I MEMS, un'opportunita' per il lavoro e la qualita' della vita.

Bruno Murari

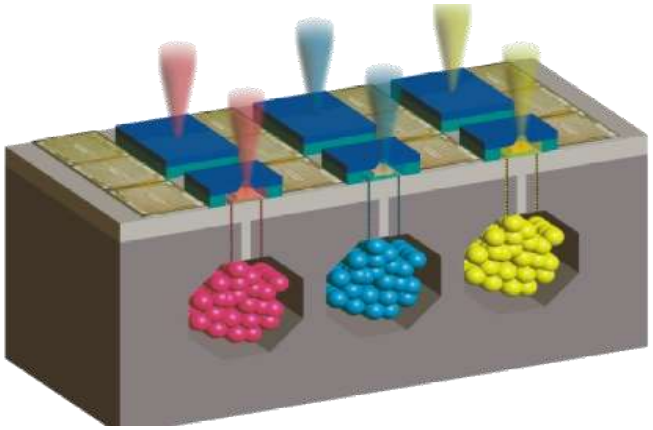
STMicroelectronics Scientific Advisor

FBK Trento - 1 giugno 2017

I MEMS:

tutto e' partito da……

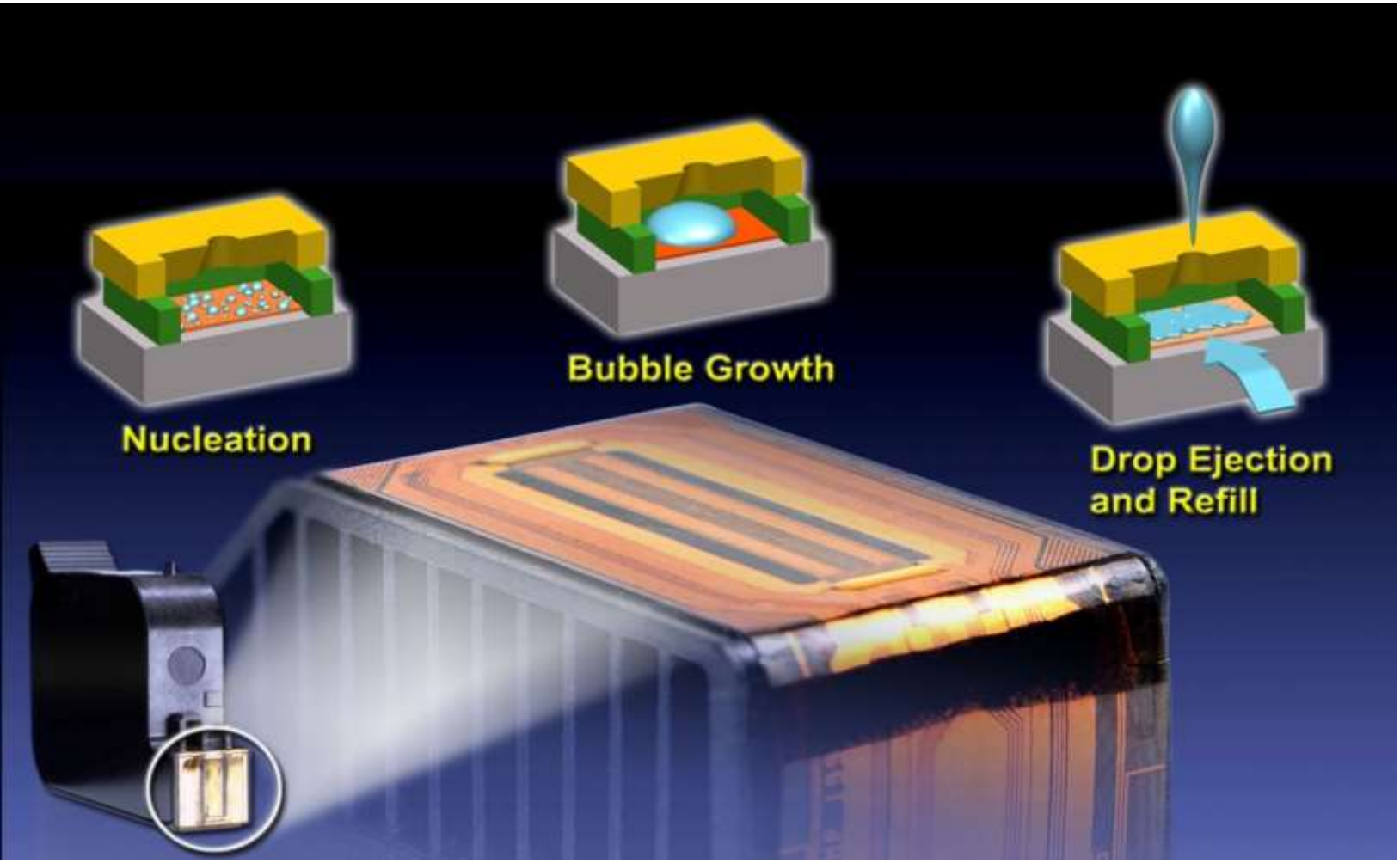
It all started with an inkjet printer

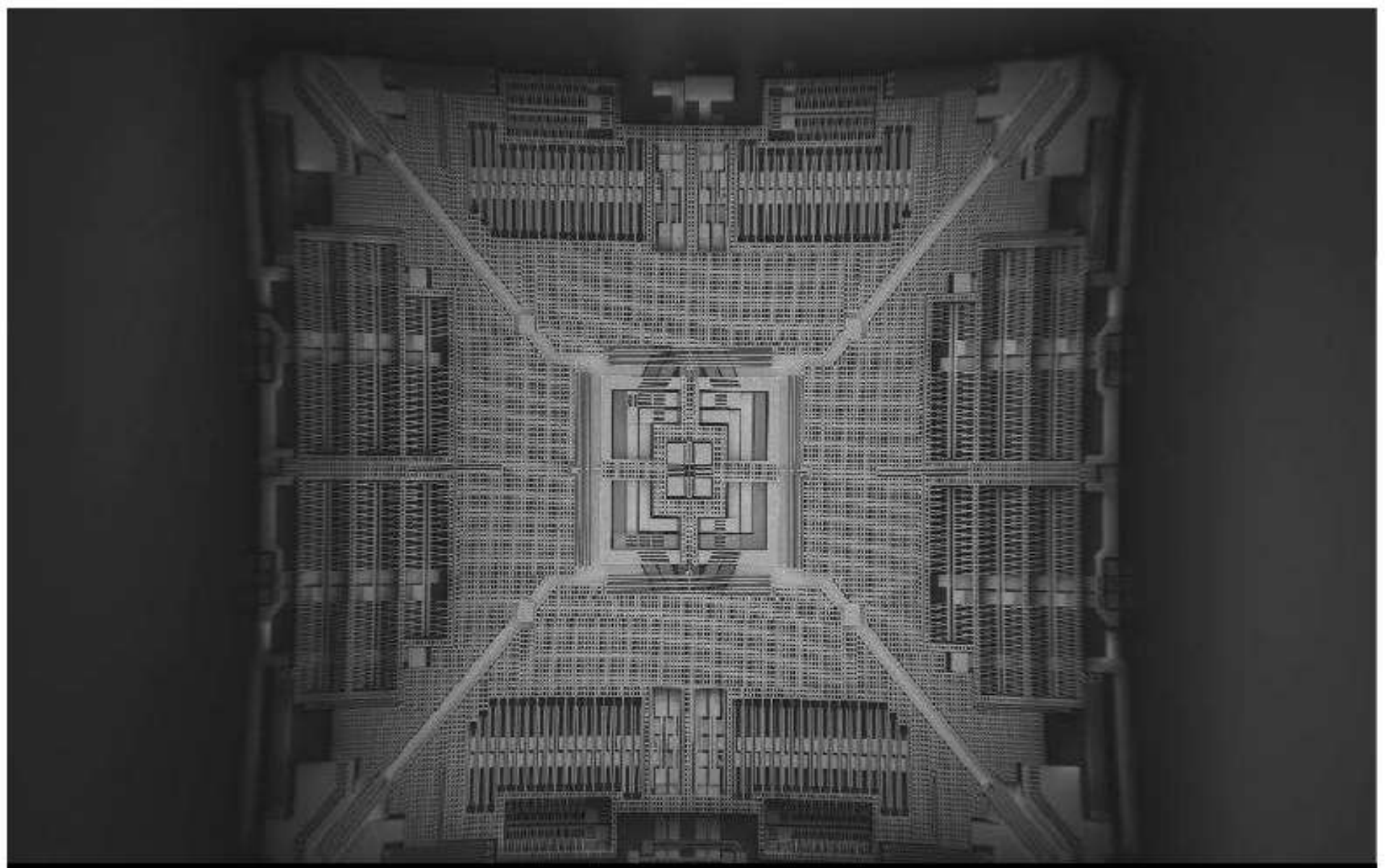


Buried channels for disposable
Ink-jet printers

Buried channels for PCR
In a disposable lab-on-chip

Inkjet cartridge

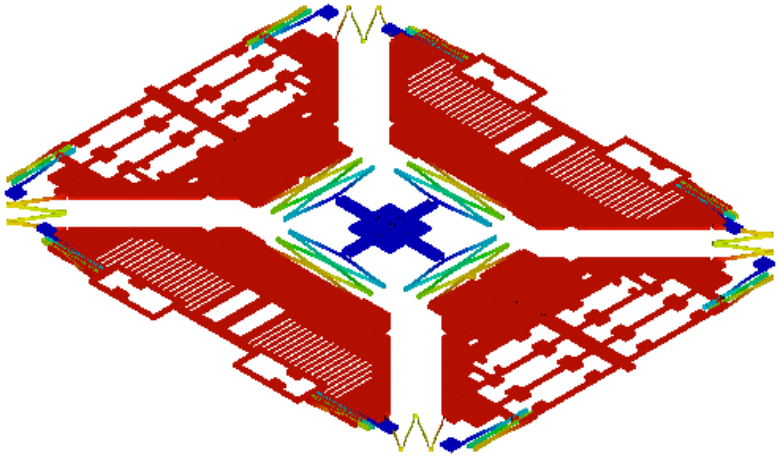




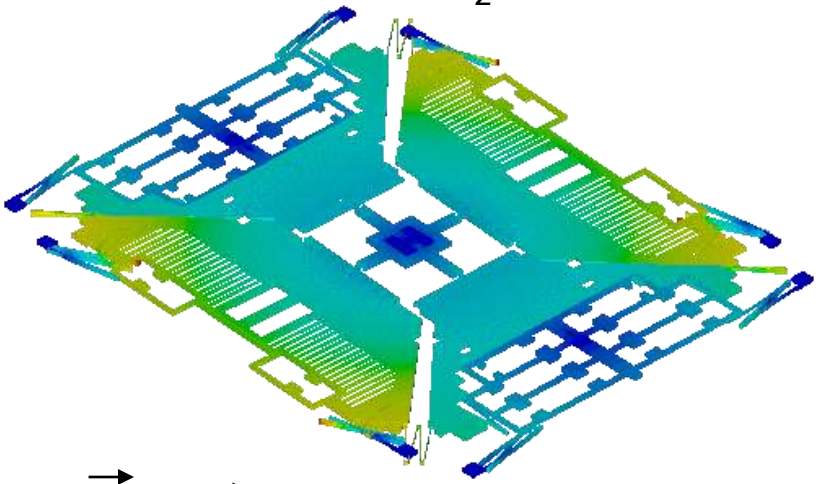
The Beating Heart

The beating hearth

Drive mode

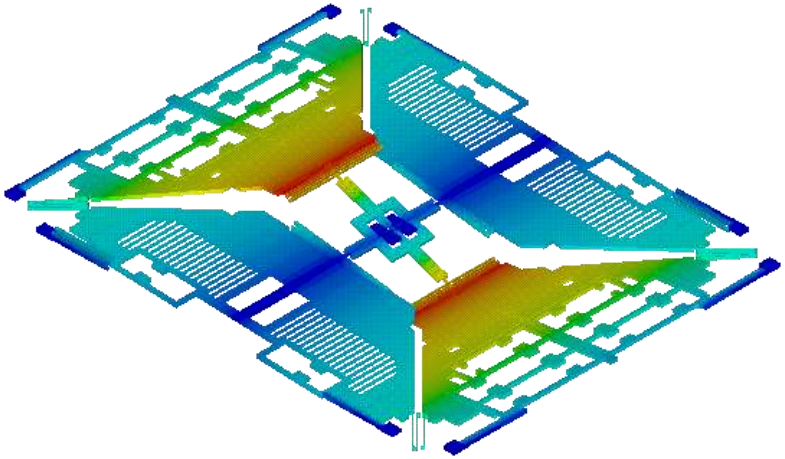


Yaw mode: Ω_z

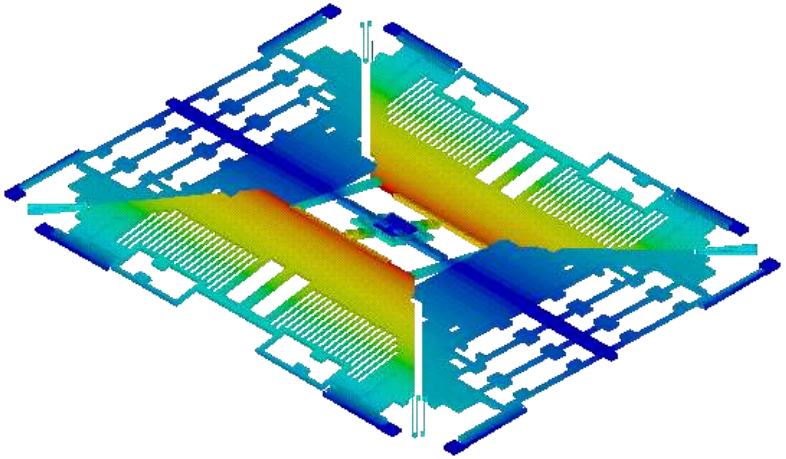


$$F_{Coriolis} = -2m\,\vec{\Omega}\,\Lambda\,\vec{v}$$

Roll mode: Ω_y



Pitch mode: Ω_x



Sensors are Changing the World

Smart City

Reduce traffic congestion

Better use of resources

Improve security

Smart Car

Reduce emissions

Increase safety

Save fuel

Smart Home

Make entertainment more interactive and immersive

Increase comfort

Save energy

Smart Me Healthcare

Empower patients

Help physicians monitor and diagnose remotely

Smart Me Fitness & Wellness

Help to lead healthier lives

Optimize sports performance

Early warning of illness

ST Winning in Wearables

Leading with the right products

- The leader in MEMS & sensors for consumer & mobile
- Leading in 32-bit low power microcontrollers
- Complementary Power management and connectivity solutions

The right sales model

- Broad market coverage
- Systems approach

Activity Monitor

Heart Monitor

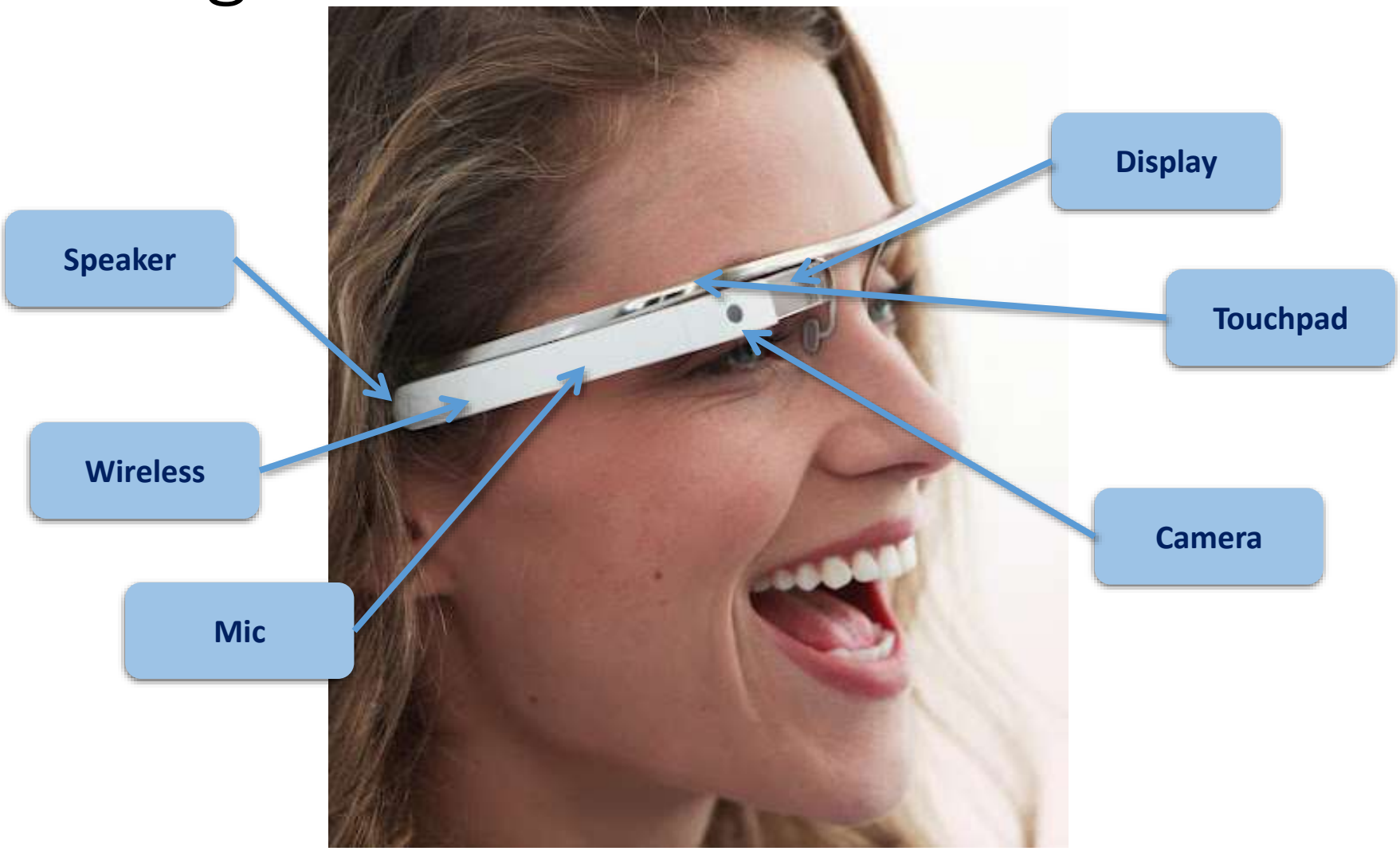
Smart Watch

Sports

Accessories

Glasses & Goggles

Google Glasses



Application Strategic Focus

1

IoT applications are changing the way we work and live by saving time and resources, and opening new opportunities for growth, innovation and knowledge creation

Smart Industry

Factory Automation
Motion Control
Industrial Robots
Industrial Lighting

Smart Home

Home & Building Automation
Smart Appliances
Smart LED Lighting
Heating & Energy Control
Security System

