3D MEMS & Semiconductor SOFTWARE

COVENTOR

Realizing the Full Potential of MEMS Design Automation

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Coventor Overview

Founded in 1996 with a focus on software for MEMS design and simulation

- Management team from MEMS and EDA
- Accelerate commercial MEMS success by reducing *"Build and Test"* cycles
- Offering software tools and expertise in design and simulation methodology

Solutions for MEMS product development

- Accelerometers, gyros, resonators, microphones, displays …
- MEMS-specific multi-physics and MEMS+IC coupling

Established proven track record with MEMS market leaders

- Top tier MEMS device makers and specialized manufacturers
- 11 of top 15 MEMS companies* use Coventor

Consumer

Automotive

Industrial & Defense

*Source: Yole Development (Feb. 2010): Top 15 MEMS companies = 80% of MEMS market

Outline

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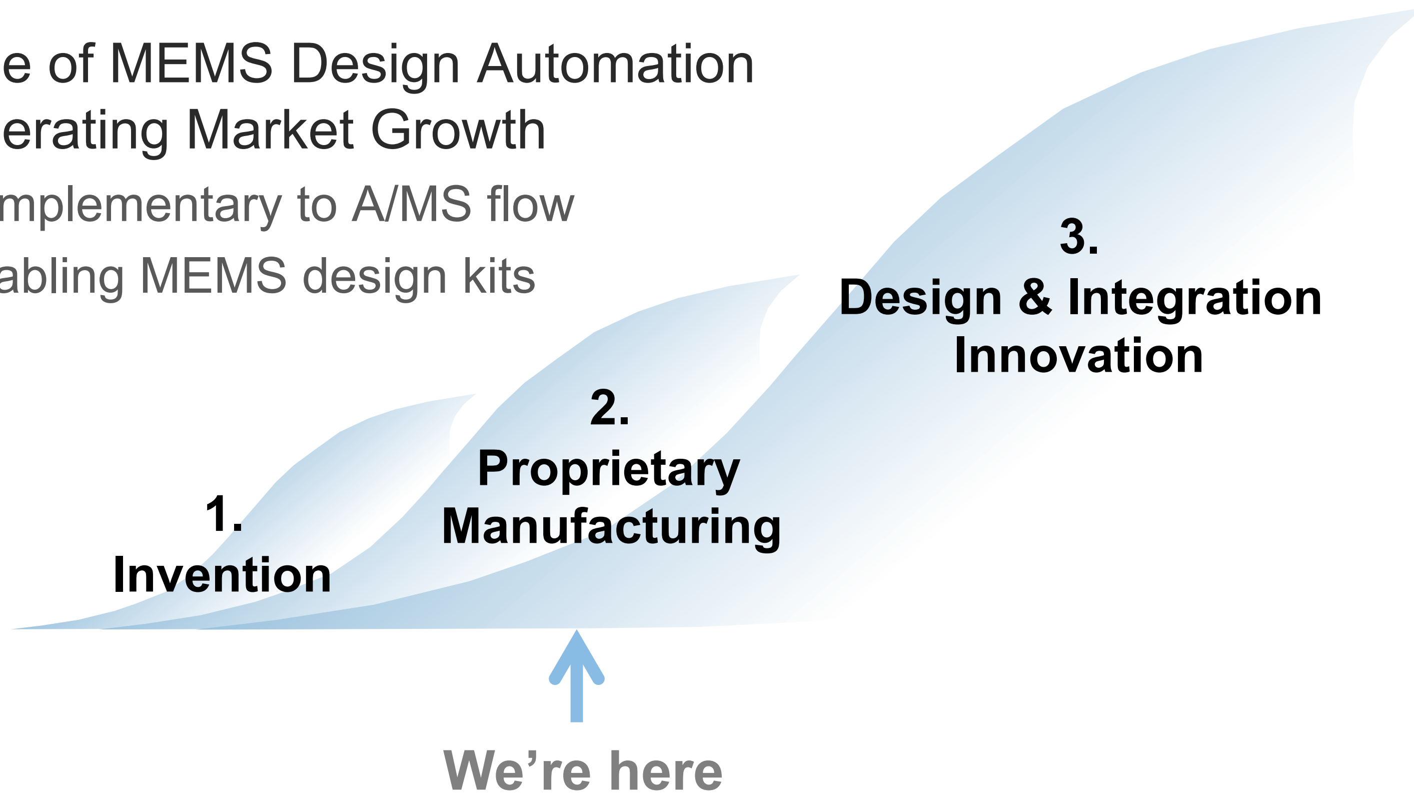
Coventor's Vision for MEMS Market Acceleration:

- 3 waves in the MEMS Market
- 3 waves in market differentiators

The Role of MEMS Design Automation in Accelerating Market Growth

- Complementary to A/MS flow
- Enabling MEMS design kits



The First Wave: Invention

"***One Product,***
One Process,
One Package"

Jean-Christophe Eloy
Yole Development

In one short phrase, an understanding of why the MEMS industry has been slow to develop

This "MEMS law" was true of the 1st wave, dominated by IDM's

- $100's Millions, if not Billions, invested developing processes, packaging and testing for seminal market successes
  - Automotive (Bosch, Analog, Freescale)
  - Inkjets (HP, Canon)
  - Projection (Texas Instruments)
- Successes, but not readily scalable internally within IDMs or to a broader market

