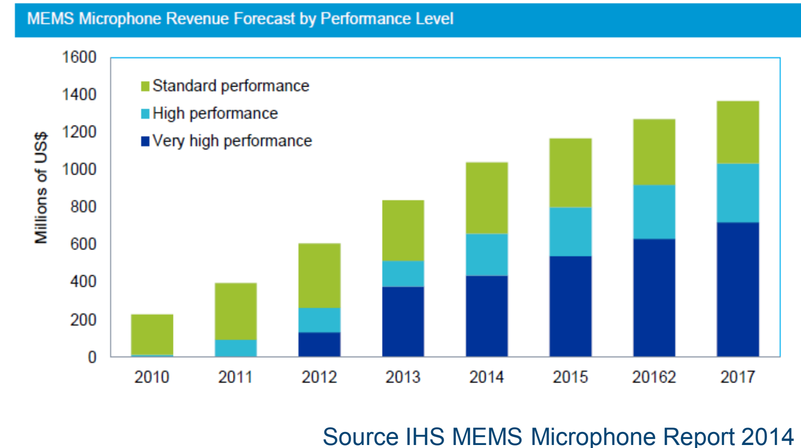
| PT100 Class A Tolerance | | |
|---|---|---|
| dT = +- (0,15 degC + 0,002 x T) | | |
| T= | 125.60 | °C |
| dT= ± | 0.40 | °C |
| T(max) | 126.00 | °C |
| T(min) | 125.20 | °C |

# MEMS Microphones

- ❑ Strong growth with the adoption of multiple microphones in consumer and mobility applications for noise cancellation, accurate voice recognition and HD video recording.
  - ❑ Future smart phones/ear buds will require up to 10 microphones
- ❑ Test solutions for previous generation microphones are not able to meet the technical and volume requirements for future high performance microphones
  - ❑ Need high parallel automated test solutions. Today solutions are able to test //144 sites.
- ❑ New technical requirements
  - ❑ Signal to Noise Ratio (SNR) 75dB
  - ❑ Sound Pressure Level (SPL) 140dB
  - ❑ Total Harmonic Distortion (THD) <0.5%
  - ❑ Digital output
  - ❑ Emerging ultrasonic applications




Source IHS




Source IHS MEMS Microphone Report 2014

# Optical Sensors

- Broad range of applications
  - Light detection for smart phone/home/automobile, bio-sensing (temperature, heart rate monitoring, blood oxygenation), gesture, proximity

- Test challenges:
  - Requires a wide range of light sources
    - RGB, ambient, multiple IR wave lengths, UV
  - Devices are small and fragile (chip on glass)
  - May need access to both sides of the device
  - May require testing at temperature
  - High volumes

Image by Samsung

Source: Check Your Kid's Fever with Your Cell Phone? Samantha Gregory, Nov 2012

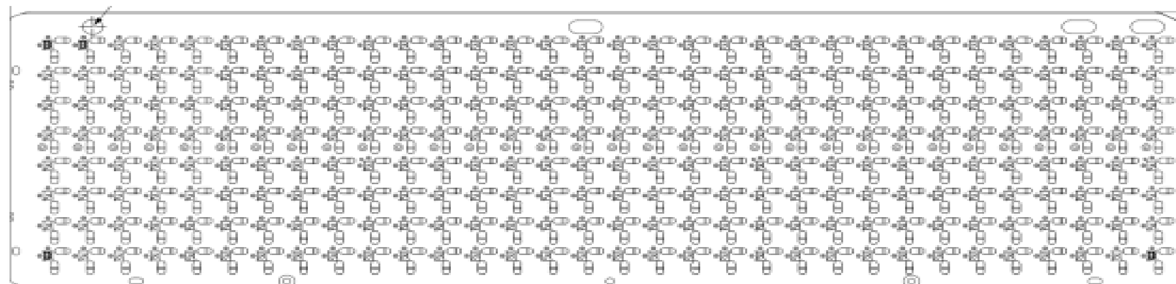
Source: Home Automation Internet Gateway Bandwidth Requirements, Paul Williams, July 2015

# High Parallelism and UPH

- To ship billions of sensors per year and get low Cost of Test, you need high UPH and parallelism
  - Minimize total test cells and CAPEX to meet volume demand
    - Minimize floor space, operators, maintenance, …

- Today 256 sites in a single touchdown.  Target future +300 sites in parallel.