Smart City

Traffic control
Smart Transportation
Smart Metering
Street Lighting

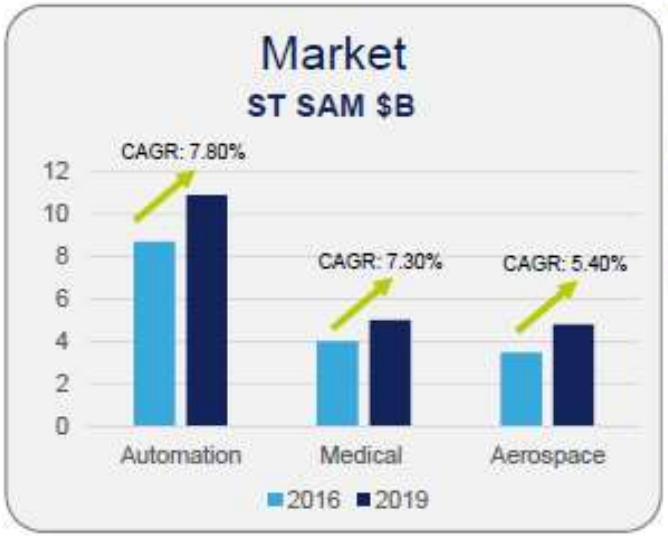
Smart Things

Wearable
Smartphones
Tablets
Smart consumer

Shaping our future with analog, sensors, smart power and connectivity to drive the evolution of IoT

Smart Industry

Smarter, safer and more efficient factories and workplaces



Key Applications

Factory Automation

Industrial Robots

Industrial Lighting

Key Enabling Products and Technologies

- BCD with Galvanic Isolation
- Real-time Communications & Interface

Market Leading positions

- Motor Control ICs
- Industrial Analog ASIC

Key success factors

- Wide range of Industrial protocols supported
- Safety-relevant protocol support
- Advanced motion control know-how

Source: IHS

Smart City

Enabling cities to make more of available resources

Key Applications

Smart Metering

Street Lighting

Smart Transportation

Multi-Service

Key Enabling Products and Technologies

- Wireless & power line connectivity
- Environmental sensors
- Smart Power technologies

Market Leading positions

- Power Line modem for smart metering
- LED driver ICs
- High voltage power management

Key success factors

- Multi-sensor network connectivity
- Expertise in digital-security technologies
- partnership with utilities and service providers, and system integrators

Sources: IHS, ABI Research

Smart Home

3

For better living, higher security, and less waste

Market

ST SAM $B

Key Applications

Heating & Energy Control

Smart Appliances

Security Systems

Home & Building Control

Key Enabling Products and Technologies

- Low-power wireless connectivity
- Power management & precision analog ICs
- Motion & Environmental Sensors

Market Leading positions

- LED driver ICs
- Motion MEMS
- Motor control ICs for Appliances

Key success factors

- Wide variety of connectivity standards to support various application needs
- Expertise in digital security technologies
- Application Know-how

Sources: IHS, ABI Research

The Smarter World of IoT

Smart City

Reduce traffic congestion

Better use of resources

Improve security

Smart Car

Reduce emissions

Increase safety

Save fuel

Smart Home

Make entertainment more interactive and immersive

Increase comfort

Save energy

Smart Me Healthcare

Empower patients

Help physicians monitor and diagnose remotely

Smart Me Fitness & Wellness

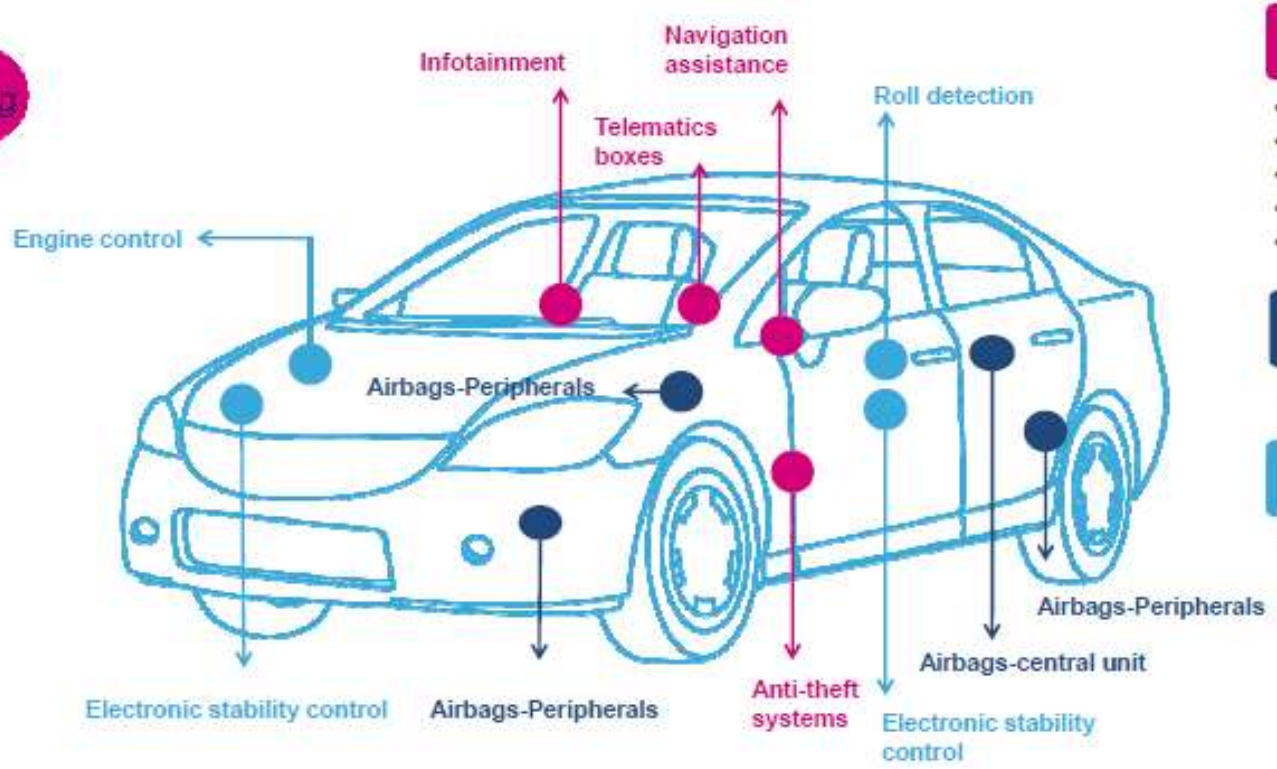
Help to lead healthier lives

Optimize sports performance

Early warning of illness

Sensor Technologies for Smart Driving

Making intelligent cars aware



NON-SAFETY

- Accelerometers
- Gyroscopes
- Inertial Measurement Units
- Environmental Sensors
- Microphone

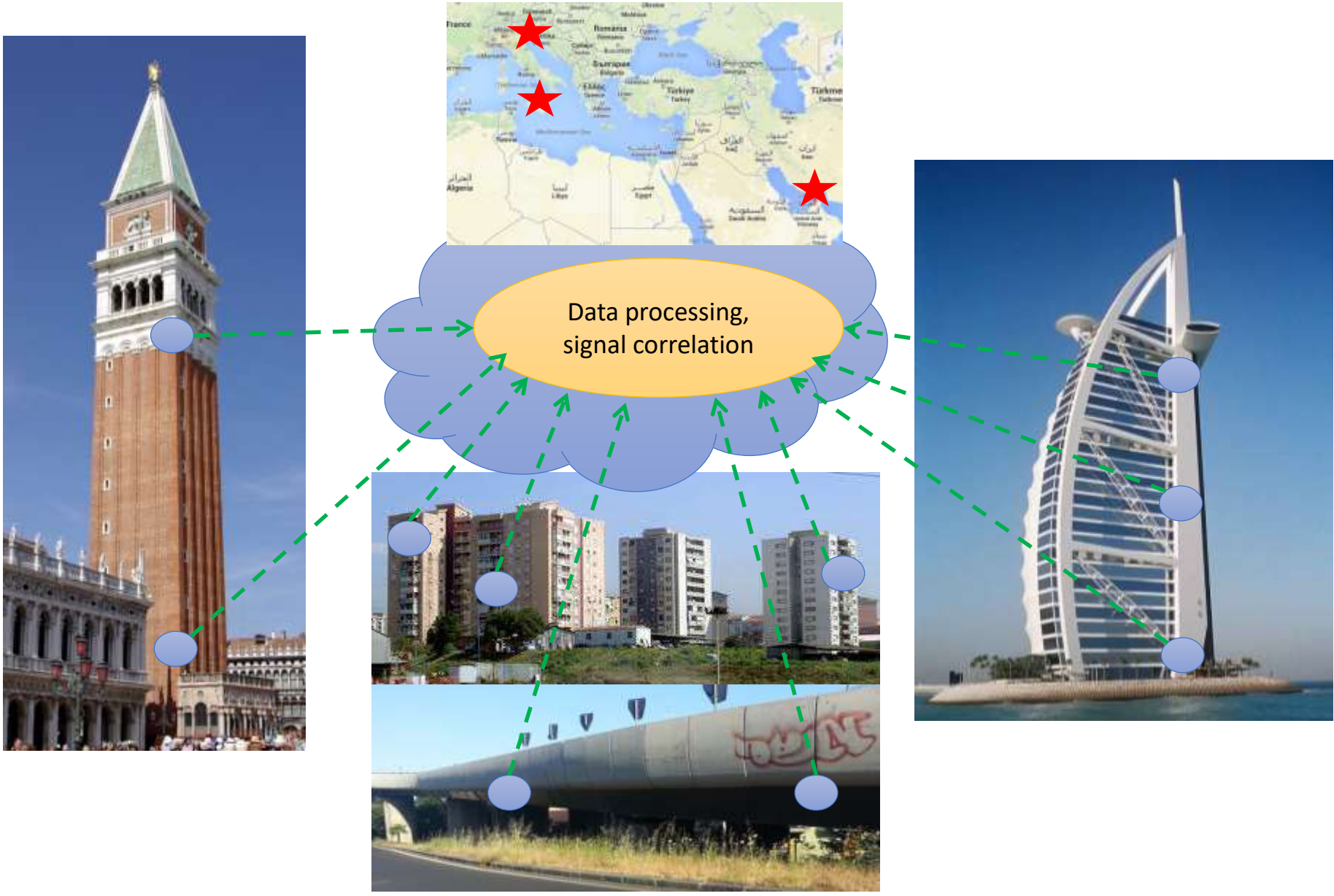
PASSIVE SAFETY

- Accelerometers

ACTIVE SAFETY

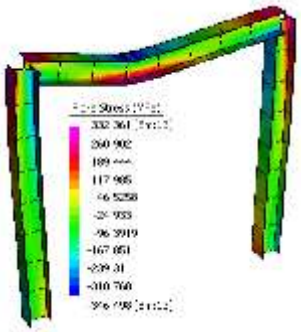
- Inertial Measurement Units

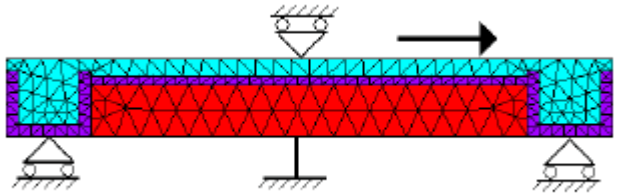
...a scalable system



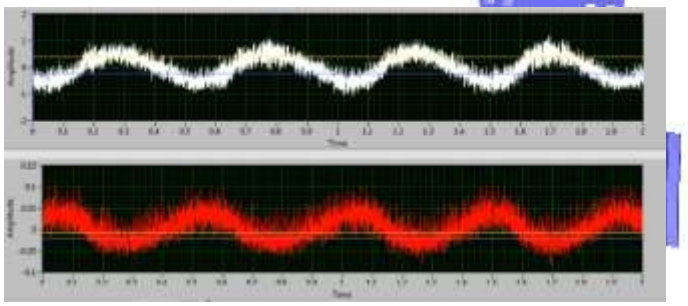
Static and dynamic monitoring

- ST is developing a new sensor to measure pressure inside a concrete beam
  - Sensors are chained and embedded inside concrete; RFID-like powered
  - High reliability and duration required
- Measuring strain distribution and its variation over time





- ST has developed a device that measures dynamic behaviour of a civil structure when different stress is applied (people, wind, traffic, earthquakes) and sends data to the cloud
  - ➔ accelerometers
  - ➔ Wi-Fi

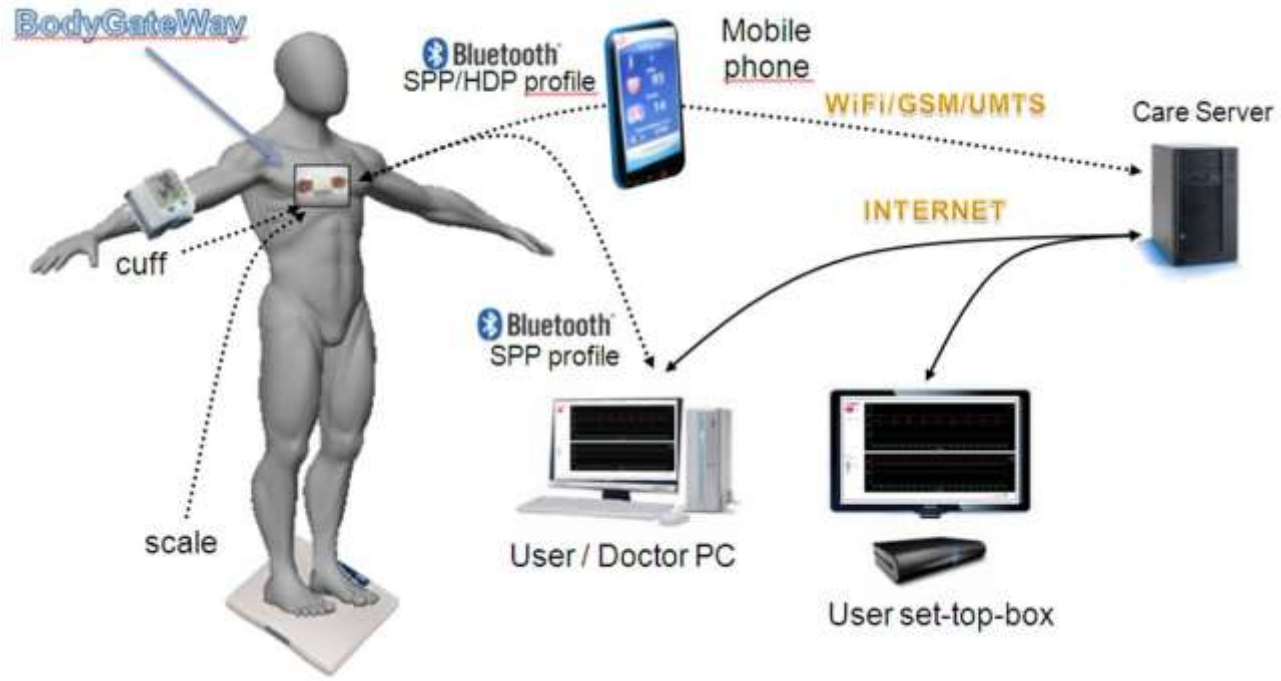


Body Gateway for remote monitoring

- **ST Solutions:** Wearable device to measure physiological parameters (ECG, Hearth Rate, Breathing Rate, etc) to enable tele-monitoring solutions for chronic disease patients

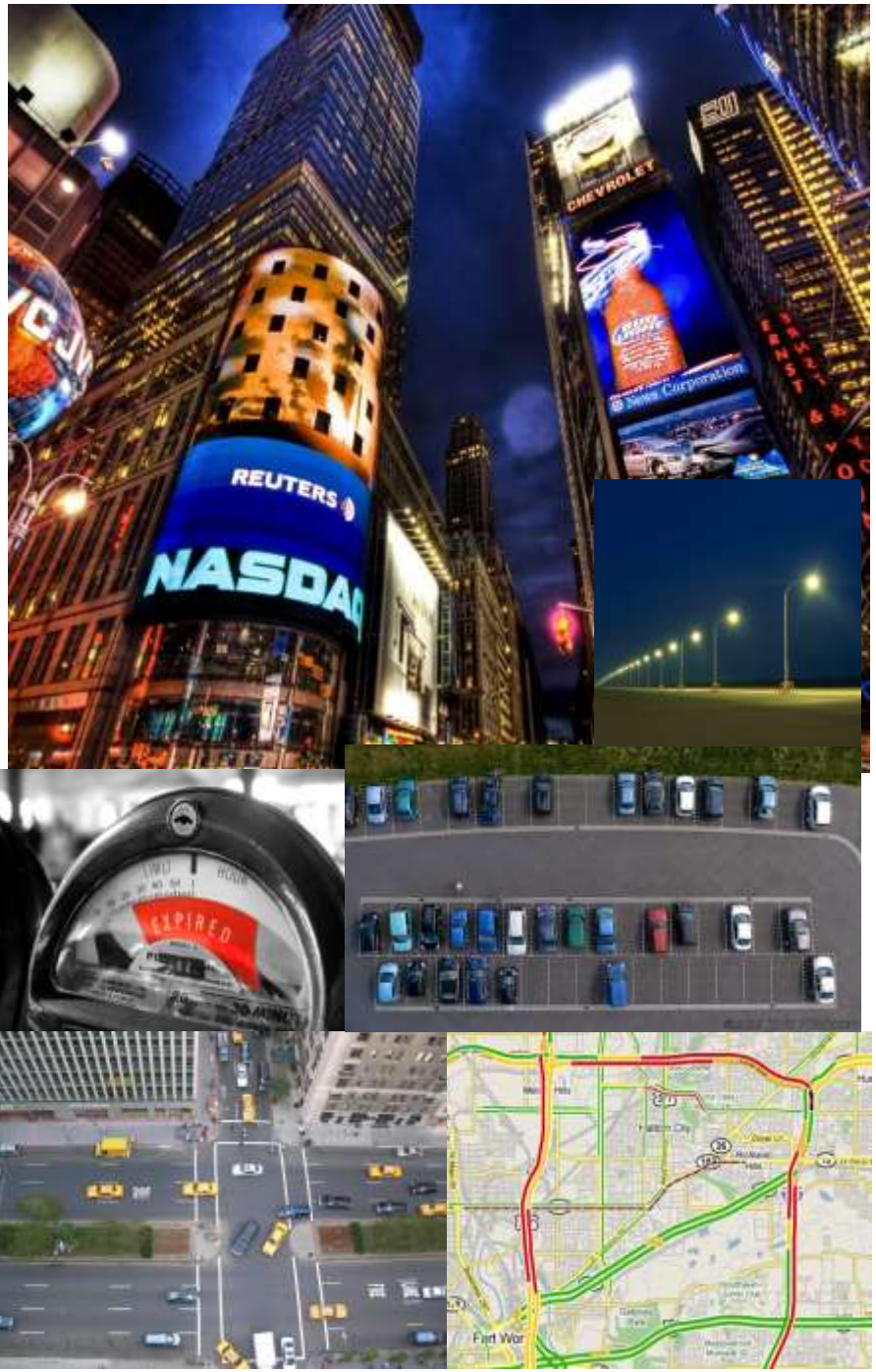
Key features

- Heart rate detection
- Physical activity estimation
- Breathing rate measurement
- Body position/activity, gait analysis, fall detection (with barometer)



