
SIXTEENTH ANNUAL
BiTS
Burn-in & Test Strategies Workshop
March 15 - 18, 2015
Hilton Phoenix / Mesa Hotel
Mesa, Arizona
Archive – Session 1
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Session 1
Marc Mössinger
Session Chair

BiTS Workshop 2015 Schedule

Frontiers Day

Monday March 16 10:30 am

Putting MEMS to the Test

"'Taking MEMS Test and Calibration to the Next Level' - An Integrated Platform Approach Driving Further MEMS Growth"

John Rychcik - Xcerra Corporation

"The Target for Consumer MEMS Testing Should Be Under 1 Cent Level"

Vesa Henttonen - Afore Oy

"MEMS IC Manufacturing Test Cost Effective Strategies"

Wendy Chen & Andrei Berar - KYEC

"BURst Pressure (BURP) Stress Test for MEMS Pressure Sensors"

Peter Jones & Ray Sessego - Freescale Semiconductor

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"Taking MEMS calibration and test to the next level" - An integrated platform approach driving further MEMS growth

John Rychcik
Xcerra Corporation

2015 BiTS Workshop
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Contents

- Cost of MEMS Calibration and Test
- MEMS Device Overview
- MEMS Calibration and Test Overview
- MEMS CoCT Factors
- Steps to Minimize CoCT with Innovative Test Cell Solutions
- Conclusion

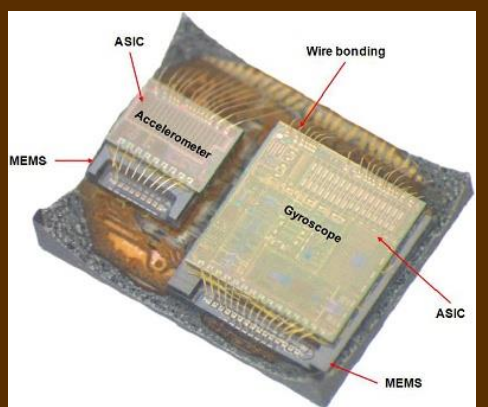
Cost of MEMS Calibration and Test

- MEMS Calibration and Test is a significant contributor to the overall MEMS device cost (Up to 30% or more of device cost)
  - MEMS Test Equipment Capital is Expensive
  - Lengthy Calibration + Test Times
  - Test Systems Not Scalable from Low Volume to High Volume
  - Test Systems Not Scalable across different MEMS product types
  - Test System Reliability and Maintenance is Costly

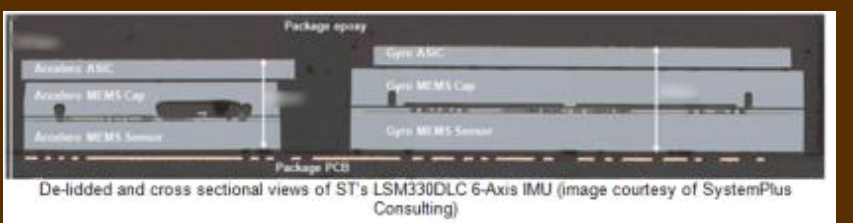
- Challenge: Provide Innovative Test Cells that Minimize CoCT for both the High Volume, Price Driven Consumer Market and the Low-Medium Volume, Performance Driven Markets (Automotive/Aerospace…)

Background: MEMS Definition

- MEMS: Micro Electro Mechanical System
  - Sensor + Control Chip + Package
- Sensor: Mechanically active device that converts physical stimulus into electrical output
- Control Chip: Converts sensor output to a calibrated digital or analog output
- Package: Physical environment where the sensor and control chip resides



