Implementing MEMS: Make vs. Buy?

Sensors Expo 2014

Alissa M. Fitzgerald, Ph.D. | 24 June 2014

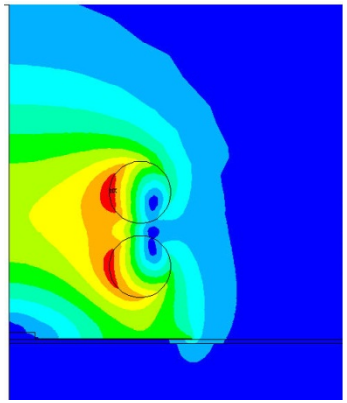
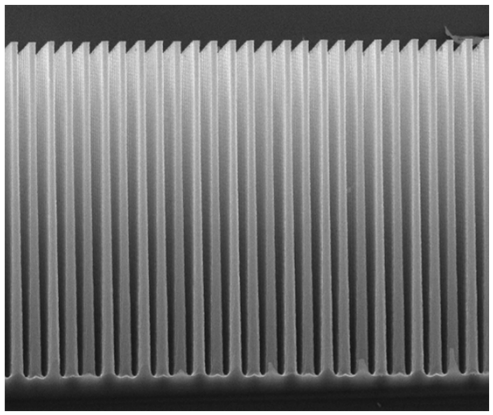
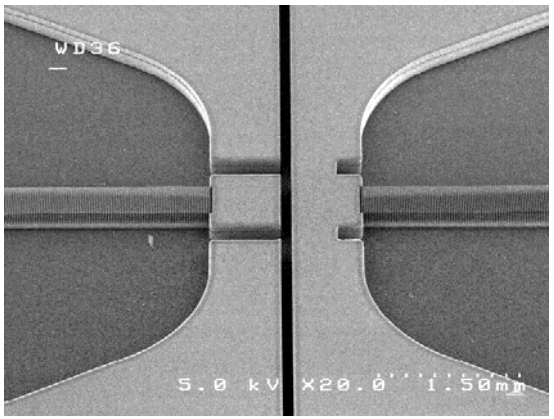
AMFITZGERALD
& ASSOCIATES

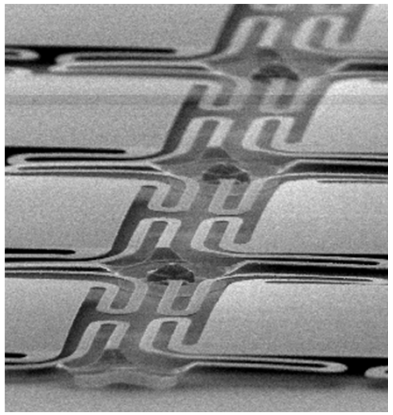
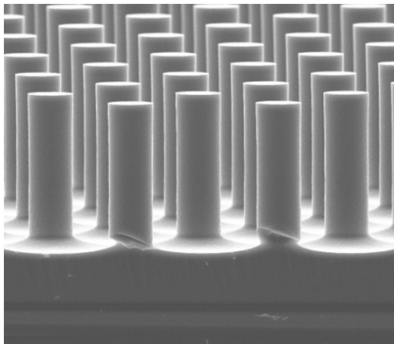
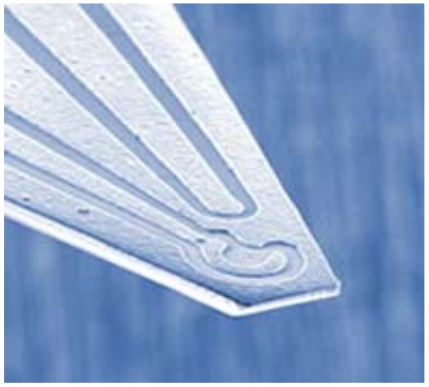
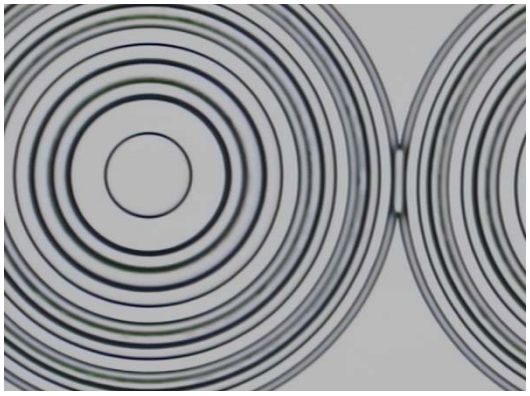
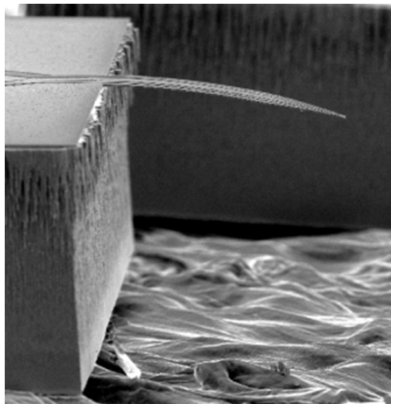
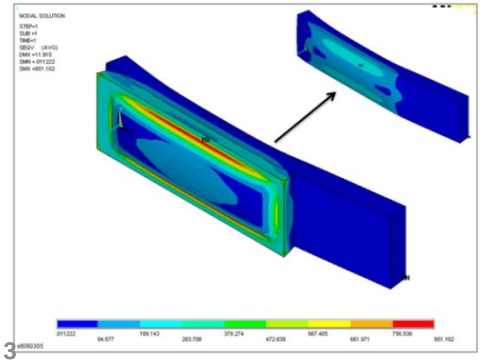
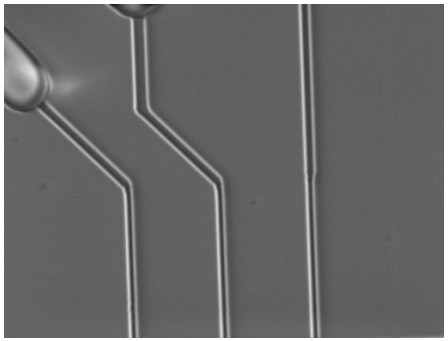
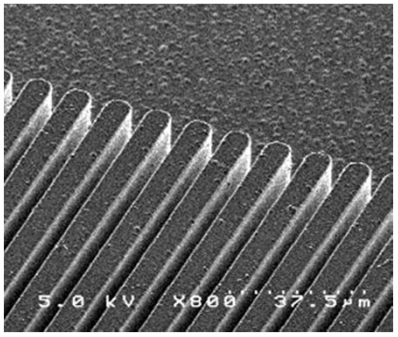
11th anniversary
2003 2014