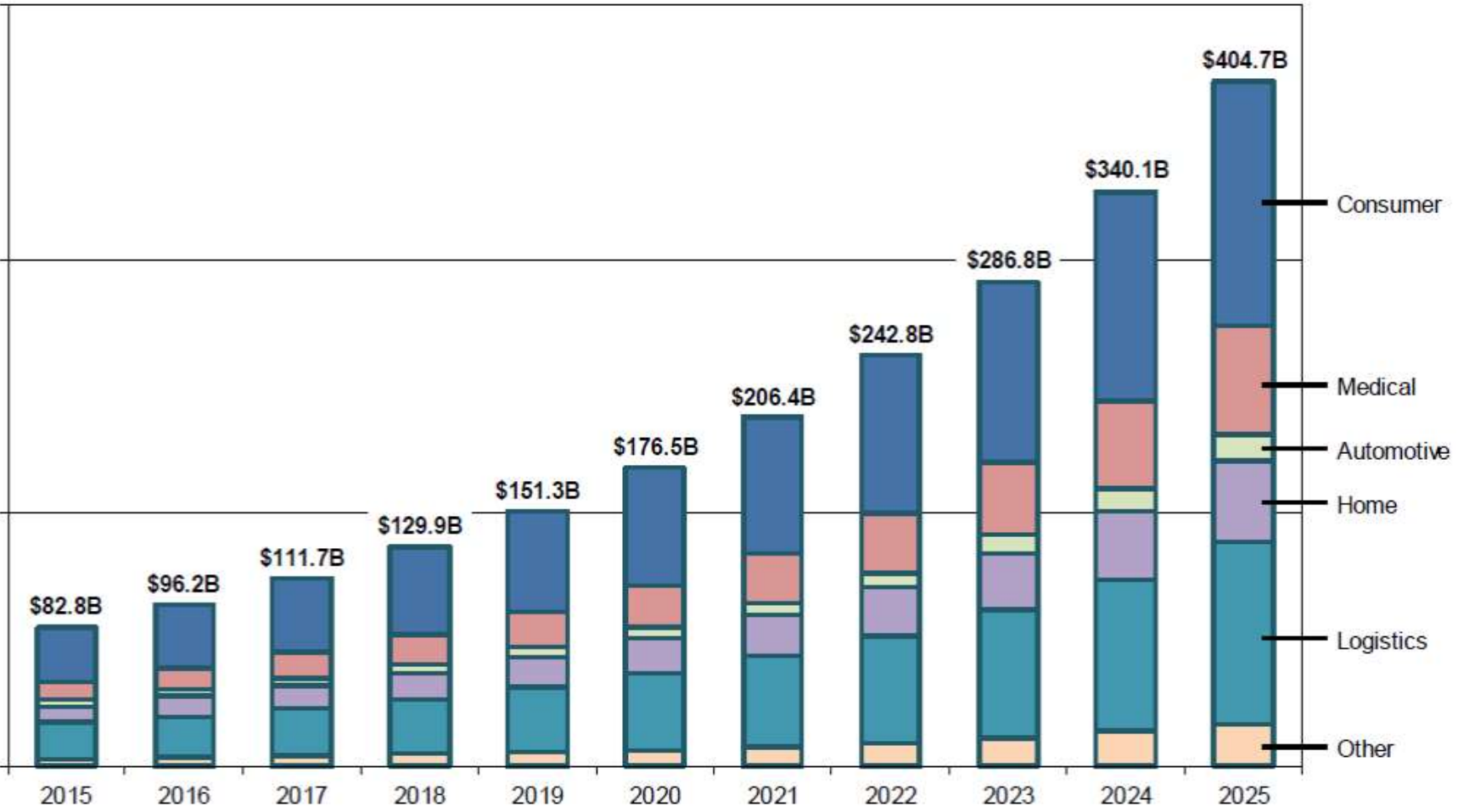
Typical applications

- Elderly people health monitoring
- Chronic cardiac disease monitoring
- Post surgery monitoring
- Event monitoring applications
- One-lead Holter applications



- **Smart Lighting**
  Intelligent and adaptive LED lamps real-time control based on traffic, weather, context (rural areas, suburbs, etc.).
- **Smart Parking**
  Monitoring of parking spaces availability in the city, automated parking violation and metering
- **Structural health**
  Monitoring of structural integrity for buildings, bridges, monuments.
- **Traffic Congestion**
  Monitoring of both car and pedestrian flow to optimize traffic lights, route planning, 3d intersection management, optimized deployment of law enforcement, etc.
- **Trash management**
  Detection of curbside trash levels for collection routes.
- **Real-time annotated urban maps**
  Air quality, sound pollution, crowd density and hang out spots, live street-view, data collected and aggregated via web aggregators

FIGURE 1.2.4
IoT Device Market



Souce: IBS (International Business Strategies INC.)

Un gioco di parole:
tre x tre :

1) tre mesi per una applicazione

2) tre anni per un circuito integrato

3) tre lustri per una tecnologia

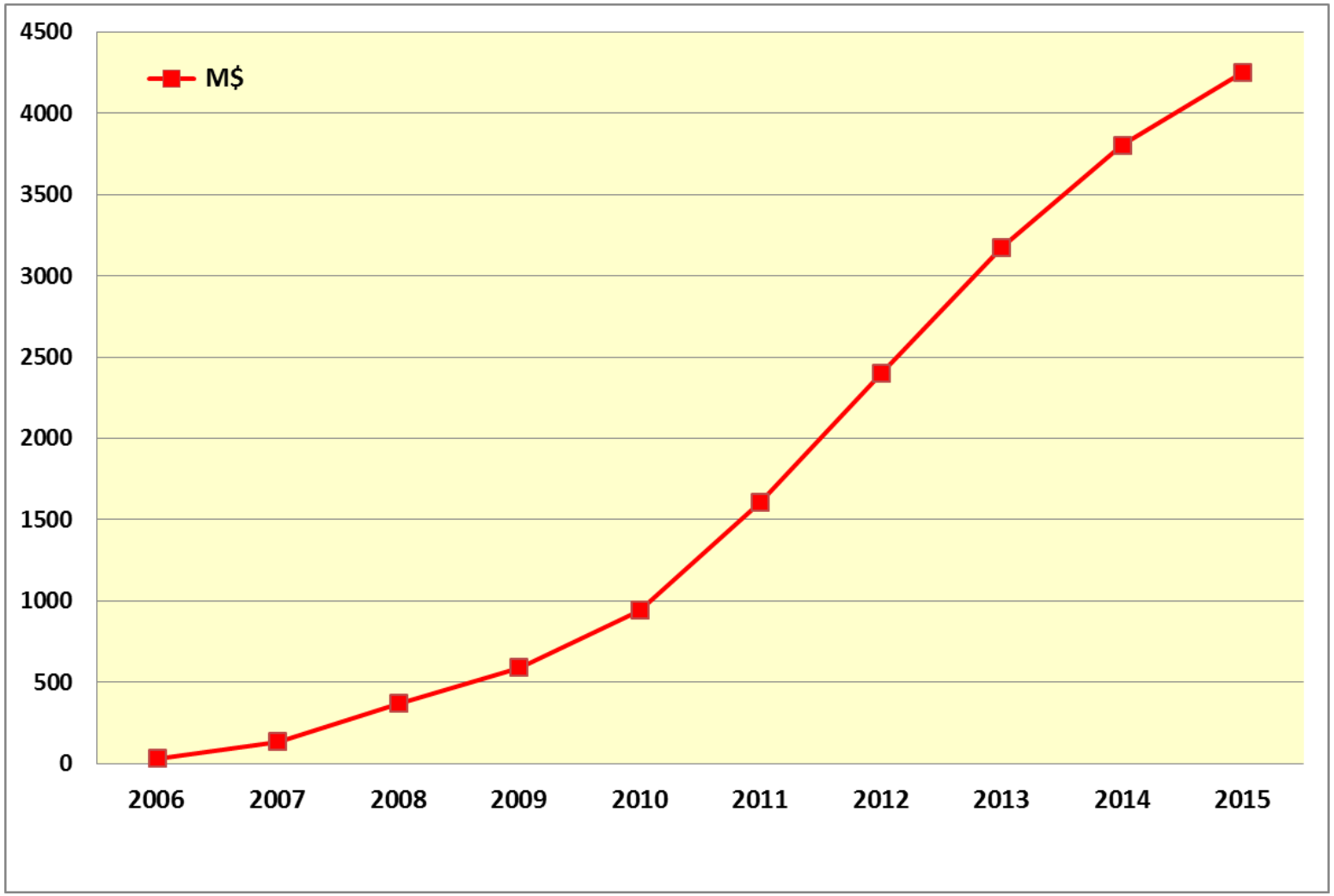
Il ritorno sul territorio:

1) per una app. Il ritorno e’ per il singolo e dura una moda

2) per un C.I. Il ritorno e’ per l’azienda fabless e dura alcuni anni

3) per una tecnologia il ritorno e’ non solo per l’azienda, ma anche per il territorio che contiene le fabbriche che producono I prodotti progettati nella tecnologia e la durata e’ di decine di anni.

ST MEMS 10 Years History
Cumulated Sales



Source: IHS - Device: Sensors & Actuators

Per concludere , come ha detto Steve Job:

1) siate pazzi

2) siate affamati e….

3) siate insistenti e persistenti per portare al successo le idee nelle quali credete!

Grazie per l’attenzione.

Dalla sabbia……

alla microelettronica……

ai BCD……..

alla microfluidica……

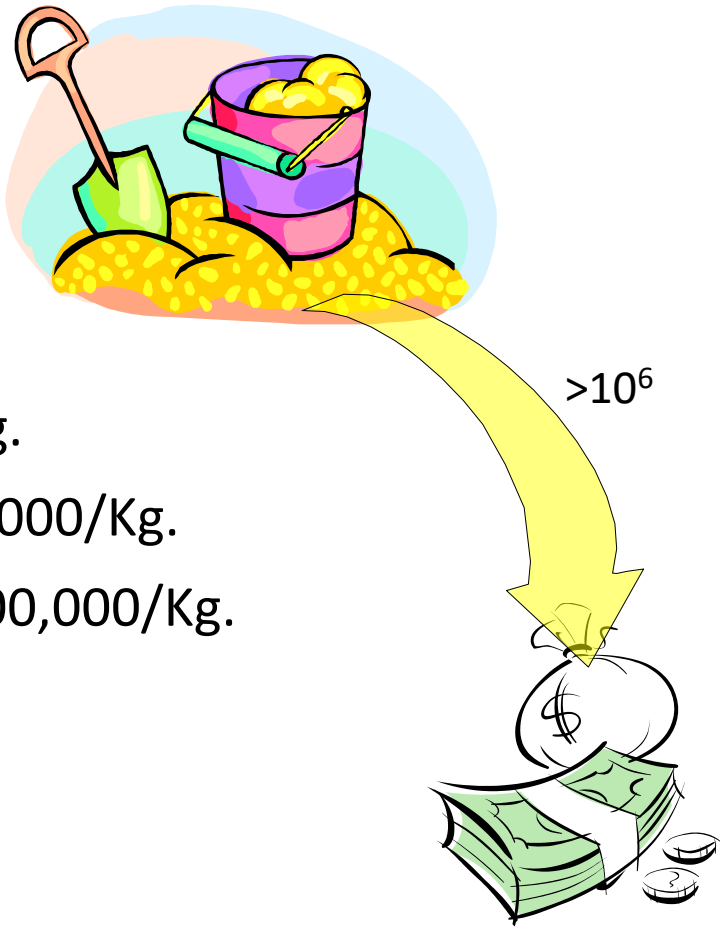
ai MEMS (Micro Electro Meccanical Systems)……

alla silicon photonics……..

…..e alla nuvola.

Semiconductors industry is…..
…an industry built on sand !!!

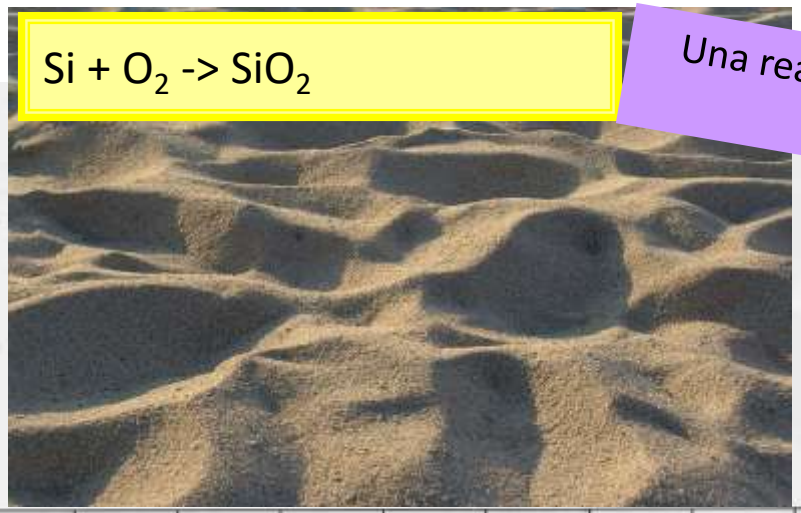
- Sand……..<<$1/Kg.
- Polysilicon……$50/Kg.
- 200mm Prime Wafer….$1,400/Kg.
- 200mm Processed Wafer….$25,000/Kg.
- Packaged Integrated Circuit…$100,000/Kg.
- Generating End Equipment Worth…$500,000/Kg.
- With A Street Value of More Than….$1,000,000/Kg.



Source: MEDEA Forum ‘99

Dal punto di vista della tavola periodica!!!

$Si + O_2 \rightarrow SiO_2$



Una reazione FONTAMENTALE

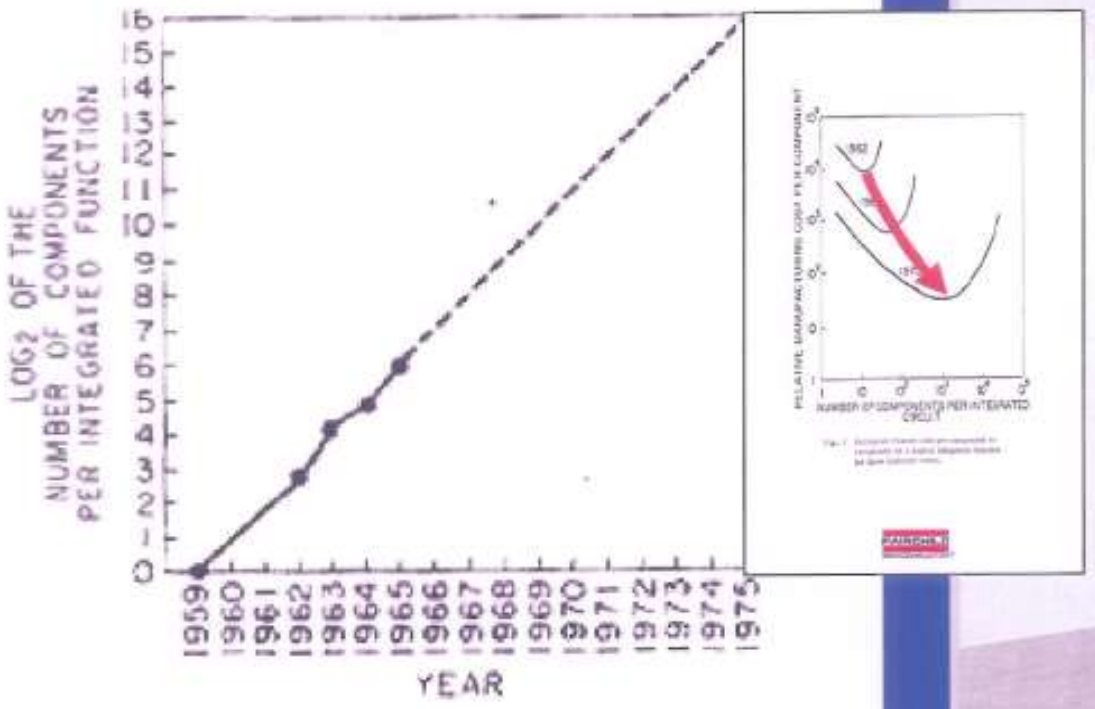
	1 IA											12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.01	2 IIA																2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31	3 IIIB										13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (265)	109 Mt (268)									

Serie dei Lantanidi	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.91)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Serie degli Attinidi	90 Th 232	91 Pa 231	92 U 238	93 Np 237	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md 1.01	102 No 1.01	103 Lr 1.01

Lingotti di puro silicio con differenti diametri

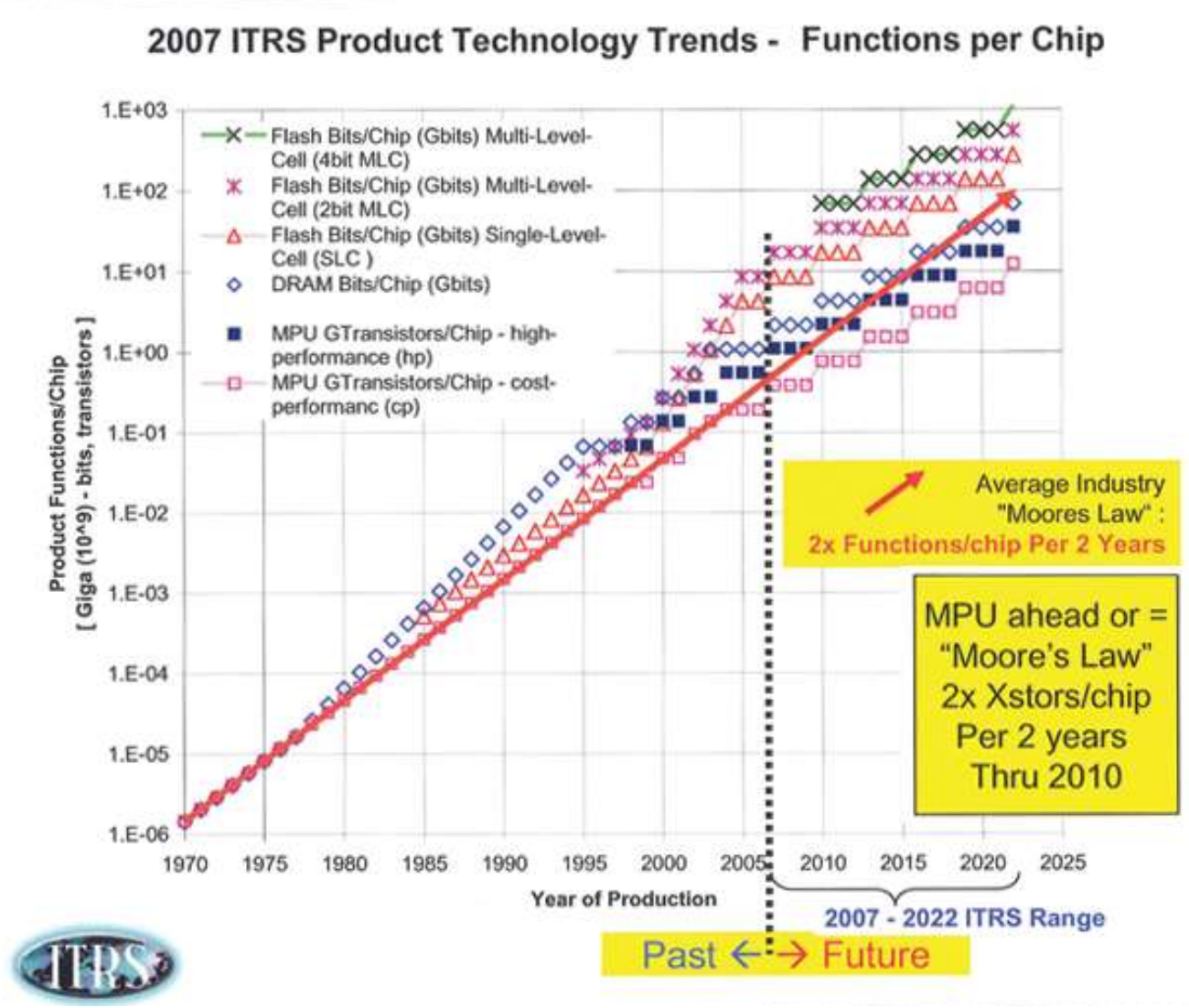
Wafer finiti…pronti per l’uso!!!