ST's 6-Axis IMU De-lidded

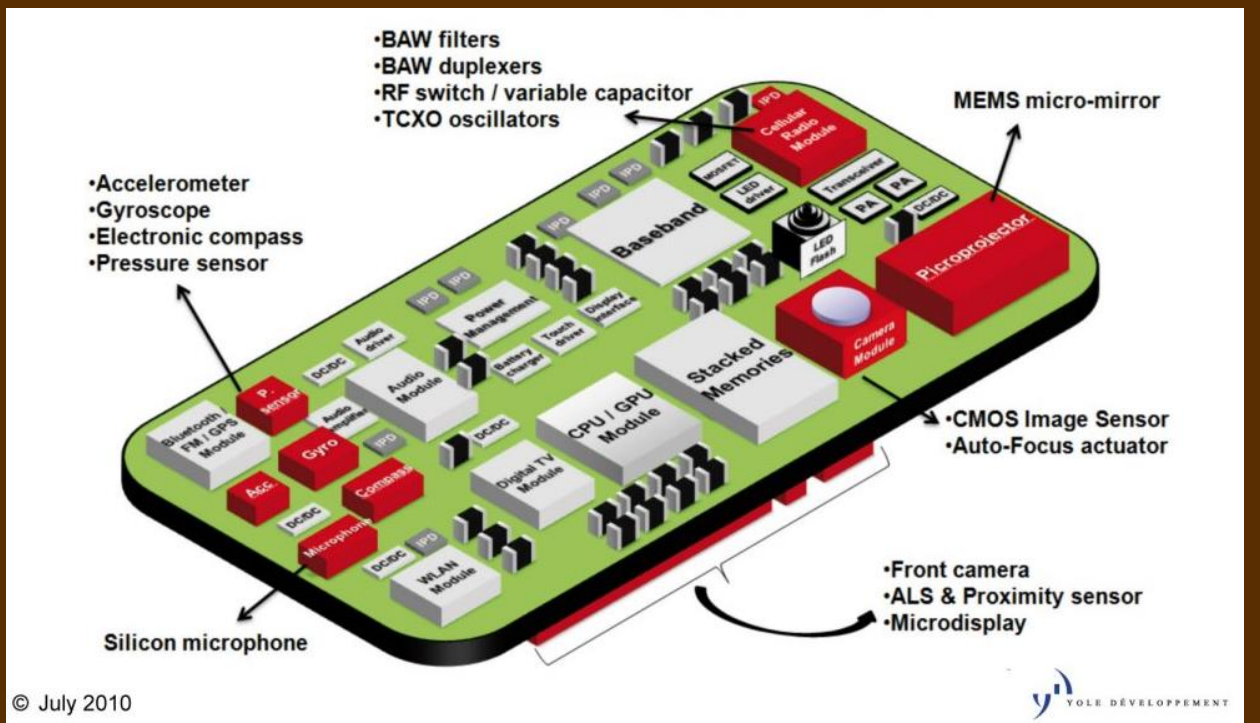


De-lidded and cross sectional views of ST's LSM330DLC 6-Axis IMU (image courtesy of SystemPlus Consulting)