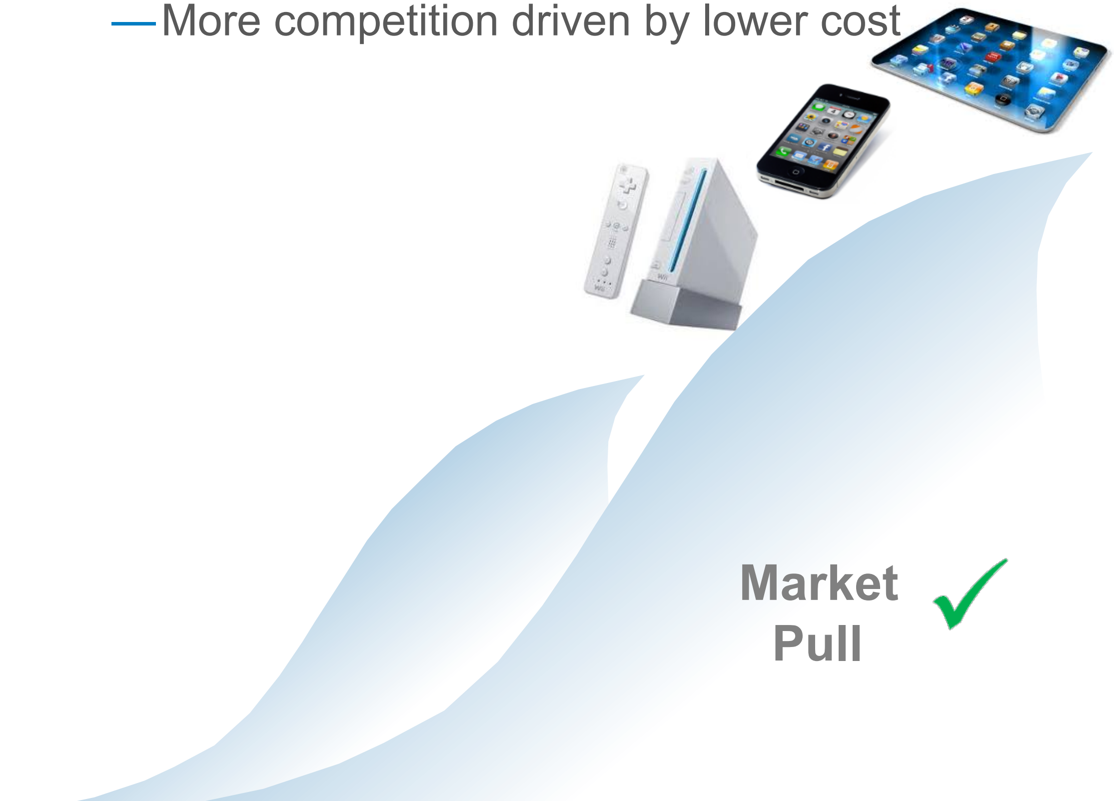
The Second Wave: Manufacturing Differentiation

Started in 2006 with the Nintendo Wii, the first **consumer product success** for MEMS motion sensors

- —Larger volumes
- —Shorter product design cycles
- —More competition driven by lower cost

The Second Wave weakened the "One Product, One Process, …" law

- — To remain competitive, IDM's had to leverage their significant investments in processes and manufacturing: *How can we re-use our process and manufacturing investment into new or derivative products?*"
- — Now, ADI, ST, Bosch, Freescale, etc. have processes and manufacturing capabilities that break the MEMS law



The end of Manufacturing Differentiation

2nd wave market leaders differentiate on **proprietary processes**

This will end because…

- Mass market pull drove leading IDMs to outsource fabrication, spreading know-how to independent foundries
- 2nd-wave entrants (Knowles, Invensense, …) leveraged growing MEMS eco system, spreading more MEMS know-how
- Large semi foundries want in on the action
  - MEMS market growing faster than the semi market
  - Lots of 200mm equipment to amortize – still good for MEMS

The end of manufacturing differentiation is **inevitable**

- Large semi foundries will come up the curve, sooner or later
- Standard(ized) MEMS process modules will be available
- Volume manufacturing will drive down costs

The Third Wave:

The Second Wave showed that the MEMS industry could grow at 15% year and could reach $15 billion market size in a few years

Industry leaders say we are at the beginning of the Third Wave

- HP's vision for 1 trillion sensors by 2020: "Central Nervous System for the Earth"
- Bosch's vision for 7 trillion devices to serve 7 billion people in 2017
- Projected to dwarf the second wave

The Third-Wave, the trillion sensor vision, the $300B - $1Trillion vision, needs more than the first 2 waves

What will drive the transition to hyper growth?

MEMS Competencies Have to be Accessible and Scalable

The Third Wave:
Design and Integration Innovation

Design Innovation =
- New applications
- Derivative designs
- Optimized designs
- New types of devices

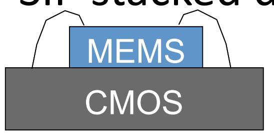
Integration Innovation =
- New applications
- Multi-device systems
- MEMS + A/MS + RF + logic
- Wafer or Package level

