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# MEMS Deployment in a Ubiquitous Intelligence Era – Foundry View

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# UMC Facts in One Slide

**34 Years Experience**

*20 Years Pure-Play Foundry*
*16,000 Employees*
*1,100 R&D Engineers*

**500,000 wpm Capacity**

*12" Fab x2*
*8" Fab x7*
*6" Fab x1*

**$4B Revenue**

*24% from <=40nm*

**28nm Ramp Up 2Q14**

*14nm Pilot 2014/E*

12A Tainan

8AB Hsinchu

Fab 12i Singapore

8C & D Hsinchu

8E Hsinchu

8F Hsinchu

8N Suzhou

8S Hsinchu

6A Hsinchu

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# Outline

- All Good Things…
- Next Semiconductor Driving Force
  - IoT
  - Wearable
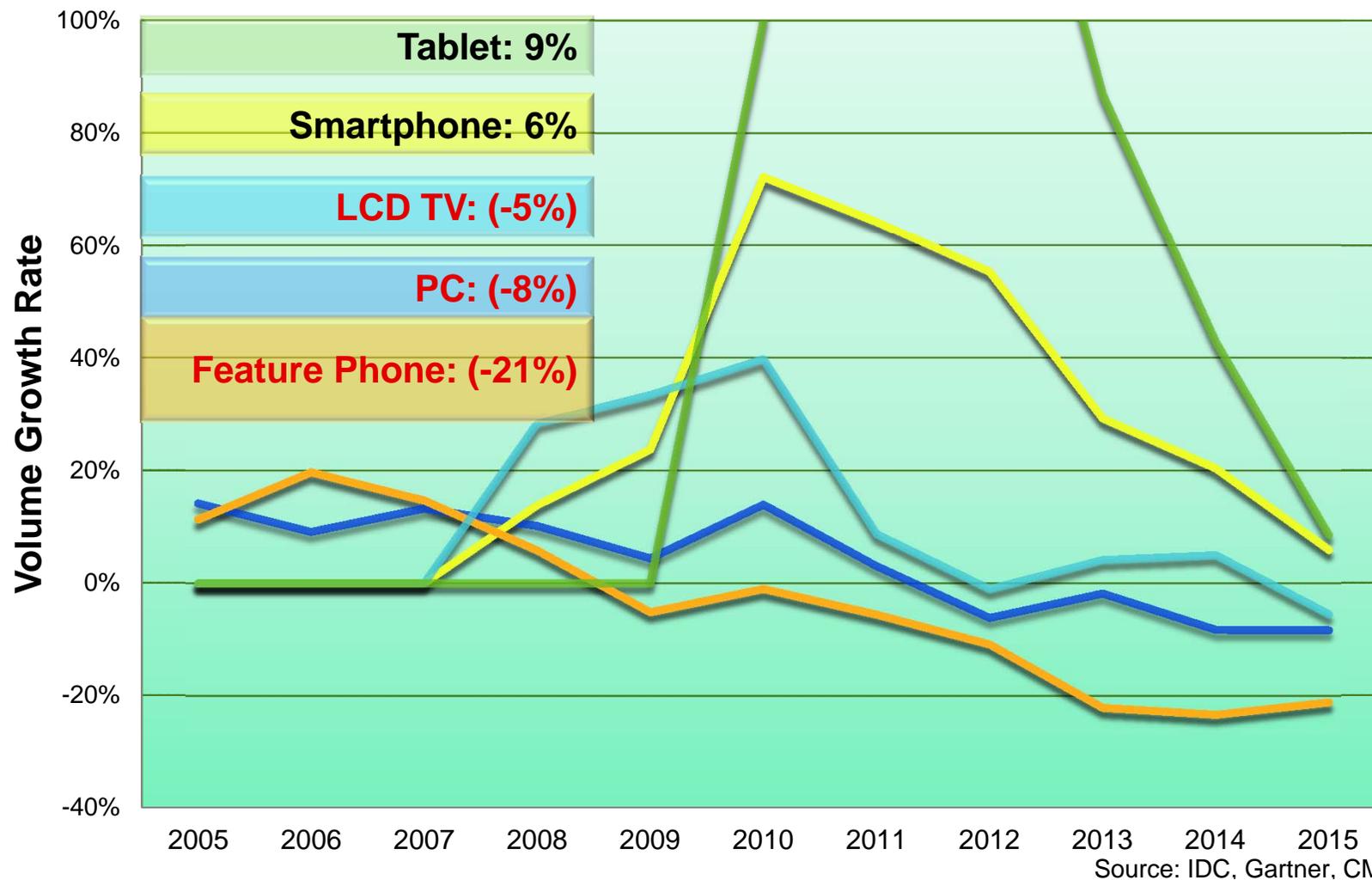- MEMS Enablement Proposal
- Summary

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# All good things, must come to an end…

Title of final episode of Star Trek, The Next Generation
Geoffrey Chaucer, father of English literature

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# Advanced Technology Driver Out of Steam

Just like everthing else…



**Volume Growth Rate**

- Tablet: 9%
- Smartphone: 6%
- LCD TV: (-5%)
- PC: (-8%)
- Feature Phone: (-21%)

Source: IDC, Gartner, CM

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Learn to see and realize that everything connects to everything else.

Leonardo Da Vinci

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# Data Alchemy Drives The Need

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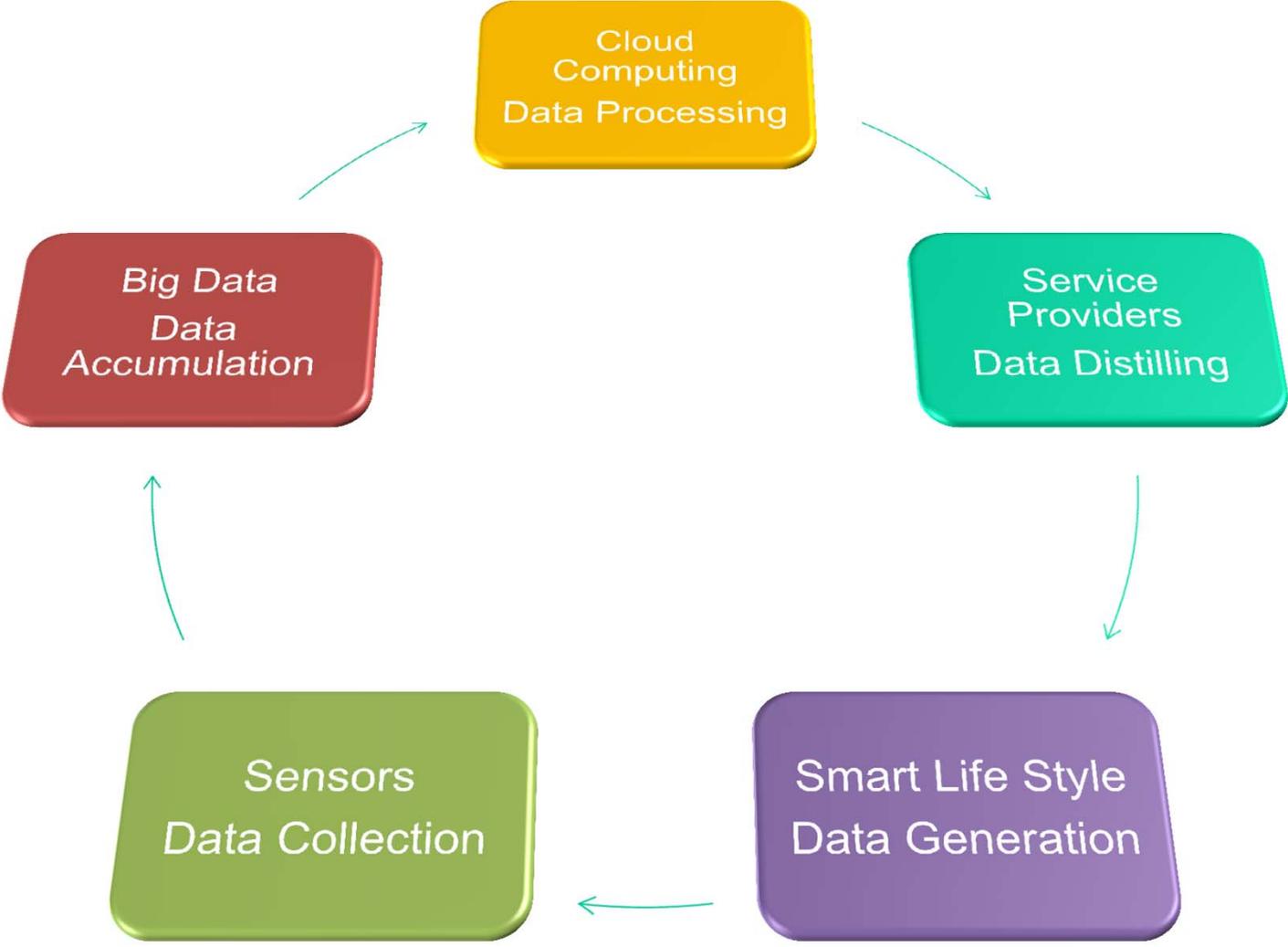
# IoT, Big Data and Cloud Computing