ST's 6-Axis IMU De-lidded Cross-Section

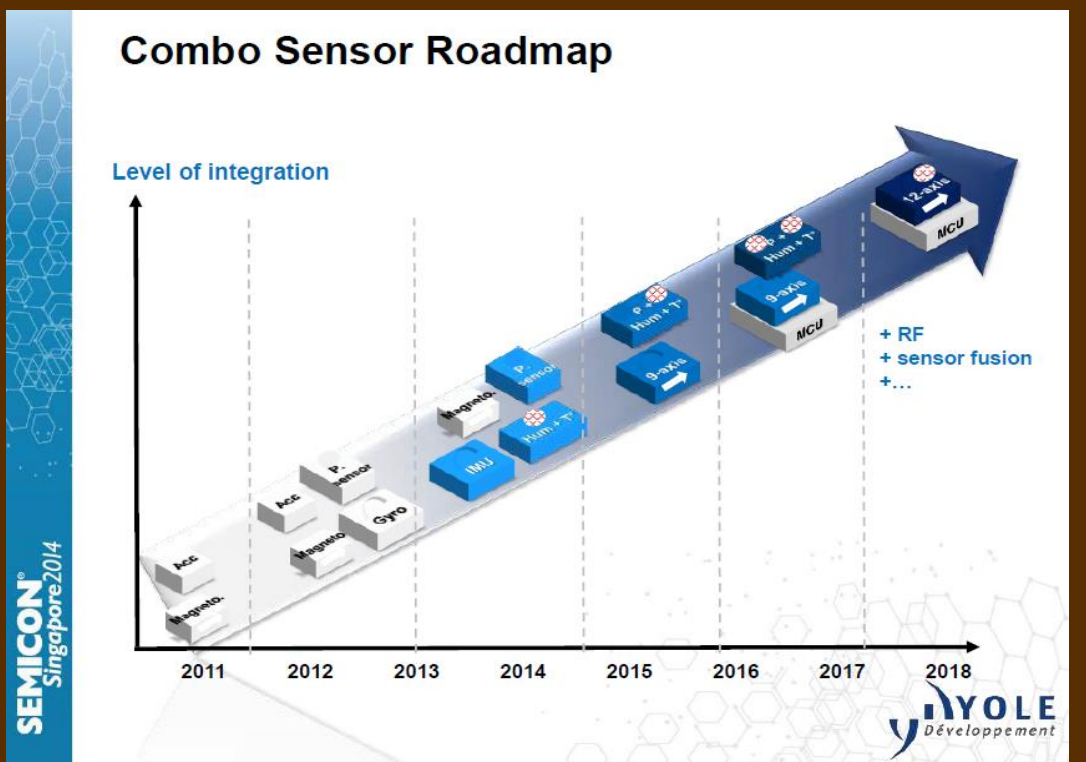
Consumer MEMS: High Volumes

Consumer MEMS Trends: High volumes with low device selling price (ASP)
Test Challenge: Provide economical, high parallel test solutions



Future MEMS: Sensor Integration

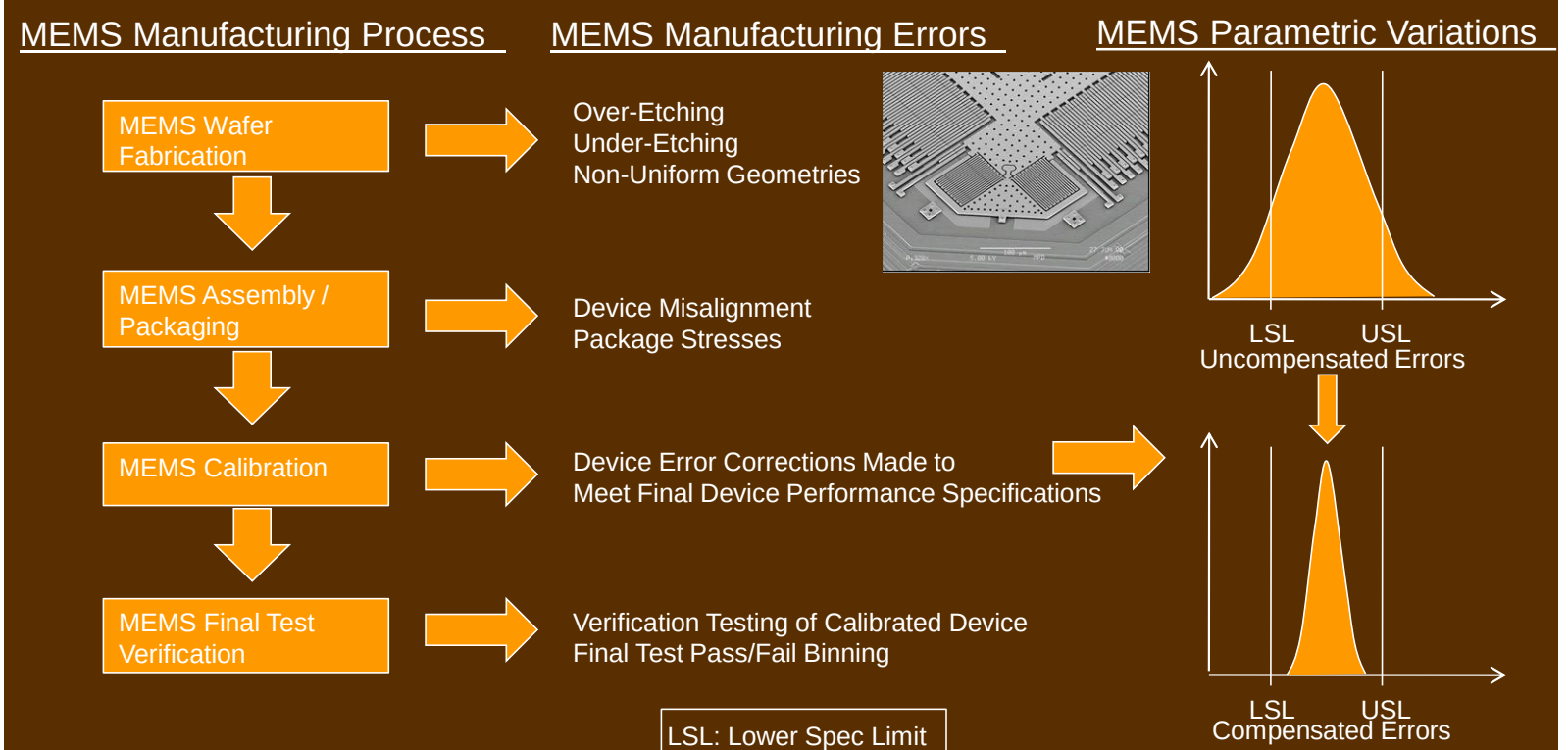
Market Trends: Sensor integration and new sensor growth
Test Challenge: Provide economical, multi-degree of freedom (DOF) MEMS test solutions



