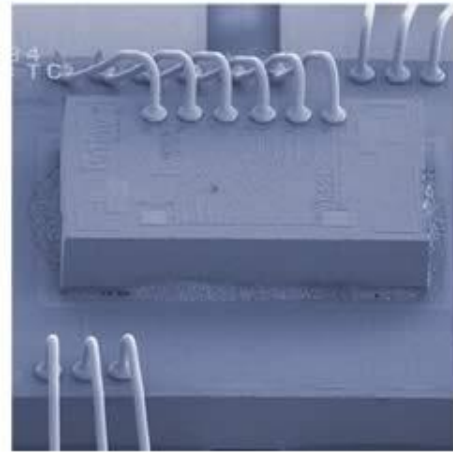
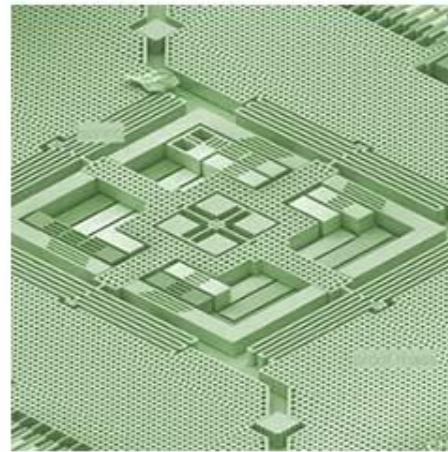
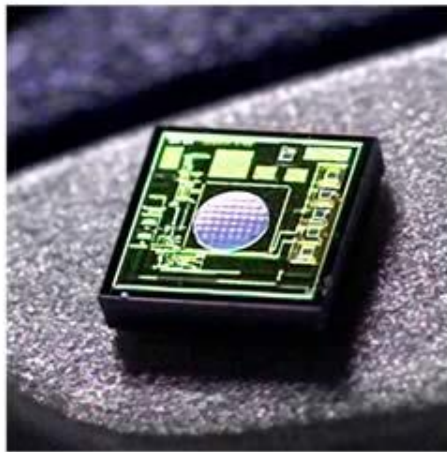
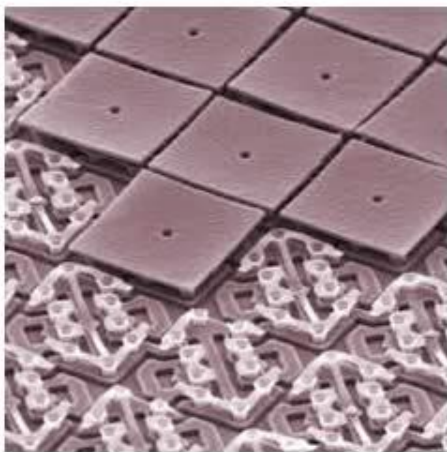


Commercializing MEMS

A View from the Trenches

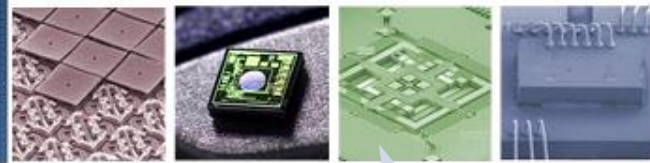


Kurt Petersen, PhD



My Background

TDI	1982	Merged with IC Sensors
Novasensor	1995	Acquired by GE
Cepheid	1996	IPO in 2000; CPHD has \$2.8B market cap and \$320M yearly revenues
SiTime	2004	Has sold >120M MEMS oscillators for video monitors, cameras, etc.
Verreon	2008	Acquired by Qualcomm
Profusa	2009	\$750K contract from DARPA \$2+M from NIH, for 2 years \$1.2M angel seed round



