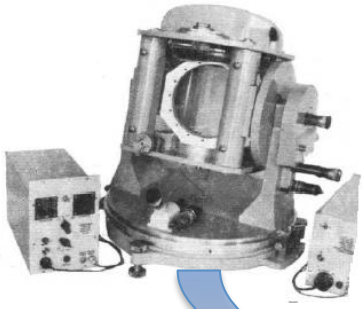


1960's

2012

Evolution of MEMS Test Solutions

Mario Correa

Dr. Janusz Bryzek

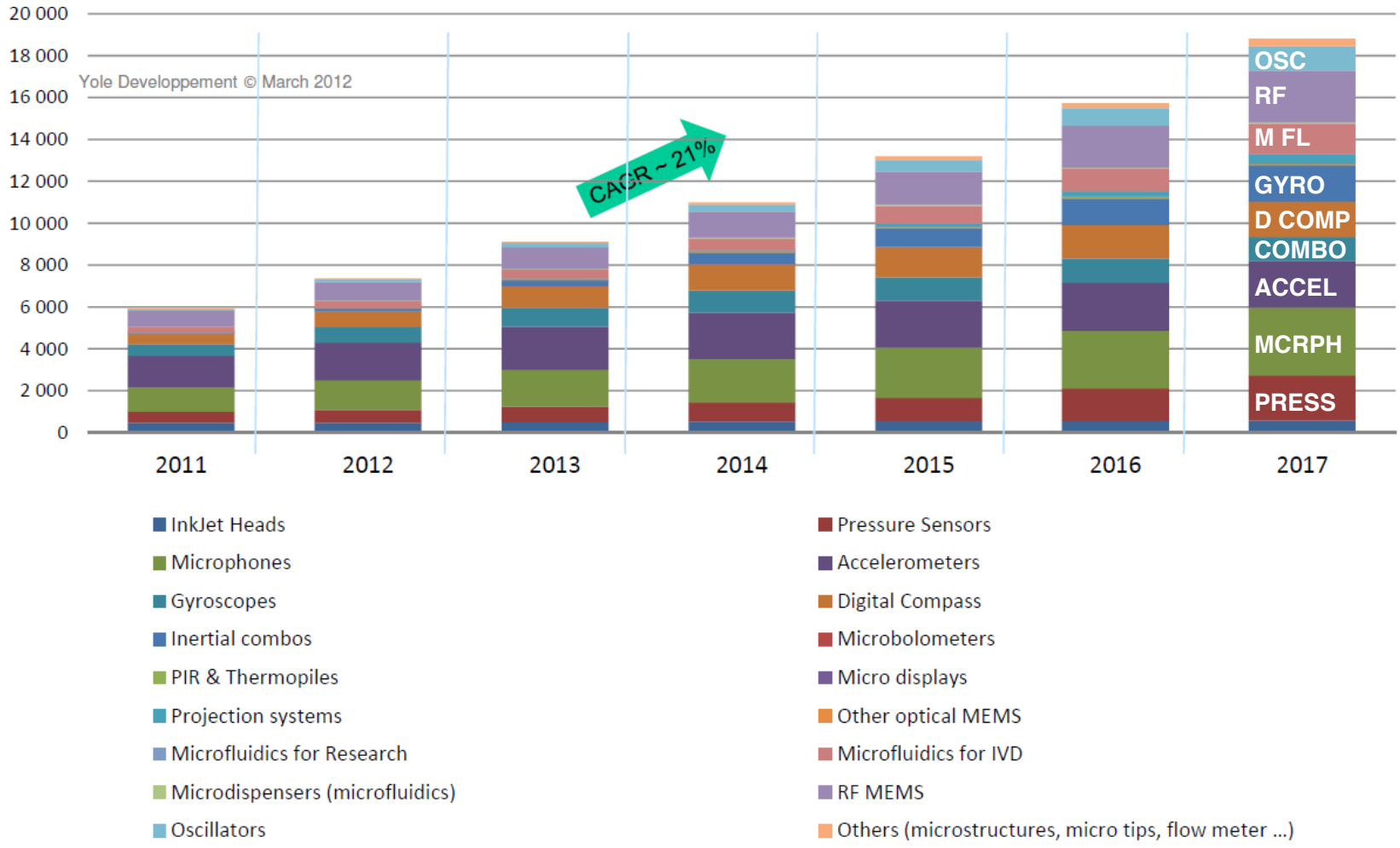
Fairchild Semiconductor

FAIRCHILD SEMICONDUCTOR®

Outline

- MEMS Market and Product Overview
- Challenges Facing MEMS Test Systems
- MEMS Test Systems Evolution
- MEMS Wafer Level Testing
- MEMS Final Product Testing
- Summary