MEMS technologies made *accessible & scalable*
by the **MEMS Eco System**

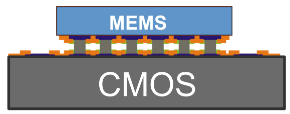
MEMS Integration Challenges

MEMS+CMOS

SIP stacked die



SIP: F2F



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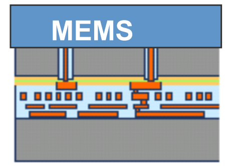
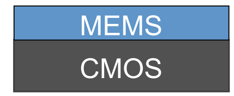
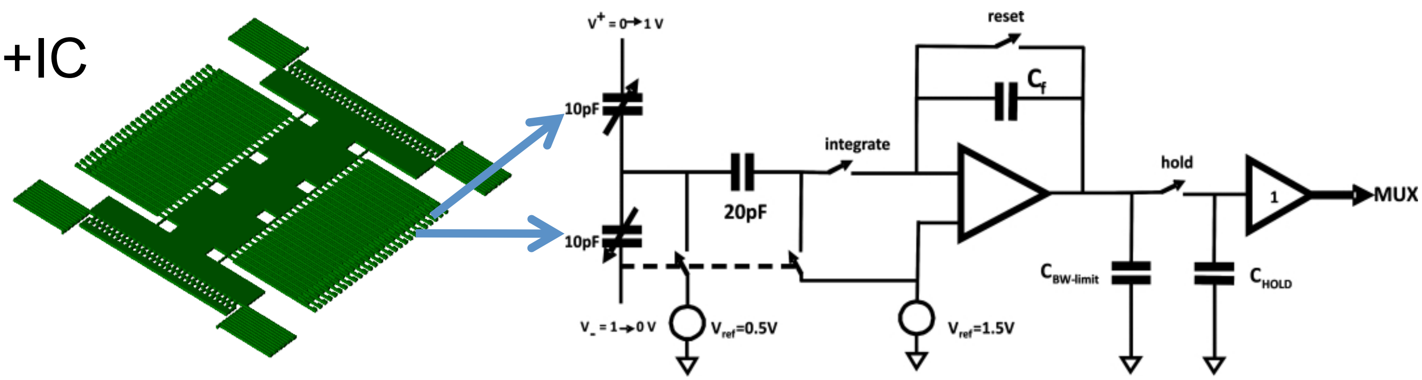


Monolithic

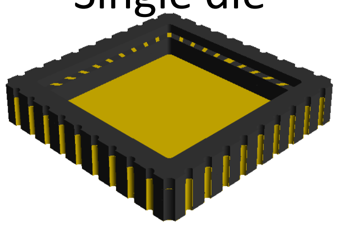


MEMS+IC

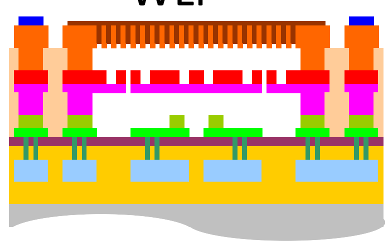


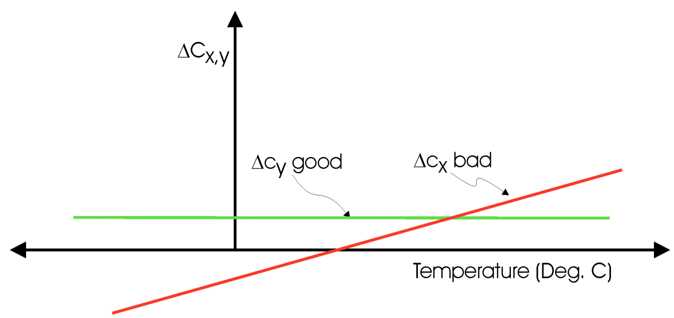
MEMS+Package – *environmental effects, parasitics*

Single die



WLP





Denser Integration is Inevitable

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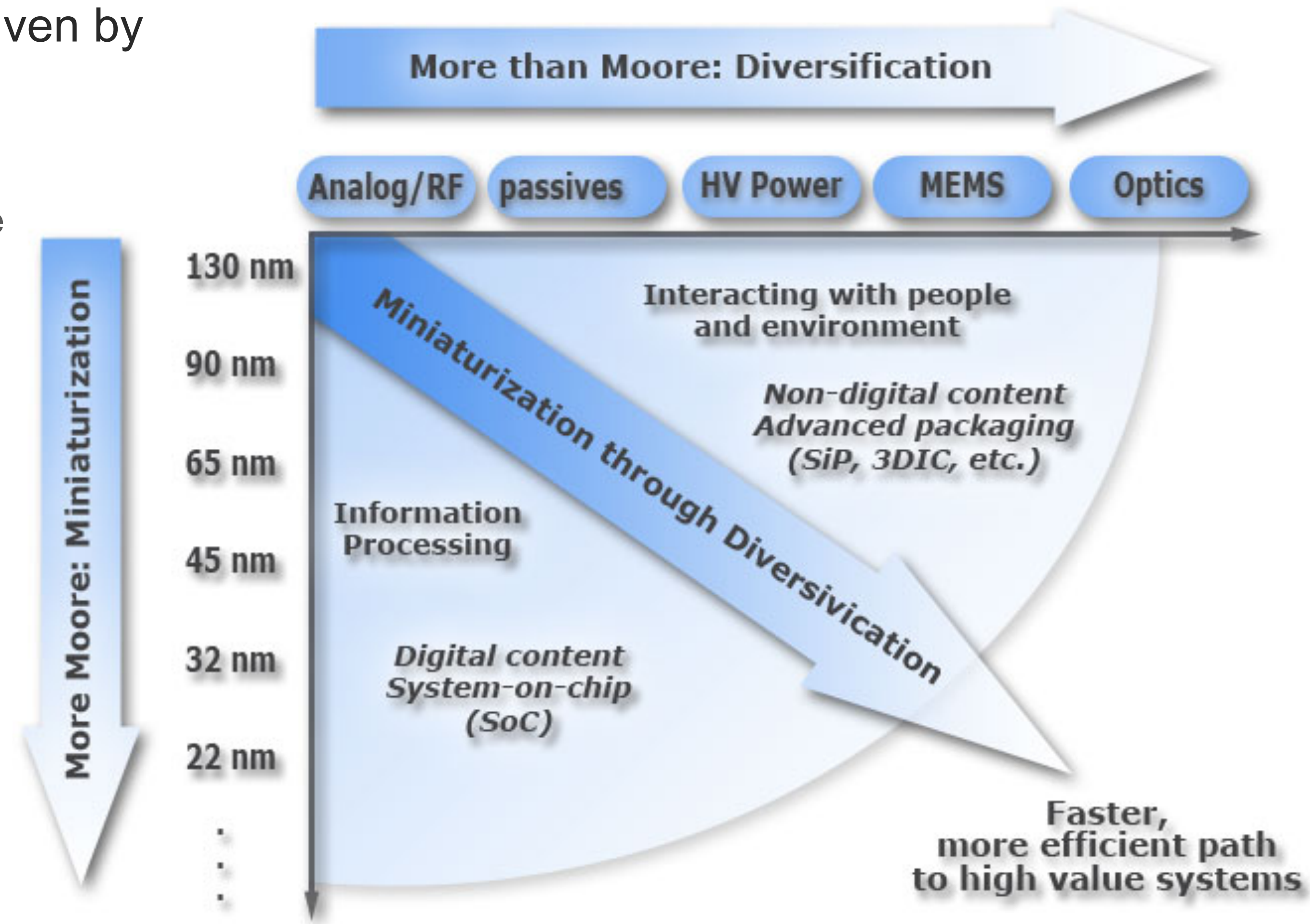
Denser integration driven by