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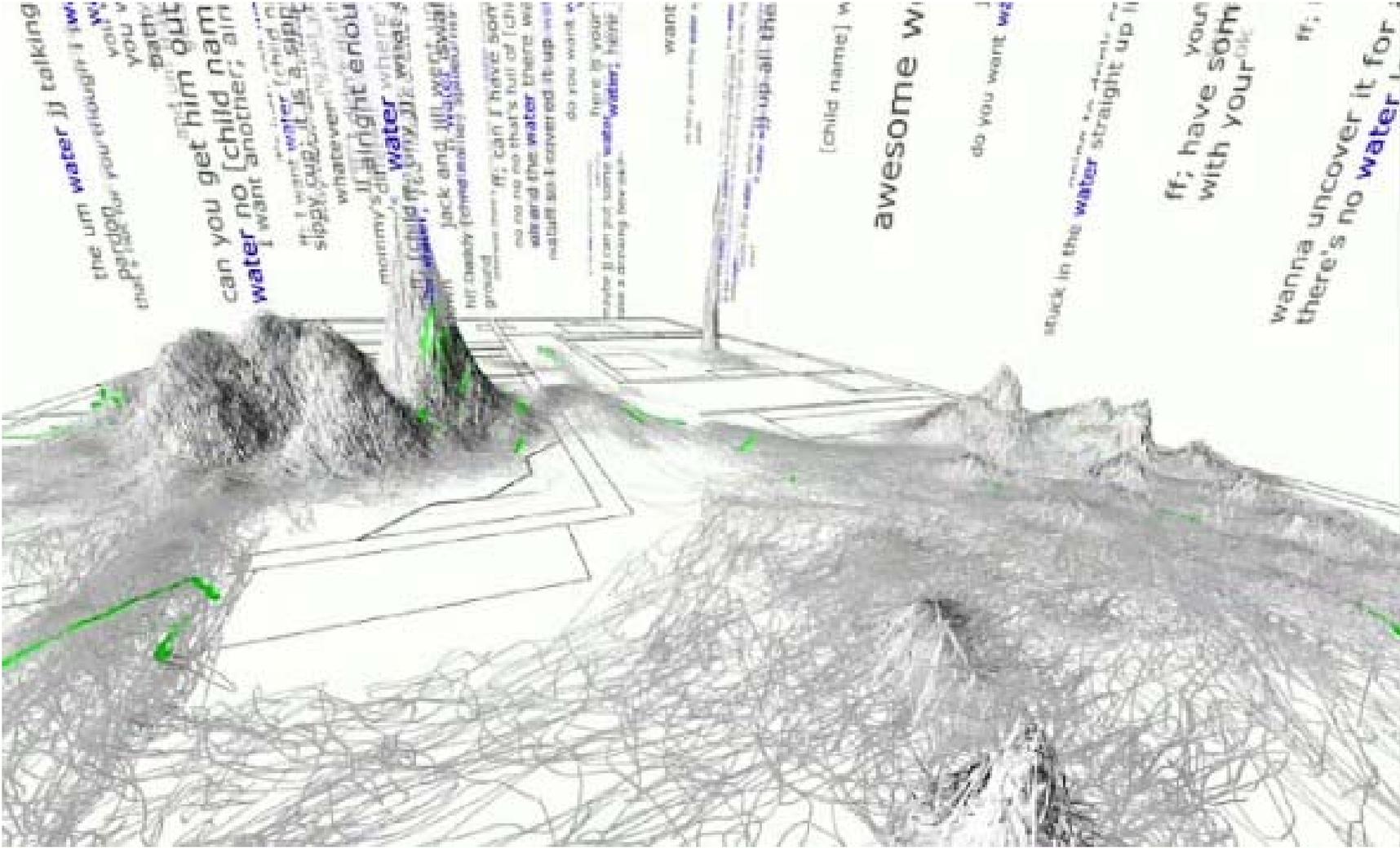
# Ubiquitous Intelligence Future