Growth of MEMS



60's - 70's
Industrial



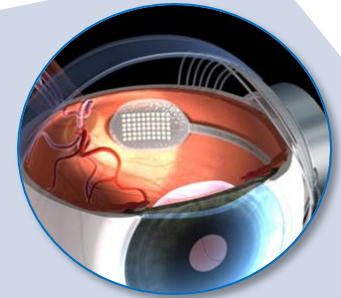
80's
Medical



80's - 90's
Automotive



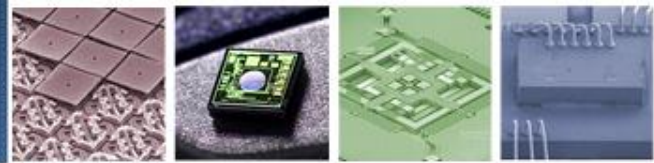
2000's
Consumer



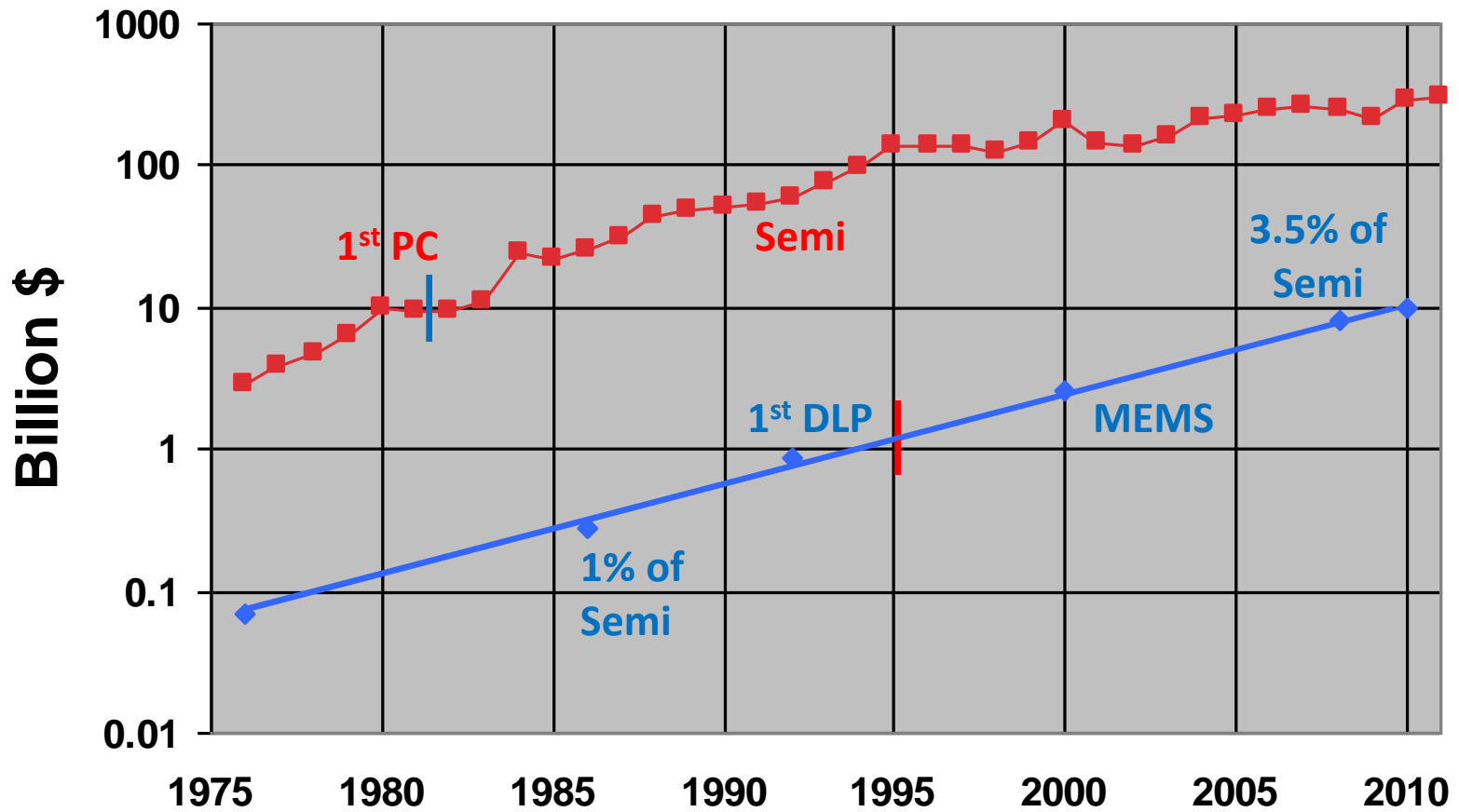
2010's
Consumer
+
Bio-MEMS
+
Environmental

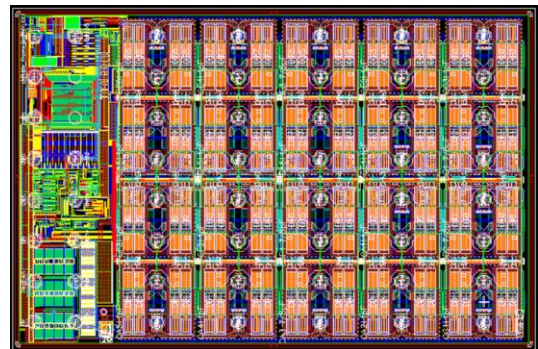
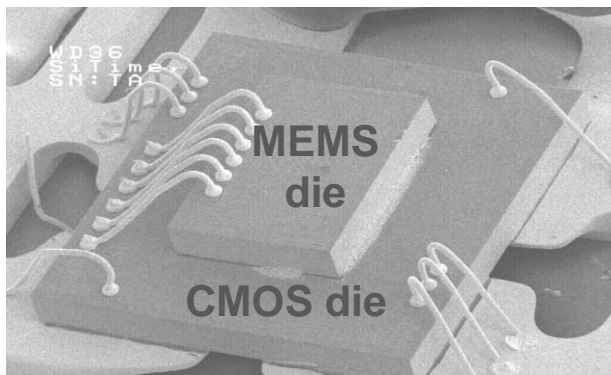
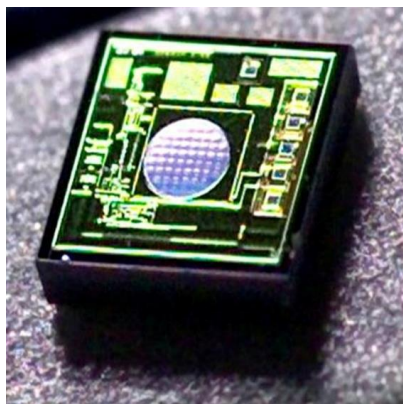
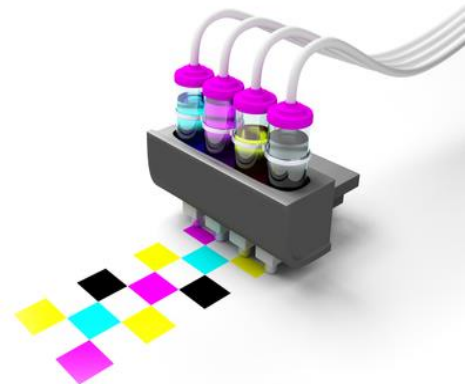
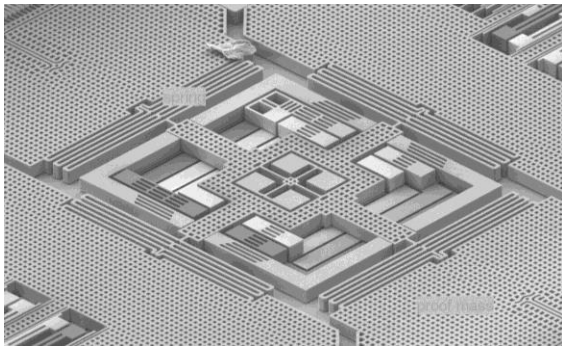
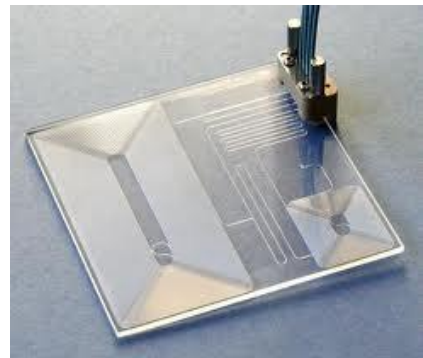
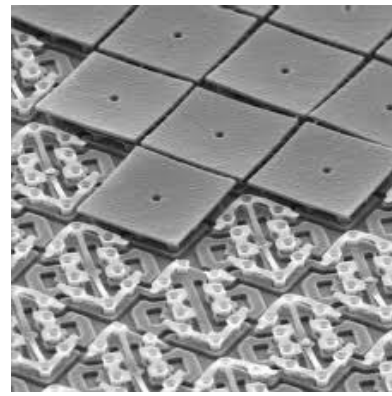
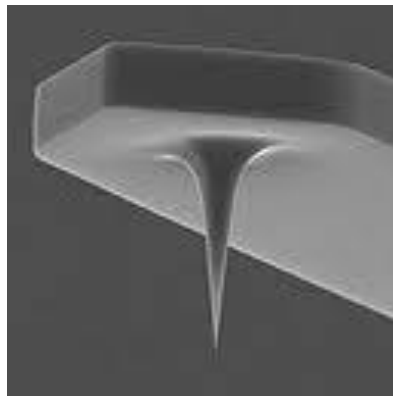
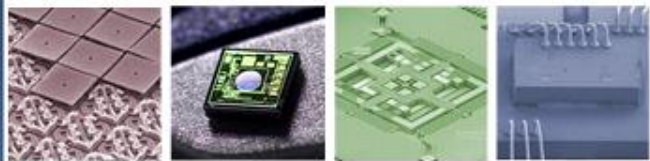
Shipped Volume - units