"Taking MEMS test and calibration to the next level" - An integrated platform approach driving further MEMS growth

Why is Calibration Required for MEMS?

Errors inherent to the MEMS manufacturing process produce variations in the sensor, therefore calibration is required to compensate for these variations.

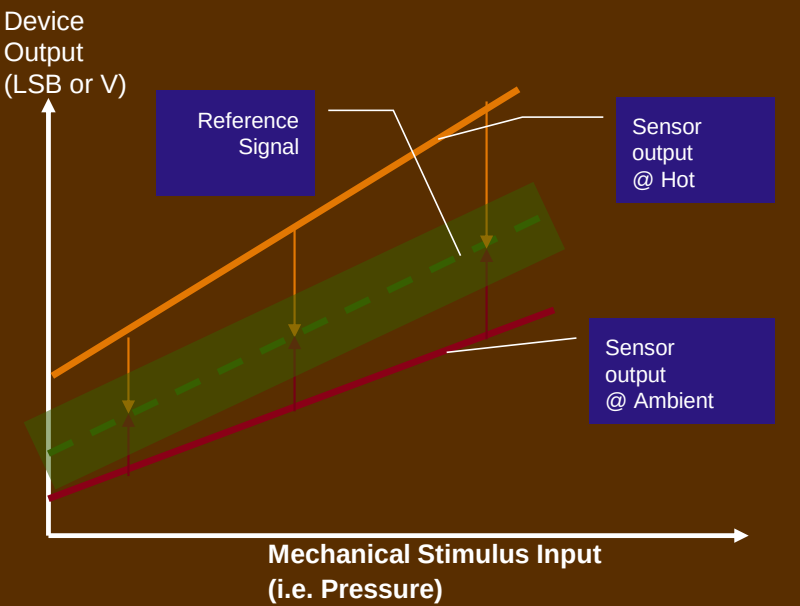


"Taking MEMS test and calibration to the next level" - An integrated platform approach driving further MEMS growth

Background: MEMS Calibration and Test

MEMS Calibration Steps:

1. .. **Calibration** mechanical stimulus is applied to the sensor during electrical test to measure the signal output offset.
2. .. **Trimming** the offset parameter is written into the MEMS memory to correct the offset.
3. .. **Test** a mechanical stimulus is applied to the sensor during electrical test to learn if the trimming parameter is correcting the offset to specification.



- Inspection of 2 or more data points to calibrate the device
- Temperature levels:
  - Consumer: Typically Ambient only
  - Automotive or Pressure: 2, 3 or more

Cost of Calibration and Test Factors

- depreciation period
- useful lifetime
- re-use for new applications

investment cost for

- handler base + change kit
- MEMS module
- tester
- manipulator + docking

- utilities (eg. power, CDA, LN2)
- labor, operations & engineering
- load boards, contactors
- maintenance & service
- spare parts

- management
- adminstration
- facilities

$$CoCT = \frac{\left[\frac{\text{Capital Cost}}{\text{Lifetime}}\right] + \text{Variable Cost} + \text{Overhead}}{\text{Yield} * \text{Utilization} * \text{Throughput}}$$

- contacting accuracy and repeatability
- open/short rate
- test yield / re-test rate

- uptime, MTBA, MTTA, MTTR
- package conversion time
- setup time
- socket cleaning & exchange
- training

- DUT test time
- handler index time
- number of contact sites
- soak speed & capacity
- effective throughput

"Taking MEMS test and calibration to the next level" - An integrated platform approach driving further MEMS growth