Moore's Law - 1965



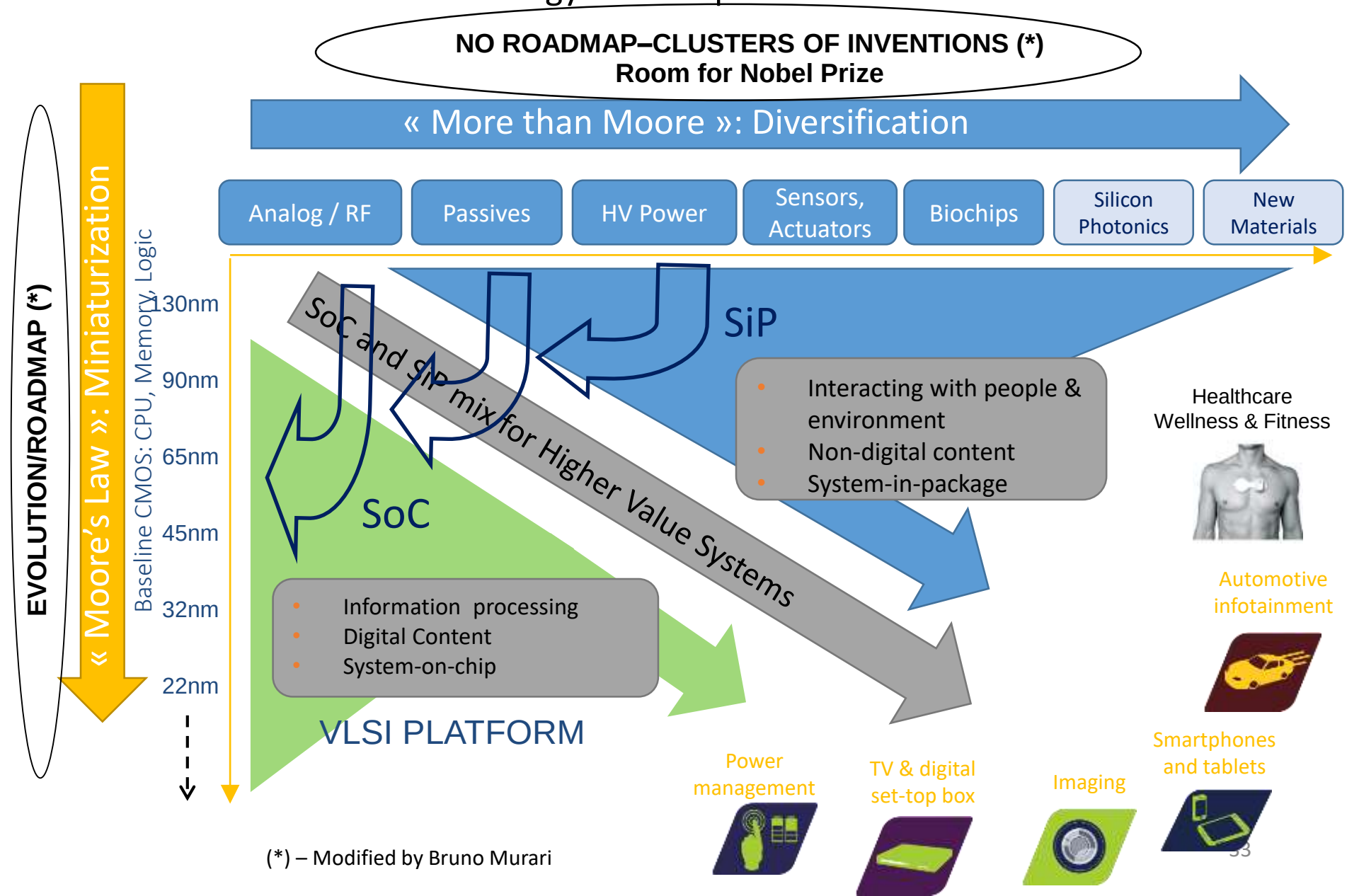
"Reduced cost is one of the big attractions of integrated electronics, and the cost advantage continues to increase as the technology evolves toward the production of larger and larger circuit functions on a single semiconductor substrate."
Electronics, Volume 38, Number 8, April 19, 1965

Chip size trends



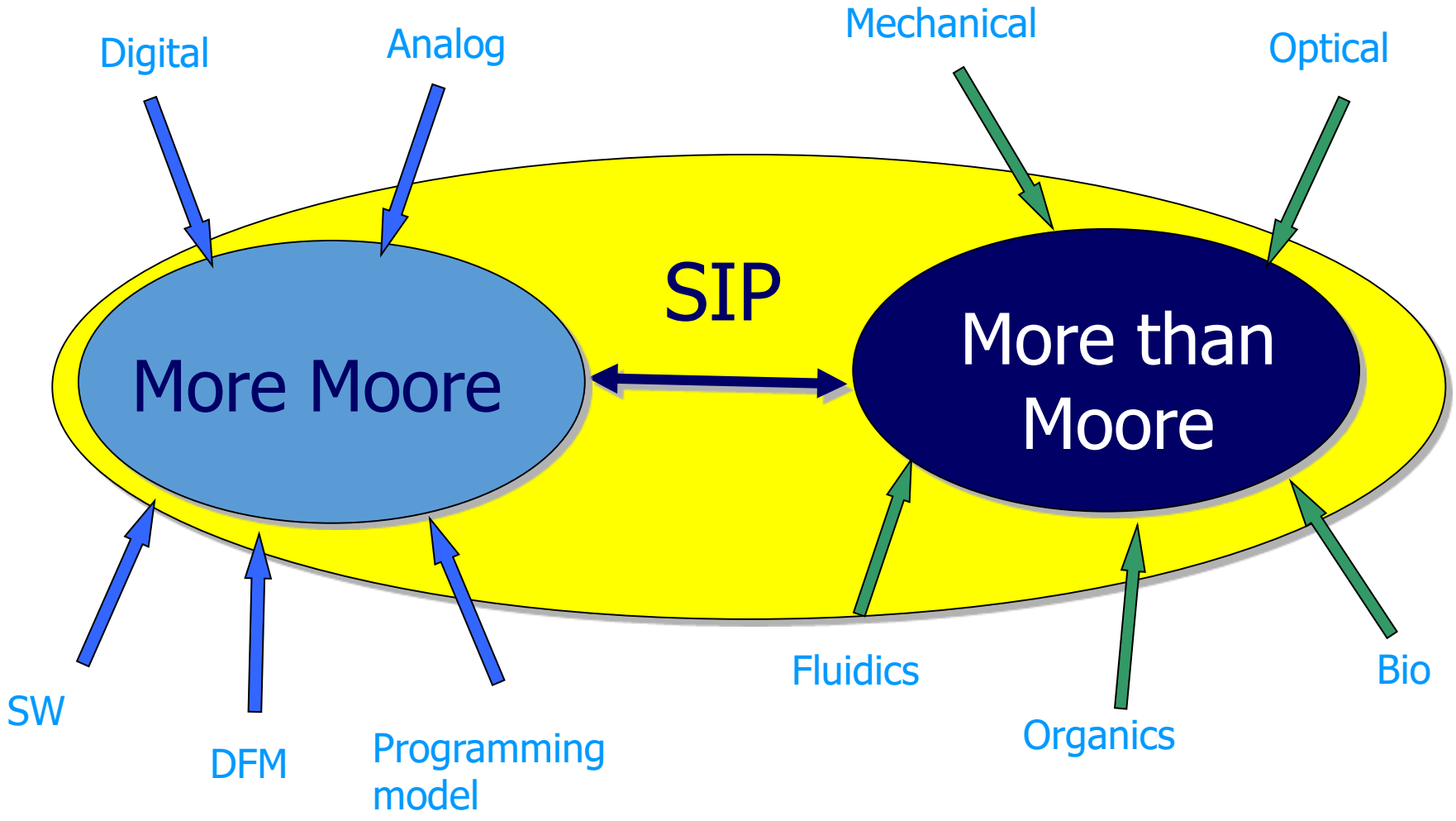
Technology Competitive Advantage

ITRS: International Technology Roadmap for Semiconductors

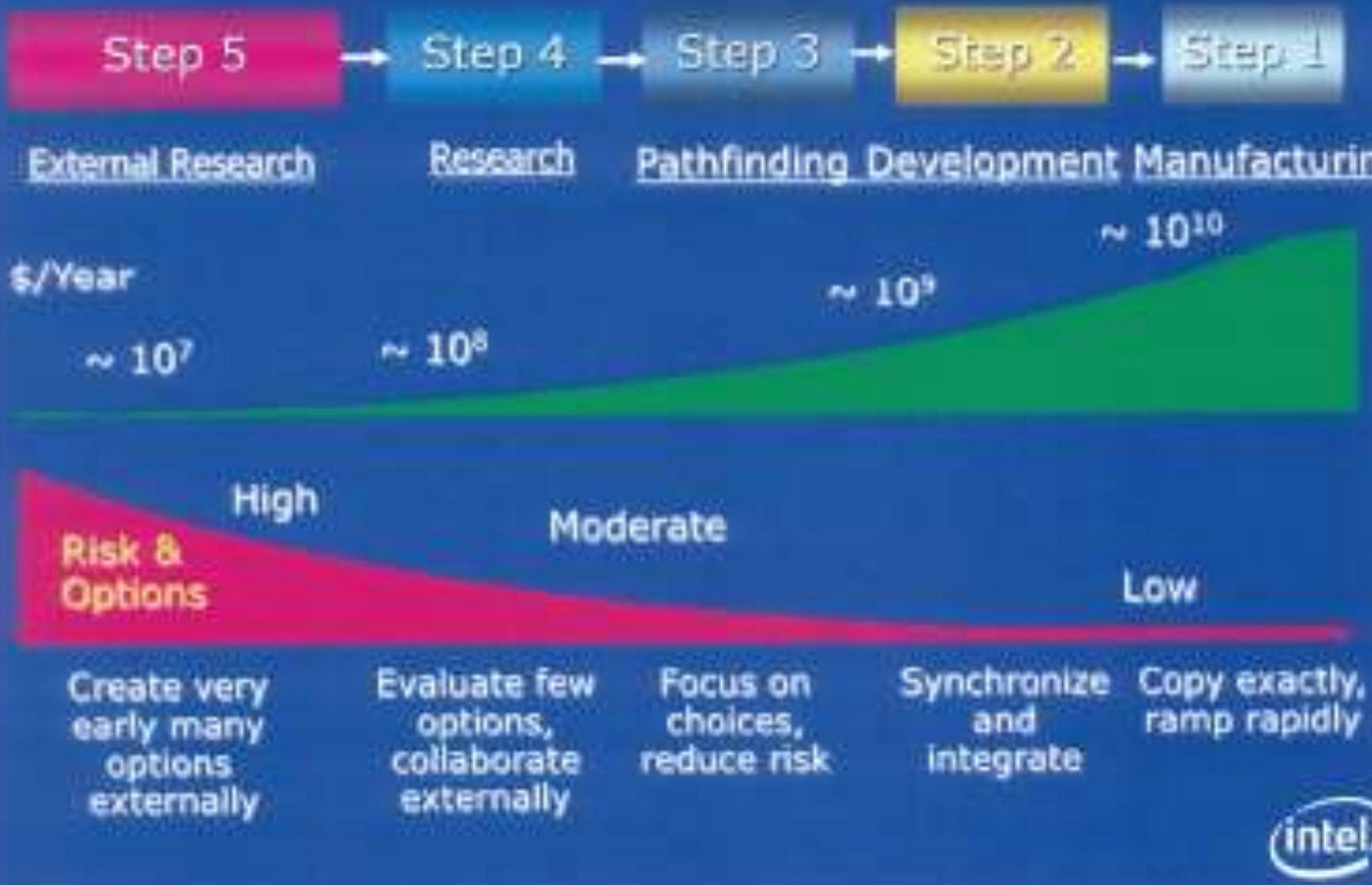


(*) – Modified by Bruno Murari

Need to bring “More Moore” and “More than Moore” at work!



Staged Investment Aligned to Risks

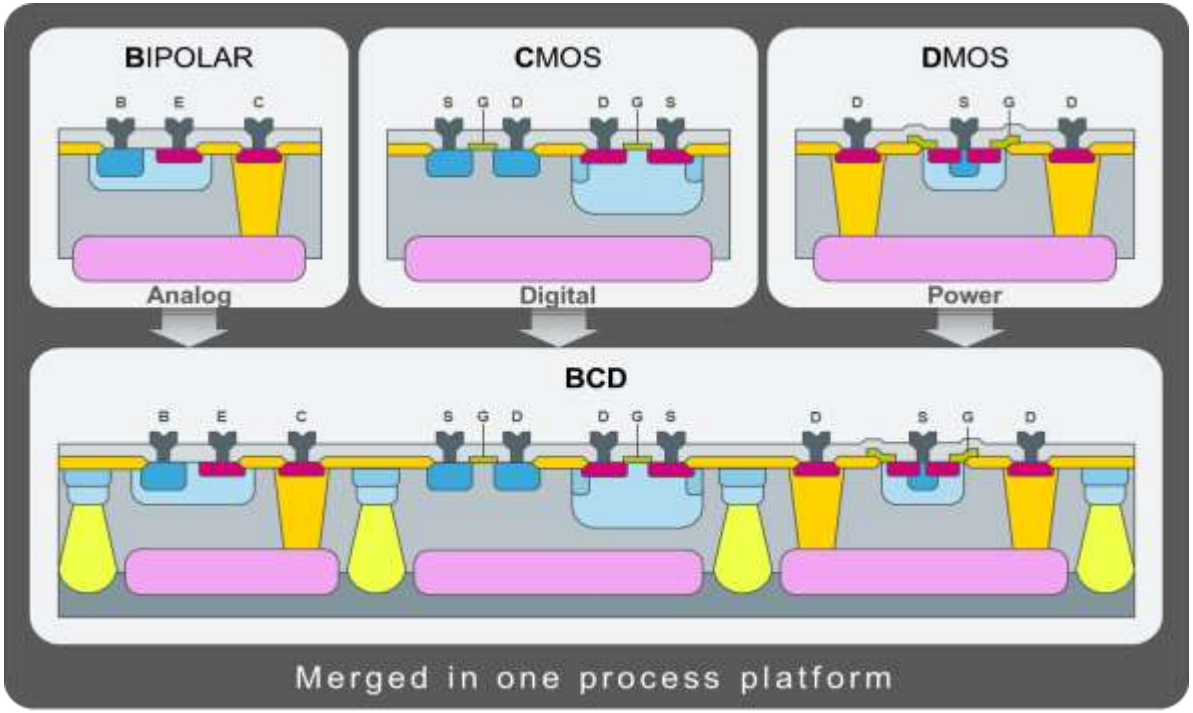


BCD
BIPOLAR CMOS DMOS

Una famiglia di tecnologie tutta italiana

What is BCD ?

A concept introduced by ST in the mid-80s [1][2][3] widely used today in the industry

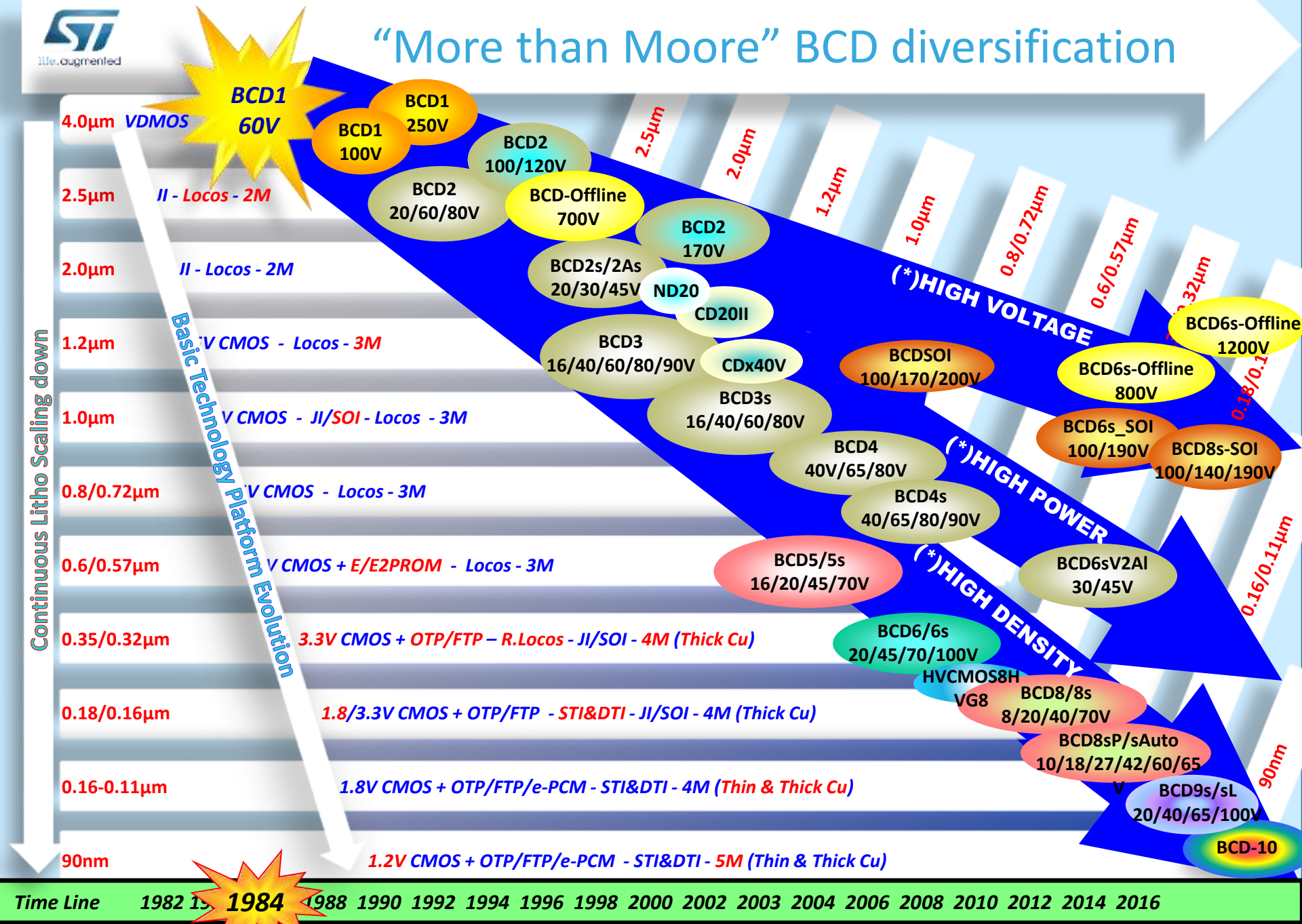


[1] ***Single Chip Carries Three technologies***, Electronics Week, December 10, **1984**

[2] *C. Cini, C. Contiero, C. Diazzi, P. Galbiati, D. Rossi, "**A New Bipolar, CMOS, DMOS Mixed Technology for Intelligent Power Applications"**,* ESSDERC '85 Proceedings, Aachen (Germany), September **1985**

[3] *A. Andreini, C. Contiero, P. Galbiati, "**A New Integrated Silicon Gate Technology Combining Bipolar Linear, CMOS Logic and DMOS Power Parts**",* IEEE Transactions on Electron Devices, Vol. ED-33 No.12, December **1986**

“More than Moore” BCD diversification



Next BCD development Challenges

Lithography Scaling

BCD below 110nm:

- VLSI materials compatibility
- 300mm fabs
- Proper Electronic System Partitioning

Power: RON X Area

How to improve:

- New architectures ?
- New Materials ?
- Strained Silicon ?