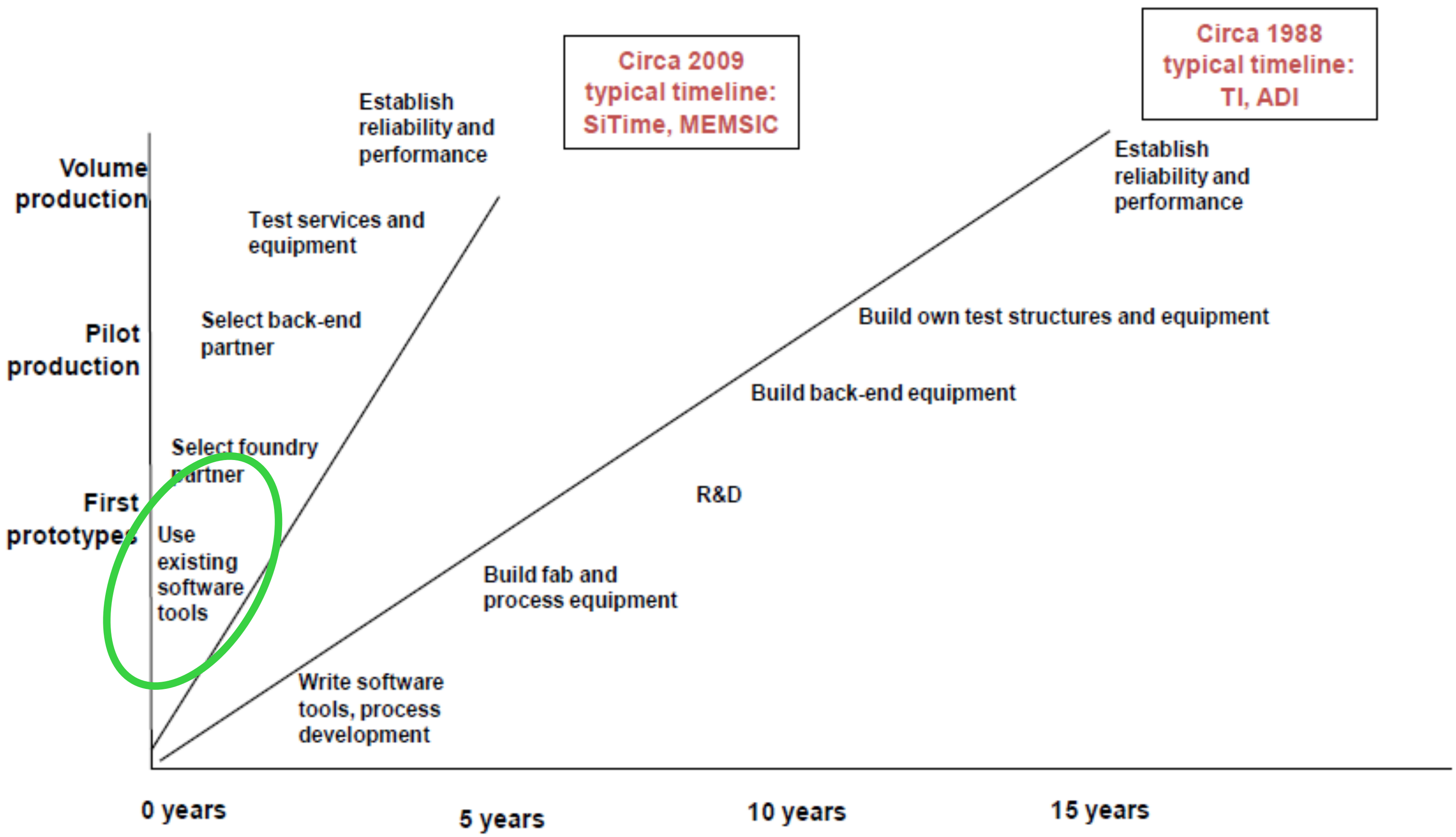
- Higher performance
  - Improved SNR
  - More dynamic range
  - etc.
- Lower cost
- Smaller form factor
- Reduced power use



Derived from G.Q. Zhang, NXP

The Role of MEMS Design Automation

In the 2nd Wave:



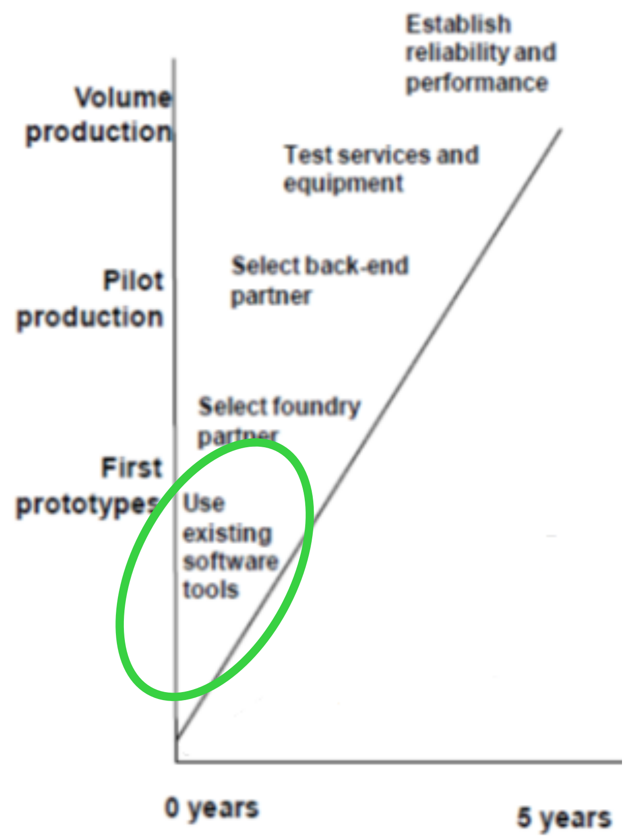
Source: A.M. Fitzgerald

The Role of MEMS Design Automation

In the 3rd Wave:

1. Simulate the complete system
   - MEMS device behavior vs. process variations
   - MEMS+IC coupled system
   - Packaging effects
   - Yield
2. Enable the MEMS ecosystem (foundries → IDMs, fabless)
   - Reference design flow, MEMS & EDA software
   - MEMS Design Kits (MDKs)

Use simulation to compress development cycle



Source: A.M. Fitzgerald

Goal: Simulate All Specs in a "Virtual" Product Data Sheet

MEMS Gyro Data Sheet

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SENSITIVITY					
Full-Scale Range	At X-OUT and Y-OUT		000		°/s
	At X4.5OUT and Y4.5OUT		440		°/s
Sensitivity	At X-OUT and Y-OUT		0.5		mV/°/s
	At X4.5OUT and Y4.5OUT		2.27		mV/°/s
Initial Calibration Tolerance	At X-OUT and Y-OUT				
Calibration Drift Over Specified Temperature	At X-OUT and Y-OUT				
Nonlinearity	At X-OUT and Y-OUT, Best Fit Straight Line				
	Factory Set		1.35		V
	Relative to VREF, With Auto Zero		±20		mV
	Relative to VREF, Without Auto Zero		±150		mV
ZRO Drift Over Specified Temperature					mV
Power Supply Sensitivity	@ 50 Hz				°/sec/V
FREQUENCY RESPONSE					
High Frequency Cutoff	Internal LPF -90°				Hz
LPF Phase De					°
MECHANICAL					
X-Axis Resona		20	24	28	kHz
Y-Axis Resona		23	27	31	kHz
Frequency Sep			3		kHz
NOISE PERFORMANCE					
Total RMS Noise	Bandwidth 1Hz to 1kHz, At X-OUT and Y-OUT		0.3		mV rms