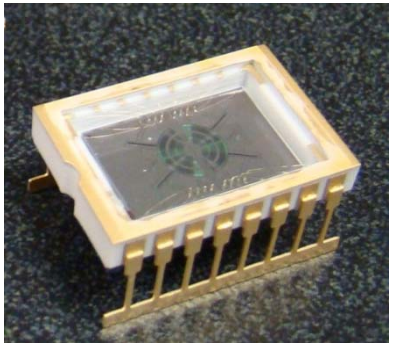
Overview

- About us
- Choosing a sensor specification
- Buy vs. make
- Other creative options to acquire MEMS

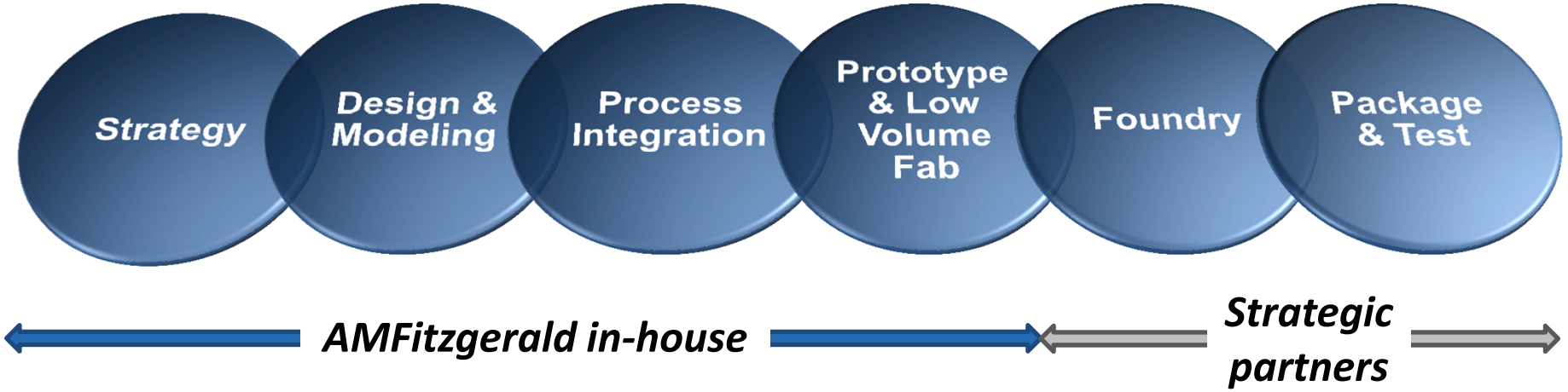
AMFitzgerald: Your Partner in MEMS Product Development



A complete supply chain from concept to production



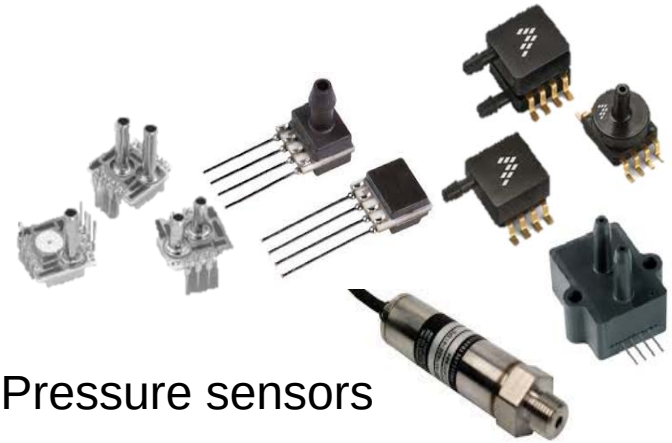
- **Multi-disciplinary, expert engineering team**
- **Custom MEMS development from start to finish**
- **Design and process integration for volume production**
- **In-house prototype fabrication, easy transition to production partners**