cloud

Data

Power Management

Games

Entertainment

Appliances

Information

Finance    location

Security
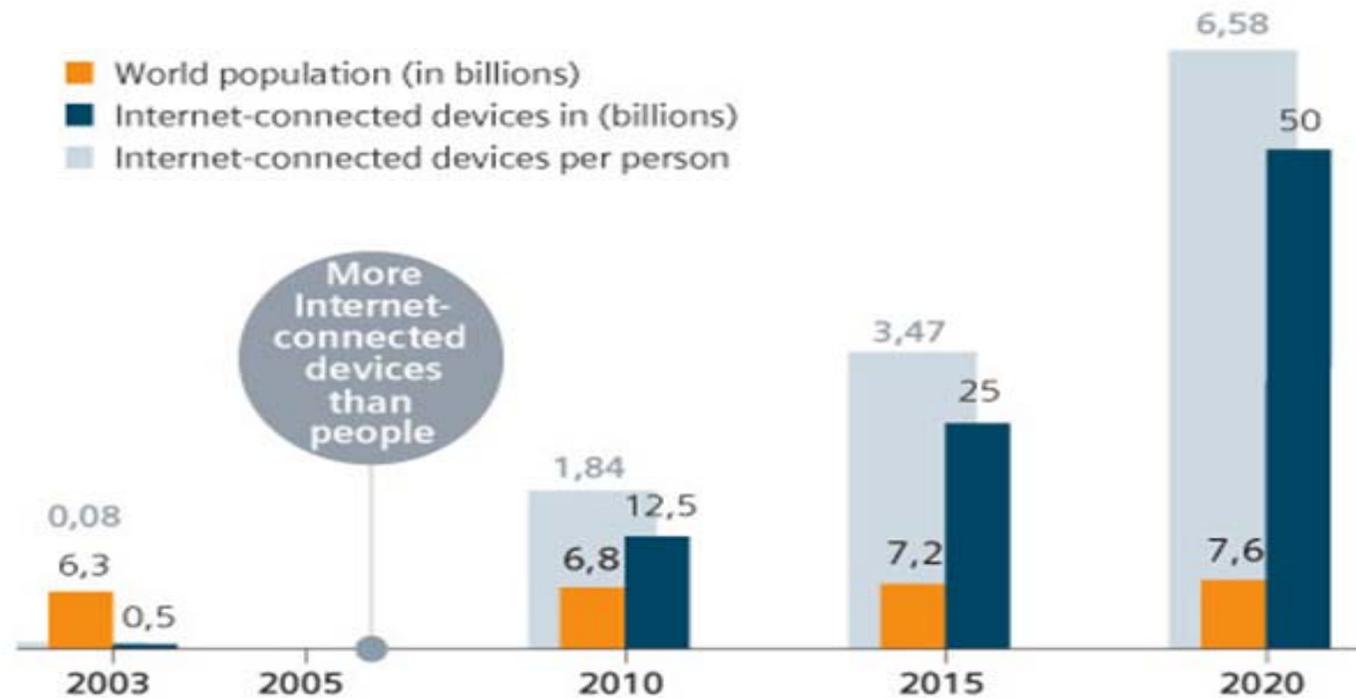
smart glass

smart mobiles

Wearable – watch, bio-info
ID

location

safety

Infotainment
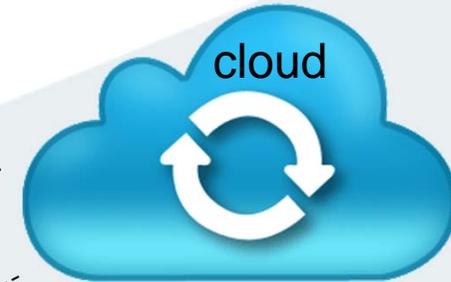
# WW IoT Market Prospect

- IoT market by 2020
  - 50bn units
  - US$ Trillions



Legend:
- World population (in billions)
- Internet-connected devices in (billions)
- Internet-connected devices per person

Source: Cisco IBSG, April 2011

# WW IoT Advocators

- Top 5 IoT Countries
  - USA, EU, South Korea, Japan, China

- Major government projects
  - China
    - Important tasks and major projects of "12th Five-Year Development Plan"
    - IoT Centers, Shanghai, Wuxi, and Guangdong
  - Europe
    - IERC, IOT European Research Cluster, is a cooperation platform and develop a research vision for IOT activities in Europe