Yearly Shipments

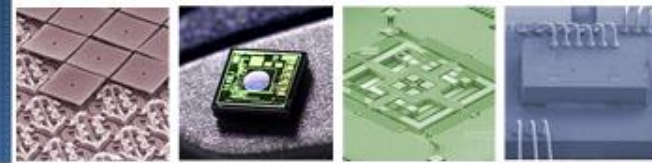






Billions of MEMS Devices Sold

Avago	>2B	Cell phone filters	As of Q2 2010
Robert Bosch	>1B	Automotive sensors	As of Nov 2008
Knowles	>1B	Microphones	As of Sept 2009
Texas Instruments	>10 ¹⁴	Light modulators	As of Dec 2009
GE NovaSensor	>750M	Pressure sensors	As of Aug 2011
ST Micro	>1B	Accels and Gyros	As of Dec 2010
HP	"Billions and Billions of ink jet nozzles"		
Cepheid	~\$1B	Microfluidic systems	As of Q4 2010
SiTime	>100M	MEMS Oscillators	As of Q2 2012



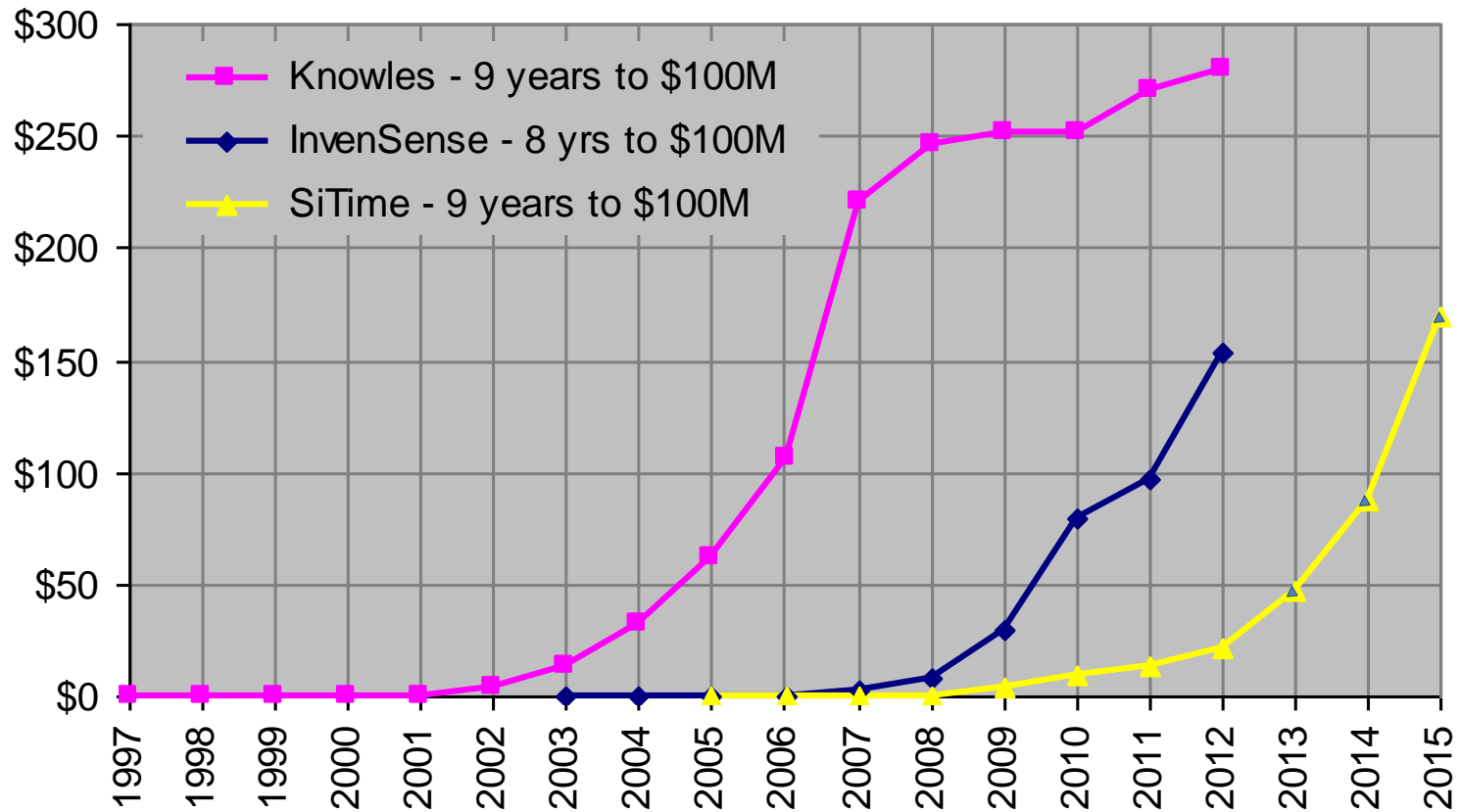
Economics

Starving Markets are **desperate**

A few Examples of MEMS Products			Competition
Ink jet printing	HP	1985	Low-resolution dot matrix printing
Accelerometer	ADI	1992	Ball bearing held in tube with a magnet
DLP	TI	1995	LCD display
Gyroscope	Bosch	1998	Complicated quartz assembly
Microphone	Knowles	2002	Electret cannot be wave-soldered
Oscillator	SiTime	2007	Quartz oscillators with 50 dpm