Choosing a sensor specification

Types of commercially-available MEMS sensors

Accelerometers

Microphones



Pressure sensors

Gyroscopes

Oscillators

Magnetometers

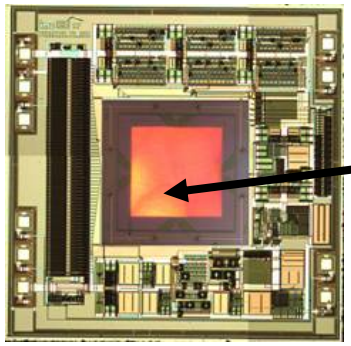
Thermopiles

RF components

Why MEMS are exciting for so many applications

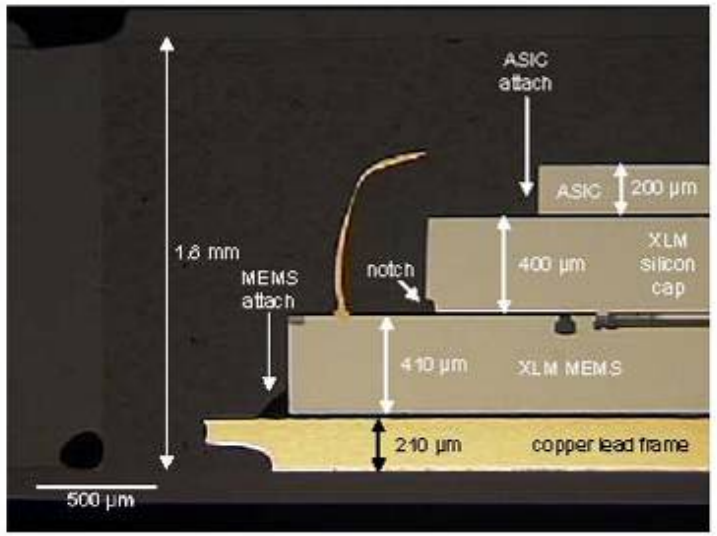
- **Smaller, better, cheaper**
  - **But not always all three**
- **Ease of electronics integration enables sophisticated capabilities in small form factor:**
  - **Multiple sensors**
  - **Signal processing and analysis**
  - **Telemetry capability**
  - **Low power**

Integrated Pressure Sensor



Source: IMD

Stacked MEMS and ASIC chips, wirebonded



Source: Chipworks/Kionix

Specifications

- **Primary**
  - **Sense range, sensitivity**
  - **Power (voltage/current)**
  - **Linearity**
  - **Accuracy, resolution**

- **What makes “great” vs. “good” sensor**
  - **Cross-axis sensitivity, noise rejection**
  - **Dynamic response, settling time**
  - **Temp coeffs of resistance, frequency, sensitivity, etc.**
  - **Stability/drift (hours, days, years?)**
  - **Noise/jitter**
  - **Overdrive protection, self-test**

Price vs. performance tradeoffs

MEMS available for a range of specifications

Quality Grade	Gyroscope Manufacturers	Typical Price	Gyro Bias Stability
Military	Silicon Sensing Systems	$500	< 0.01 deg/s
Automotive	Bosch	$8	1 deg/s
Consumer	InvenSense	$2	10 deg/s

"You get what you pay for"

Compensation tactics for sensor shortcomings

- **ASIC**
  - **Signal conditioning**
  - **Noise rejection, filtering**
  - **Amplification**
- **Sensor Fusion**
  - **Accel + Magnetometer = Simple Gyro**
- **Software**
  - **“Never solve in hardware what you can solve with good software”**

Buy vs. Make

First, know what's important to your business and product

- **Strategy**
  - **First to market?**
  - **Raise barriers to entry?**
- **Tolerance for risk**
  - **Technical vs. marketing**
  - **IP**
- **Resources**
  - **Engineering staff**
  - **Supply chain**
  - **Budget**
  - **Time**