# 'Internet Of Things', Where The Money Goes
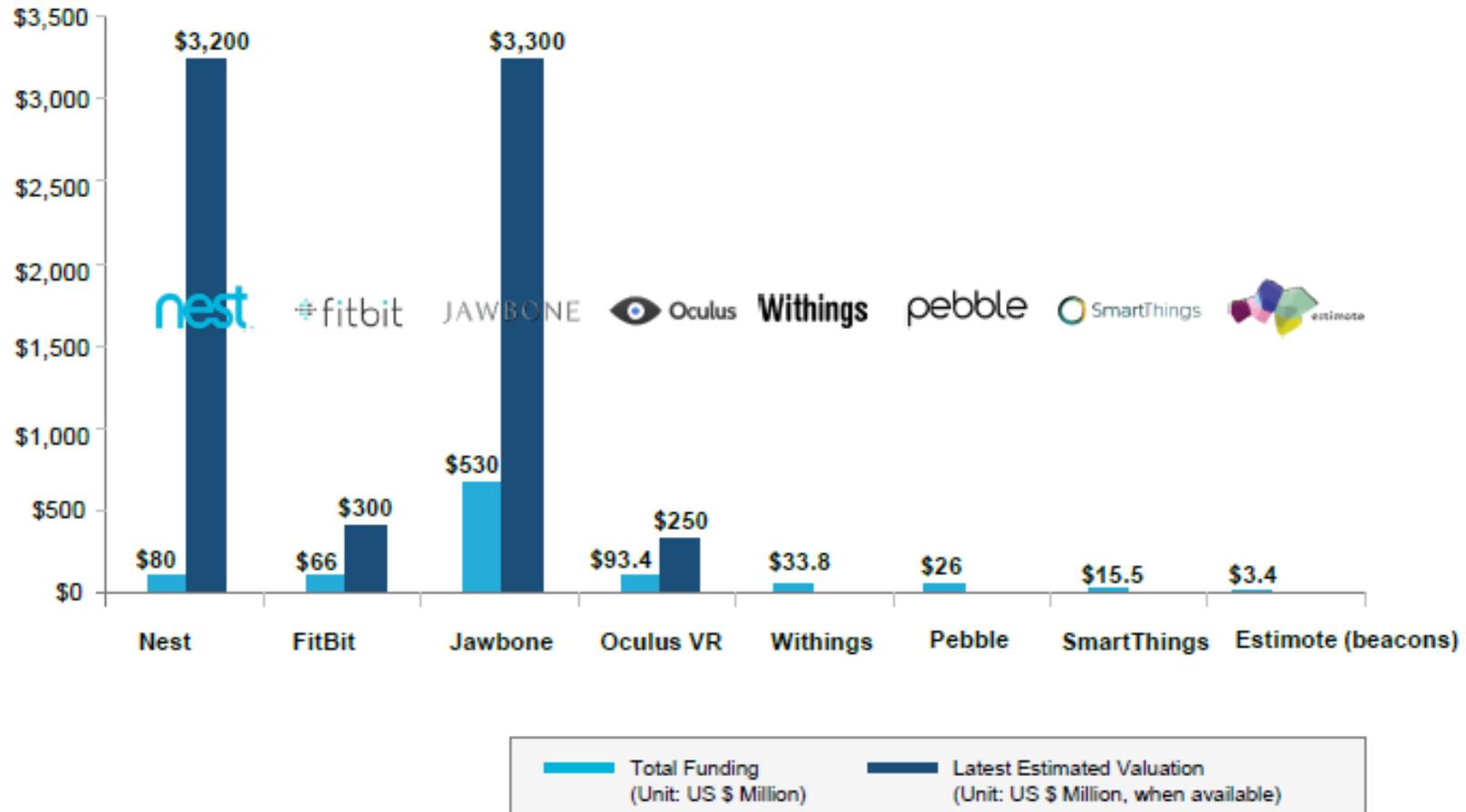


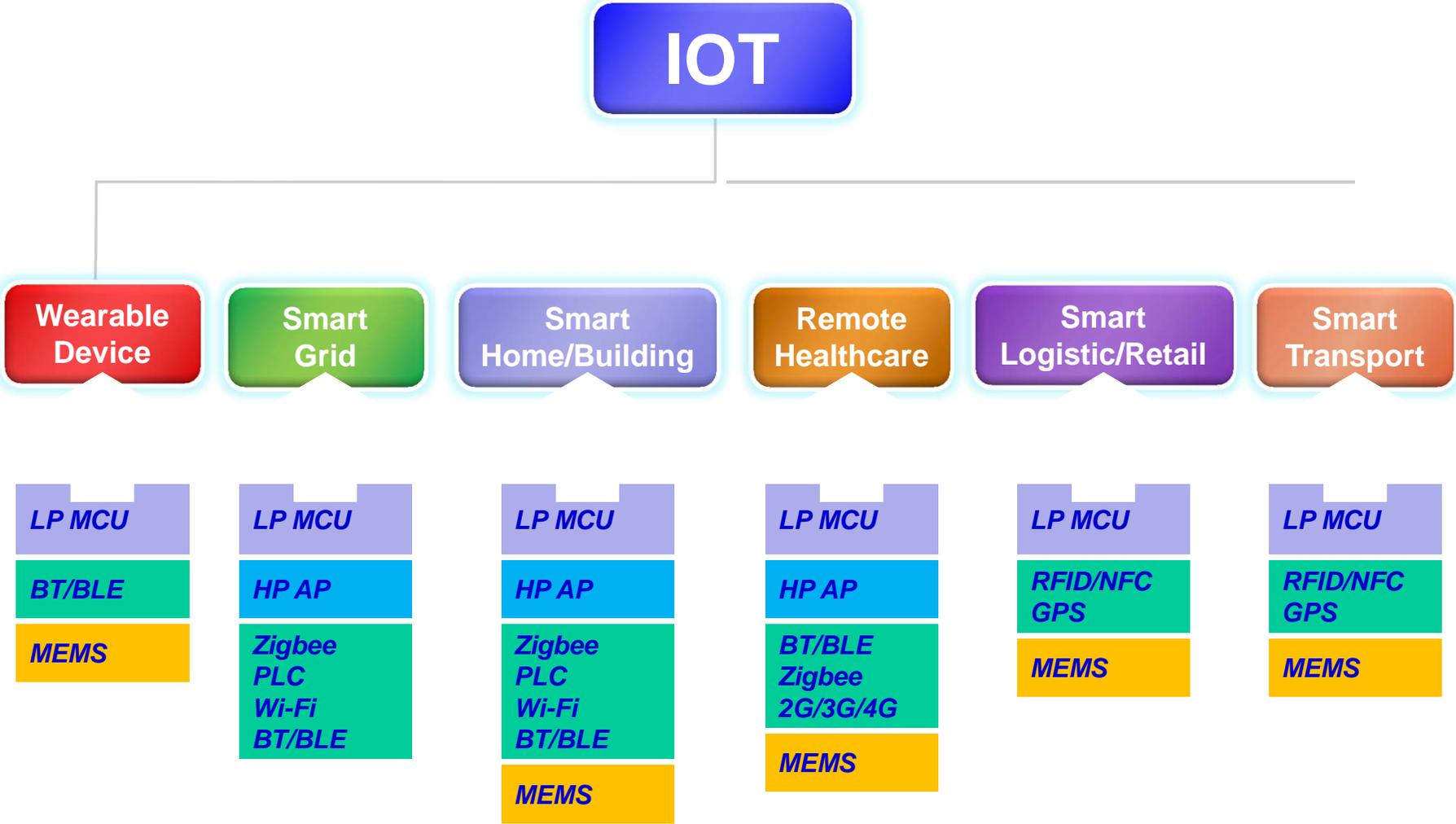Source: Business Intelligence, The Internet of Everything: 2014

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# IoT Engine Revving Up

Inflection at 2017, enough time for preparation

- 5 quintillion byte data per day generated
- 50B devices by 2020, inflection point 2017
  - >30% CAGR from 2013 to 2020
  - >200KWPM (12in) in 2020
- Market fragmented, commodity process won't cut it!
  - System knowhow, tailor-made processes, partnership
- Most devices in mature nodes, but new requirements, especially power the major concern.
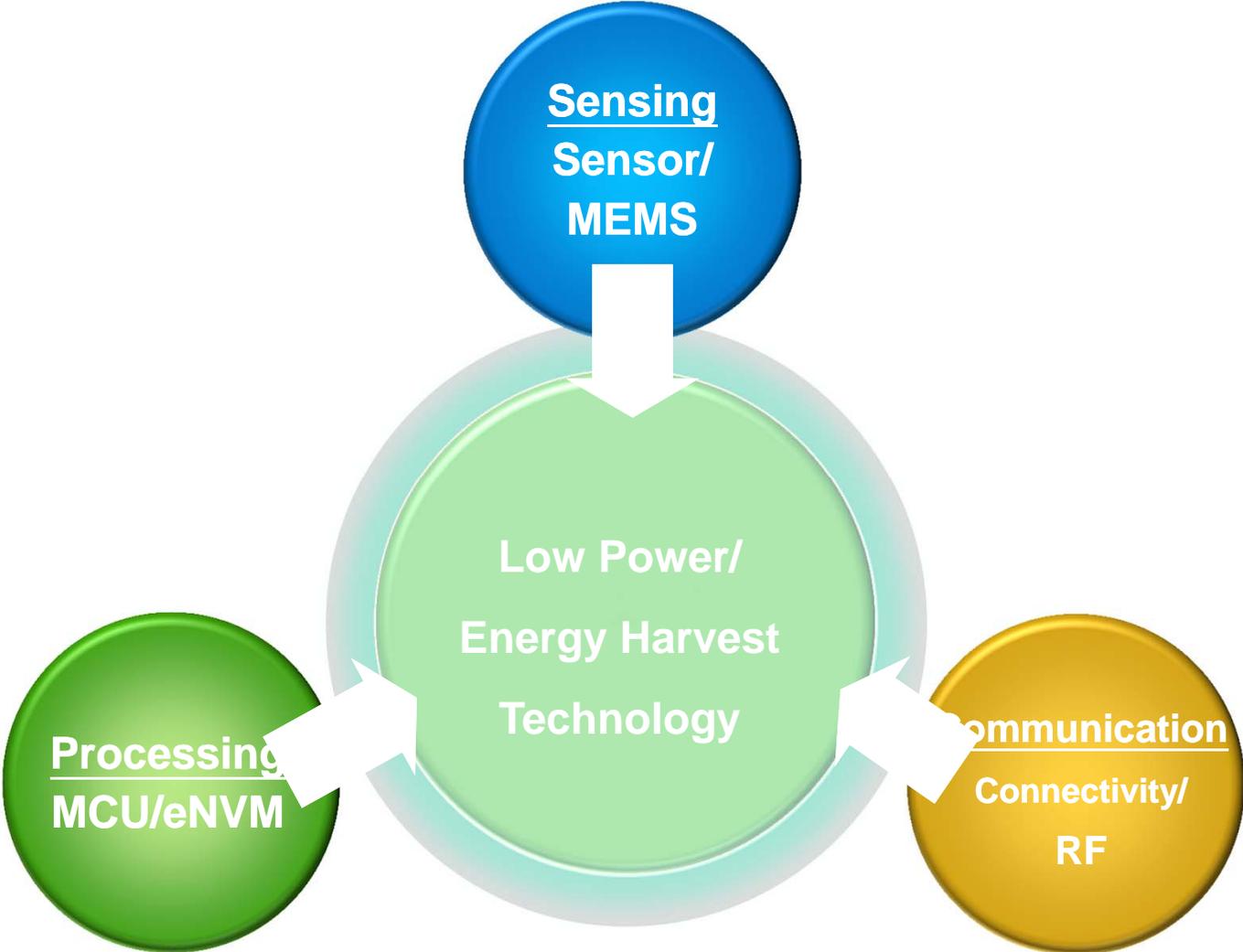
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# Main IOT Applications & Key Technologies