MEMS Test Cell Definition

- What Equipment is required to Calibrate and Test a MEMS Device?
  - Physical Stimulus (i.e. Shaker, Rate Table) with high accuracy reference sensor (typically 10x more accurate than DUT)
  - Handler for automated device handling of different input and output media (tubes, trays, wafer tape, tape and reel), temperature controlled environment and pass/fail binning
  - Tester for device electrical testing, handler and stimulus control

MEMS Handler And Stimulus Solutions

	Singulated Package Test Low/Med Volume (Automotive, Industrial...)			Strip Test / Test in Carrier
handler platform	Gravity	Gravity	P&P	Instrip
application	 tube x4	 tube x4 / x8	 tray x4 / x8 / x16	 strip x42 / x72 / x144
Accelerometers				
20g/ 50g /100g	X, Y, Z, 45°	Y, Z, X+Y	on request	
3 axis low g	Z+X, Z+Y		on request	InFlip 3DOF; InFlipM 6DOF
Gyroscopes	YZ = 5DOF	Z sinusoidal; XYZ = 6DOF	Z sinusoidal; XYZ = 6DOF (9DOF on request)	InGyro 6 DOF, InGyroM 9DOF
Pressure / Gas	up to 20 bar absolute Gas detection		Barometric abs.& rel.(on request) Gas detection	InPressure (20bar abs.+ gas d.) InBaro absolute
Magnetometer	Z = 1DOF, MRS XY = 2DOF, XYZ = 5 (8) DOF	MRS XY = 2DOF, XYZ = 3DOF	MRS XY = 2DOF, XYZ = 3/6DOF (9DOF on requ.)	InFlipM 6DOF, InGyroM 9DOF
Microphone				InPhone
Humidity		humidity MEMS		InHumid
Optical Sensors		specific solutions available	specific solutions available	InOptic
Oscillators		temp. calibr. up to +/- 0,2°K	on request	on request

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Steps to Minimize CoCT

1. Standardization
2. Modularity
3. High Parallel Test
4. Multi-DOF Test

Step 1: Standardization

Standard
Gravity or Pick & Place test handler

> Singulated device handling tube to tube, bowl to bulk, tray to tray

> Up to 8/16 contact sites

> Temperature Conditioning
(-55°C to +155°C
at +/- 3°C accuracy)

Standard
MEMS Stimulus Module

> Same MEMS stimulus Cart used on a range of MEMS products

> Configurable for multiple MEMS applications
- Accelerometer high g
- Accelerometer 3 axis
- Yaw-Rate (Gyro)
- Pressure
- …..

> Fast package conversion

Step 1: Standardization

Standard Sensor Stimulus Equipment
replaces cost-intensive custom designs.

MEMS Stimulus Cart

Cost of Test Advantages:

- > Convertibility to other sensor applications, exchangeable stimuli
- > Ease of operation
- > Ease of maintenance
- > Leverage skills / low additional training
- > Global support
- > Convenient spares supply

MEMS Stimulus Modules inside Cart

Step 2: Modularity

New sensor types and applications require changing the stimulus module ONLY

Standard Handler
- > Loading
- > Soaking
- > Sorting

+

MEMS Module:
- Stimulation
- Calibration
- Contacting

or

Integration of 3rd party tools for
- Stimulation
- Calibration

Step 2: Modularity

Sensor Stimulus Equipment is combined with Standard Handling Equipment

- **MEMS Cart can be used with a variety of Stimulus Types and MEMS package types.**

Cost of Test Advantages:

> **New sensor applications require only changes in the sensor test modules -> fast time to market**

> **Ease of operation / maintenance - similar to standard process**

> **Leverage skills / low additional training**

Standard Pick & Place Test Handler with MEMS Stimulus Cart

Step 3: High Parallelism

Sensor Test Equipment is combined with **Strip-Like Test Equipment and Carrier Loading / Unloading**

- **InCarrier is ideal for high volume MEMS applications (i.e. Consumer)**
- **Addresses the concern of MEMS output changes after singulation**

Cost of Test Advantages:

- **Leverages advantages of strip test for singulated packages**
- **High throughput (up to x288 parallel test capability, depending on package size)**
- **Supporting smallest packages (including WLCSP)**
- **Full device traceability**