What you can purchase/license

IP, Patents

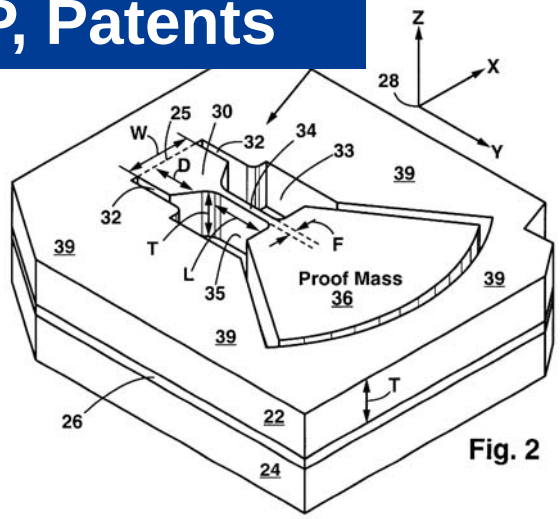
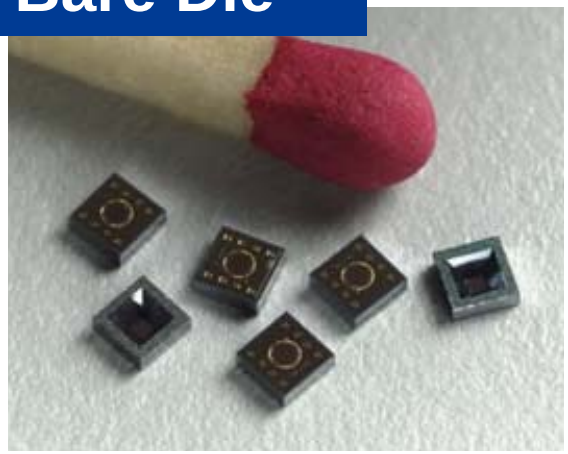
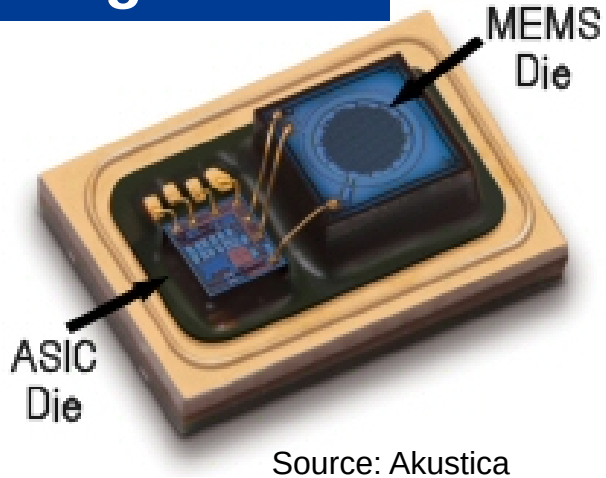