**IOT**

| Wearable Device | Smart Grid | Smart Home/Building | Remote Healthcare | Smart Logistic/Retail | Smart Transport |
|---|---|---|---|---|---|
| LP MCU | LP MCU | LP MCU | LP MCU | LP MCU | LP MCU |
| BT/BLE | HP AP | HP AP | HP AP | RFID/NFC GPS | RFID/NFC GPS |
| MEMS | Zigbee PLC Wi-Fi BT/BLE | Zigbee PLC Wi-Fi BT/BLE | BT/BLE Zigbee 2G/3G/4G | MEMS | MEMS |
| | | MEMS | MEMS | | |

: MCU    : AP    : RF/Connectivity    : Sensors

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# IOT Solution at Low Power Platform

**Sensing**
**Sensor/**
**MEMS**

**Low Power/**

**Energy Harvest**

**Technology**

**Processing**
**MCU/eNVM**

**Communication**
**Connectivity/**
**RF**

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# A Wearable Deluge

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# IoT Application Heats Up -- Wearables

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# IoT Can Be A Blessing or Curse…

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# How Will MEMS Participate in IoT Party?

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# Diversified Usage Scenarios for MEMS Sensors



- Pico Projector
- RF MEMS
- RH/T Sensor
- e-Compass
- Auto Focus
- Micro Fuel Cell
- P-sensor
- MEMS Mic.
- MEMS Oscillator
- Gyroscope
- Accelerometer
- 6-/9-axis IMUs
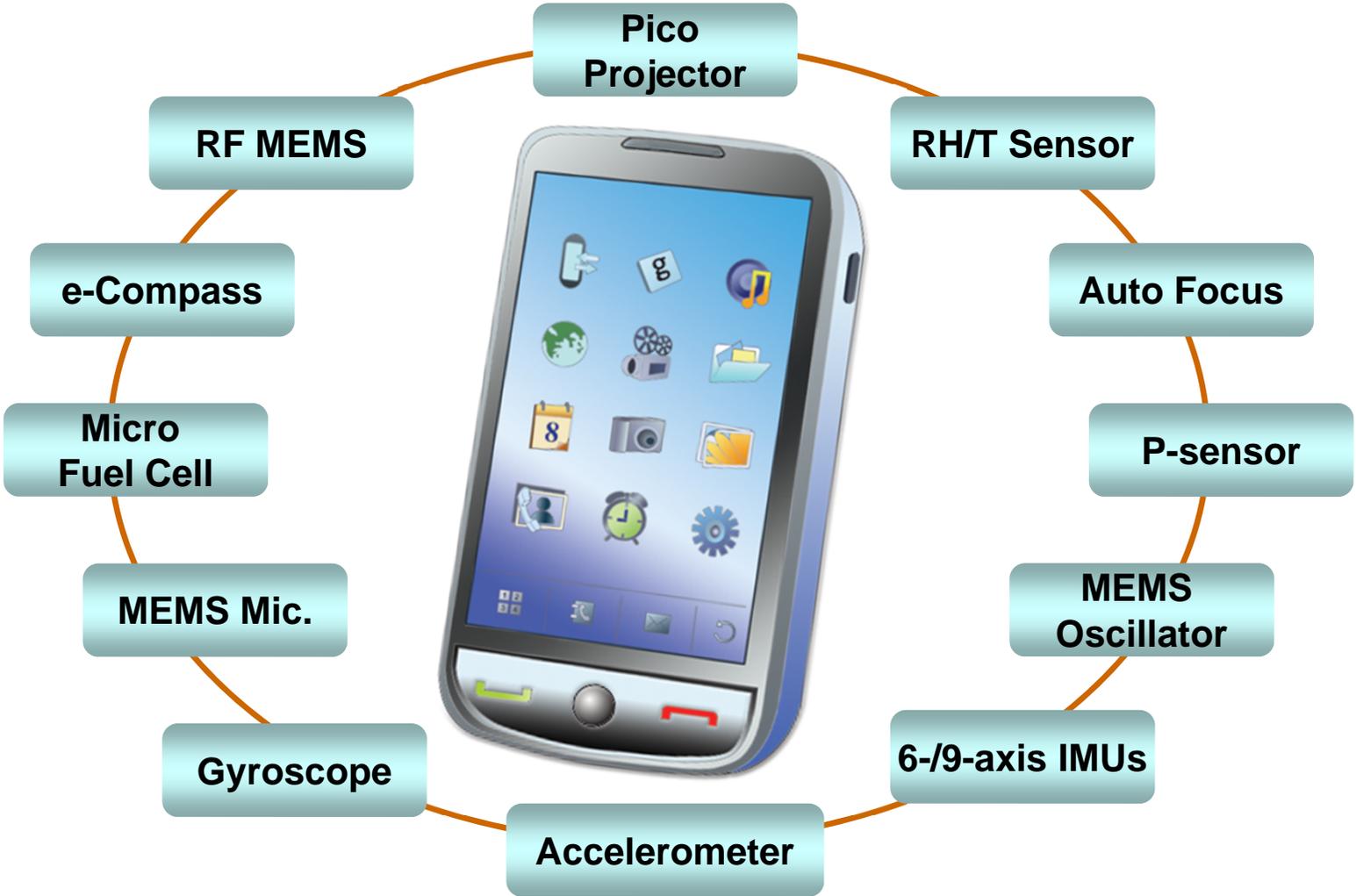
# Existing Working Model: Modular Process



MEMS Platform + CMOS Platform

| | | | |
|---|---|---|---|
| | Oxide Wet Release | Si DRIE | |
| Wafer Bonding | Si Dry Release | Oxide DRIE | Thick Poly |
| Wafer Thinning | Oxide VHF Release | Double Side Alignment | Lift Off |
| Thick Oxide | PIQ Release | Stress Controllable SiN | Stress Controllable Poly |