Variable Cap Array	WiSpry	2011	Low-Q CMOS capacitor arrays



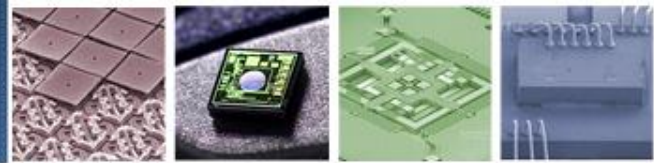
MEMS Production Ramp-up



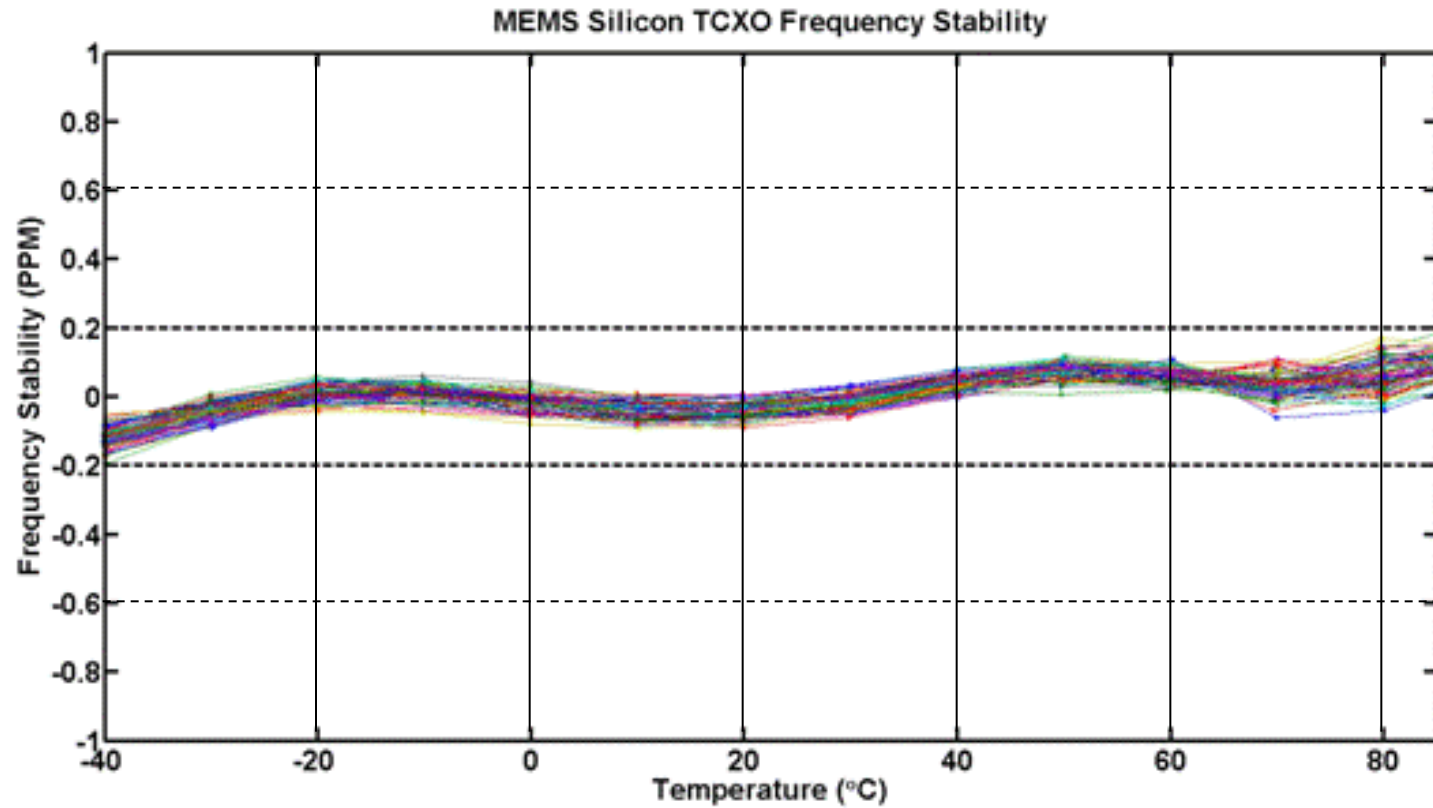


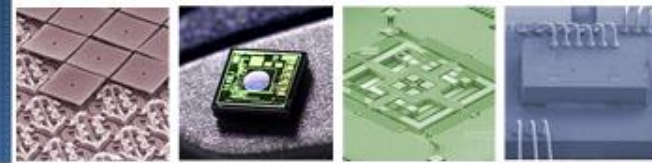
MEMS oscillators are now Better than Quartz in every way

- Lower cost - >70,000 MEMS die/8" wafer, 1.5 cent/oscillator
- Higher reliability
 - typically <<5dpm defects, compared to >50dpm for quartz
- Better temperature performance than quartz
 - SiTime is now shipping ± 0.5 ppm over 125°C
- Improved stability of frequency over time than quartz
- Phase noise (or jitter) is now better than most quartz
- Smaller footprint on the Printed Circuit Board
- Faster deliveries - no special tooling required
- Today, >120M SiTime MEMS oscillators have been sold for cameras, displays, PCs, servers, etc
- Thousands of customers like Apple, Sony, Panasonic,
- MEMS is having a dramatic impact on this **\$5B** market