MEMS Market Forecast



Source: Yole 2012

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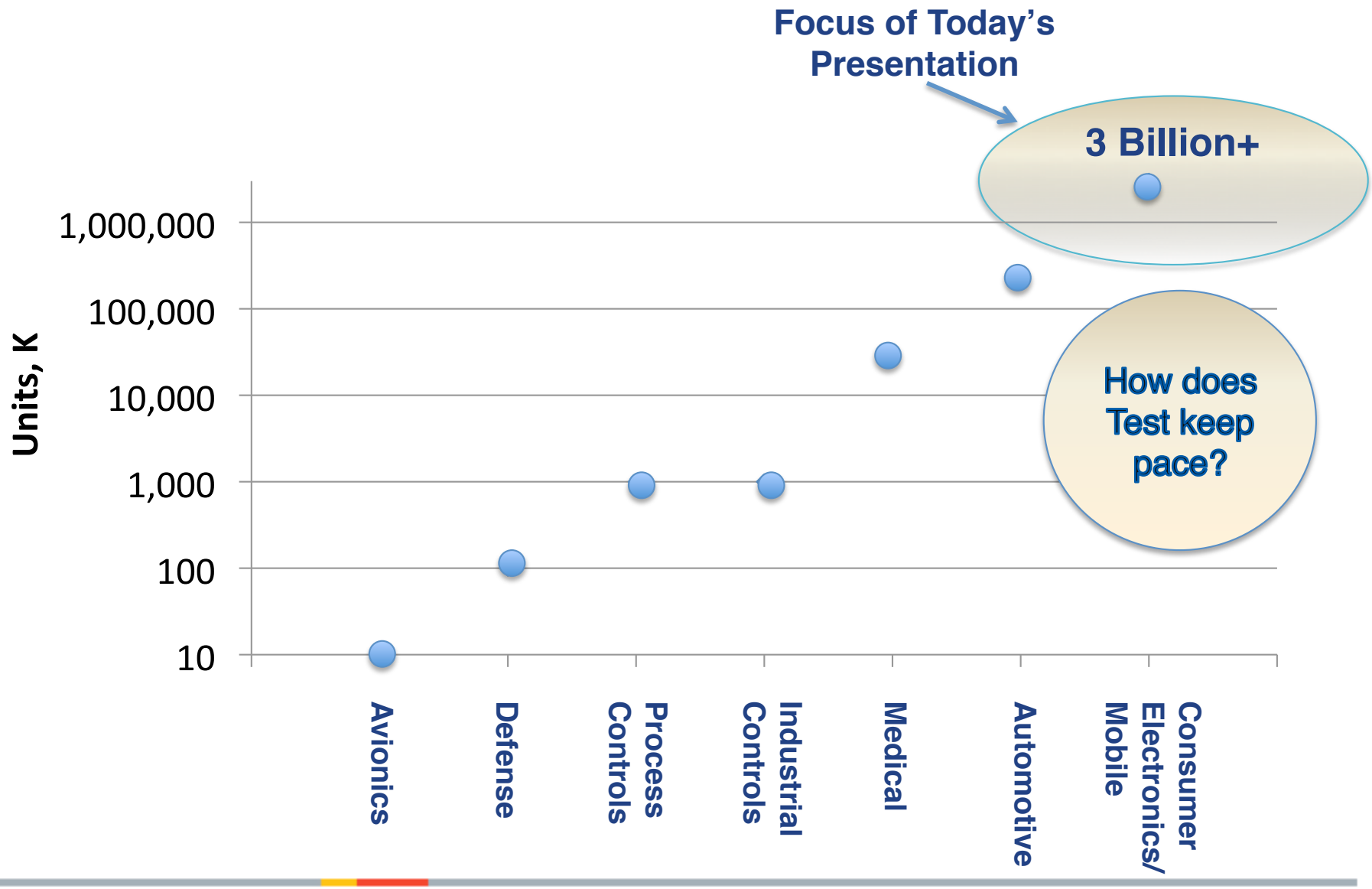
Industries Driving Growth Rates



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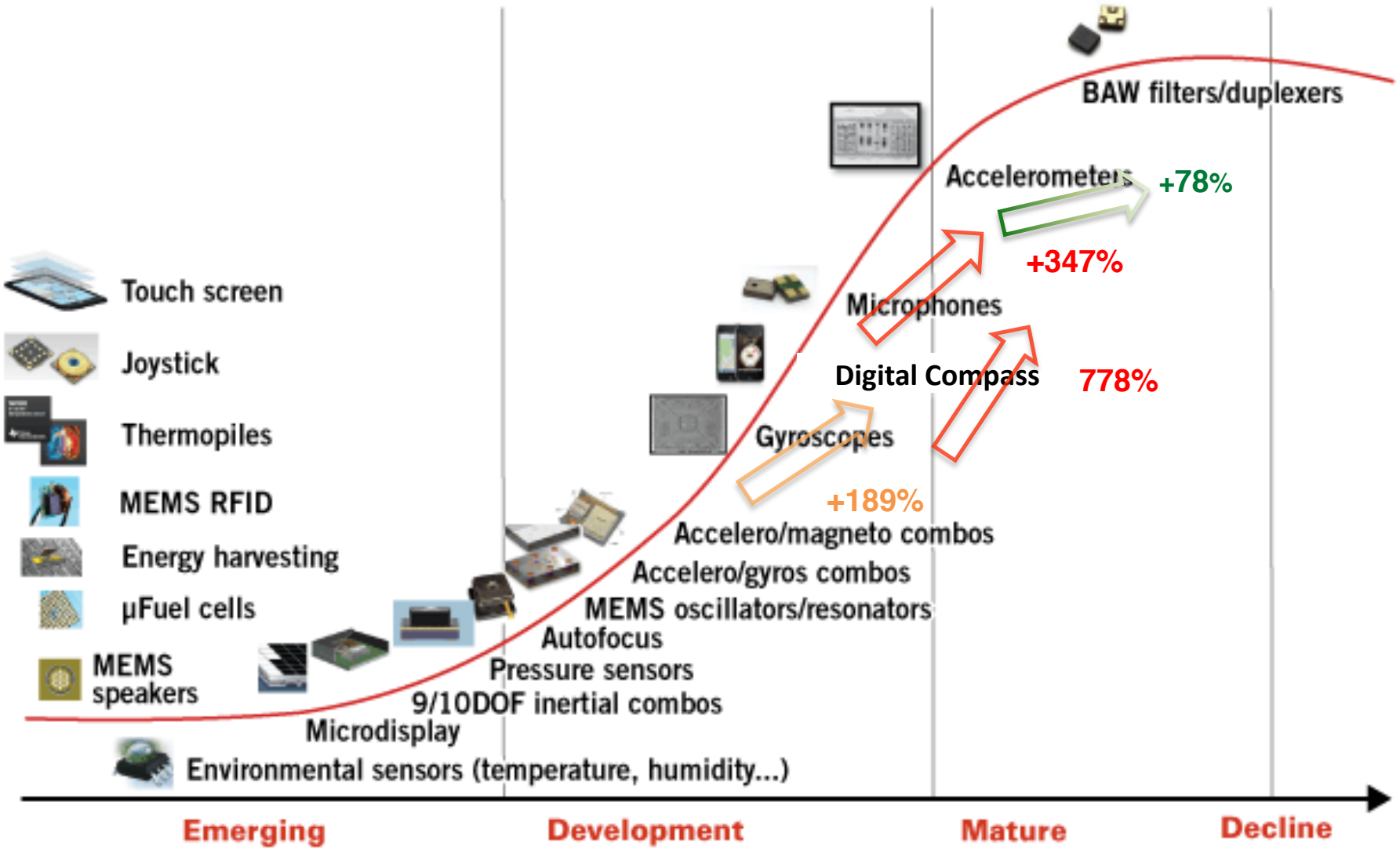
MEMS Mobile Products Maturity (Growth 2009-2012)