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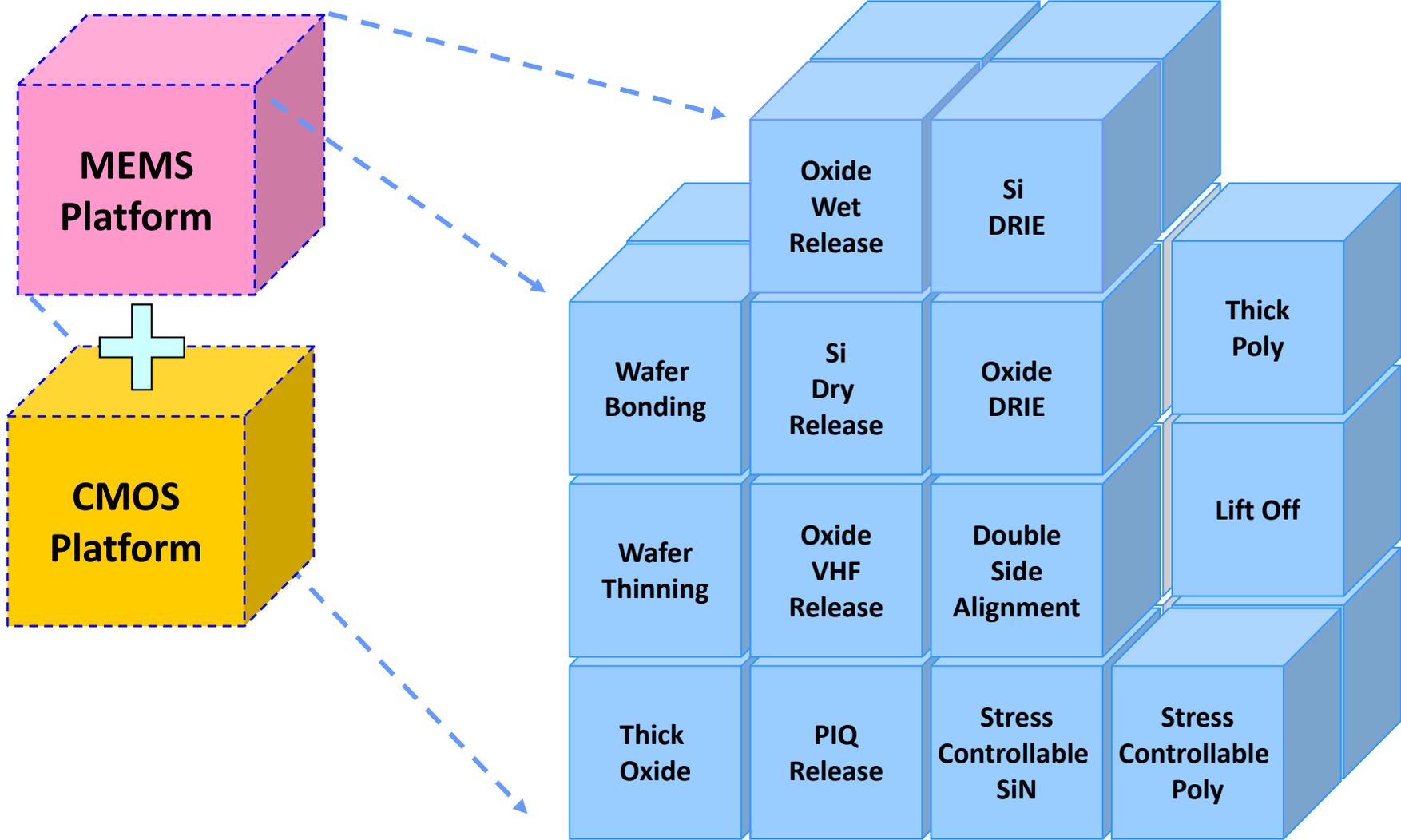
# MEMS Modules Production Examples

| Application | Double Side Aligner | Si DRIE | Ox DRIE | PIQ release | Ox Vapor HF | Wet Ox HF release | Pt dry etch |
|---|---|---|---|---|---|---|---|
| Micro- phone A | V | V | | | | V | |
| Micro- phone B | V | V | V | V | | | |
| Micro-phone C (CMOS+ MEMS) | V | V | | | | V | |
| Accelerometer | | | | | V | | |
| Gas sensor | V | V | V | | | | V |

# DRIE Process for Si Etching

- Scallop control vs process through-put
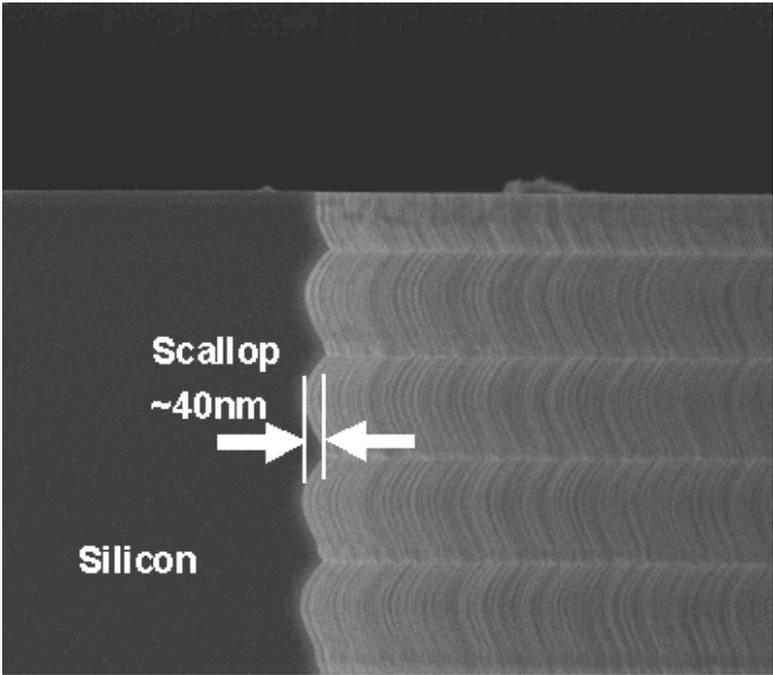