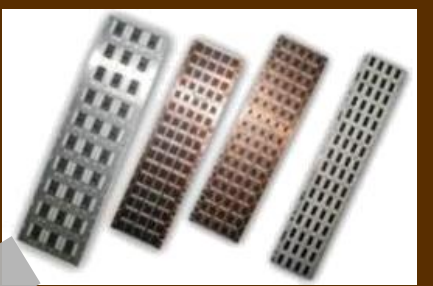
Example: InCarrier

Step 3: High Parallelism

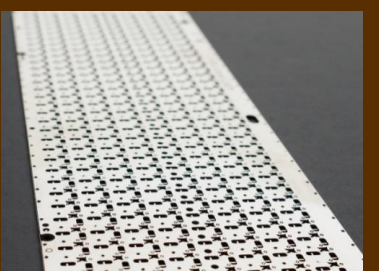
InCarrier: Combined advantages of Singulated Test and InStrip Test

Singulated IC Test

InStrip® IC Test



InCarrier™ IC Test



Patented

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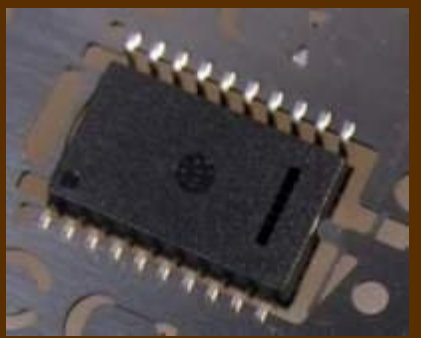
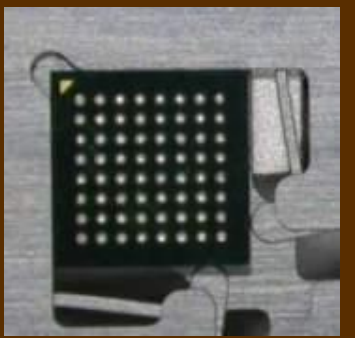
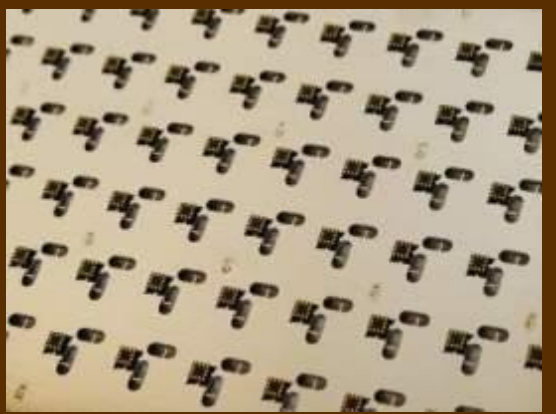
Step 3: High Parallelism



SO Device in InCarrier



BGA 64 in InCarrier



InCarrier in standard slotted strip cassette (cassette is shown open)

Step 3: High Parallelism

Sensor Stimulus is combined with Standard Strip Test Equipment

- Ideal for High Volume Consumer MEMS Market for lowest CoCT

Cost of Test Advantages

> high throughput (up to x288 parallel test capability depending on # device I/O)

> up to 1200 signal lines

> supporting smallest packages (including WLCSP)

> Modular MEMS Stimulus attaches to Top Strip Base Unit

Example: Standard Strip Test Handler with MEMS Box

Step 3: High Parallelism

High Volume MEMS Test Cell Example:

MEMS Stimulus Module
- Physical Stimulus with Reference Sensors

Soft Dock or Hard Dock
-Integration of Tester to Handler

InStrip Base Unit Handler
- Automated Strip or Carrier Handling
- Temperature Controlled
- Strip/Carrier/Device Auto Vision Alignment
- Device Contacting
- Device Pass/Fail Binning

Diamond$_x$ Tester
- Handler Control
- Physical Stimulus Control
-Device Electrical Calibration and Test