NEXT BCD CHALLENGES

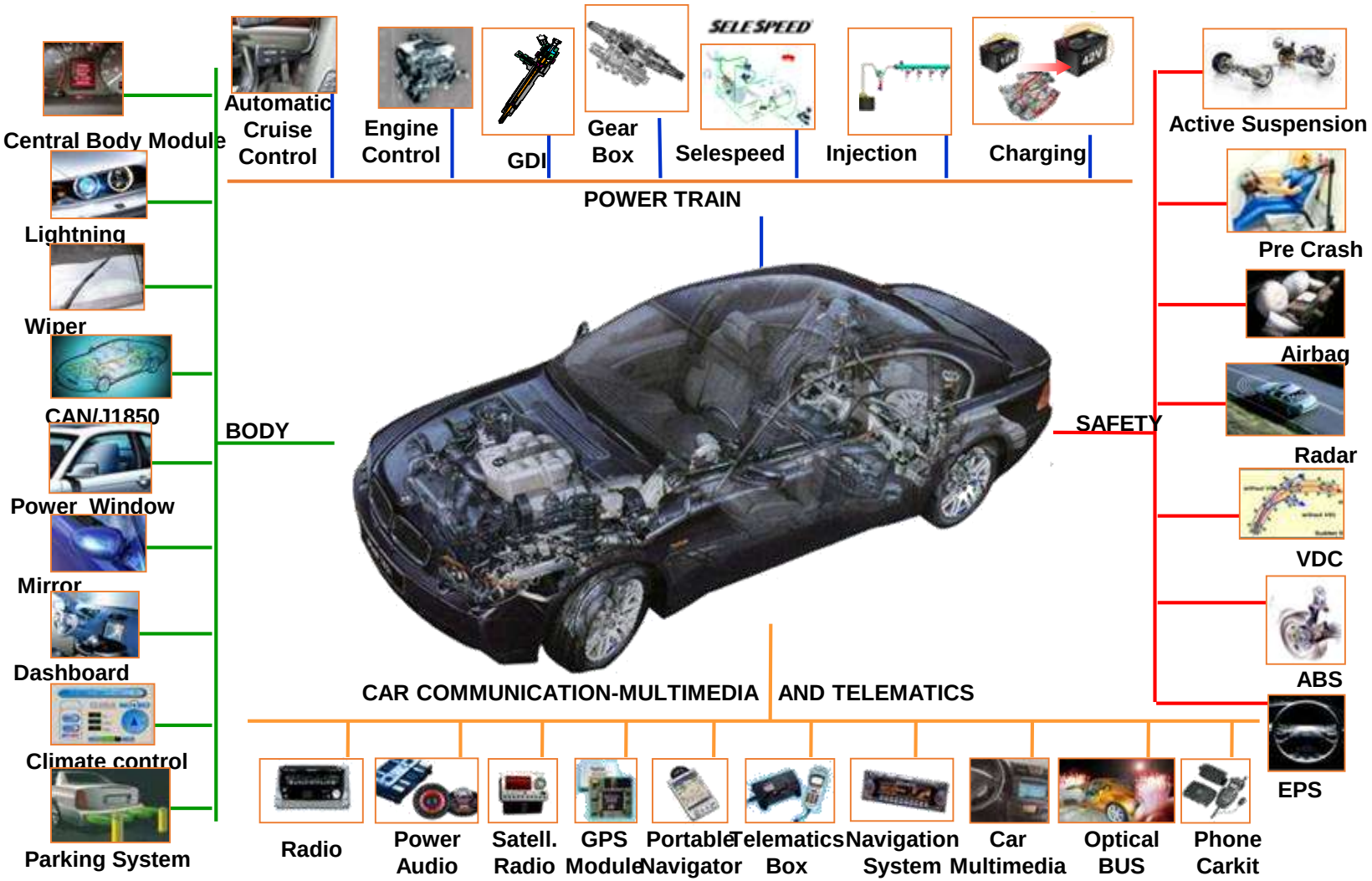
Energy Dissipation

- Limited by thermo-mechanical effects on Metal Layers and Inter-metal Dielectrics
- Wide band-gap materials

Heterogeneous Integration

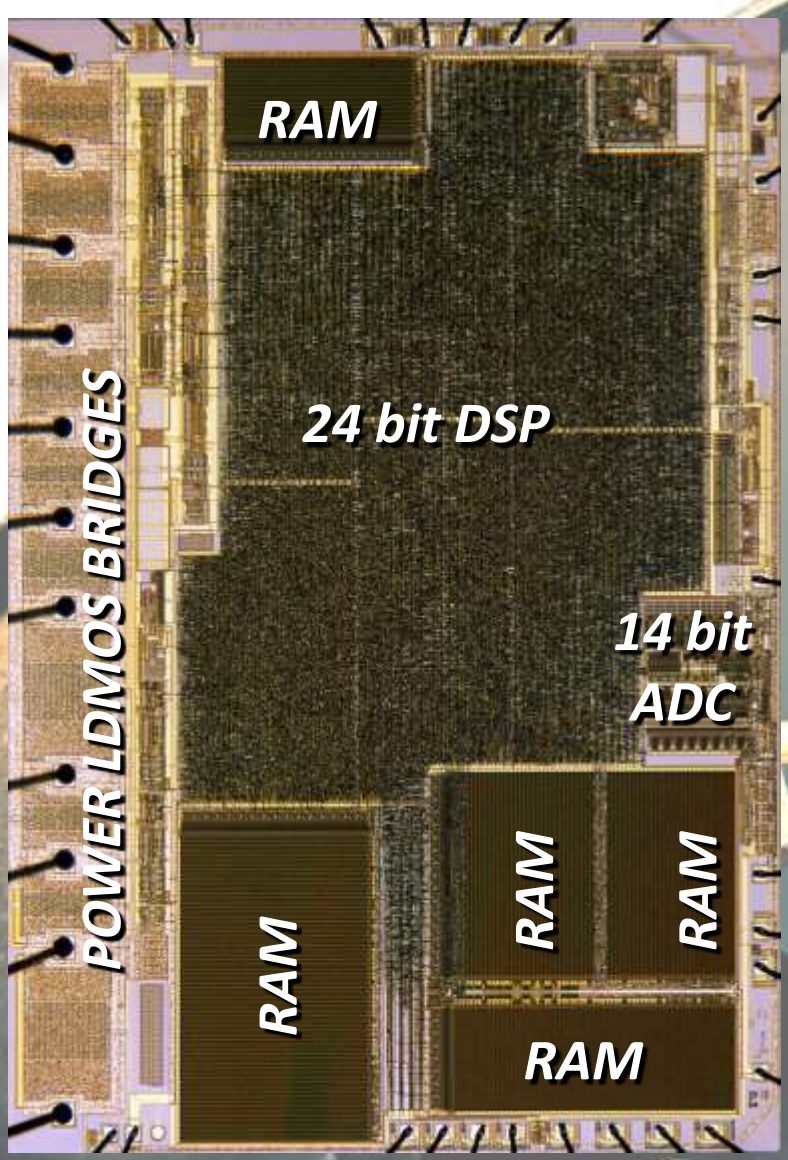
- Magnetic Materials
- High Performance Passives
- High Value Capacitors
- 3D integration

The automotive challenge

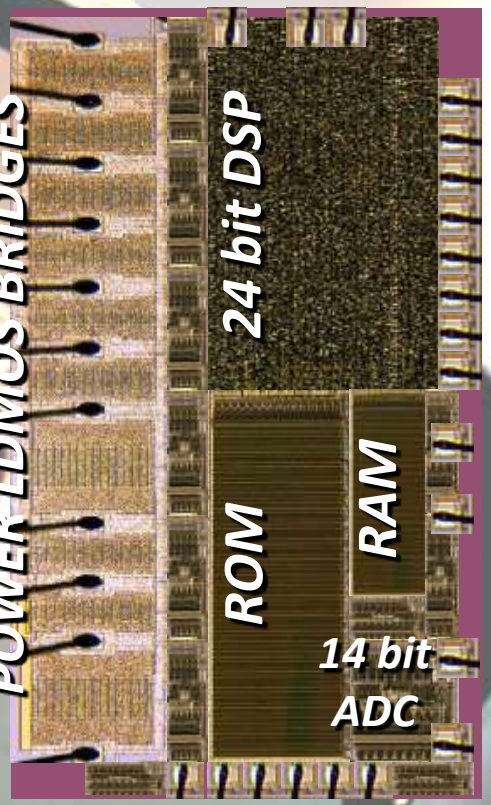


60V 10A Switch mode power supply

VLSI BCD technology allows "Super Smart Power" Systems controller



From BCD5 to BCD6



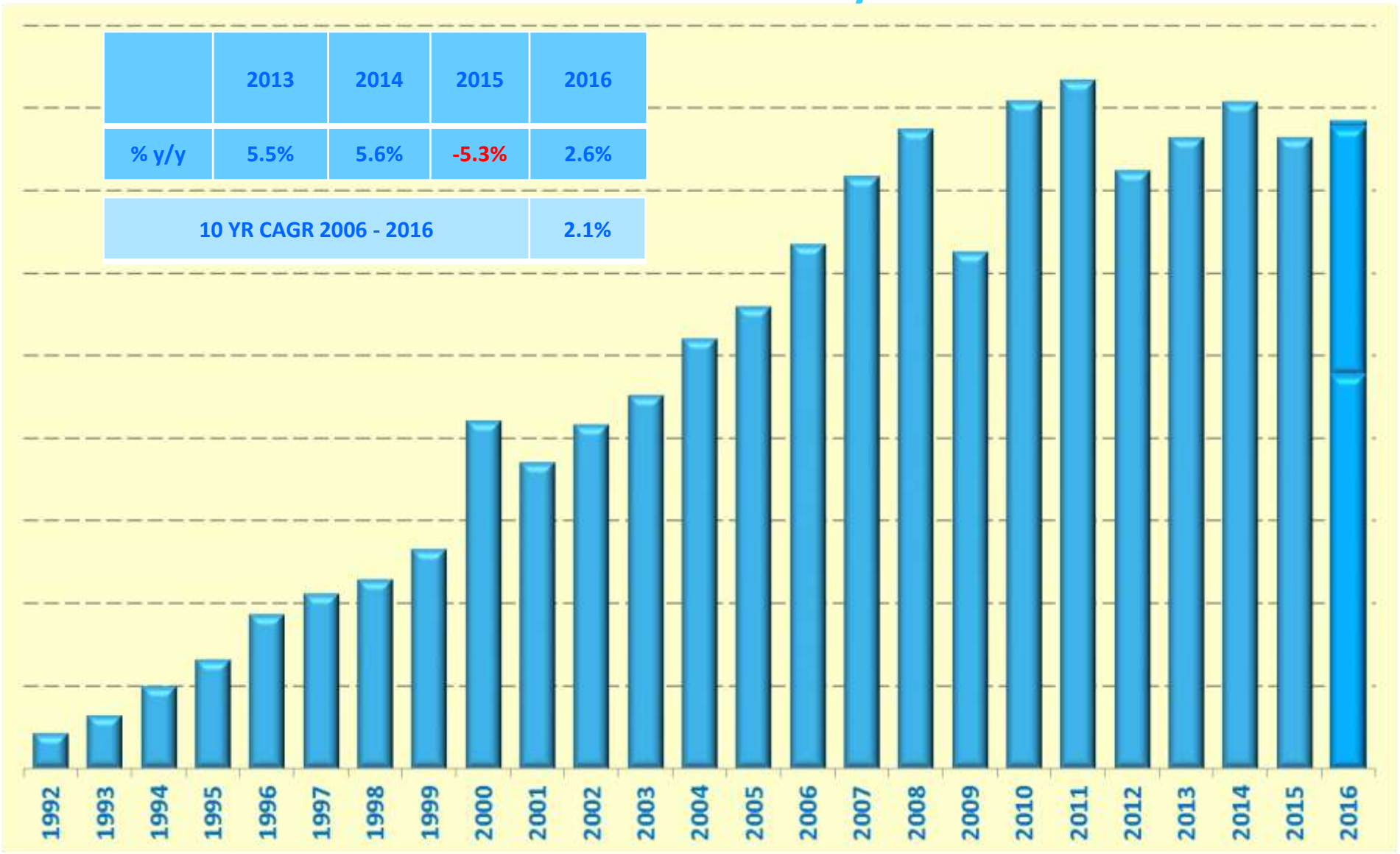
- 10 Power DMOS to drive motors
- 24 bit DSP 50MIPs
- RAM memory
- Precise ADC and DAC
- Low Noise analog amplifiers

TPA R&D BCD Process Development

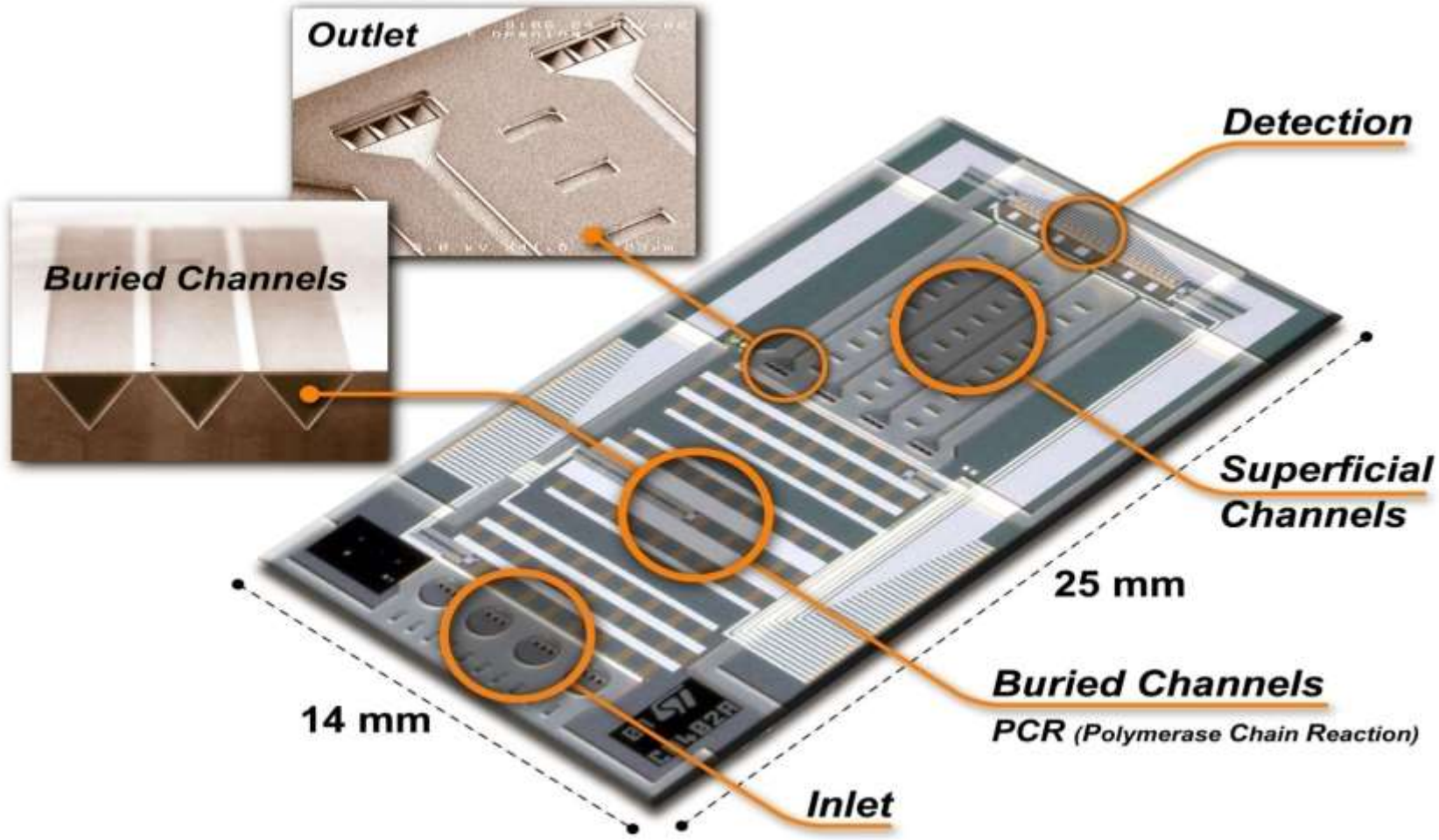

U775
2542334
322CG0020
MALTA

Smart Power ST BCD products
1992 - 2016 Bill history

	2013	2014	2015	2016
% y/y	5.5%	5.6%	-5.3%	2.6%
10 YR CAGR 2006 - 2016				2.1%



Lab-on-Chip


Outlet
Buried Channels
Detection
Superficial Channels
25 mm
Buried Channels
PCR (Polymerase Chain Reaction)
14 mm
Inlet

Motion MEMS – Leading Innovation

Higher integration

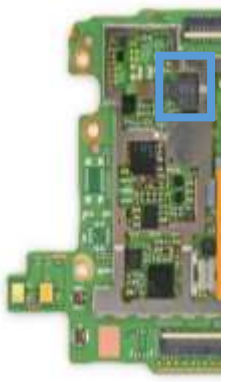
iNEMO - **LSM6DB0**
Accelerometer + Gyroscope
Sensor Hub / Microcontroller

The smartest and most flexible sensor hub
Full offload of the application processor