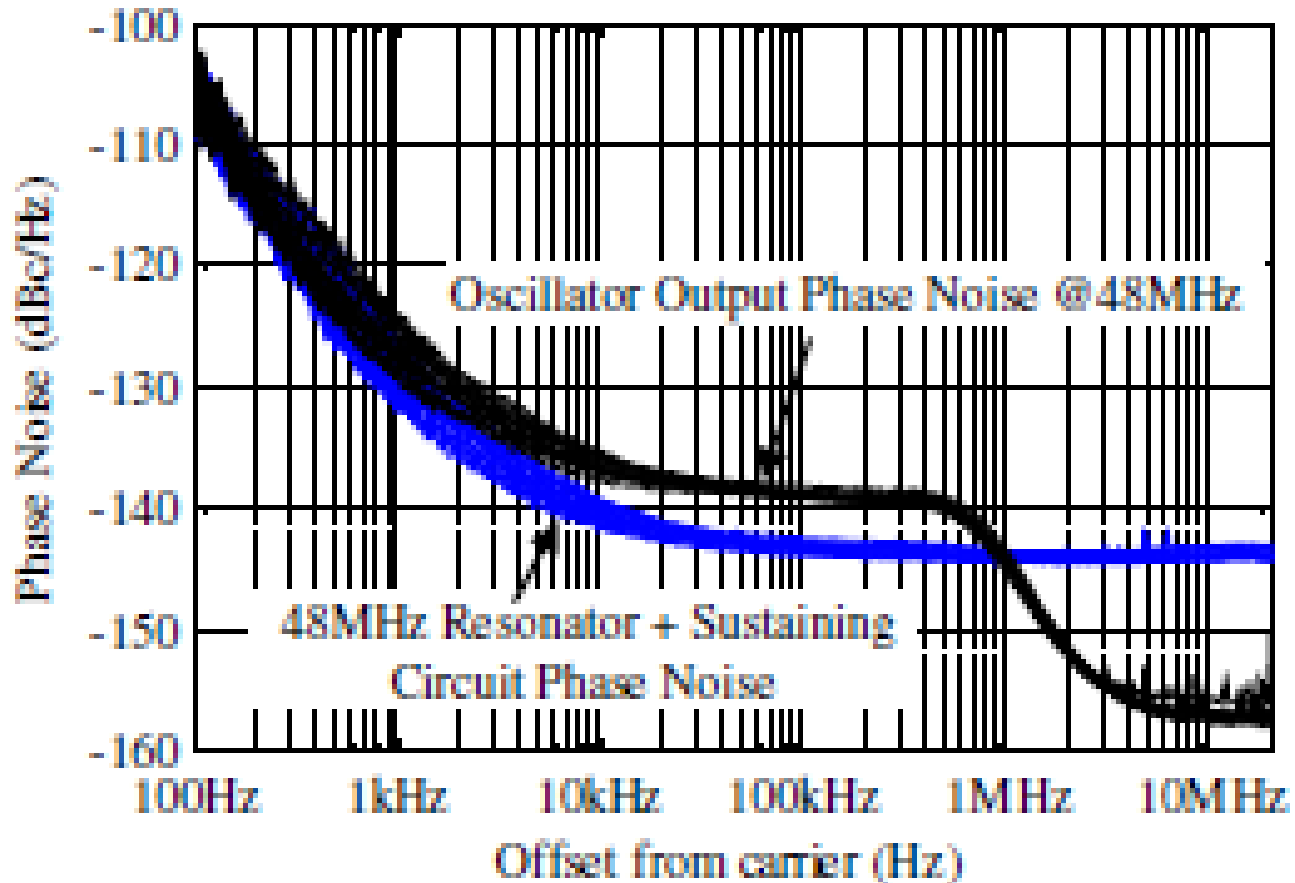


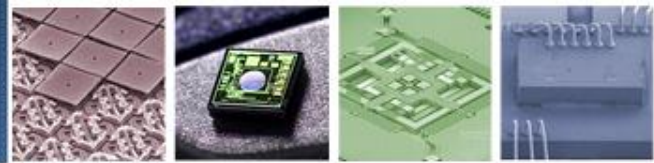
SiTime can now attack TCXO





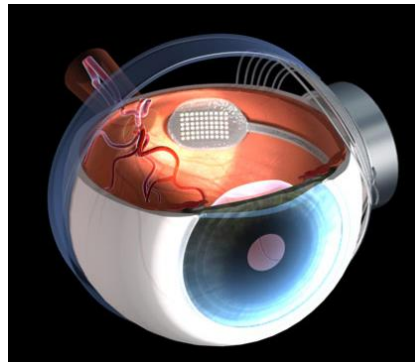
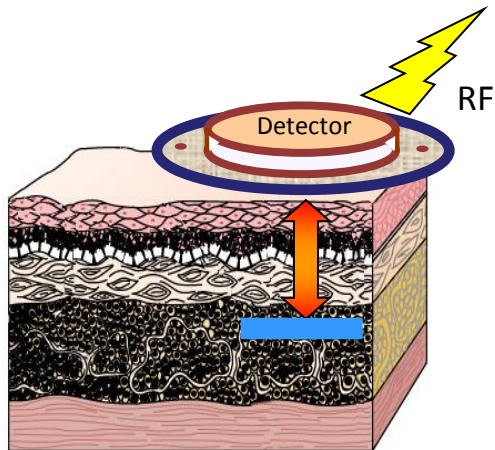
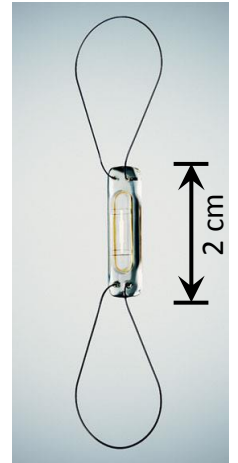
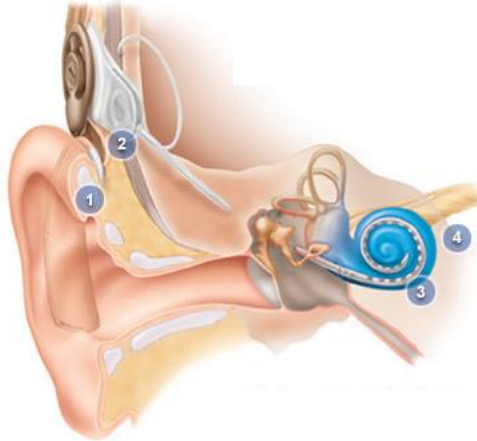
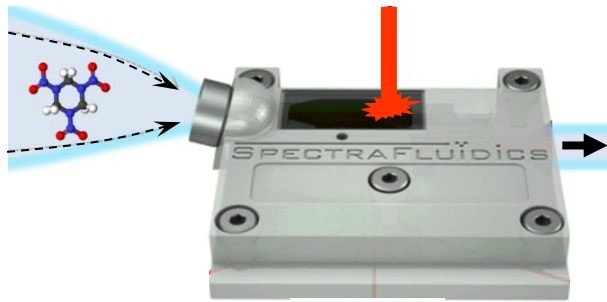
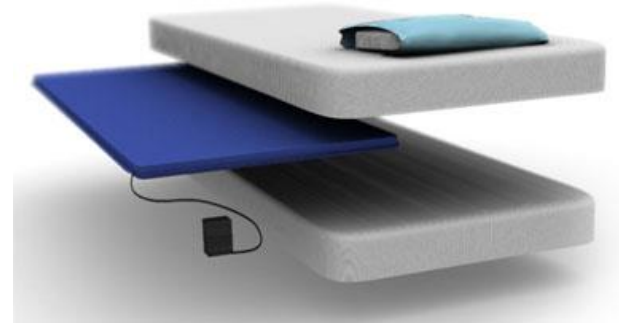
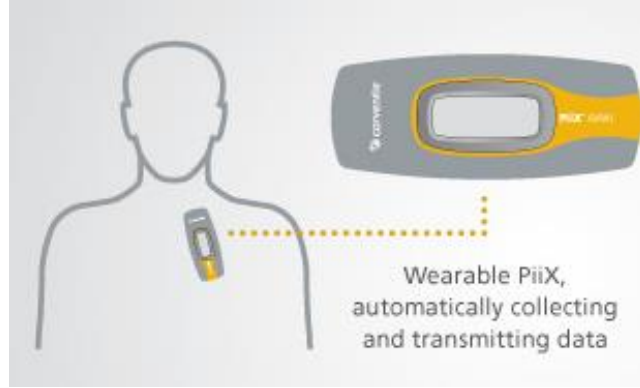
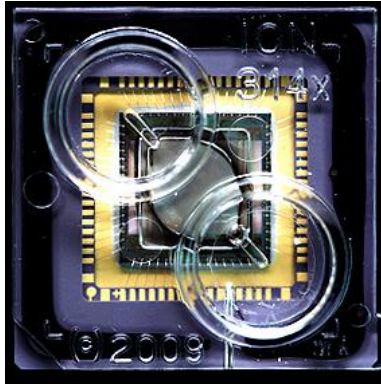
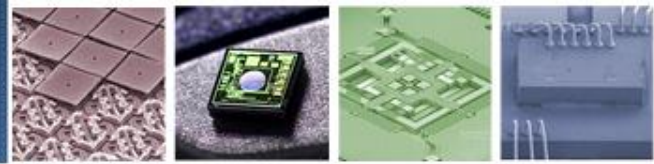
SiTime can now do communications





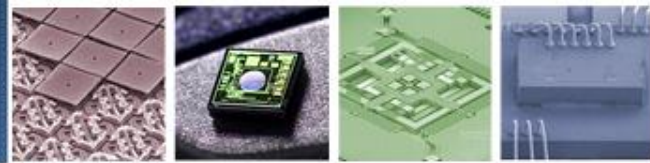
New Killer Apps for MEMS?

- SiTime was started in Dec 2004
 - oscillators were not even mentioned in any market forecasts
- WiSpry started as a MEMS switch company, transitioned into variable capacitor arrays
- Cell phone manufacturers are scrambling to put whatever sensors they can on a phone; humidity, gas sensors, IR imagers, chem sensors, gesture recognition, etc
- Sensor-Fusion: overlapping, over-sampled sensing to compensate for inherent sensor inaccuracies
- Contextual Awareness will require entirely new sensor concepts