Yield / Cost

Most specs are electrical, requiring MEMS+IC simulation

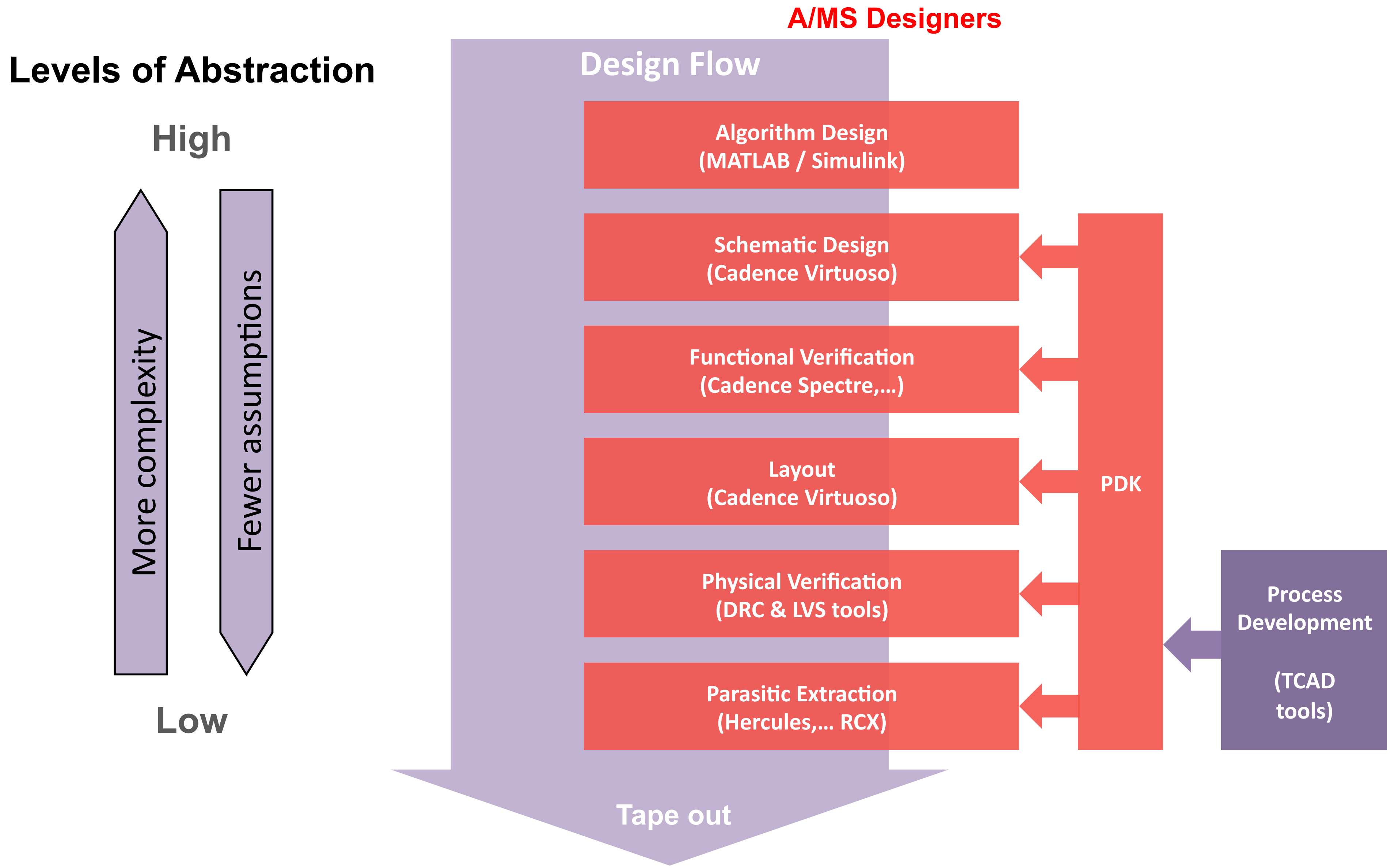
Many specs involve packaging effects

Must know process variations

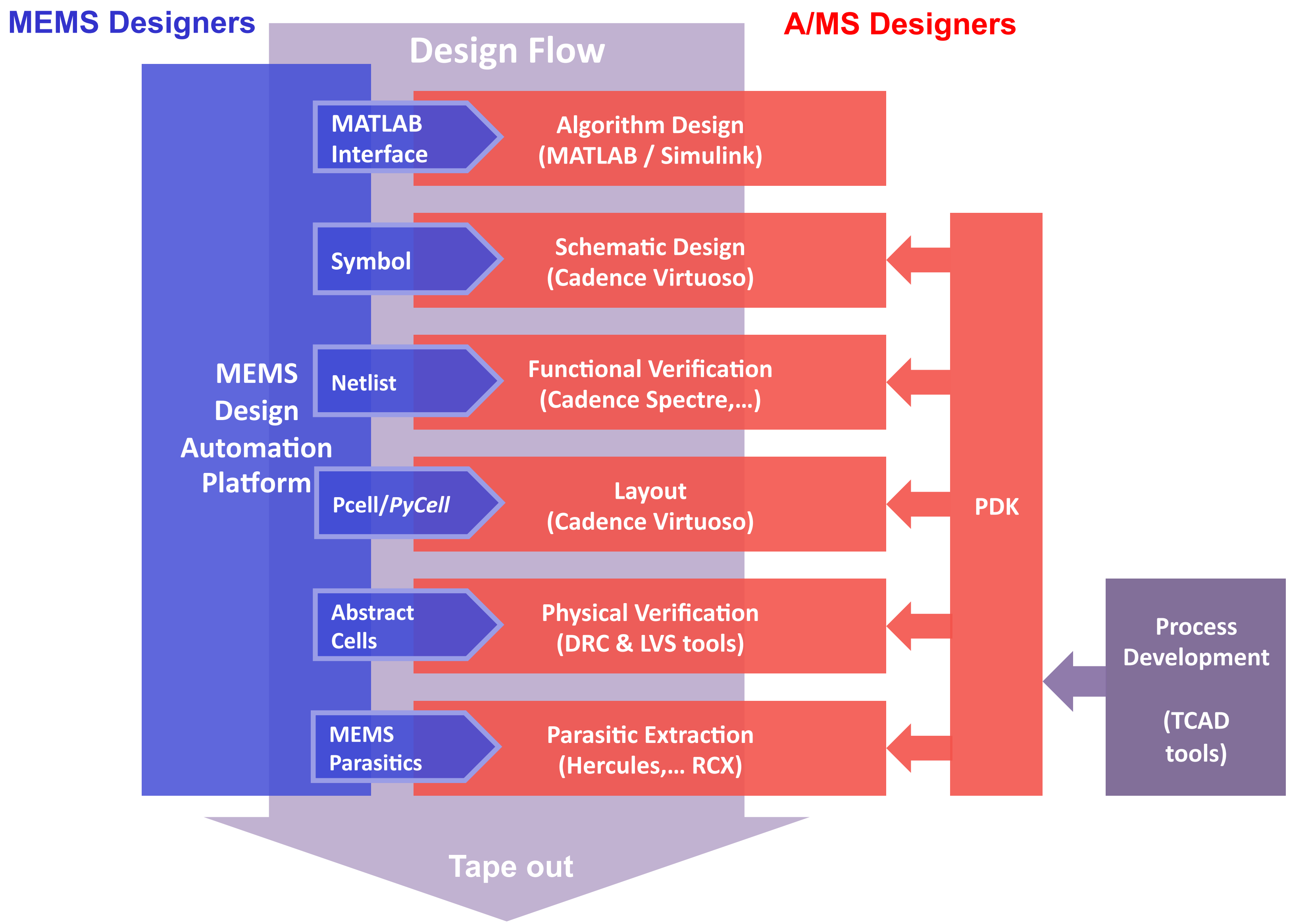
MEMS/IC coupling parasitics matter