- Challenges in HVM
  - Handling large quantity of devices in parallel
  - Uniformity of stimulus
  - Uniformity of temperature across all devices throughout test for high yield
  - Contacting fine pitch devices (0.3mm)



InCarrier for //256 sites parallel test

# Sensor Integration

- Need to test multiple DOF or stimulus
  - 9DOF inertial sensors
  - Environmental combo devices (pressure, temperature, humidity, gas)
  - 10/11/12 DOF:  9DOF + environmental, 9DOF + microphone
  - Fingerprint + optical

Image by ST

- Integration with other devices
  - Sensor, microcontroller, memory, RF and smart power

- Wide variety of packages and sizes
  - Multi-chip packages, caps, chip-on-glass, 3D…

- New requirements
  - Modularity to test all types of sensors
  - Flexibility to test all package types
  - Minimum number of insertions
  - Tester capable of testing integrated IoT devices

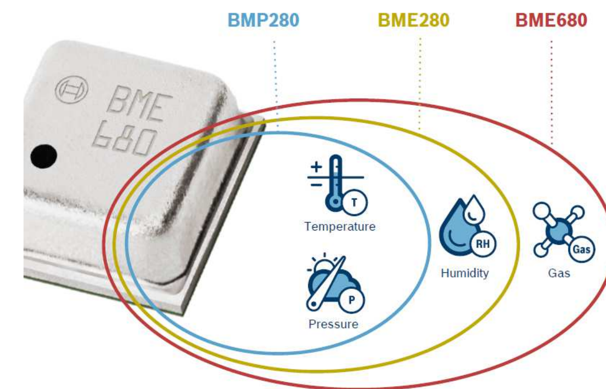
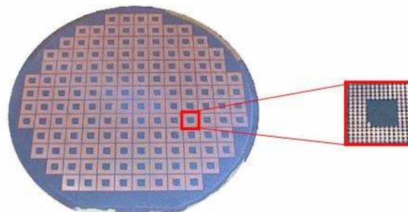



Image by Bosch

# Testing MEMS WLCSP

- Growth in MEMS WLCSP
- Requires post saw test on singulated MEMS to ensure quality
- Challenges of handling MEMS WLCSP
  - Small size and thickness 1x1x0.2mm
  - Handler and MEMS stimulus needs to transport fragile singulated die
    - Minimizing handling steps challenging for pick and place handlers
- Other requirements
  - Input wafer ring/blue tape, output tape and reel
  - Stringent vision inspection requirements
  - Device tracking
  - RMA and retest challenges of WLCSP devices