**Scallop control of DRIE Bosch Si etching**
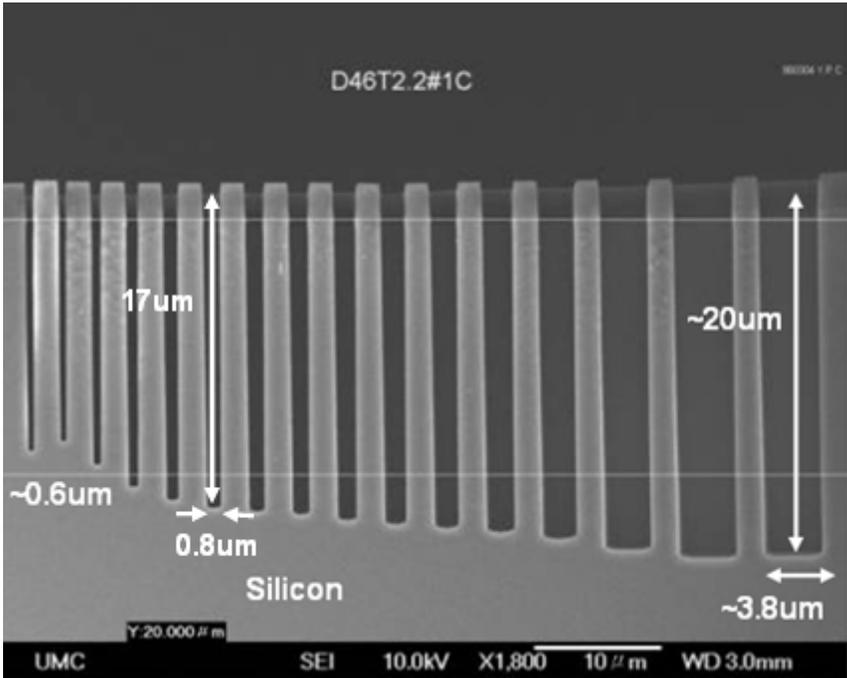


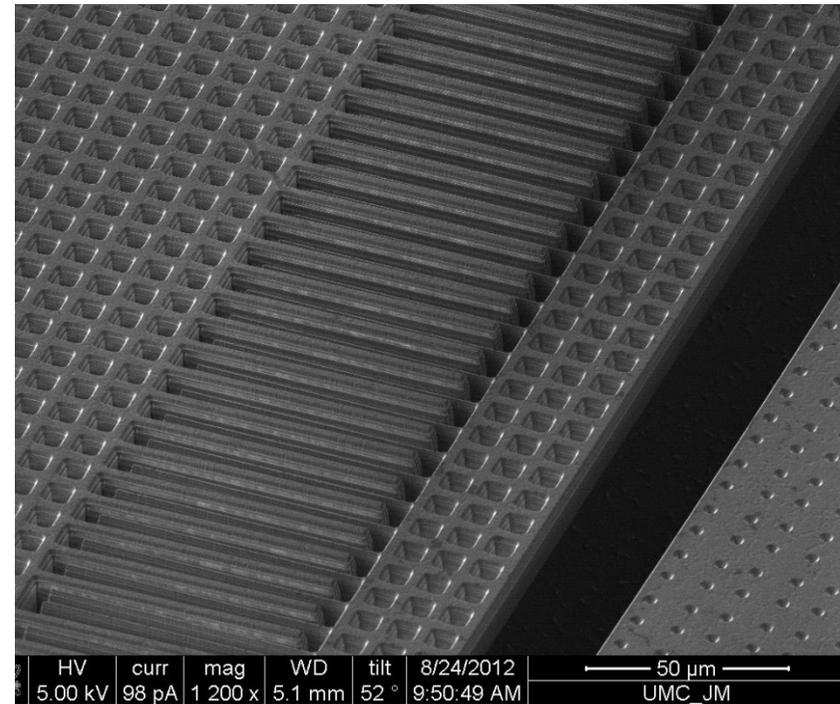**Through-pitch profile control of DRIE Bosch Si etching**

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# Oxide DRIE & Isotropic Si Etching

- MEMS structure fine tuning by Oxide+Si DRIE
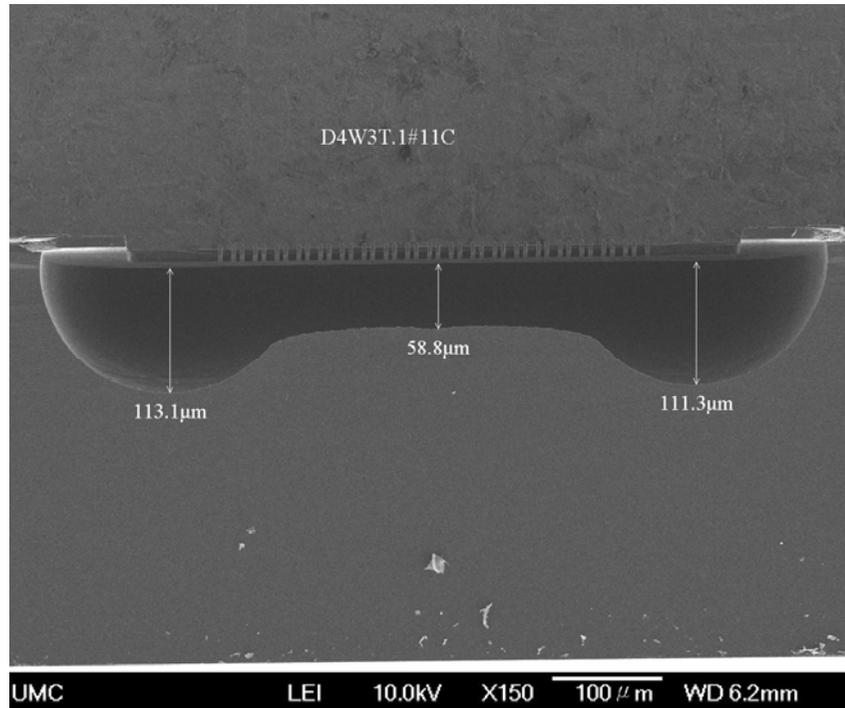


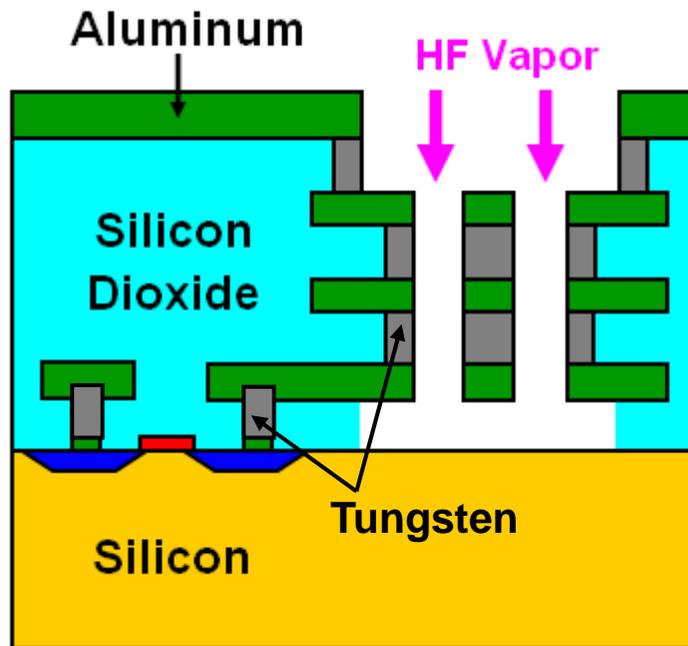**Cross section of accelerometer with silicon released underneath**



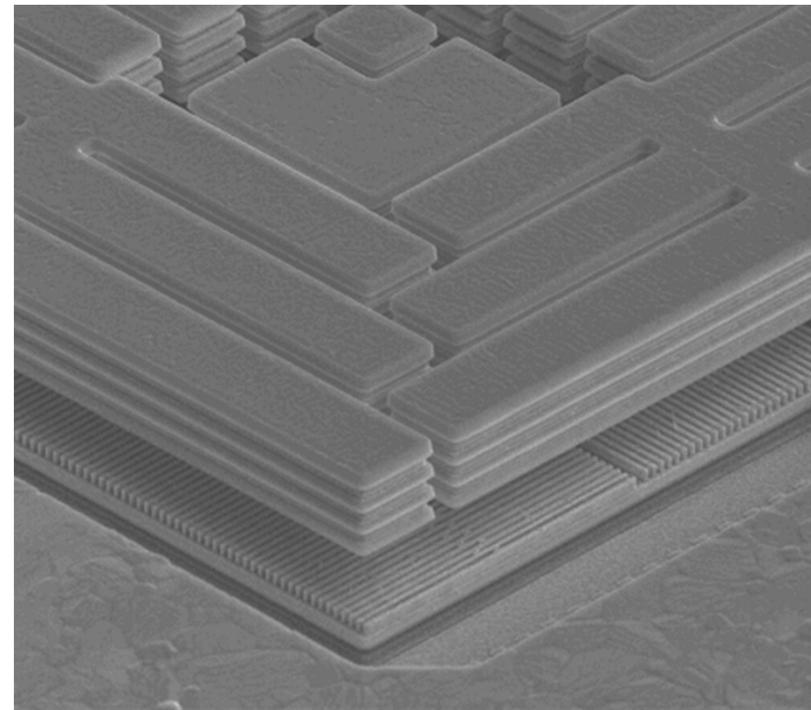**Top view of MEMS structure with silicon released underneath**