Fig. 2

Bare Die

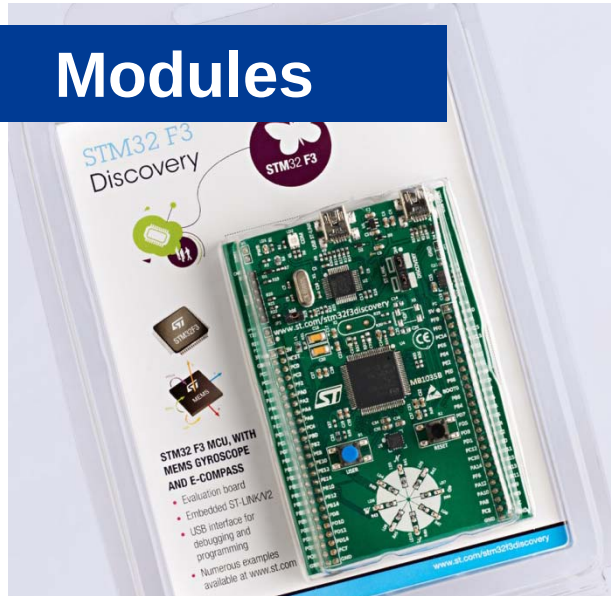

Source: NASA

Packaged Die



Source: Akustica

Modules

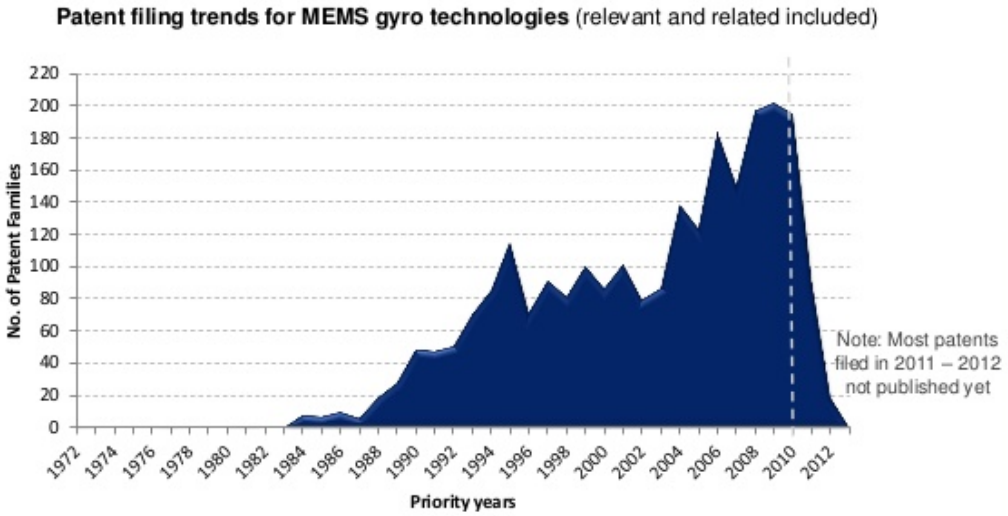


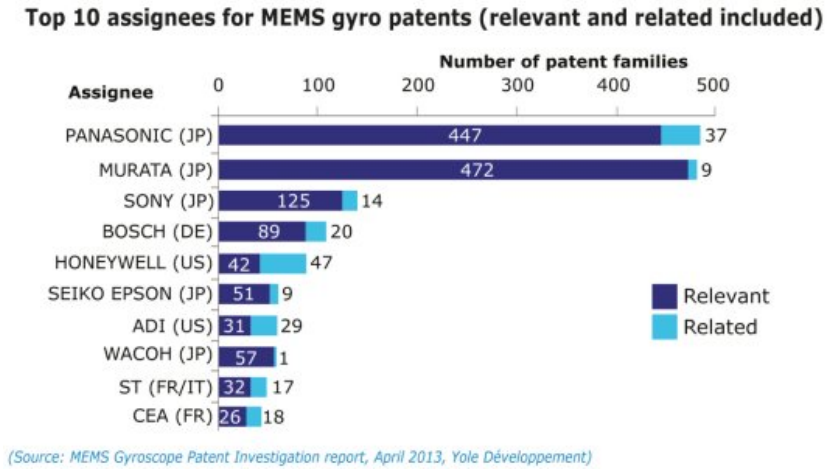
When to buy

- **Short time to market (< 3 years)**
- **Unit cost is a priority**
- **Loose sensor specifications, or**
- **System can add value or compensate for sensor shortcomings**
- **Lack of silicon supply chain and domain expertise**

When to buy: IP considerations

- **MEMS has crowded IP landscapes with litigious stakeholders**
  - **Microphone**
  - **Gyroscope**





Source: Yole Developpment

The “white-label” model: microphones

Top Global MEMS Microphone Suppliers Ranked by Revenue
(Millions of US Dollars)

Rank	Company	2012 Revenue	2011 Revenue	2012 Market Share %
1	Knowles	$291	$272	50%
2	AAC	$98	$48	17%
3	Analog Devices	$78	$45	13%
4	Goertek	$46	$12	8%
5	STMicroelectronics	$21	$6	4%
6	Hosiden	$12	$7	2%
7 & 8	BSE	$10	$6	2%
	Wolfson	$10	$1	2%
9	Bosch	$9	$9	2%
10	NeoMEMS	$4	$0	1%
11 & 12	MEMSensing	$1	$0	0%
	TDK-EPC	$1	$1	0%
	Others	$2	$1	0%
	Total	$583	$408	100%

Source: IHS Inc., May 2013

Infineon supplies “white-label” MEMS microphones to these reseller companies

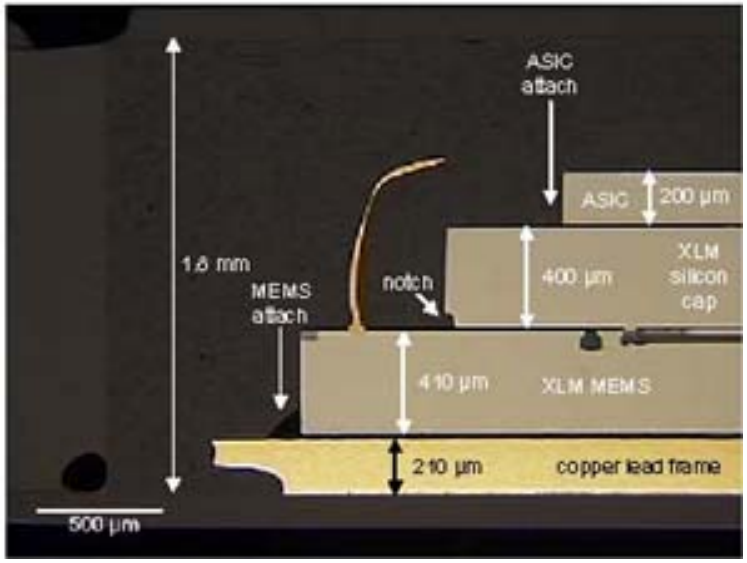
- **Resellers add value on ASIC (sensitivity, signal-to-noise), packaging (acoustic performance, reliability).**

When to make

- **Unusual sensor specifications**
  - **Form factor, performance, environment**
  - **Medical, scientific instruments, aerospace, oil/gas**
- **Sensor itself enables major competitive advantage for your product**
- **New sensor technology with strong patent opportunities**
- **Critical need to control the supply chain**
  - **Quality control**
  - **Regulatory issues**
  - **Barriers to competition**