ADI ADXRS620

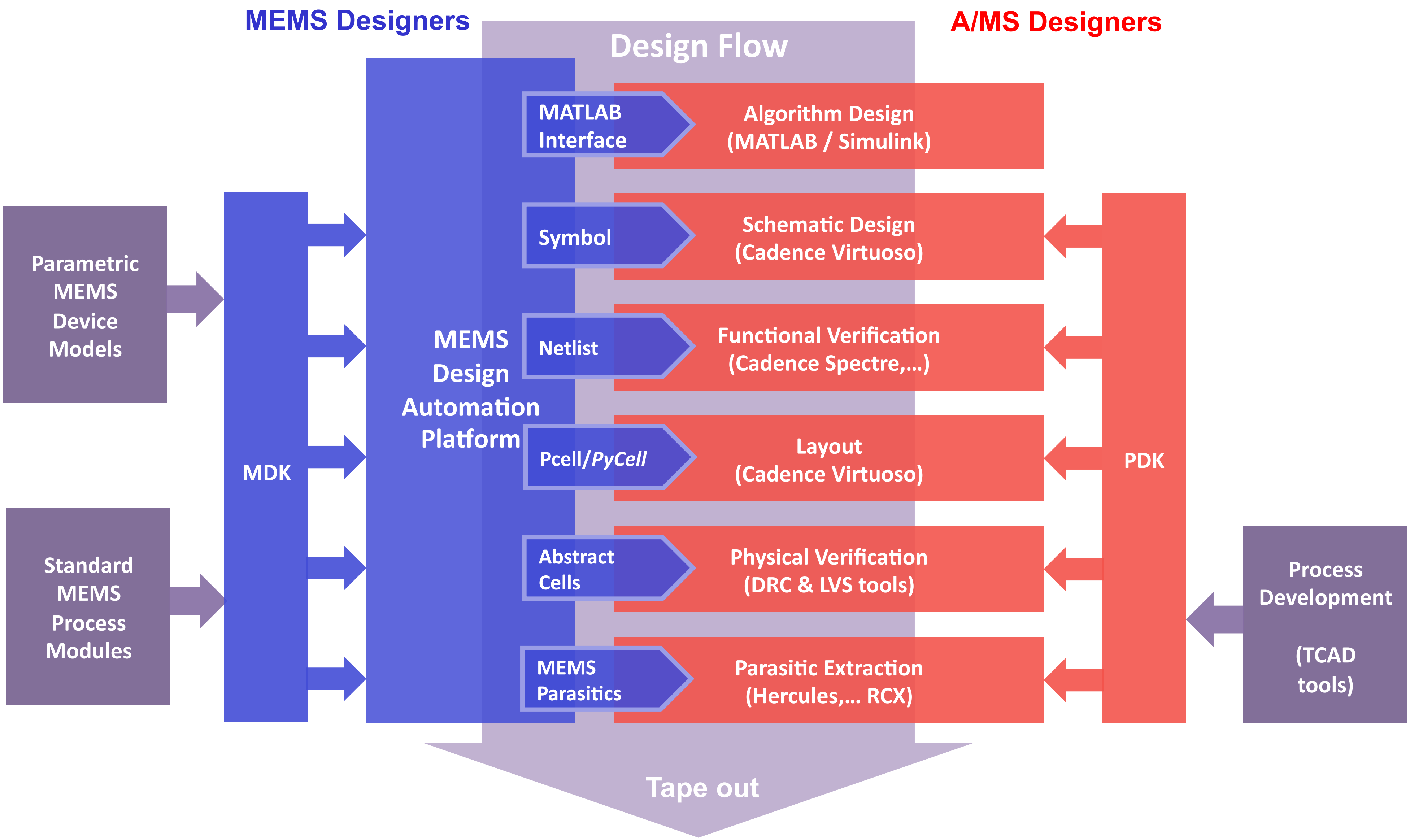
Analog / Mixed-Signal Reference Design Flow



Coventor's Vision for a MEMS+IC Reference Flow



Completing the Vision: MEMS Design Kits

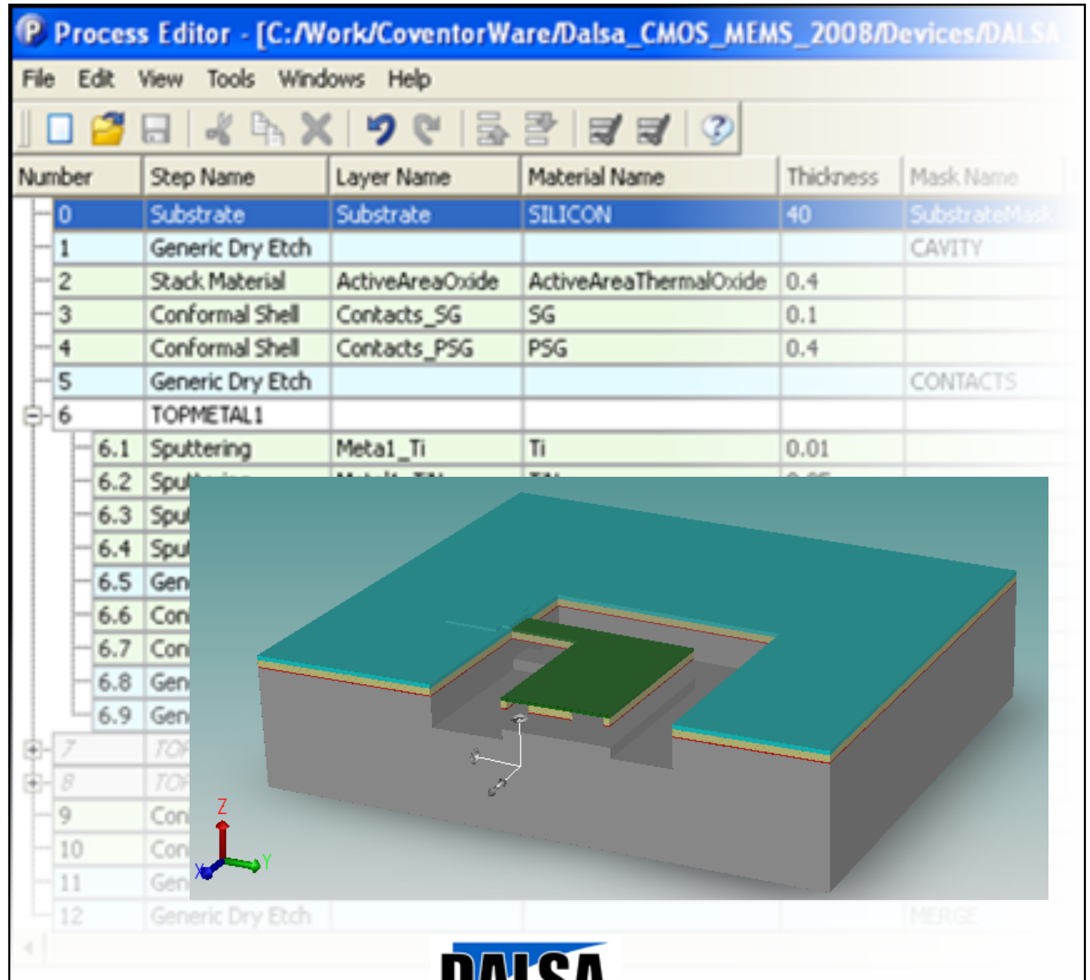


What's in a MEMS Design Kit?