Source: Yole 2012

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MEMS Test Systems Challenges

- Stimuli challenge:
  - Apply external physical / chemical / optical stimuli such as acceleration, rotation, pressure, magnetic field, vibration, etc. to calibrate sensors.
  - May require temperature compensation.
- Packaging challenge:
  - Industry presses for smaller package footprints eventually trending towards a 1x1 mm footprint.
  - Current package probe technology is reaching its density of pin limitations.
    - MEMS probes are likely to migrate to MEMS test systems.
  - Tester induced stress on DUTs may impact calibration results.
    - Needs custom test head designs.
- Capacity challenge:
  - Enabling high UPH capabilities.

MEMS Test Systems Challenges

- Wafer probe challenge:
  - Mechanical / optical / chemical testing on the wafer to provide good known die (KGD).
- Test cost challenge:
  - Test cost for current generation of acceleration and gyro sensors has already reached 8.4% of selling price (Yole 2012) and needs to go down in the future.
- Time to market challenge:
  - Requires modular design of test systems.
- Scalability challenge:
  - Larger volumes require multiple test systems.
  - As volumes continue to expand into the multi billion range, UPH per test system must increase significantly.
- Dual functionality challenge:
  - Sensors start to use complex ASICs with uC and memories.
  - MEMS testers start to embed IC testing during idle time of MEMS testing.

Test Equipment, Early Phases

- **Early Inertial Test Systems, 1960's**: non-MEMS Sensors
  - Random vibration and rates applied via simple drive systems.
  - Custom developed systems designed in house.

- **Test System Development, 1970's**
  - Initial industrial interest focused on aerospace and process control applications.
  - Late 1970's development expanded into the automotive industry: engine controls for emissions and fuel economy.
  - Custom developed systems designed in house.

Test Equipment, 1980's – 1990's

- **MEMS Test System Development, 1980's**
  - Driven by the manufacture of pressure sensors.
  - In the late 1980's low cost / mass-produced silicon accelerometers emerged.
  - Late 1980's also saw the commercialization of inertial sensors in automotive applications.
  - Test systems become more complex as new sensor types are introduced, however they are still custom systems developed in house.
- **MEMS Test System Development, 1990's**
  - First dedicated MEMS test company emerged for automotive pressure and accel test systems.
  - The integration of CMOS interfaces into MEMS sensors adds additional complexity to test systems.
  - Mid 90's sees development of custom ATE systems designed in house incorporating off-the-shelf stimulus equipment, data acquisition equipment and communication interfaces.
  - Begin to see fully integrated systems developed by companies specializing in test, measurement and automation.

Test Equipment, 2000's - 2012

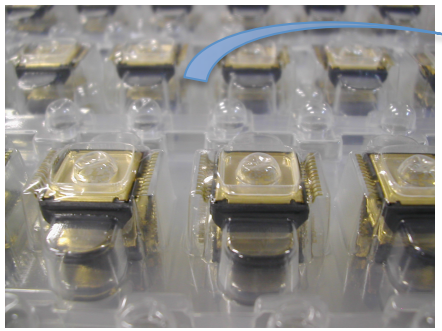
- **MEMS Test System Development, 2000's**
  - Universal MEMS standards do not exist.
  - The MEMS law is still in effect – "one product - one process – one package – one test procedure" – however changes are emerging.
  - Offshoots from traditional IC ATE vendors begin to emerge, specializing in MEMS.
  - Mid 2000's design begins to shift towards "standardized" test solutions.
- **MEMS Test Development, Today**
  - Over the last five years ATE vendors have made large strides in providing standardized test solutions for those sensors in high-volume production.
  - The need to provide KGD in the final assembly process has lead to new test systems focused on wafer level testing.
  - Vendors have expanded their IC test system capabilities to include MEMS testing.
  - New vendors focusing solely on MEMS package level testing have entered the market place.
  - Emergence of Test Labs specializing in MEMS testing services.