More sensitive

LSM6DS0
Accelerometer + Gyroscope

Gyroscope rate noise down to
0.008 dps / √Hz typical



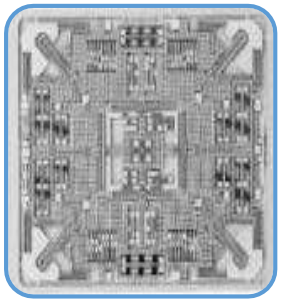
HTC One (M8)

www.ifixit.com/Teardown/HTC+One+%28M8%29+Teardown/23615

Lower power

LSM6DS1
Accelerometer + Gyroscope

40% power improvement
for 6-Axis motion sensing



Xiaomi Mi1S

More robust

LIS2HH12
3-axis accelerometer

New internal structure more
resilient to mechanical and thermal stress

Thinner

R2G3IST
OIS Gyroscope

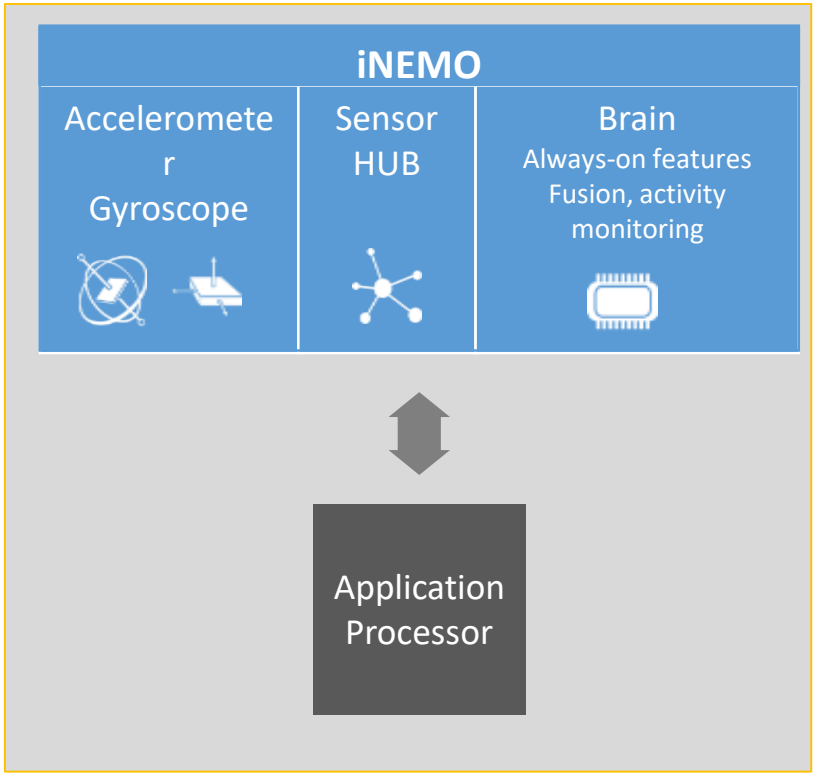
0.7mm thin OIS gyroscope

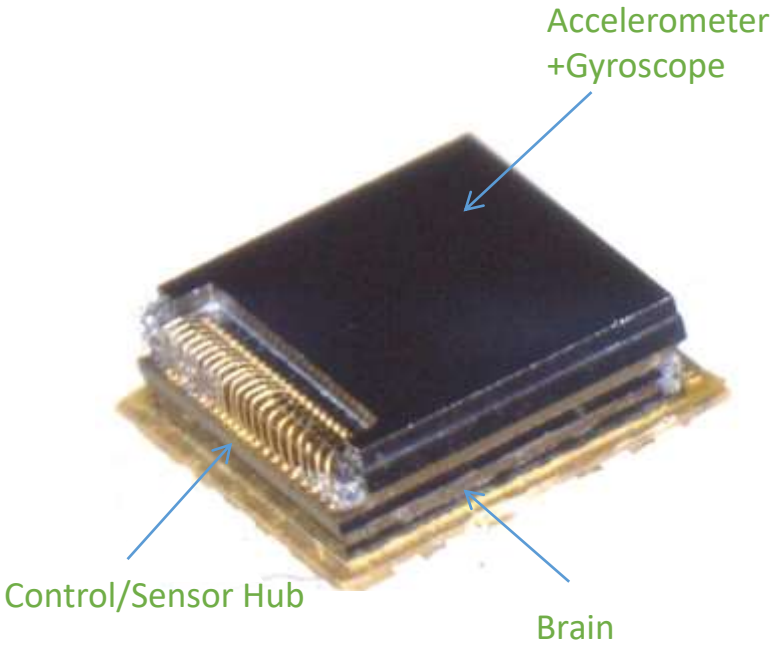
Smaller

LSM303C
Accelerometer + Magnetometer

The world smallest
compensated compass

Smart Sensors in a Tiny Package

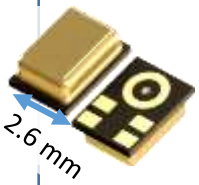


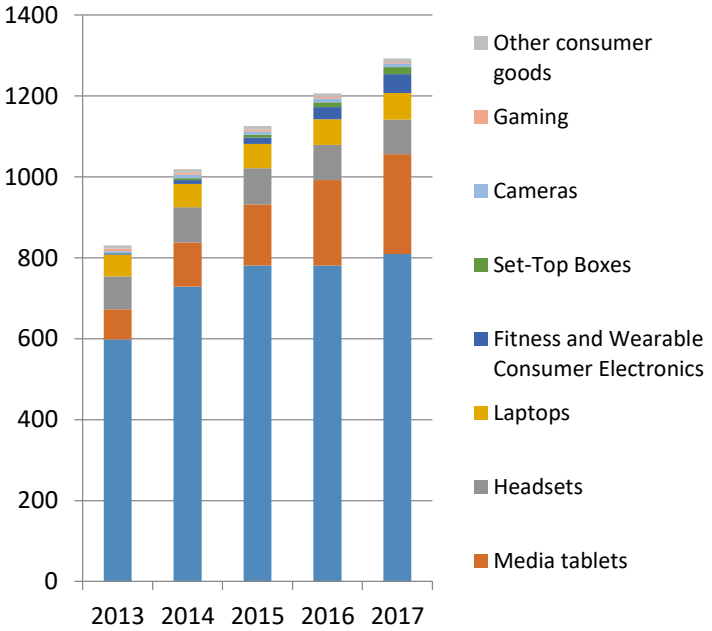


LGA 3mmx3mmx1mm

MEMS Microphones

- High growth market with multiple microphones per end device
- Over 100M microphones shipped in 2013
- Win for high volume smartphones and tablets
- Expanding portfolio of analog and digital, top and bottom port microphones
- Expertize in delivering the right trade-off between performance, reliability and form factor





chipworks
inside technology

November 1, 2013

Inside the iPad Air - New Info

- Two STMicroelectronics 331 microphones

http://www.chipworks.com/en/technical-competitive-analysis/resources/blog/inside-the-ipad-air2/

3-axis accelerometer, ST

Digital MEMS Microphone, ST

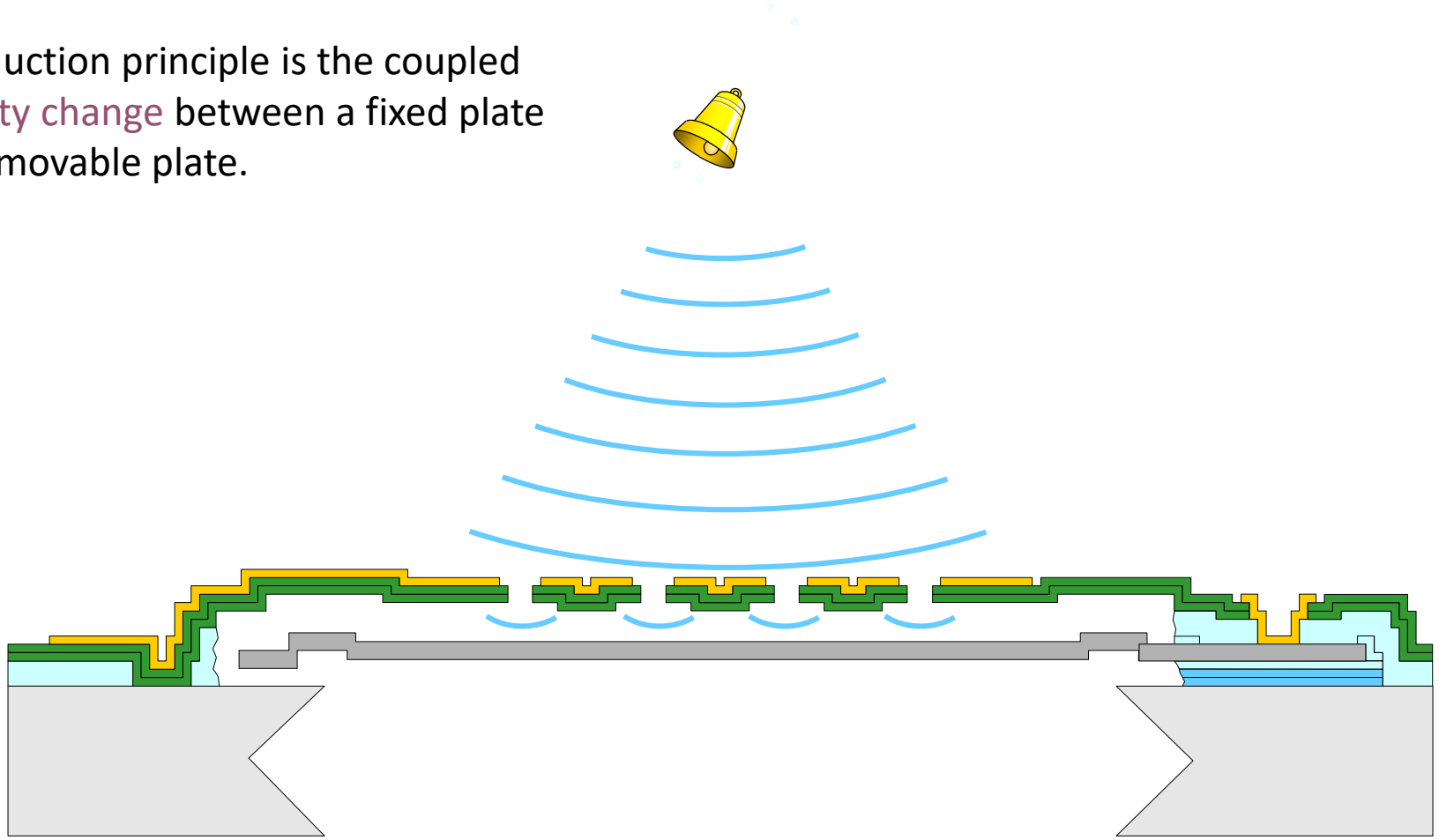
Google Glass XE-C

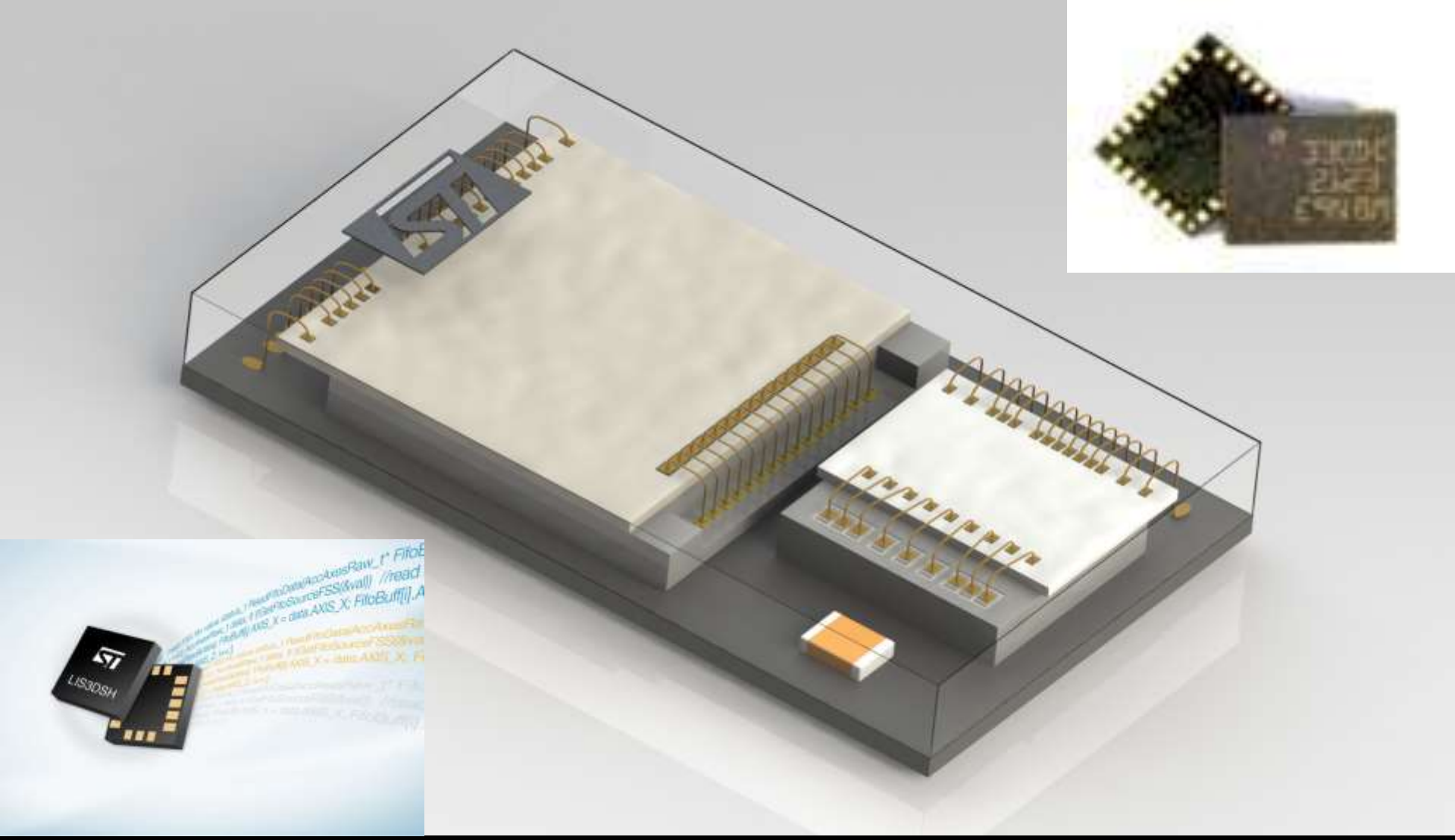
IHS Teardown, May 2014

Source: IHS MEMS Market Tracker - Consumer and Mobile - H2

MEMS microphone structure

Transduction principle is the coupled capacity change between a fixed plate and a movable plate.





SENSORS + MICRO-CONTROLLER + RADIO

Optical Image Stabilization

- Growing inclusion of optical image stabilization (OIS) within smartphones
- Launched 3rd generation of gyroscope for OIS
- Thinnest Gyro for OIS
- Traction with major manufacturers

3rd Generation Ultra-compact Gyro For OIS

- 2-axis gyro for OIS: ±100/±200 dps full-scale
- High temperature stability
- Embedded temperature sensor
- Power Supply range: 1.7V to 3.6V
- Advanced power management functionality

Environmental Sensors

Rapidly growing penetration in smartphones and Augmented Things

Humidity Temperature

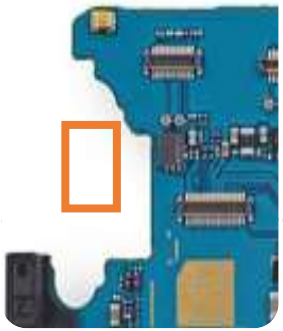
- Combined temperature & humidity sensor in final productization stage
- Market introduction in 2Q

Pressure

- Introduced fully molded pressure sensor in tiny package (2.5x2.5x1.0mm)
- Water resistant
- 100% share at a leading smartphone manufacturer

UV

- UV sensor in development
- Market introduction in 3Q



www.ifixit.com/Teardown/Samsung+Galaxy+S5+Teardown/24016

Samsung Galaxy S5

Touchscreen Controllers

- Targeting Smartphones and **Tablets** with focused portfolio
  - High volume mid-range smartphones
  - Premium/Flagship smartphones
  - Tablets

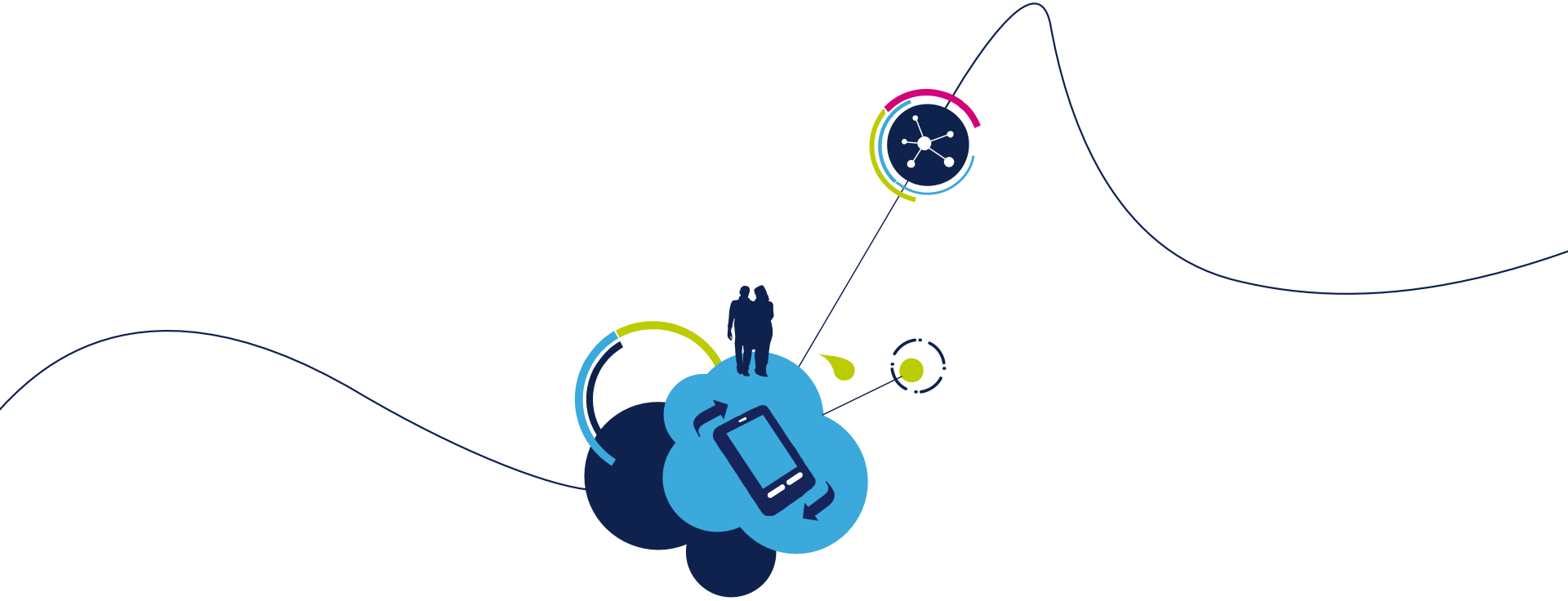
3.0 Billion Touchscreens in 2016

Source:IHS

Ultramobile Projector

Revolutionary laser-based MEMS mirror projection technology

- Smaller, lighter and more flexible than competing technologies
- Easy focus free operation
- Vibrant colors projected up to 20” picture size