- You can define “human” as “interacting with the environment”
 - One thing this means is SENSORS
- So, Great, new opportunities abound



- Protein Panels
- Cellular Manipulation
- More Fluidics
- More Optics
- More RF
- Energy Scavenging

...



Recent Smart-Phone Peripherals

Credit Card Reader



Glucose Finger-stick Sensor



Blood pressure monitoring cuff



Pico-Projector



Ultrasound machine from Mobisante went on sale in October 2011



Mobile Health



Competition Details

Media

Blog

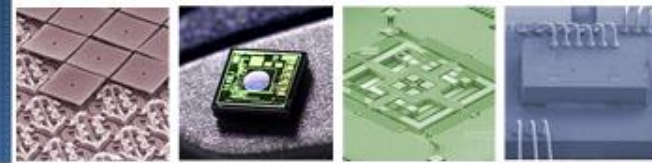
About



As envisioned for this competition, the device will be a tool capable of capturing key health metrics and diagnosing a set of 15 diseases. Metrics for health could include such elements as blood pressure, respiratory rate, and temperature. Ultimately, this tool will collect large volumes of data from ongoing measurement of health states through a combination of wireless sensors, imaging technologies, and portable, non-invasive laboratory replacements.

Introducing the Qualcomm Tricorder X PRIZE.

A \$10 million competition to bring healthcare to the palm of your hand.