Test System Evolution, MEMS Inertial Test Systems

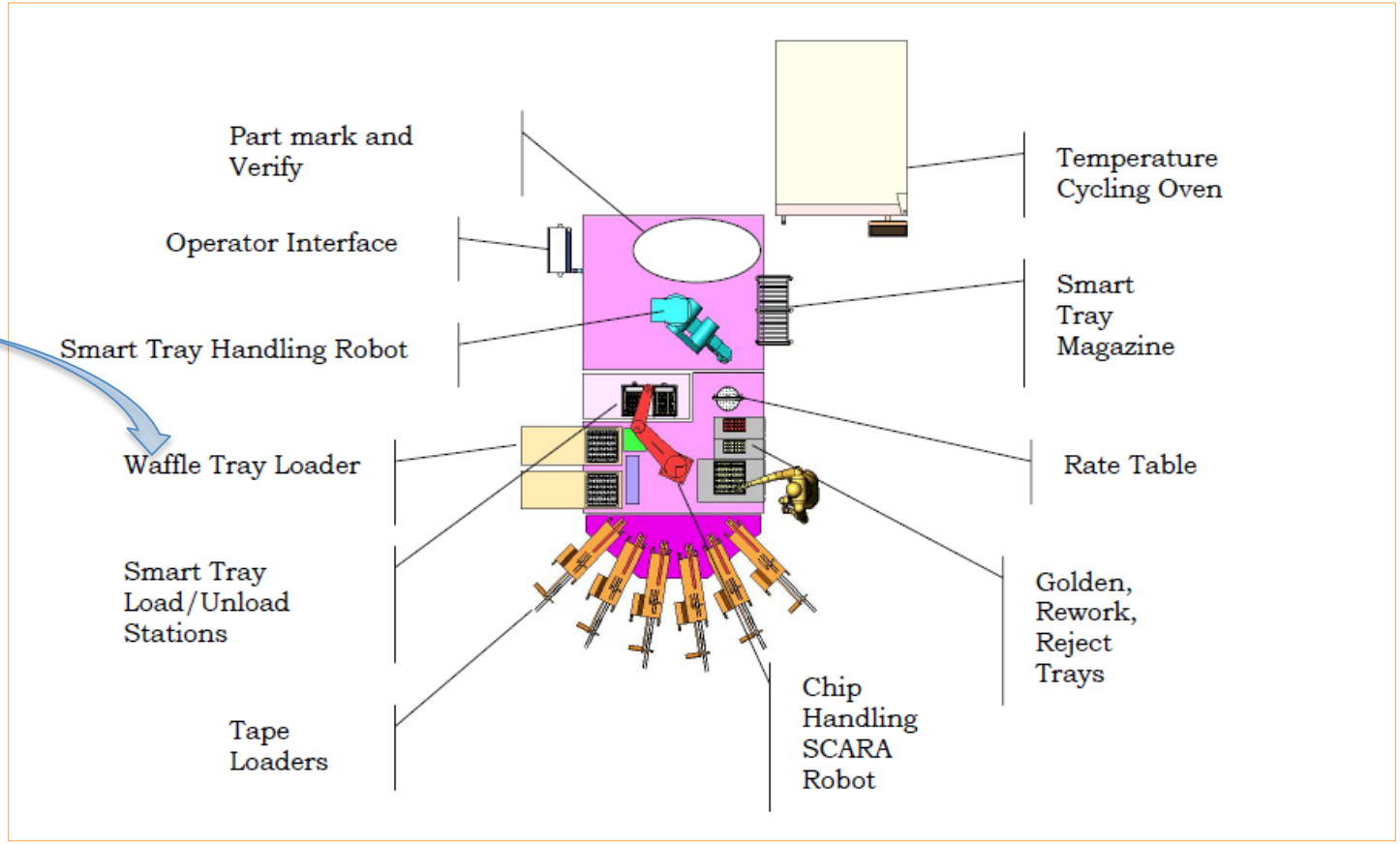
	1997	2005	2012
Cost	$150 -250 K	$1.8 M	$1 – $2 M
UPH	75	2000	7,500 – 10,000
Axis	1	1	6
Sensor Type	Gyro, accel, pressure	Gyro, accel, pressure	Gyro & accel
Description	Custom in-house	Custom – 3rd Party	MEMS ATE Vendors
Cost/UPH/Axis	$2700	$900	$30

Test System Sample, Mid 2000's

MEMS Sensor Automotive Stability Control



MEMS Single Axis Test Cell



Source: Systron Donner

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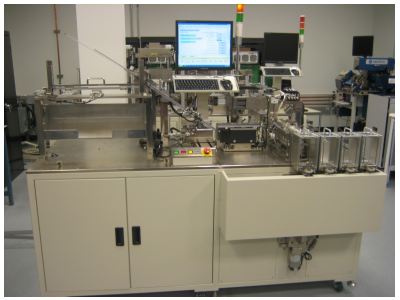
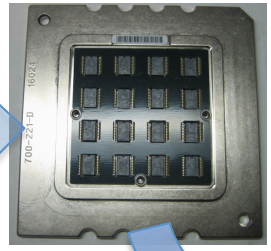
Test System Sample, Late 2000's

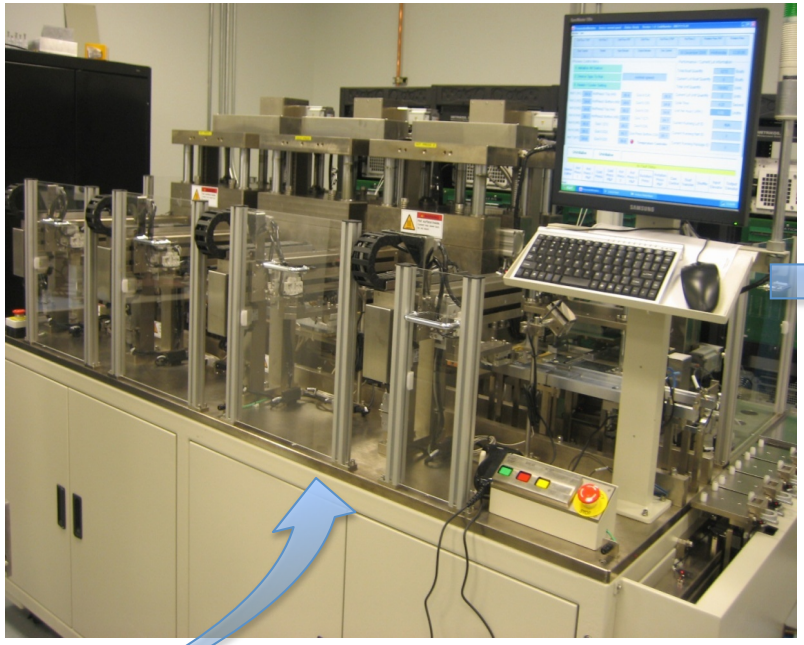
Tube-To-Boat Transfer System



16 Up DUT Boat



Tri-Temp Pressure and Accelerometer Calibration & Test Module



Sorter

Source: LV Sensors

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EMERGENCE OF MEMS WAFER LEVEL TEST

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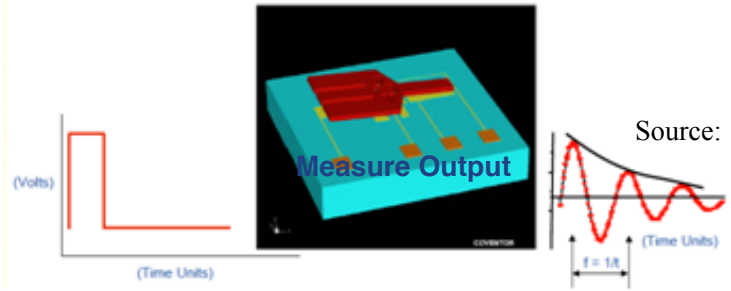
Dynamic Wafer Testing

- Dynamic Wafer Testing - the ability to move a MEMS element and measure the movement or behavior.