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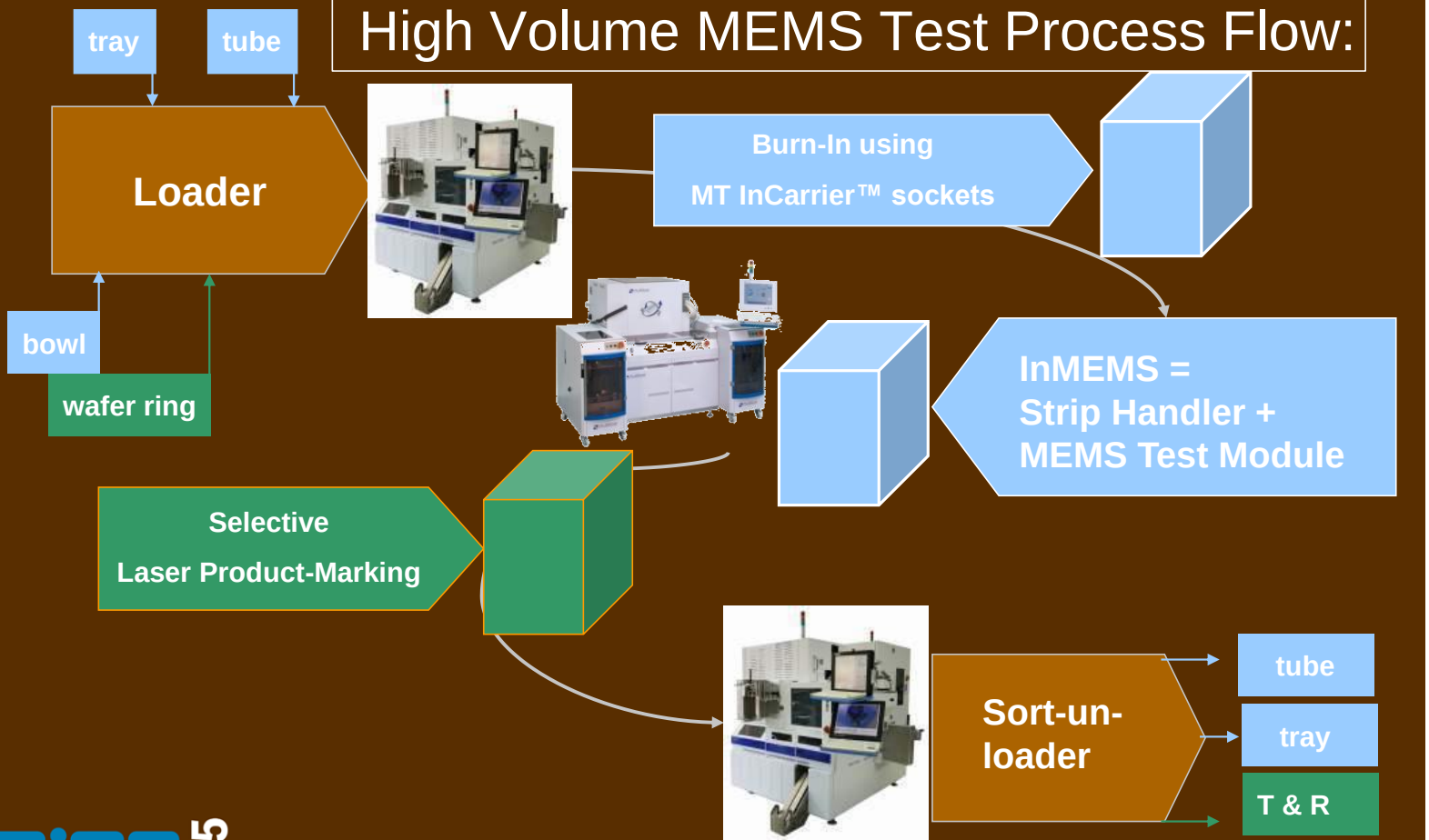
Step 3: High Parallelism

High Volume MEMS Test Process Flow:



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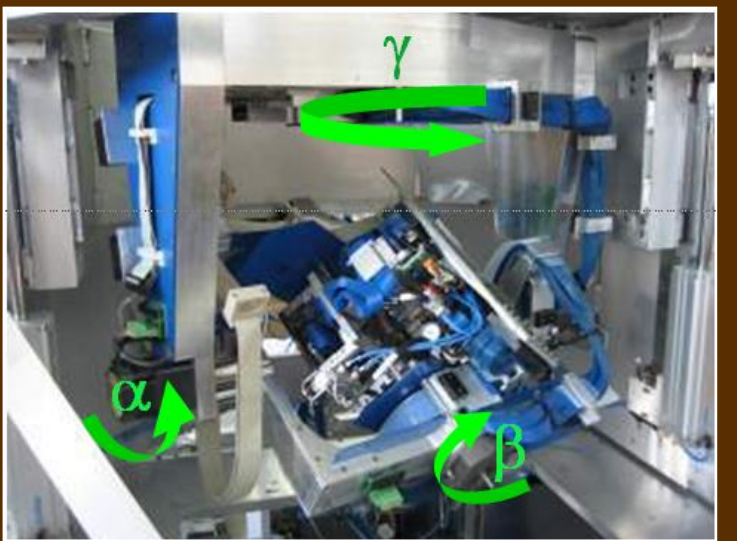
Step 4: Multi DOF Test in One Insertion