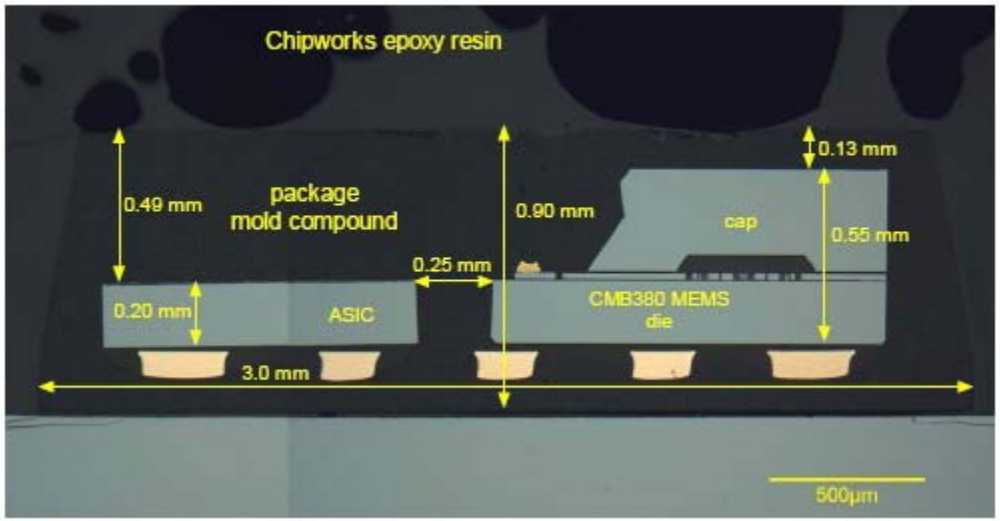
Make: You'll need an ASIC* and a package, too