Monitoring Our Environment

- The Fusion of Wireless/Sensors/Energy-harvesting will be HUGE
- The Vision is : a **TRILLION** sensors distributed over the planet
- One portion of the Internet of Things
- HUGE opportunities for MEMS and sensors



Courtesy of Janusz Bryzek;
The Trillion Sensor Roadmap



Magnitude of Upcoming Change Will be Stunning - We are Still in Spring Training

- **Nearly Ubiquitous High-Speed Wireless Access in Developed Countries**
- **Unprecedented Global Technology Innovation**
- Ultra Competitive Markets for Mobile Operating Systems + Devices
- Broadly Accepted 'Social Graphs' / Information Transparency
- **Fearless (& Connected) Entrepreneurs**
- Difficult 'What Do I Have to Lose' Economic Environment for Many
- **Available (& Experienced) Capital**
- **Fearless (& Connected) Consumers**
- **Inexpensive Devices / Access / Services (Apps)**
- **Ability to Reach Millions of New Users in Record (& Accelerating) Time**
- 'Social Emerging as Starting Distribution Point for Content,' (Brian Norgard, Chill)
- Aggressive (and Informed) 'On My Watch' Executives at 'Traditional' Companies
- Unprecedented Combo of Focus on Technology AND Design
- Nearly 'Plug & Play' Environment For Entrepreneurs – Marketplaces / Web Services / Distributed Work / Innovative Productivity Tools / Low 'Start Up' Cost
- Beautiful / Relevant / Personalized / Curated Content for Consumers

KPCB



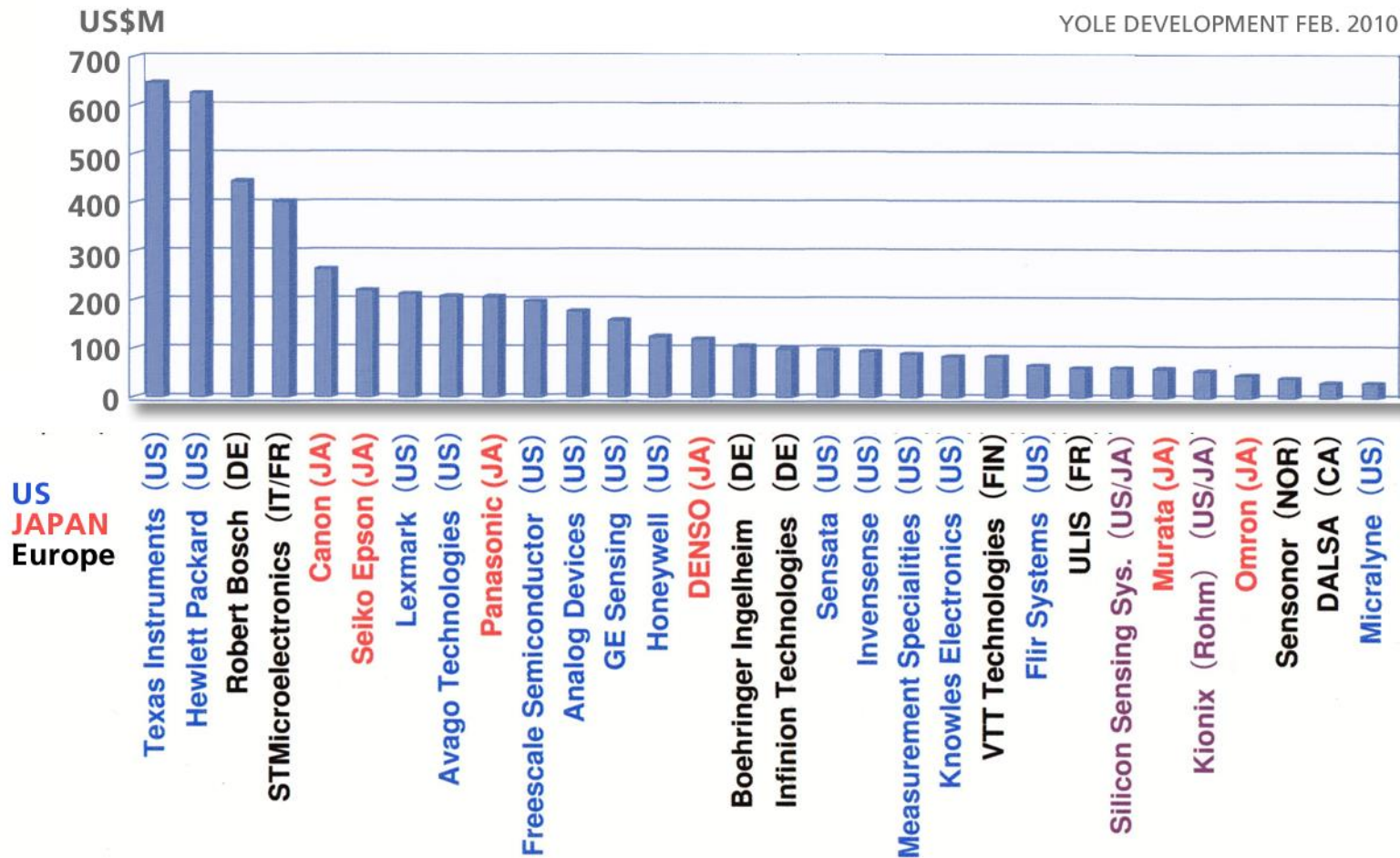
World-wide Competition – getting stronger

- Europe: Bosch, ST Micro, Silex, VTI (now Murata)
- Japan: Denso, Panasonic, Seiko, Murata, Rohm, Sony
 - has trouble in highest volume MEMS markets
- Taiwan: Foundries !!
- South Korea: watch out !!
- Singapore: Trying hard
- China is desperate to be a leader in N/MEMS
 - But, infrastructure/culture is lacking
 - Chinese industry, right now, is “distracted” being the world’s manufacturing resource
 - currently, weak interactions between industry & academia
 - **BUT**, strong, concerted efforts are underway
- Russian government is now investing in high tech
 - RUSNANO Capital invested in SiTime (now needs a facility in Russia)