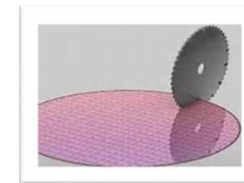
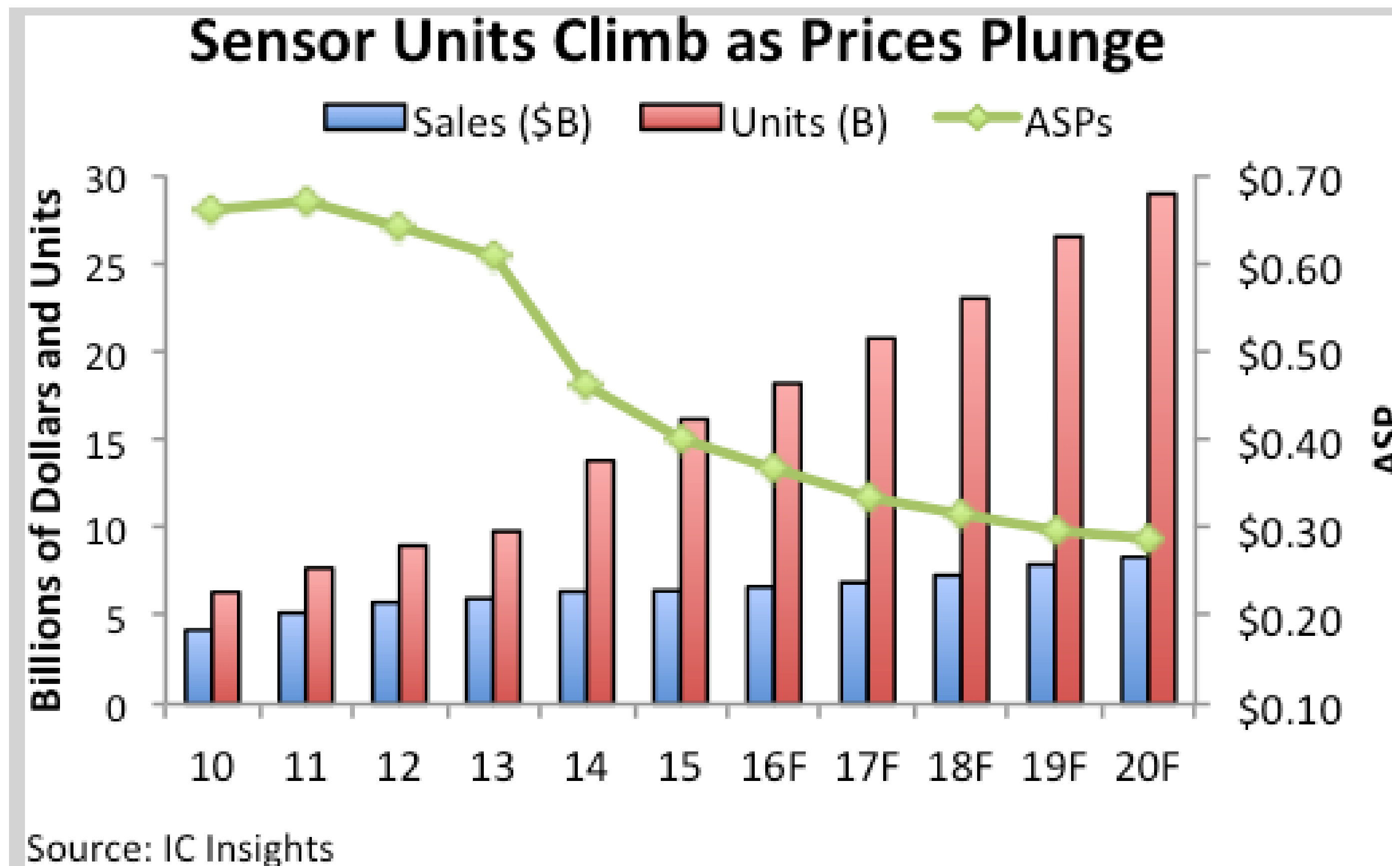


Image by Gila Tool

# Record Sensor Unit Shipments and Revenues

## Wearables, vehicle automation and Internet of Things

- ❑Unit shipment CAGR 12.4% 2015 – 2020
- ❑Revenues CAGR 5.3% 2015 – 2020
- ❑ASP CAGR -5.7% 2015-2020 (biggest decline in discrete inertial sensors)



# Sensor Test Cell for High Volume Manufacturing

- Fully automated test cell solution
  - Proven technical capability and experience in MEMS/sensor test
    - Advanced tri-temperature capability
    - Highest stimulus performance and accuracy
  - Highest parallelism and UPH
  - Integrated and optimized test cell for fast ramp and highest performance

- Flexible
  - High Return on Investment
    - Multi-use equipment for all types of devices (MCU, wireless, ….)
    - Standardized equipment instead of dedicated MEMS solutions
  - Modular MEMS stimulus for a wide range of sensor types
  - Ability to test integrated sensors with single insertion
  - Handle diverse package types and sizes on same equipment
    - WLCSP, strip, packages, less than 1x1mm size
  - Simple and fast change kit conversion

InStrip with InFlip MEMS Test Cell

# InMEMS Modules Available for InStrip

InFlip / InFlipM
Accelerometer Magnetometer

InBaro / InHumid / InGas
Environmental Combo

InGyro
9DOF

InStrip Base Unit

InPressure
TPMS

InPhone
Microphone

Xcerra
measured by your success