Stacked



Source: Chipworks photo of Kionix KXM52

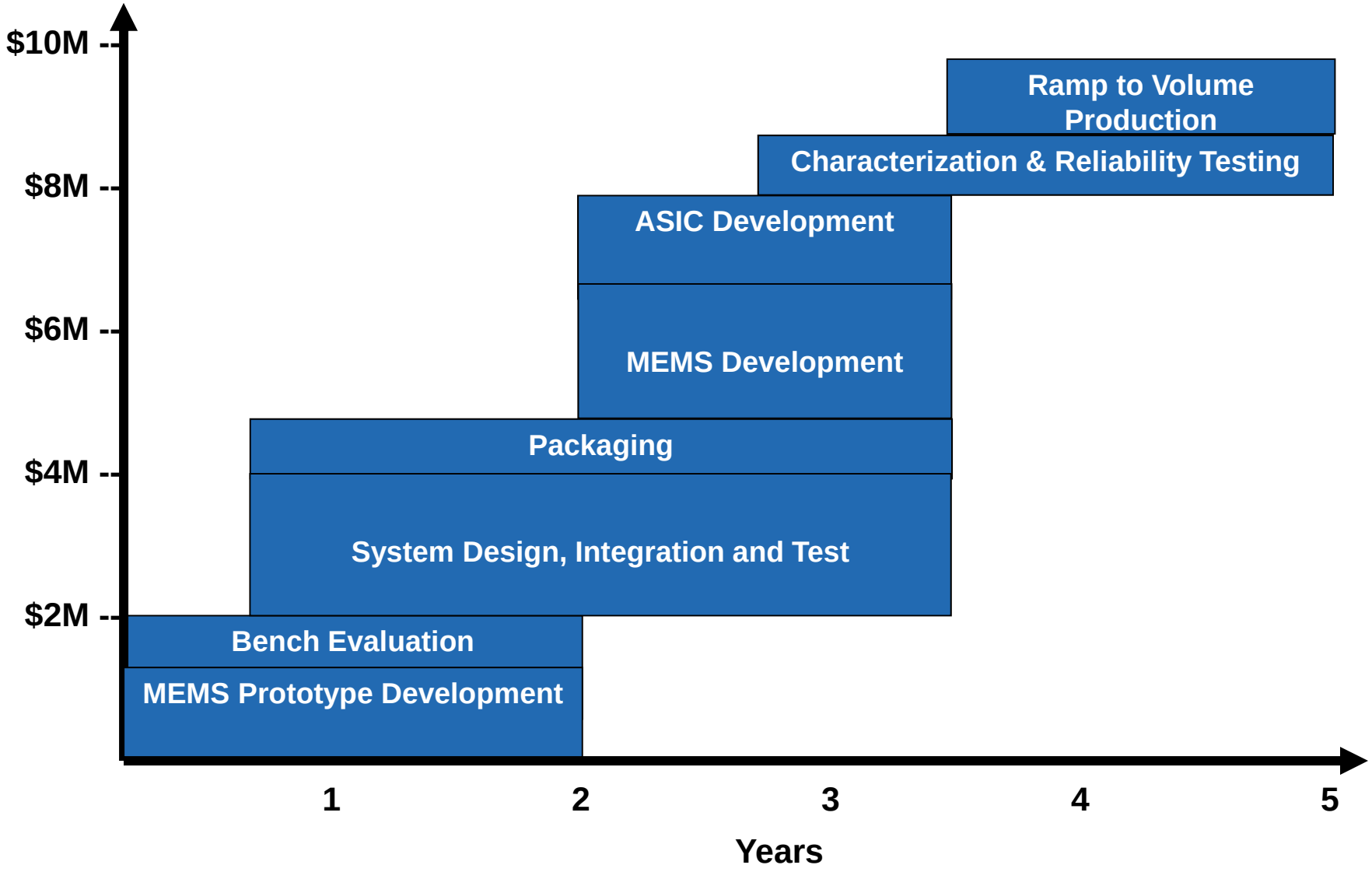
Side-by-side



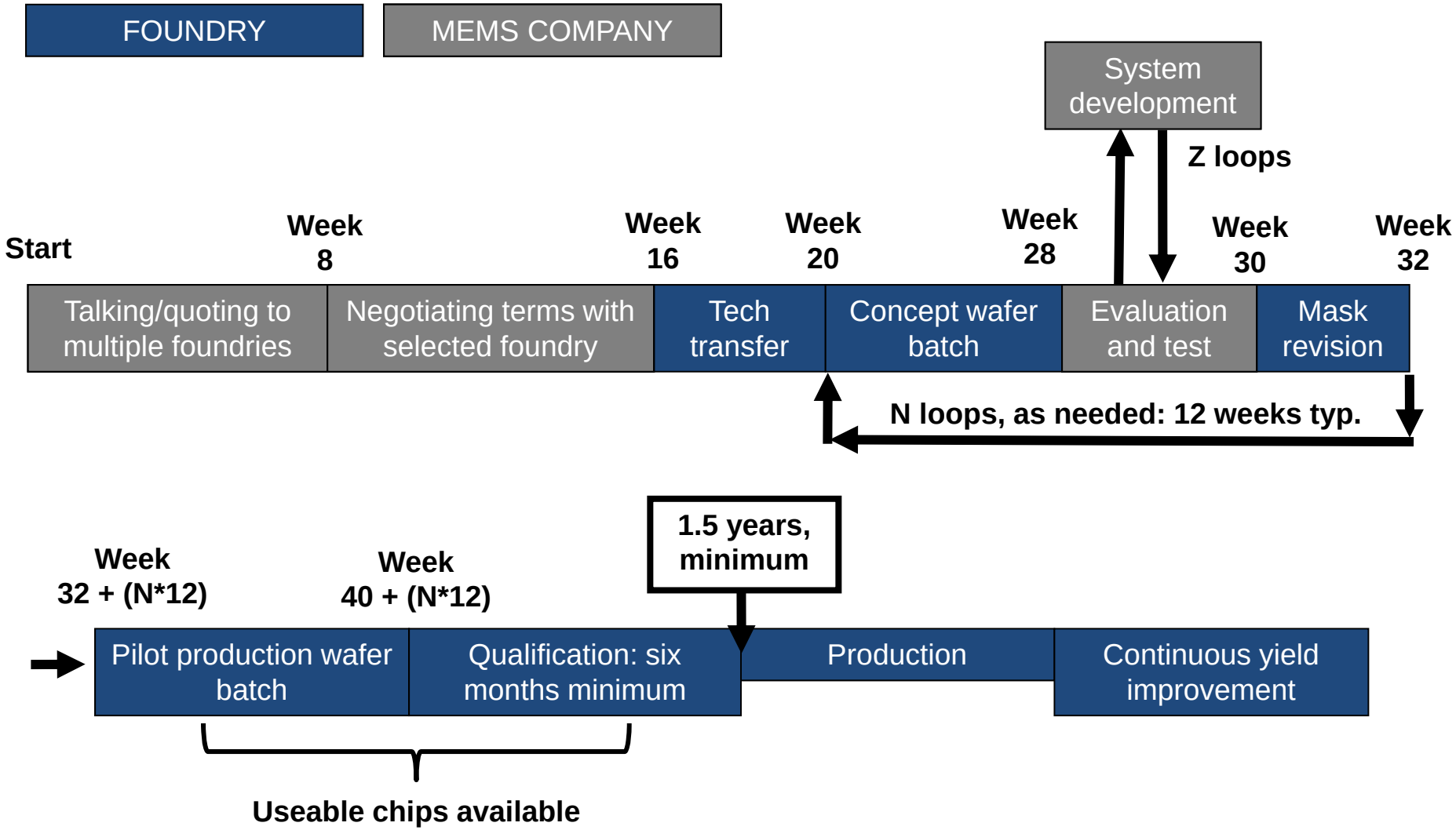
Source: Chipworks photo of Bosch SMB380

*Application-Specific Integrated Circuit

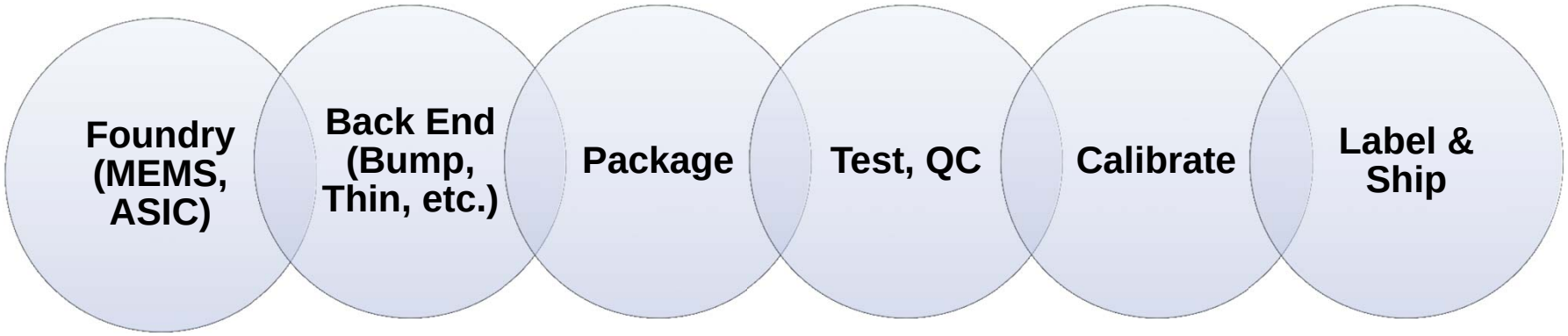
Make: everything from scratch, cost and timeline minimums