Source: Solidus Technologies

- Benefits
  - Determines performance at wafer level.
  - Identify Known Goods Die.
  - Prevents yield loss multiplication at final assembly.
  - High-volume capabilities.

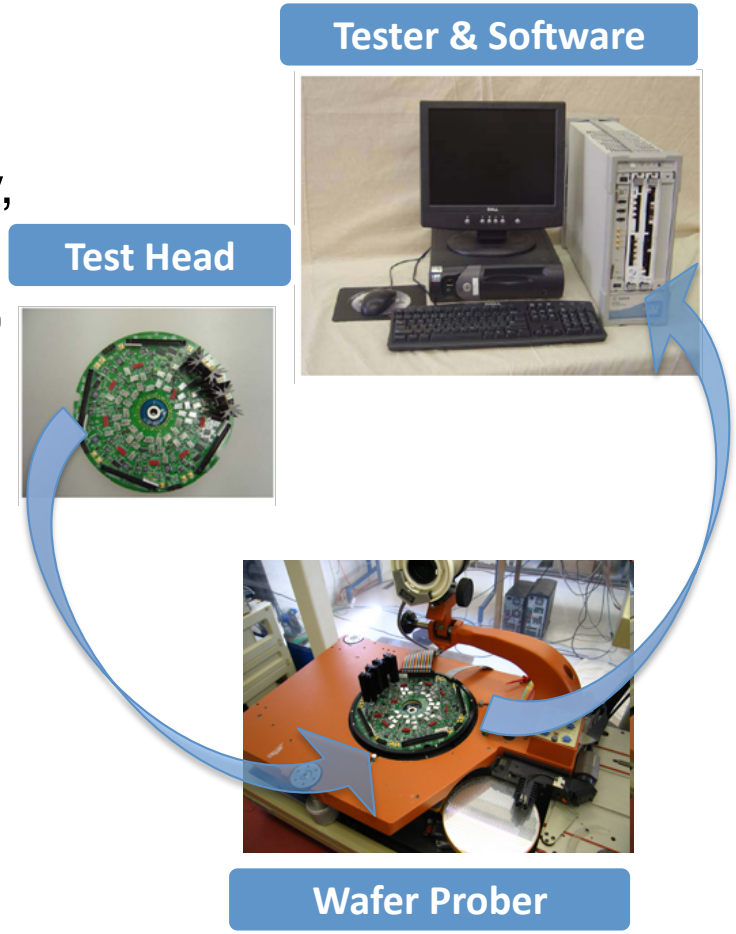
- May be implemented for Characterization, Engineering and Production Testing
  - Modular: commonality between test system types including hardware, prober and software.

Dynamic Wafer Testing, Inertial Sensors

- Measurement Capabilities Include:
  - Resonant Frequency
  - Spring Constant
  - f3dB Frequency
  - Q Factor
  - Gyro Quadrature Error
  - Mechanical Hysteresis
- Advantages:
  - Validates MEMS Design
  - Monitors Fab Process
  - Increases final product yield
- Detects Failures and Defects:
  - Stiction
  - Particulate Obstruction
  - Broken Elements

Solidus Technologies Wafer Probe Test

- Tests the “Dynamic” Mechanical Performance of MEMS Capacitive Elements at Wafer-Level, including Natural Frequency, Damping, Quality Factor, Stiction, Gyro Quadrature Error, Frequency, Phase, Amplitude, etc.
- Volume Capability: configurable to + 7,500 UPH
- Modular System, components include:
  - Tester & Software
  - Test Head
  - Note, prober is not included
- System allows for reusability
  - Production Test is a subset of Engineering Test.
  - Common components: tester, test head, and software.



Source: Solidus Technologies

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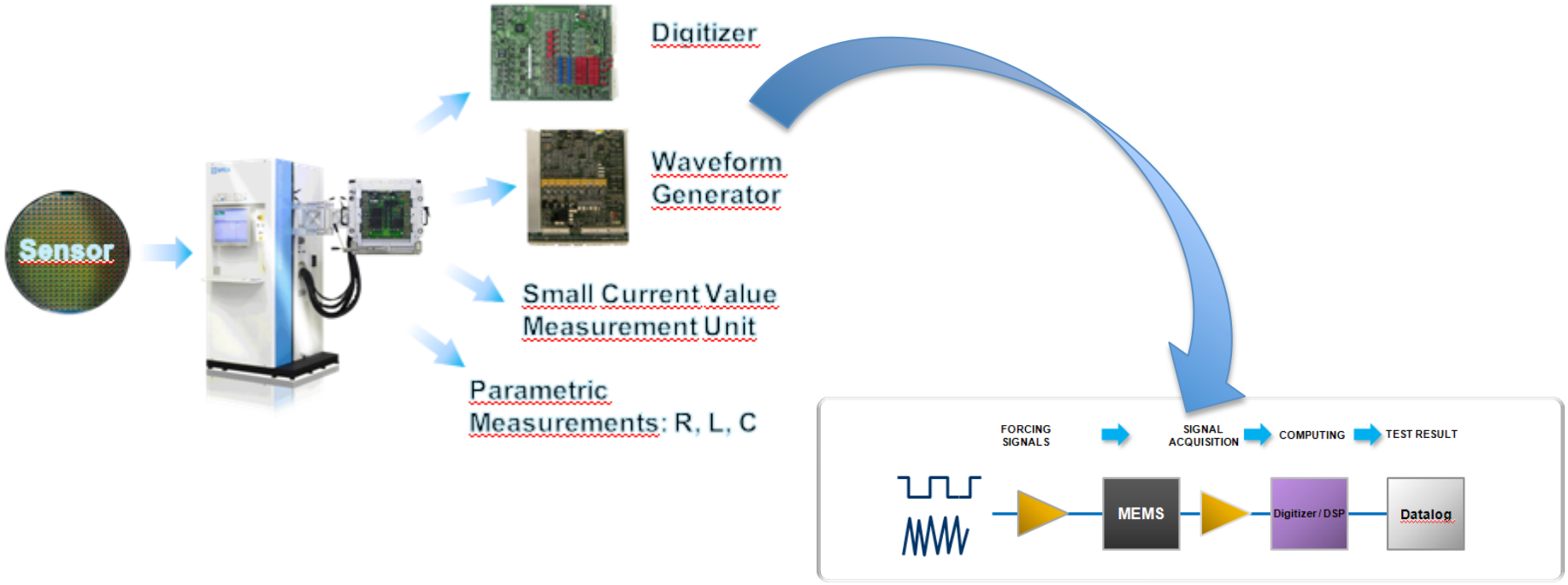
SPEA Wafer Probe Test