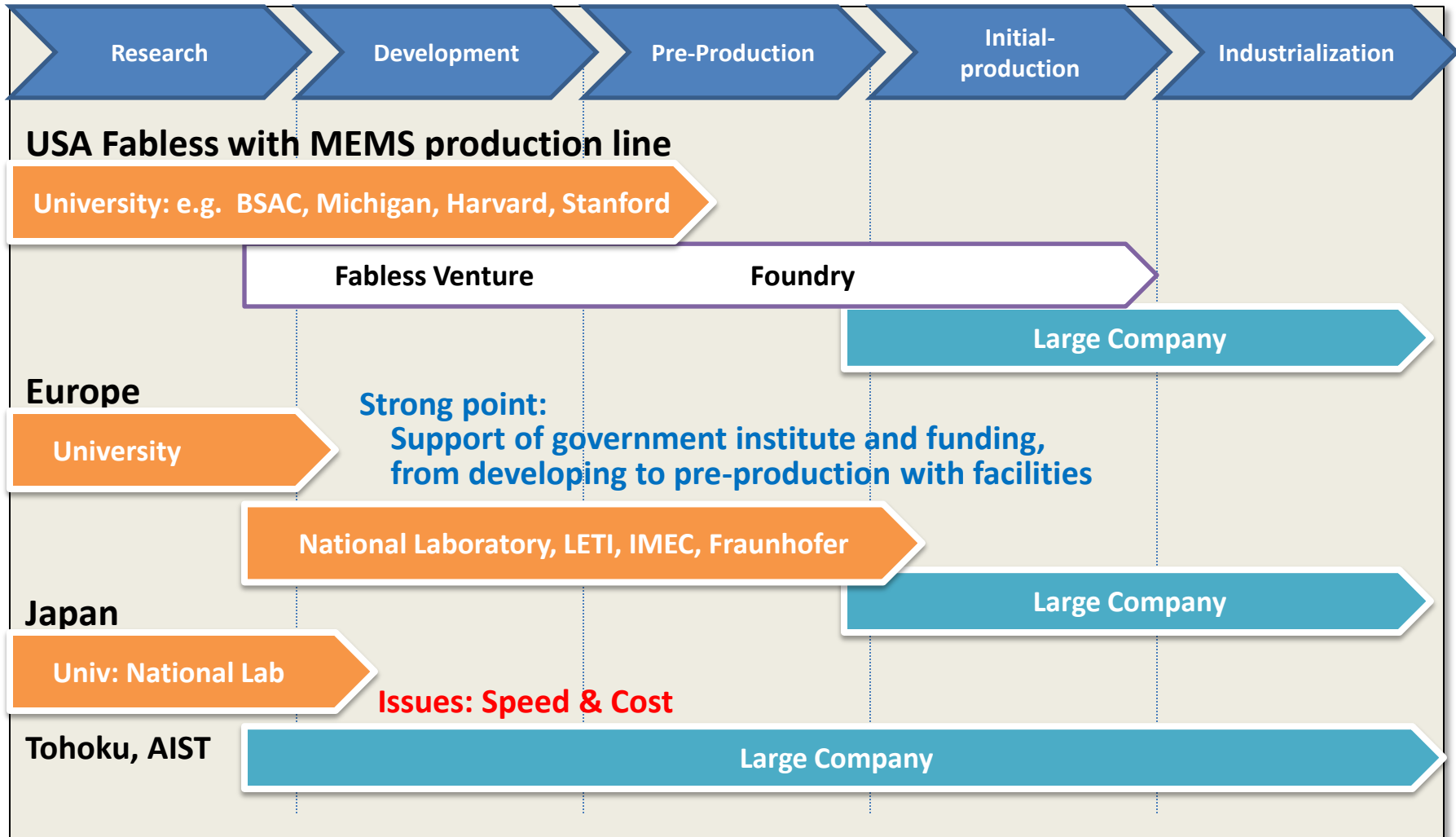
Top 30 MEMS Companies

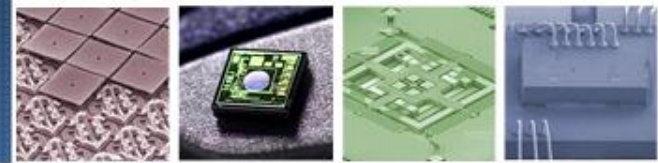
YOLE DEVELOPMENT FEB. 2010





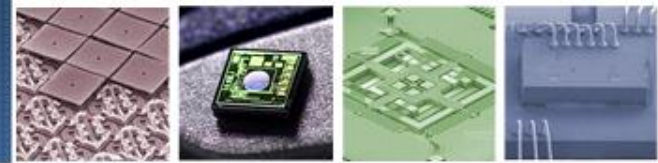
How others view MEMS commercialization





Two Economic Crashes in Less Than 10 Years

- Venture Capital have severely retrenched
 - Series A funding of “hardware” companies has plummeted
- Entrepreneurs have not gone away, but have also retrenched
 - MUCH scrappier attitudes
 - MUCH more dependence on government money
 - Much more use of angel investors
 - More early partnering with large companies
 - More exploration of Chinese/Russian funding
- The funding Bar has also been raised for Angel investors
 - Nearly completely developed products should be available
 - Should have engagements with customers/collaborators
 - IP should be well underway
 - Typical ~\$3.0M pre-money valuations; trying to raise ~\$0.6-1.0M

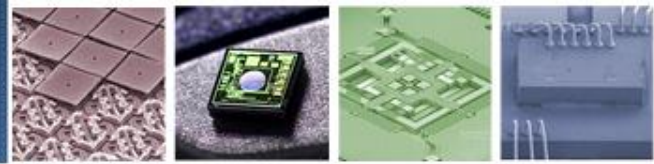


MEMS - where do we go from here?

- Over the past 30 years, MEMS has grown at a faster rate than the semi industry, from 1% to 3.5% of semi shipments
- Within only the last 3-4 years, many MEMS manufacturers have announced cumulative shipments of over 1B devices
- HUGE commercialization opportunities for sensors and MEMS
 - Consumer electronic goods
 - Healthcare
 - Environmental monitoring

have only scratched the surface

- But, world-wide competition is rapidly gaining momentum
- And, rather than **just** R&D, we need to invest more resources in easing the transition from R&D to production



Thank You