Bringing a mature prototype to production



Make: Supply chain creation and management



- **An entire supply chain must be qualified, developed and managed**
- **Time and money to link the supply chain is easily underestimated**

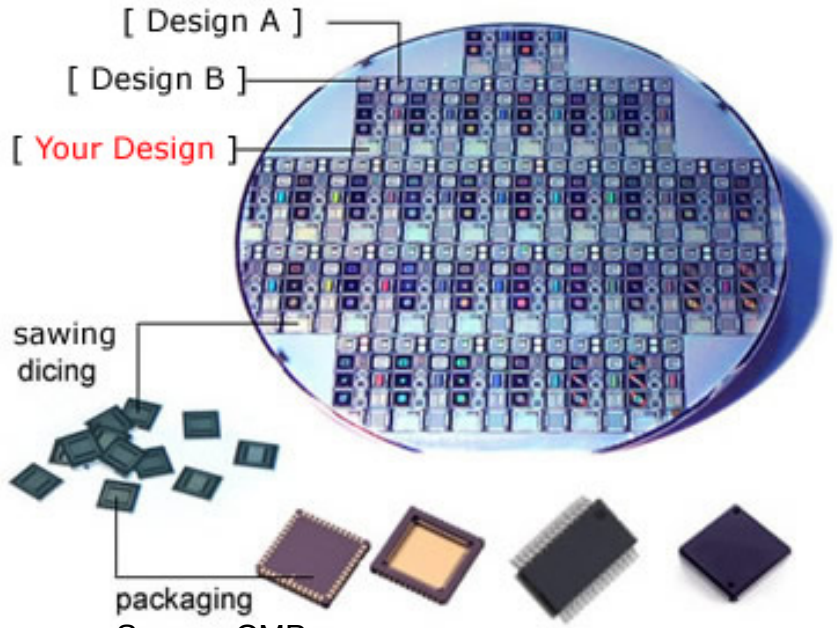
Other creative options

Hybrid: Buy (or License) and Make

- **Save 1-2 years of development by licensing existing MEMS technology**
  - **Universities: Stanford, Michigan, Georgia Tech, etc.**
  - **R&D groups: Fraunhofer, Leti, parc, imec, etc.**
  - **Corporate Portfolios: HP accelerometer, etc.**
- **Make sure prototypes already exist and function well!**
  - **“Paper” designs are not production-ready**
  - **Lack of standard MEMS processes**
- **Then modify licensed IP to suit**

Multi-project wafers (MPW)

- **Leverage qualified processes**
- **Customer must provide the chip design**
- **Small chip volumes**
  - **Good for samples**

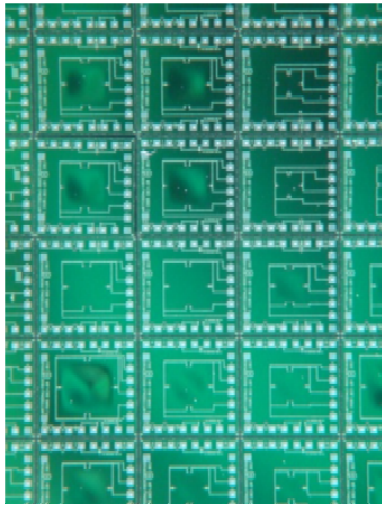


Source: CMP

Some MEMS MPWs

Facility	Service Name	Target Market	Process	Wafer size
ST	Thelma	Motion sensors	Thick epi-poly	200
Dalsa	MIDIS	Motion sensors	SOI with vacuum and pressure cavity	200
X-FAB	XMB-10	Motion sensors	Cavity SOI	150, 200
InvenSense	NF Shuttle	Motion sensors	CMOS cap, SOI wafer	200

AMFitzgerald's RocketMEMS^{TM}: Semi-custom sensors



Variety of RocketMEMS Pressure Sensors

- **MEMS solutions for OEMs and system integrators**
  - **AMFitzgerald reference designs**
  - **ISO-certified foundries**
  - **Cost-effective multi project wafer runs**

1. **Customer provides desired sensor specification**
2. **AMFitzgerald tailors reference design to meet customer's spec**
3. **Silex manufactures wafers**
4. **AMFitzgerald tests and delivers sensors to customer**

Pitfalls

- **Very little in MEMS is “turnkey”**
  - **“Buy” is not always a fast option**
  - **“Make” does not always provide a high level of control**
- **Caveat emptor**
  - **“Show me the silicon…and the data”**
- **Pick your IP battles**
  - **The more valuable patents may be in the package or system, not the MEMS chip**

Summary

- **Make vs. buy choices are very specific to application and business profile**
- **MEMS industry ecosystem offers a lot of options in either path**

- **We can help you – please visit us at Booth #311**


AMFITZGERALD
& ASSOCIATES