- Provides test capability for ASIC Test and Wafer Parametric / Dynamic Testing.
- Scalable architecture.
- Commonality between tester for wafer probe and final package test.



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FINAL PACKAGE TEST

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MEMS Test System Infrastructure, Final Package Test

- Driving factors in ATE development:
  - Need for package-level calibration and verification.
  - Rapid volume expansions, high UPH numbers, scalability.
  - Commonality between engineering and production systems, periodic validation of production platform.
  - Mixed-signal testing (digital communication and analog measurements).
  - High volumes and need for faster test times.

MEMS Test System Architecture, Final Package Test

- System design is gravitating to the Test Cell approach
  - Expandable pick and place handlers and test heads.
  - Modular stimulus components, tri-temp capable.
  - Standardized tester and test software tailored to the MEMS device.
  - Multiple sort options.
  - Multiple loading options including socket, tray, strip and active load boards.
  - Can be scoped from low volume engineering tester to high-volume production systems.

- Handler:
  - Expandable to meet engineering and production requirements.
  - MEMS handlers are reusing IC handler designs.
  - Support strip, tray and singulated configurations.

MEMS Test System Architecture, Final Package Test

- MEMS Stimulus Unit
  - Common to engineering and production systems.
  - Custom developed by each vendor based on sensor type.

- Tester:
  - Expandable to meet engineering and production requirements.
  - Commonality with dynamic wafer probe.

- Thermal Testing
  - Approaches:
    - Multiple temp stations, one for each test temperature.
    - Individual temp environment for each device under test, clam shell approach.
- Sorter
  - Tray to tray, tray to reel, etc.

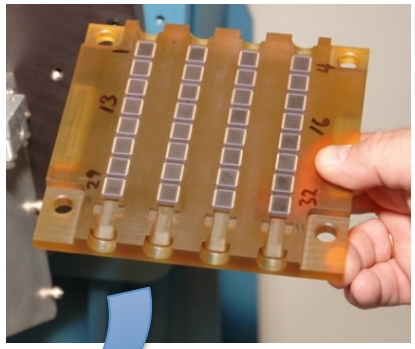
MEMS Test System Architecture, Final Package Test

- Loading Options:
  - Strip
    - Based on existing test methodology.
    - DUTs singulated after test.
    - High Parallelism
    - Application may be limited due to possible calibration issues arising after singulation.
  - Socket:
    - Singulated DUTs
    - Expandable
    - Stress exerted on package may impact calibration at final assembly.
  - Tray
    - Singulated DUTs
    - DUTs inserted in customized trays which secure them during test.
    - High Parallelism
  - Active Load Board
    - Integrates local measurement capabilities into stimulus unit.
    - Reduce tester resources.
    - Multiple trays allow for higher parallelism and scalability.

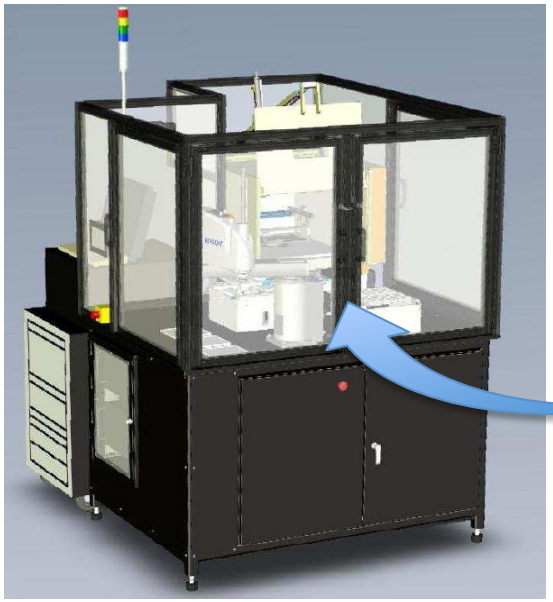
MEMS Test System ATE Vendors

- Modular Test Cell Approach, turn-key system
- Stimulus Unit
- Tester
- Tri -Temp Capable
- Tray System, 32 Site