MDK Contents

- High-level process description
  - —Deposit thickness, conformality
  - —Etch depth, sidewall profiles
  - —Mask names
- MEMS-specific design rules
  - —Release etch hole specs
- Material properties
  - —Process-specific
  - —Pre-stress, stress gradient
- Device IP
  - —Parametric device models

Example: DALSA CMOS-MEMS PDK



DALSA

Standardized process + reference flow + MDKs

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MEMS Design Automation

MEMS Eco System Partnership

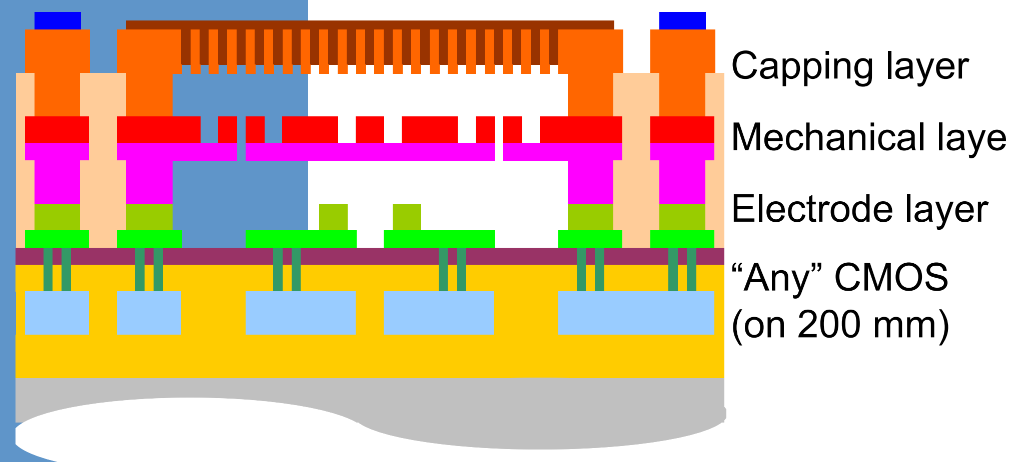
imec

Monolithic SiGe MEMS+CMOS Process

MEMS+™

Coventor*Ware*™

SEMulator3D™



- MEMS Design Kits (MDKs) for Coventor tools
- Reference flow for integrated MEMS+IC design

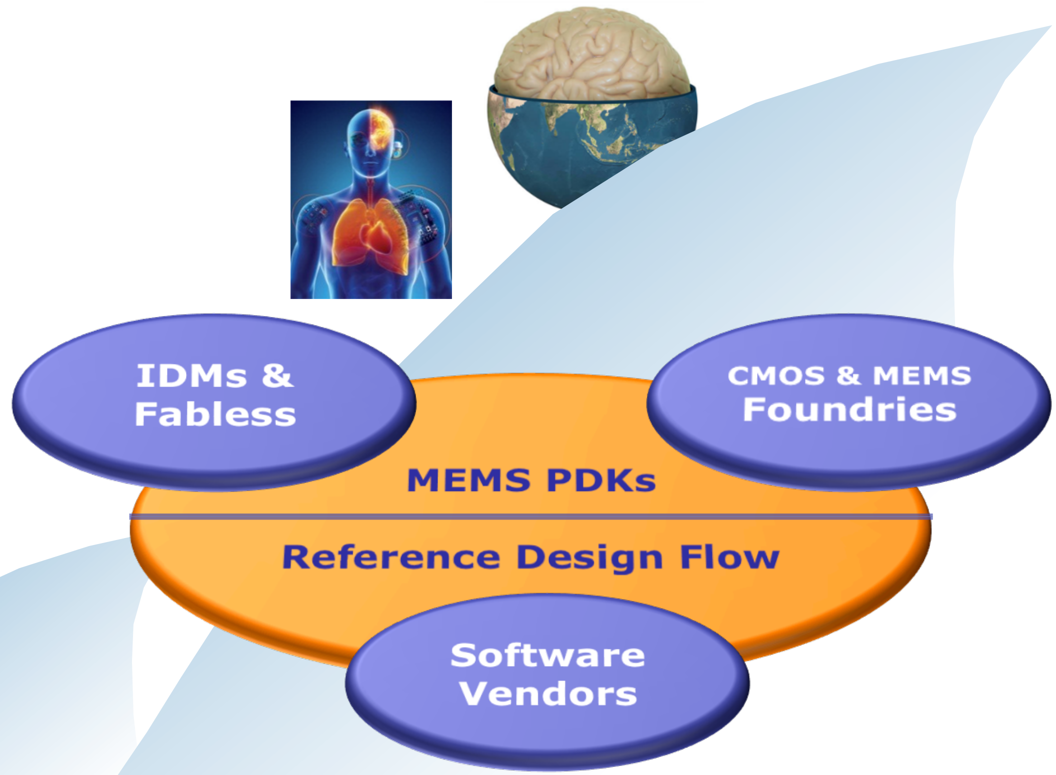
Conclusions

Wave 2 leaders rely on proprietary MEMS processes

Wave 3 leaders will rely on **Design & Integration Innovation**

–Think

Call to Action:
Collaboration among eco-system leaders to make MEMS competencies *accessible & scalable*



1. Invention

2. Manufacturing

3. Design & Integration Innovation