Remote monitoring of civil structures
June 2014

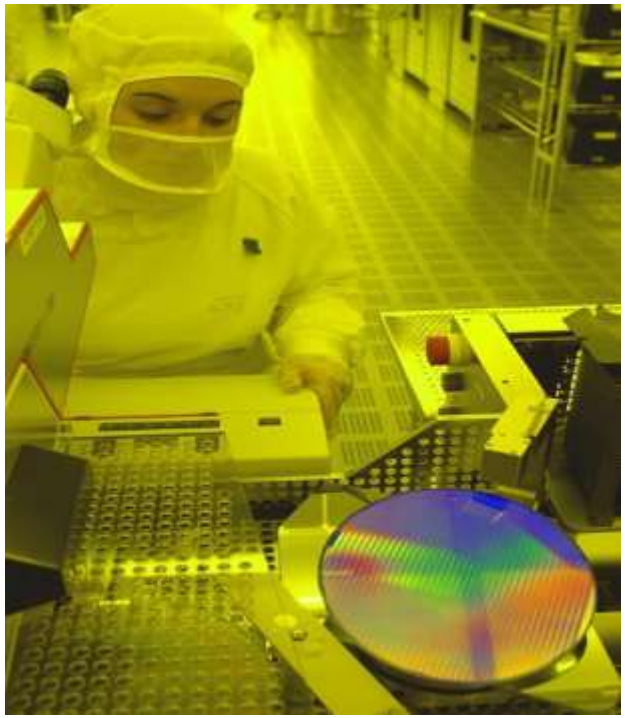
DYSP

- Compact system, powered at 230V, mounted as a wall plug
- Uses **Wi-Fi** to send accelerometer reading to a server on the Internet
- Measurements: acceleration (3 axes), temperature, barometric pressure, sound + link with SmartConcrete sensors
- In case of alarm, loads can be disconnected through a relay (to stop water of gas flows)
- In case of power failure, data stay stored in the micro RAM for one week (supercap back-up)

Main plug with sensors ad WIFI

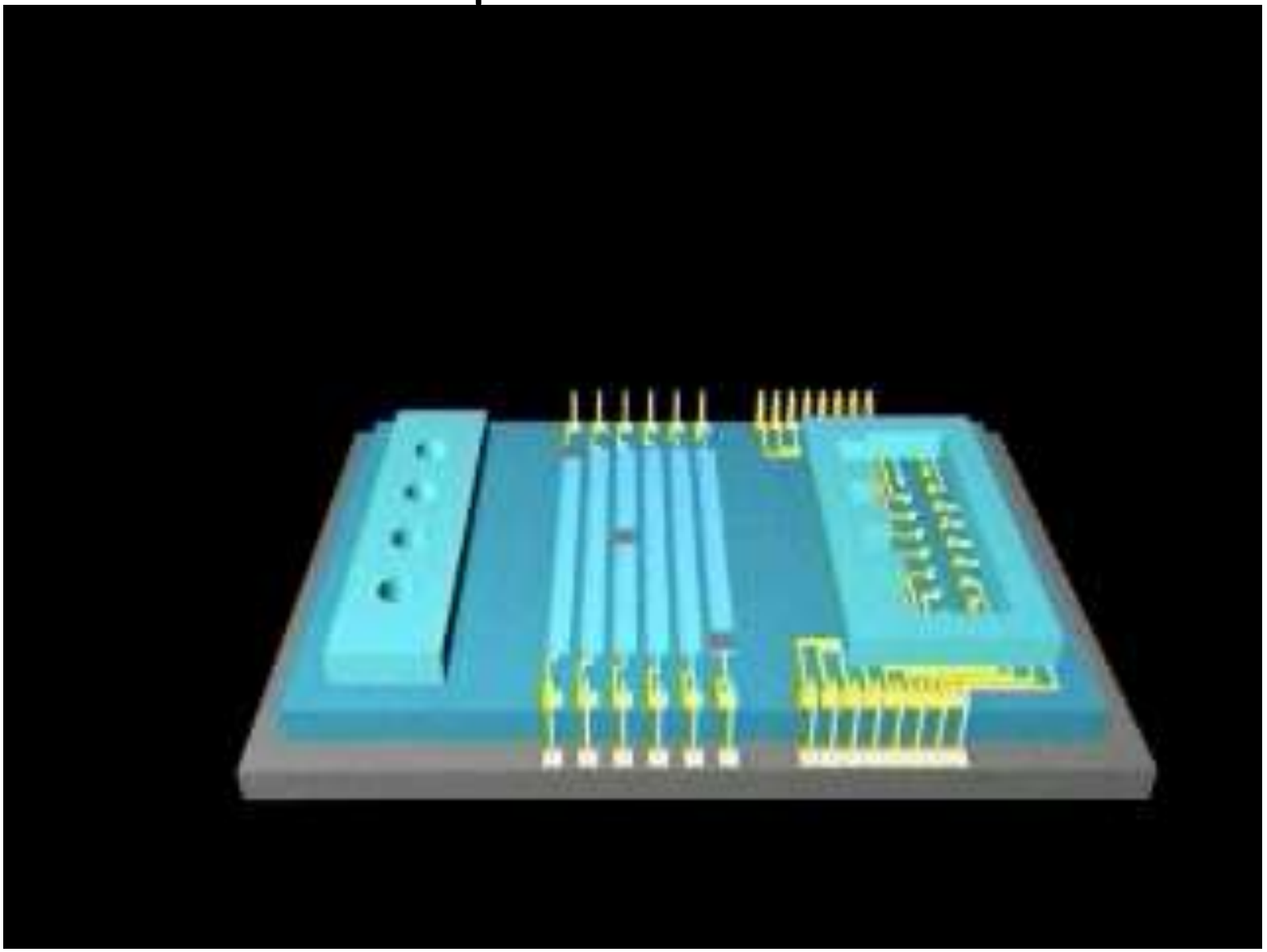
Silicon and Biology

Microelectronics and…



Bio Systems

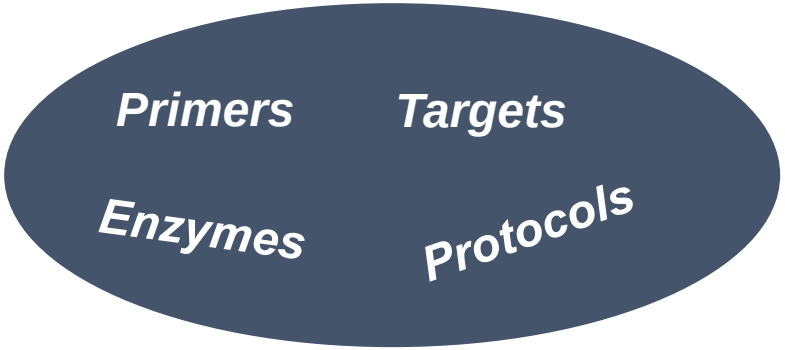
Lab on chip



AST Molecular Biology

Real-time PCR platform

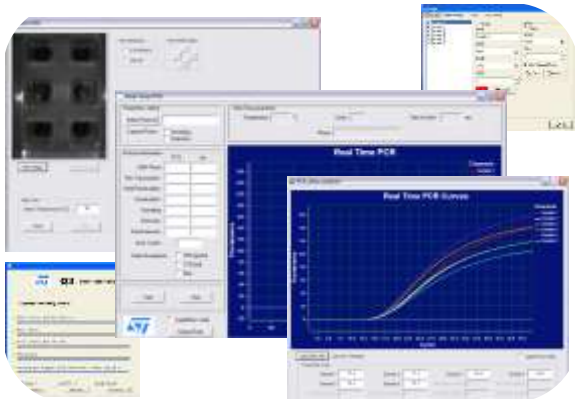
Biological content

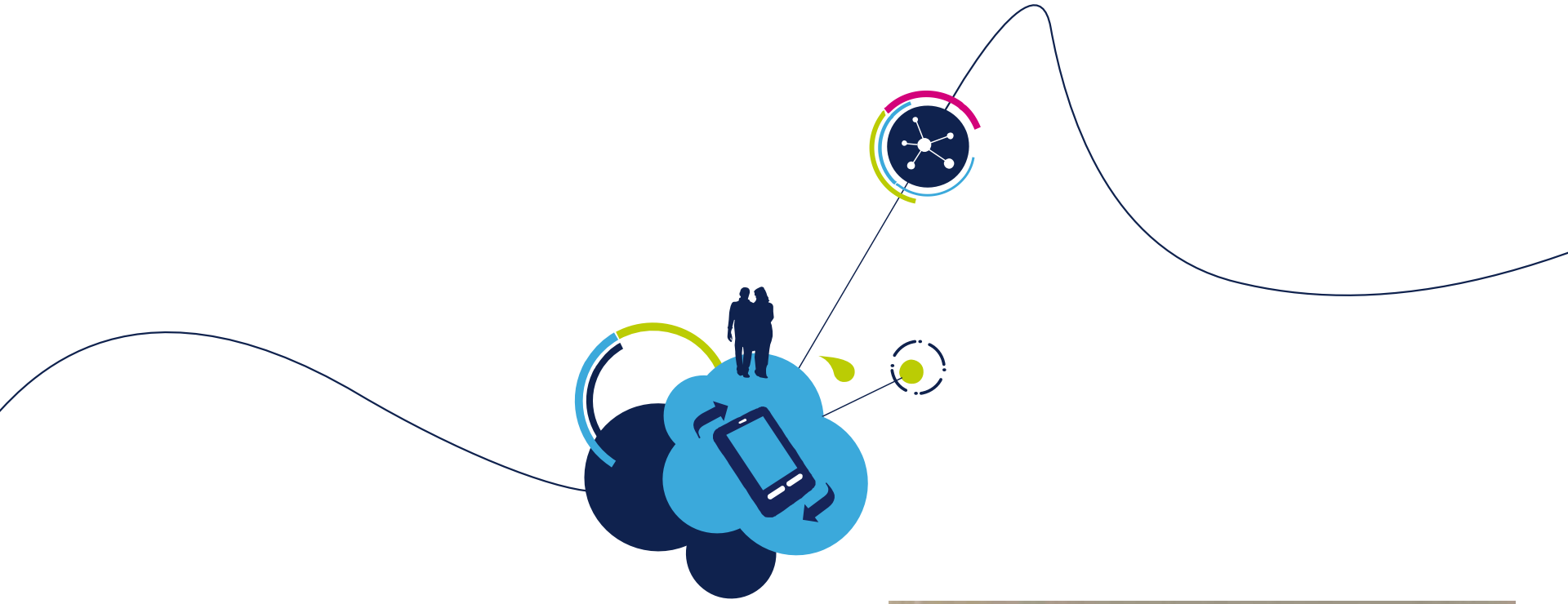


Disposable cartridges

Instrument

Control software

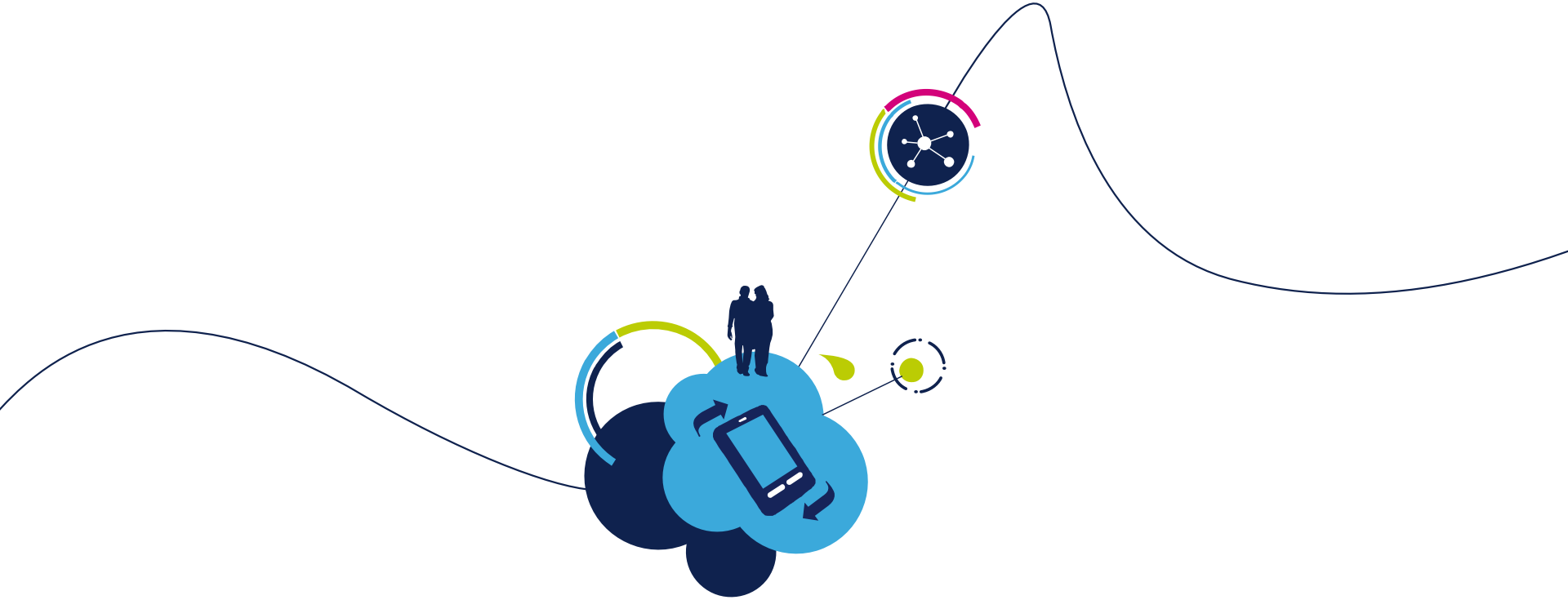




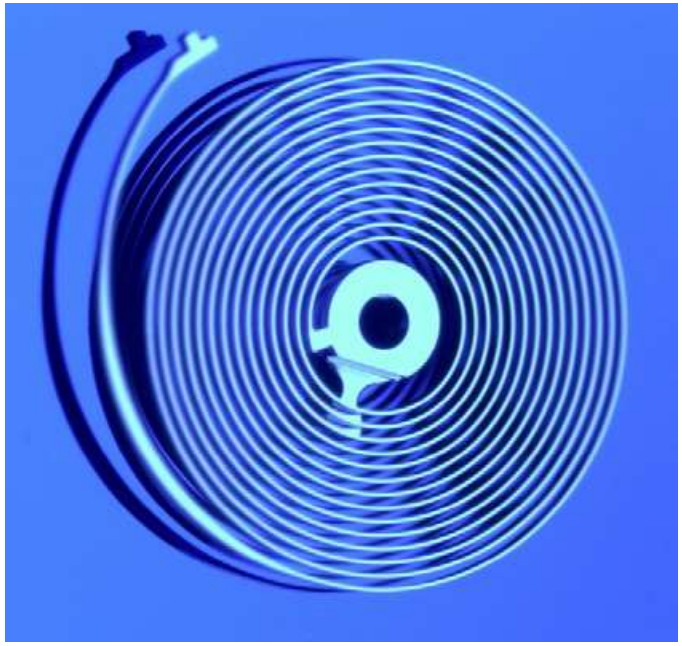
Remote Monitoring

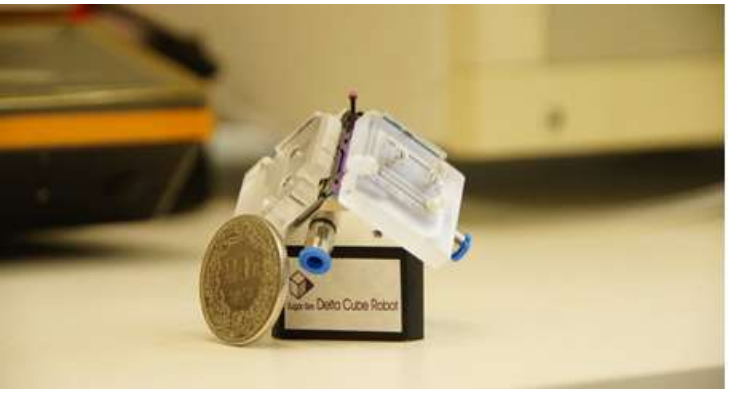
ECG Body Sensor

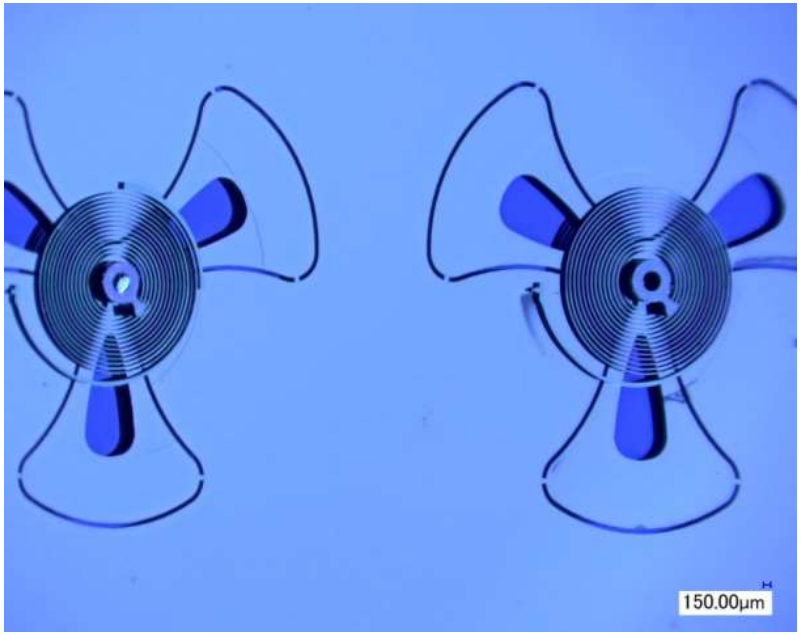
- **The Body Gateway recorder is a wearable, battery operated device intended for use as a part of a multi-parameter analysis system: it acquires, digitalizes, stores and periodically transmits via a Bluetooth radio link with a host device, connected to a medical service.**
- **Key features**
  - Heart rate detection
  - Physical activity estimation
  - Breathing rate measurement
  - Body position
- **Applications**
  - Chronic cardiac disease monitoring
  - Elderly people home monitoring
  - Event monitoring
  - Single lead holter