Tray, Singulated DUTS



Test Cell

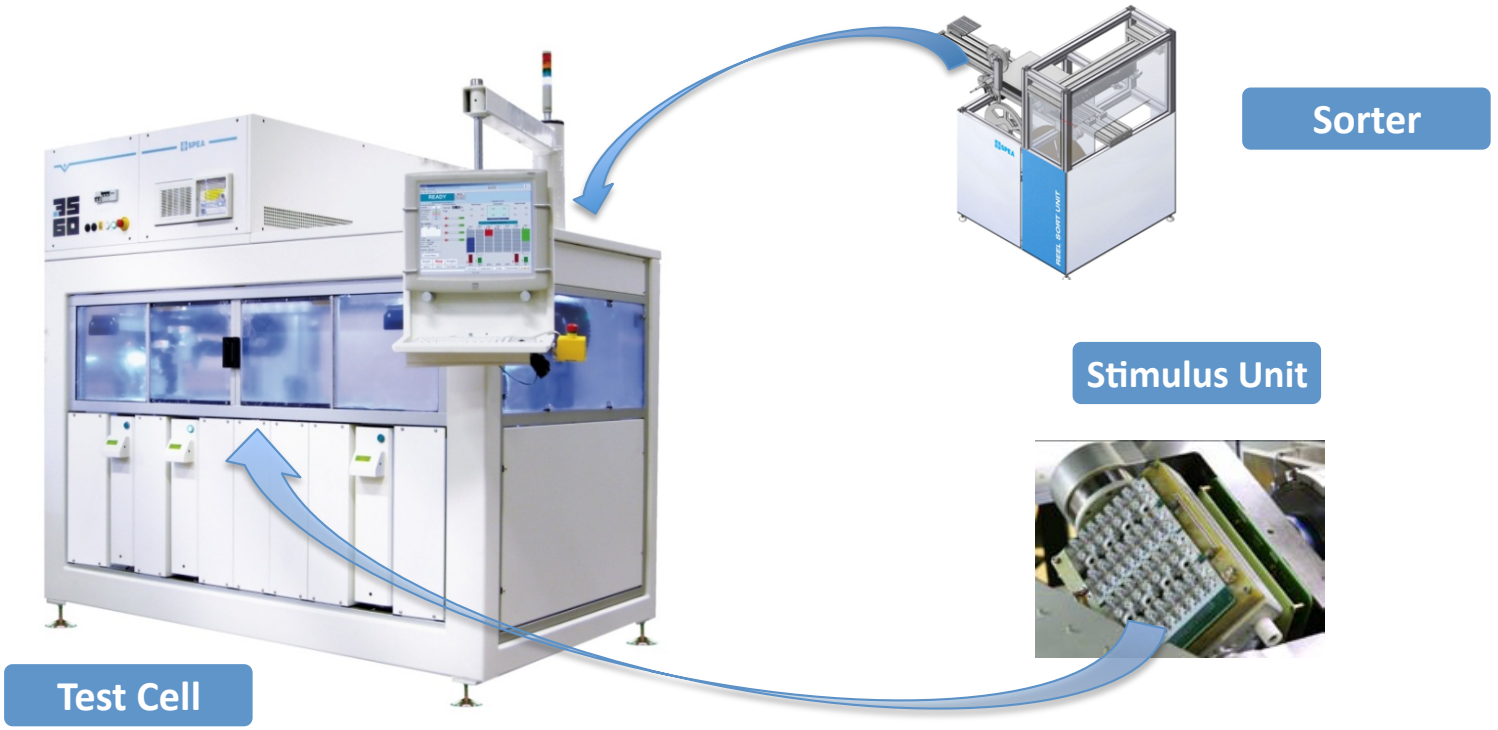


Accelerometer / Gyroscope Test System

Source: Focus Test

MEMS Test System ATE Vendors

- Modular Test Cell Approach, turn-key system
- Socket (expandable to 32 up)
- Multi Sort Options
- Tri Temp Capable



Source: SPEA

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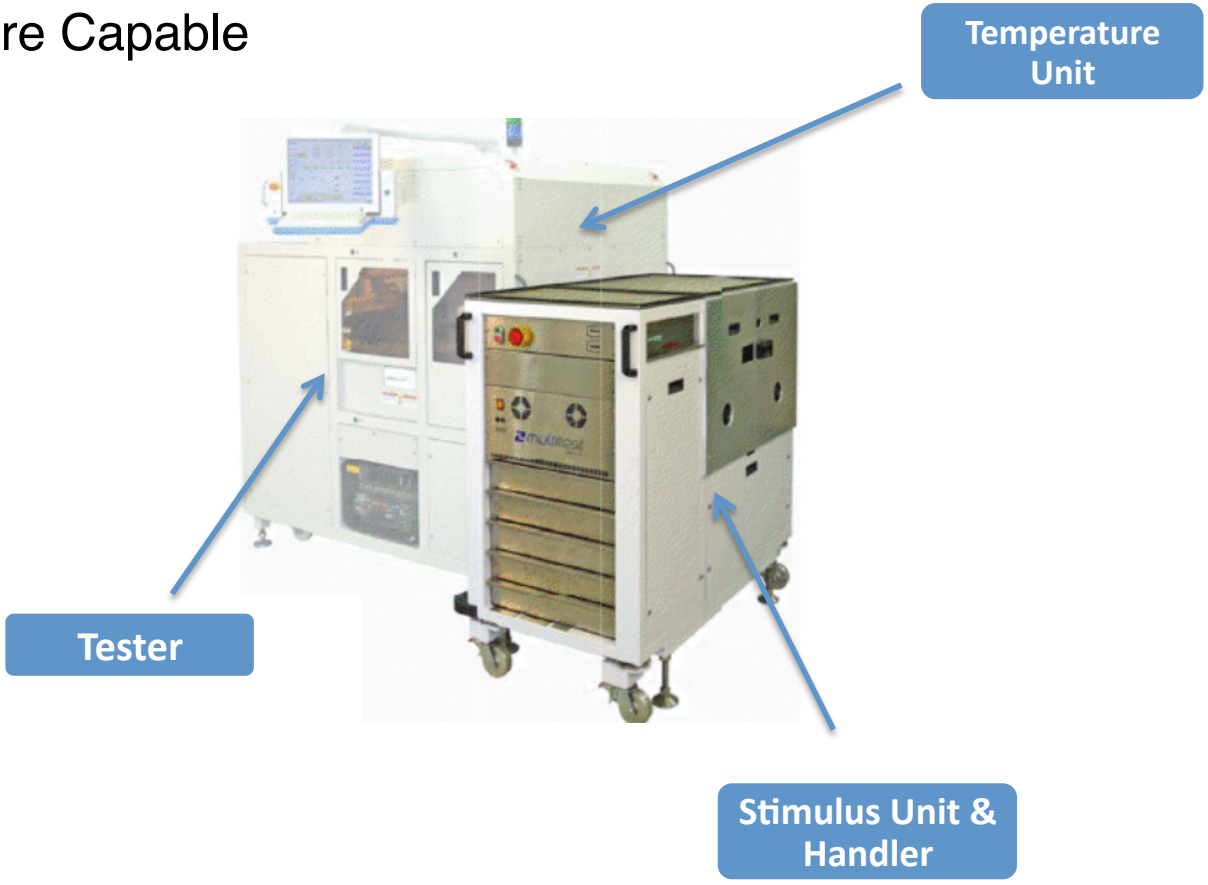
MEMS Test System ATE Vendors