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# Oxide Release Process

- Vapor HF (dry) oxide release process uniformity control vs. through-put
- Pattern loading effect considerations


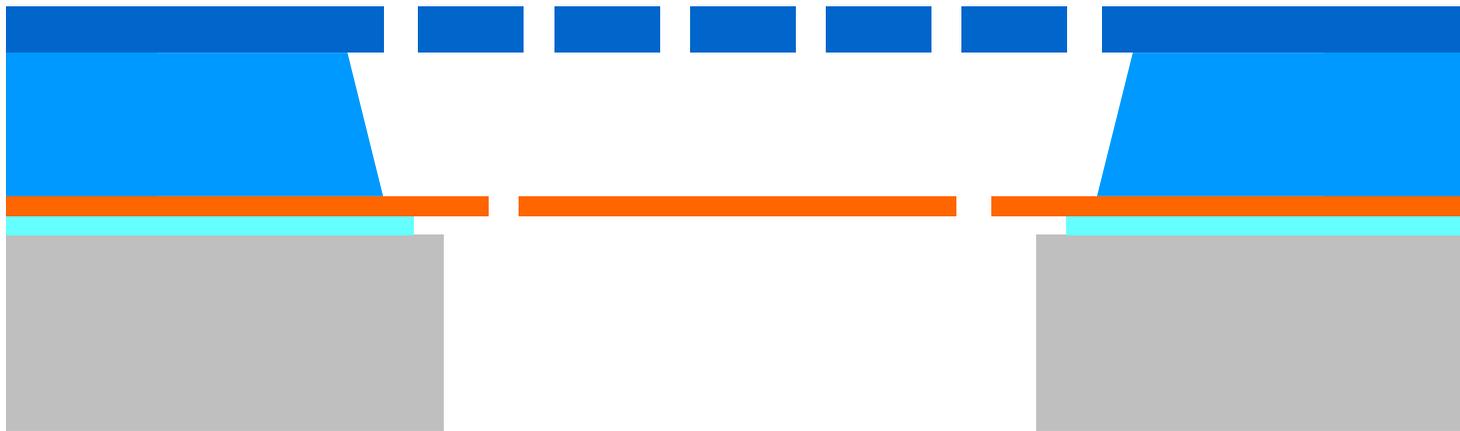
**Process scheme of VHF oxide release**



**SEM view of MEMS structure after VHF oxide release**

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# Difficulties Persist With Modulized Processes...
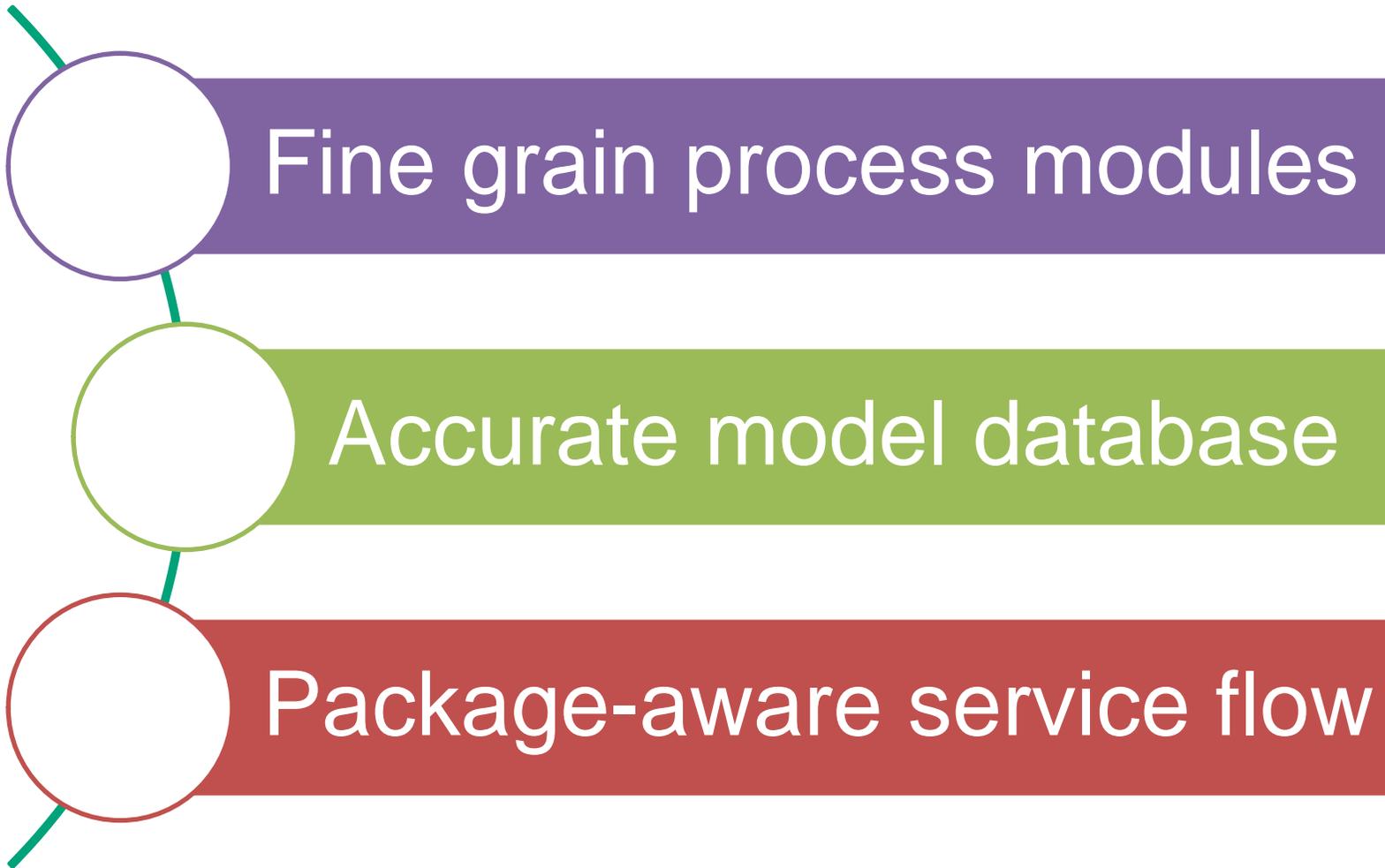
- Film stress control
  - Chemistry, temparature, RF Power, …
- Chamber release uniformity
  - Etching recipe, drying procedures, …

More than a year proces tuning typically

Lose-lose case for customer and foundry

Things need to be done differently!

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# An Open MEMS Design Environment Proposed

Fine grain process modules

Accurate model database

Package-aware service flow

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# Summary

- IoT will drive MEMS shipment

- MEMS market diversified, process development cycle too long

  - Slow time to market, high entry barrier, deter innovation

- Cowork with supply chain to facilitate delivery

  - Fine grain process modules

  - Accurate model database

  - Package-aware service flow

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# Thank You

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