Sensor Stimulus Equipment to **fully support multi-axis / combo sensors**

Cost of Test Advantages

- **Multiple actuations in ONE insertion**
- **Increases UPH for Combo Sensors**
- **Reduces manufacturing process complexity**



Example: 9 DOF Test Setup

Step 4: Multi DOF Test in One Insertion

9DOF Combo Sensor Test Example:
6 Axis Inertial MEMS Test = 3 Axis Gyroscope + 3 Axis low g Accelerometer with non magnetic contact environment for passive 3 DOF Magnetometer test

1 Test Insertion for

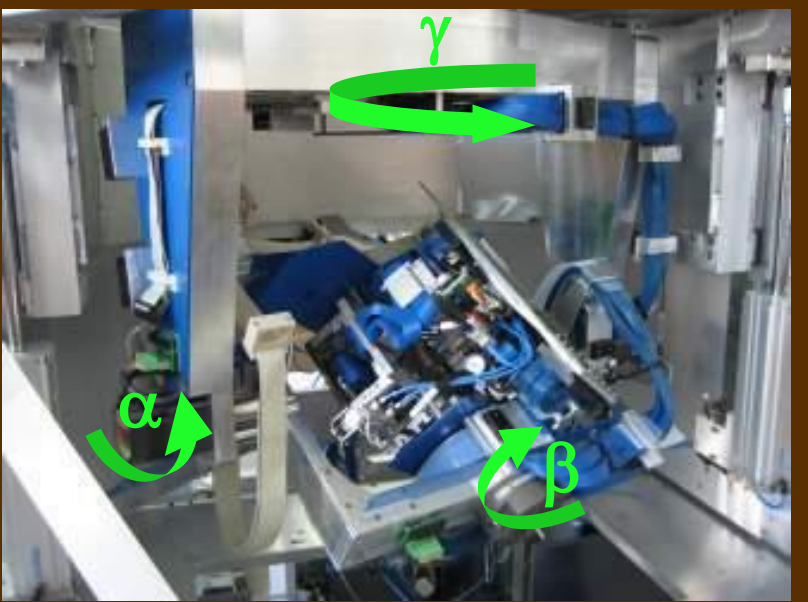
3D Accelerometer

+

3D Gyroscope

+

3D Magnetometer



Conclusion: Optimizing MEMS Test Cell to Minimize CoCT

$$CoCT = \frac{\text{Capital Cost}}{\text{Lifetime}} + \text{Variable Cost} + \text{Overhead}$$

$$\text{Yield} * \text{Utilization} * \text{Throughput}$$

- depreciation period
- useful lifetime
- re-use for new applications

investment cost for

- handler base + change kit
- MEMS module
- tester
- manipulator + docking

- utilities (eg. power, CDA, LN2)
- labor, operations & engineering
- load boards, contactors
- maintenance & service
- spare parts

- management
- adminstration
- facilities

- contacting accuracy and repeatability
- open/short rate
- test yield / re-test rate

- uptime, MTBA, MTTA, MTTR
- package conversion time
- setup time
- socket cleaning & exchange
- training

- DUT test time
- handler index time
- number of contact sites
- soak speed & capacity
- effective throughput

Conclusion: Minimize CoCT through Test Cell Innovative Solutions

Best Cost of Test and Calibration is ensured by

- Standardized MEMS handler and stimulus cart adaptive to various package types
- Exchangeable MEMS Stimuli
- Modular Test Cell Concept that Combines Handler with MEMS Stimulus
- MEMS High Parallel Handling and Stimulus Solutions (strip test, test in carriers)
- Multi-DOF solutions with only ONE insertion (ie 6DOF, 9DOF)