- Modular Approach
- Stimulus Unit & Hander
- Tester and Sorter must be subcontracted
- Socket
- Temperature Capable



Source: Multitest

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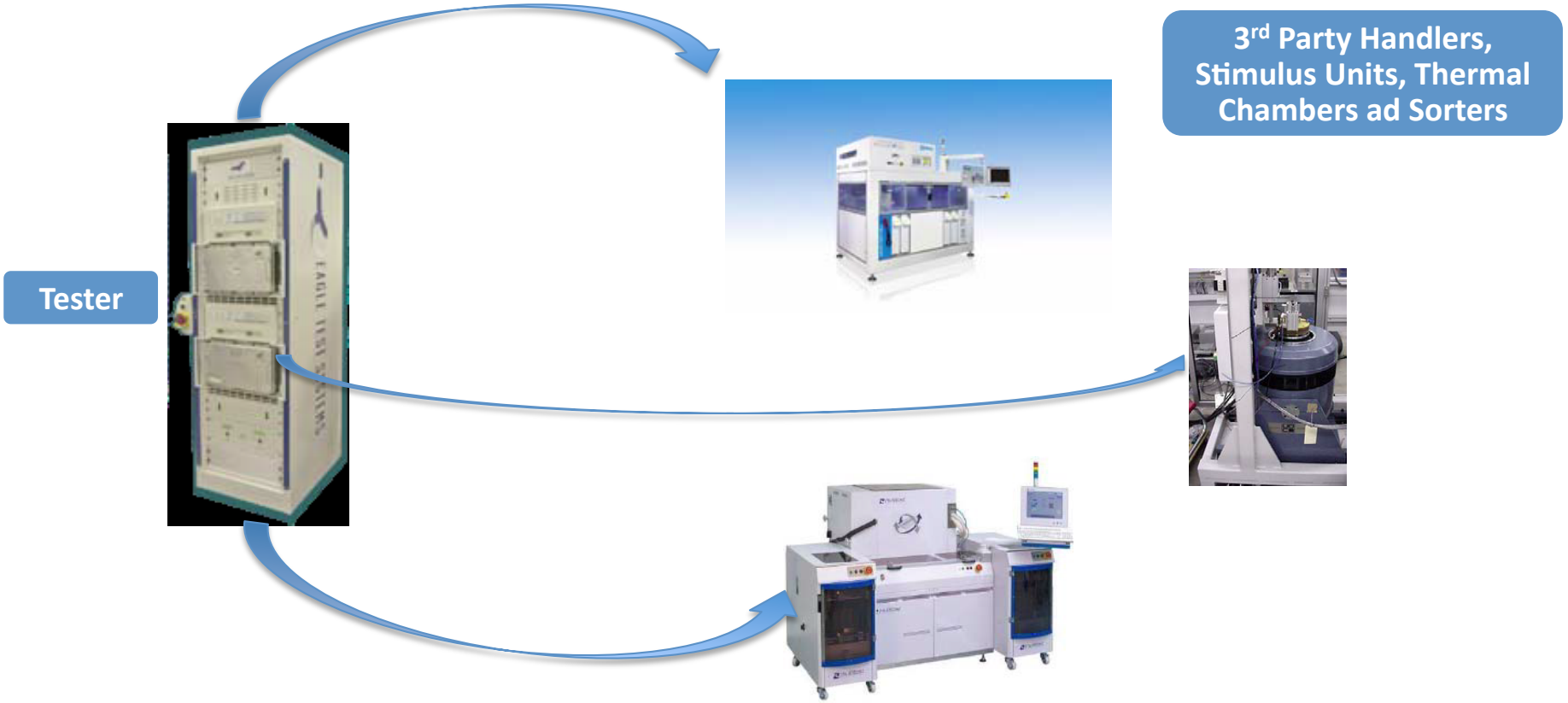
MEMS Test System ATE Vendors

- Provide Tester and Software
- Integrate with Third-Party Handler, Stimulus Units, Thermal Chambers and Sorters



Source: Teradyne

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MEMS Test System ATE Vendors

- Other MEMS ATE Vendors / Test Labs / Partners
  - Advantest
  - Centipede Systems
  - Acutronic
  - Ideal Aerosmith

Conclusion / Summary

- The MEMS sensor industry will continue to be driven by an incremental increase in performance, and decrease in package size and cost.
- Rapid volume growth is forcing MEMS Test to gradually adopt the high-volume IC infrastructure.
- ATE vendors specializing in MEMS Test Systems as well as specialty MEMS Test Labs have emerged to meet industry needs.
- The criticality of KGD for final assembly is driving the development of MEMS dynamic wafer level testing.
- MEMS test system development will be driven by new sensors for which a high-volume test infrastructure doesn't yet exist, such as:
  - Multi-sensory systems on a chip or in a package
  - MEMS/NEMS integration
  - Sensor fusion
- Combined, all of these items create major challenges and business opportunities for the test industry.