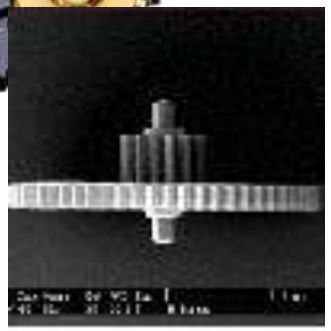


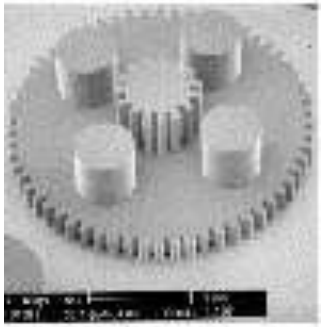
MACRO MEMS




Delta Cube Robot


150.00µm



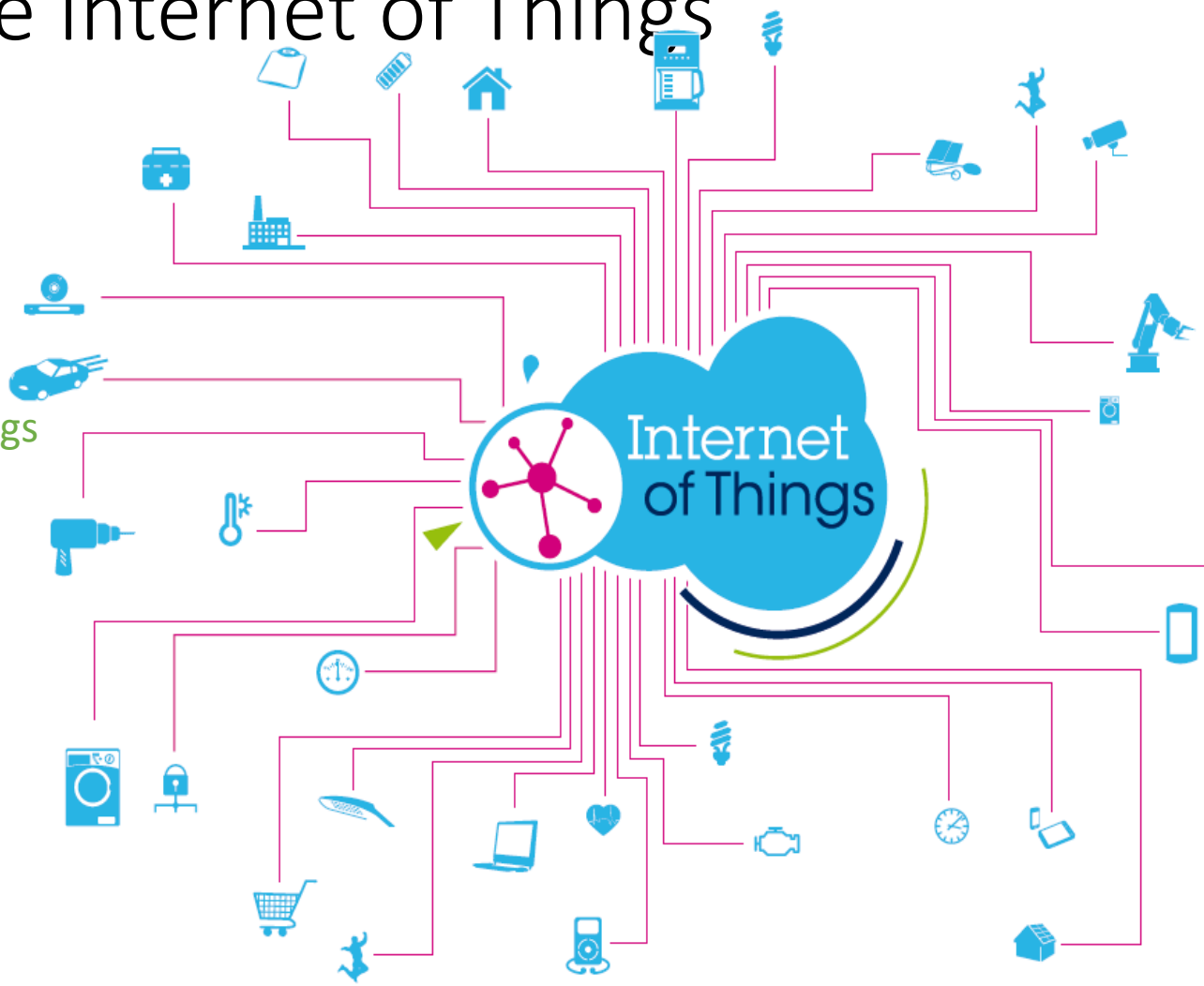


Cosa ci aspettiamo per il futuro?

l' Internet delle Cose (IoT) :

- dalla Smart City……
- alla Domotica…….
- alla Rivoluzione Industriale 4.0 ….
- agli Oggetti Indossabili Connessi….
- alla mobilita' senza pilota…….
- alla gestione della Nuvola

The Internet of Things



Existing Things augmented

New Things to augment life

"Things that leverage the internet to make them smarter…"

Existing Things Augmented
(Making Things Smarter)

It used to tell you the time

Now it tells you what to do

It used to just provide power

Now it talks to your machines and tells how you much they are consuming

It used to remind you of someone close to your heart

Now it reminds you to take care of your heart

They used to help you see clearly

Now they help you to see more

IoT è l'artigianato dell'elettronica……

……E QUESTA VOLTA ABBIAMO NOI
L' ECOSISTEMA GIUSTO CHE SERVE PER FARE LE COSE.

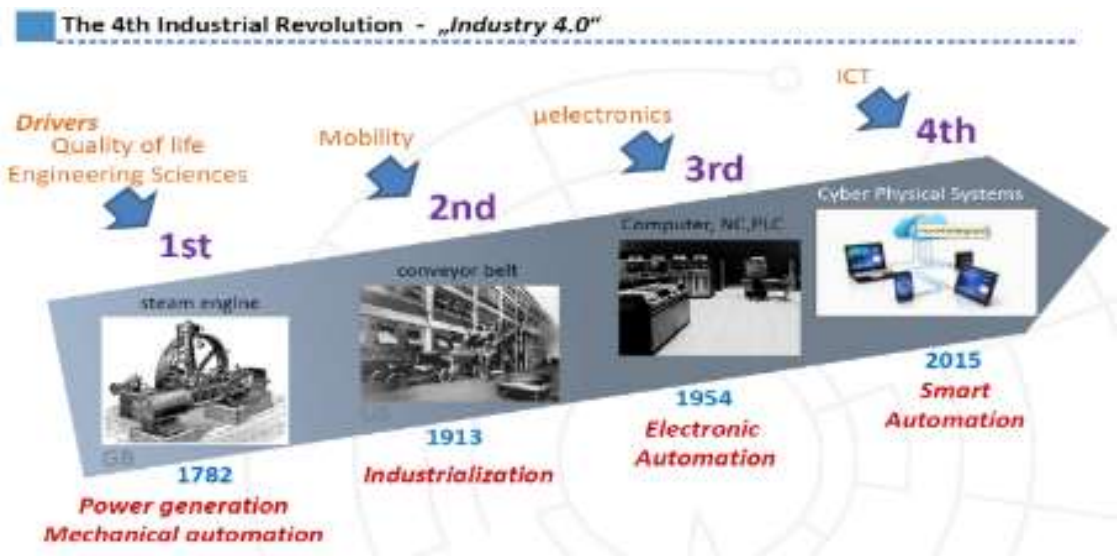





The new Industrial Revolution

- An industrial revolution is taking shape around the globe
  - “Industrie 4.0” (Germany)
  - “Re-industrialization”, “Smart Manufacturing Leadership Coalition” (USA)
  - “Industrial Internet” (GE)
  - “Connected Enterprise” (Rockwell Automation)
  - “Industrial Intelligence” (Japan)
  - “Manufacturing Intelligence 2025” (China)
  - “Manufacturing Innovation 2.0” (Korea)
  - Piano Industria 4. 0 (Italia)

- Redefining manufacturing with the use of
  - Real Time Information
  - Communication
  - Connected Objects
  - Energy Management
  - Advanced Logistics

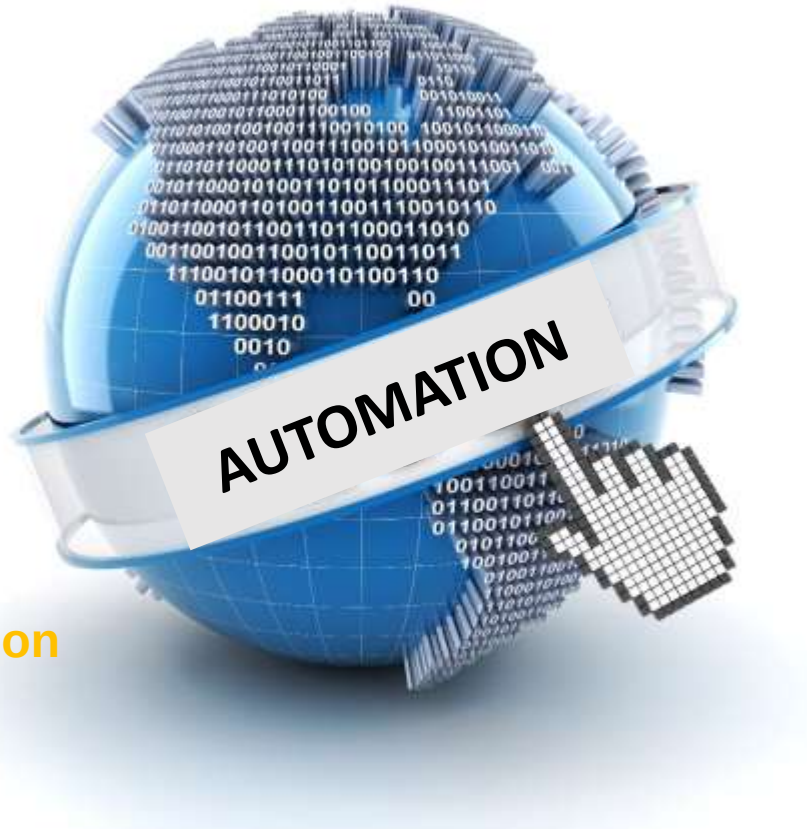


La Rivoluzione Industriale 4.0

- Sistemi operativi aperti
- Condivisione dei dati
- Lavoro in gruppi multidisciplinari
- Utilizzo dei data base e servizi della Nuvola
- Creazione di nuovi mercati per soddisfare i bisogni
- Garanzia della sicurezza

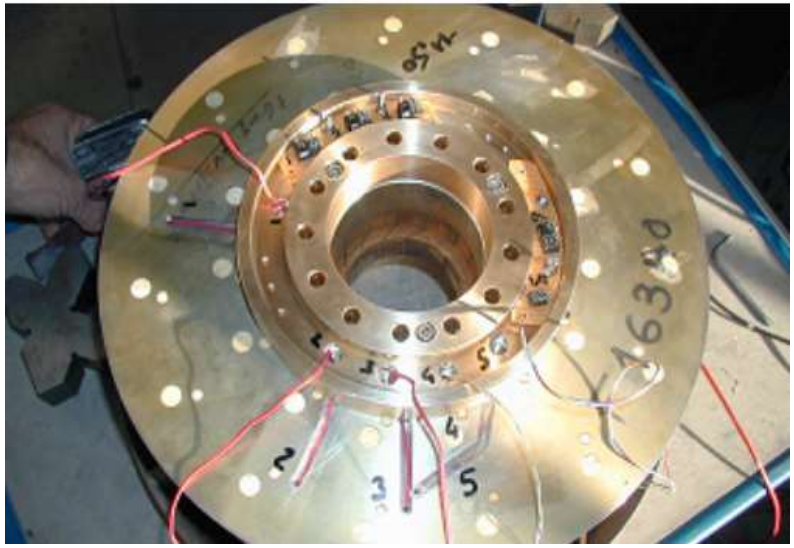
Toward better automation of everything !

- **Energy**
- **Environmental balance**
- **Clean transportation**
- **Nutrition**
- **Health and Life Science**
- **Ageing wealthy population**
- **……..**



Robotizing the World !

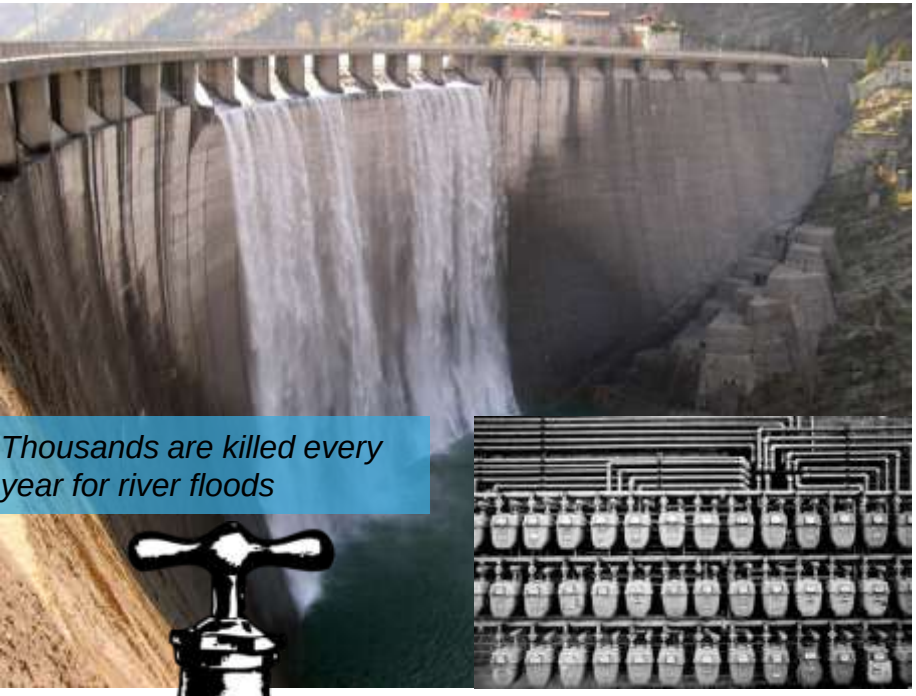
Industrial control



- **M2M Applications**
  Machine auto-diagnosis and assets control.
- **Indoor Air Quality**
  Monitoring of toxic gas and oxygen levels inside chemical plants to ensure workers and goods safety.
- **Temperature Monitoring**
  Control of temperature inside industrial and medical fridges with sensitive merchandise.
- **Acoustic levels and Electrosmog monitoring**
- **Ozone Presence**
  Monitoring of ozone levels in food factories
- **Indoor Location**
  Asset indoor location by using active and passive tags (RFID/NFC).

life.augmented

Smart Water & Gas



- **Water and gas metering**
  Remote water & gas metering (wireless, energy scavenging)
- **Water Quality**
  Fine grained monitoring of water quality and pollution for rivers, reservoirs, tanks, etc.
- **Water and gas Leakages**
  Detection of liquid presence outside tanks and pressure variations along water & gas pipes, illegal water connections, etc.
- **River Floods**
  Monitoring of water level variations in rivers, dams and reservoirs
  Visual monitoring of river beds and banks for obstructions and litter

226 Millions euros/year industrial loss due to leaks

2.61 Billions of m^3/year

3 Billion euros lost revenues overall per year

Just for Italy

An average of 274 euros per m^3/year are invested in Europe for water infrastructures

Smart Logistic

1 every 200 shipments is lost

- **Quality of Shipment Conditions**
  Monitoring of vibrations, strokes, container openings and data logging
- **Food & perishable products safety**
  Monitoring of temperature for maintenance, validation and data logging of cold chain
- **Item Location**
  Locate individual containers in warehouses, harbors or even trucks
- **Fleet Tracking**
  Control of routes for parcels, acoustic or visual cues for misplaced crates

life.augmented

Robots: Un’ altra opportunità

- Personal Service Robots

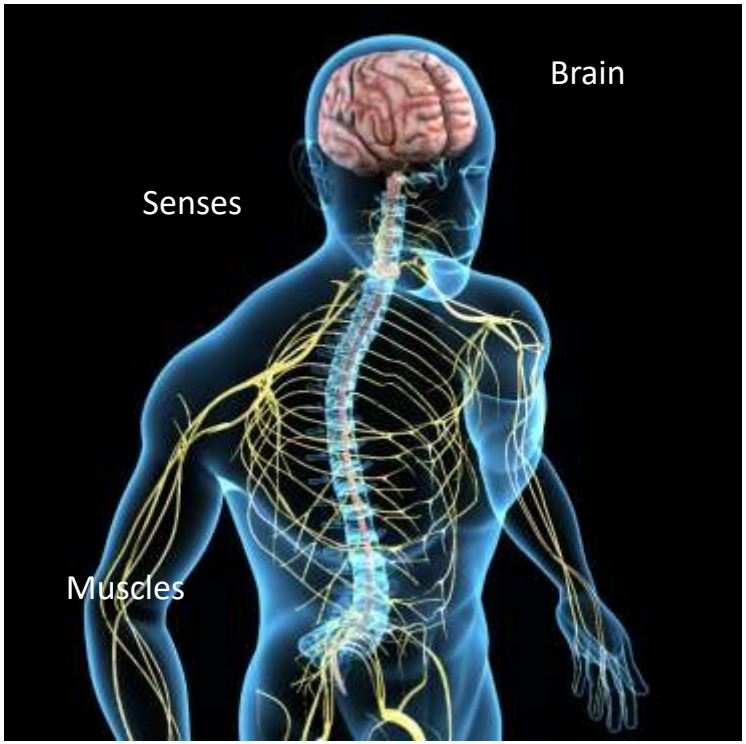
- Robots for domestic tasks
- Entertainment robots
- Handicap assistance
- Personal transportation
- Home security & surveillance
- Flying (UAV) and Visual Inspection (Rover)
- …

Professional Service Robots

- Field robotics (Agriculture, Milking, Forestry, …)
- Professional cleaning
- Inspection and maintenance systems
- Logistic systems (Courier/Mail, Cargo handling, …)
- Medical robotics
- Defense, rescue & security applications
- Underwater systems
- Robot arms in general use
- Public relation robots (Marketing, Information, …)
- …

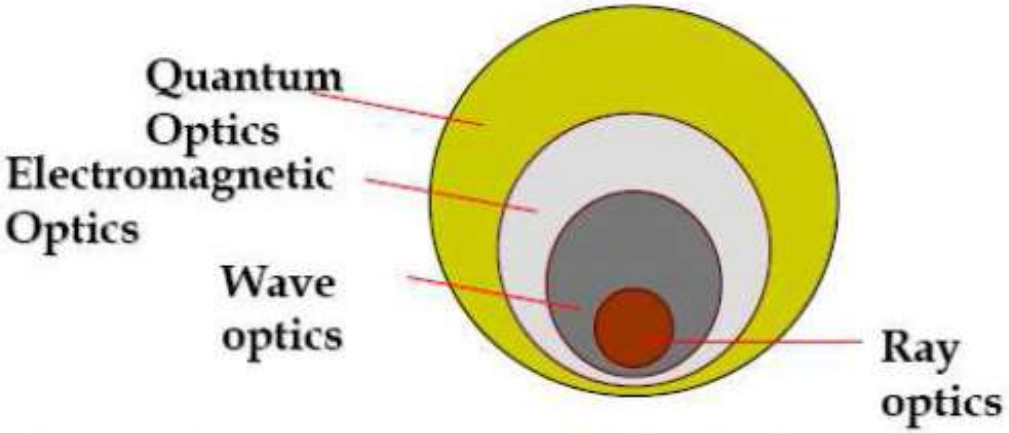
Source: IFR, International Federation of Robotics

IoT + Cloud enables the world to Sense and Act



- In 2012 more data produced than in previous 5000 years
- 90% of data produced in last two years
- **Less than 1%** of data analyzed today

The targets of the light models



- ***Ray optics:*** propagation of **light rays** through simple optical components and systems.
- ***Wave optics:*** propagations of **light waves** through optical components and systems.
- ***Electromagnetic optics***: description of light waves in terms of **electric and magnetic fields**.
- ***Quantum optics***: emission/absorption of **photons**, which are characteristically quantum mechanical in nature and cannot be explained by classical optics (e.g. lasers, light-emitting diodes, photodiode detectors, solar cells)

Ottica classica

Ottica geometrica

Si ignora il carattere ondulatorio della luce e si parla di raggi luminosi che si propagano in linea retta.

Fenomeni descritti dall'ottica geometrica: riflessione e rifrazione

Ray Optics

Wave Optics

Electromagnetic Optics

Ottica fisica

Si occupa:

- Della natura ondulatoria della luce, fenomeni interpretabili sono: interferenza, diffrazione e polarizzazione

- Della interazione con la materia: emissione e assorbimento

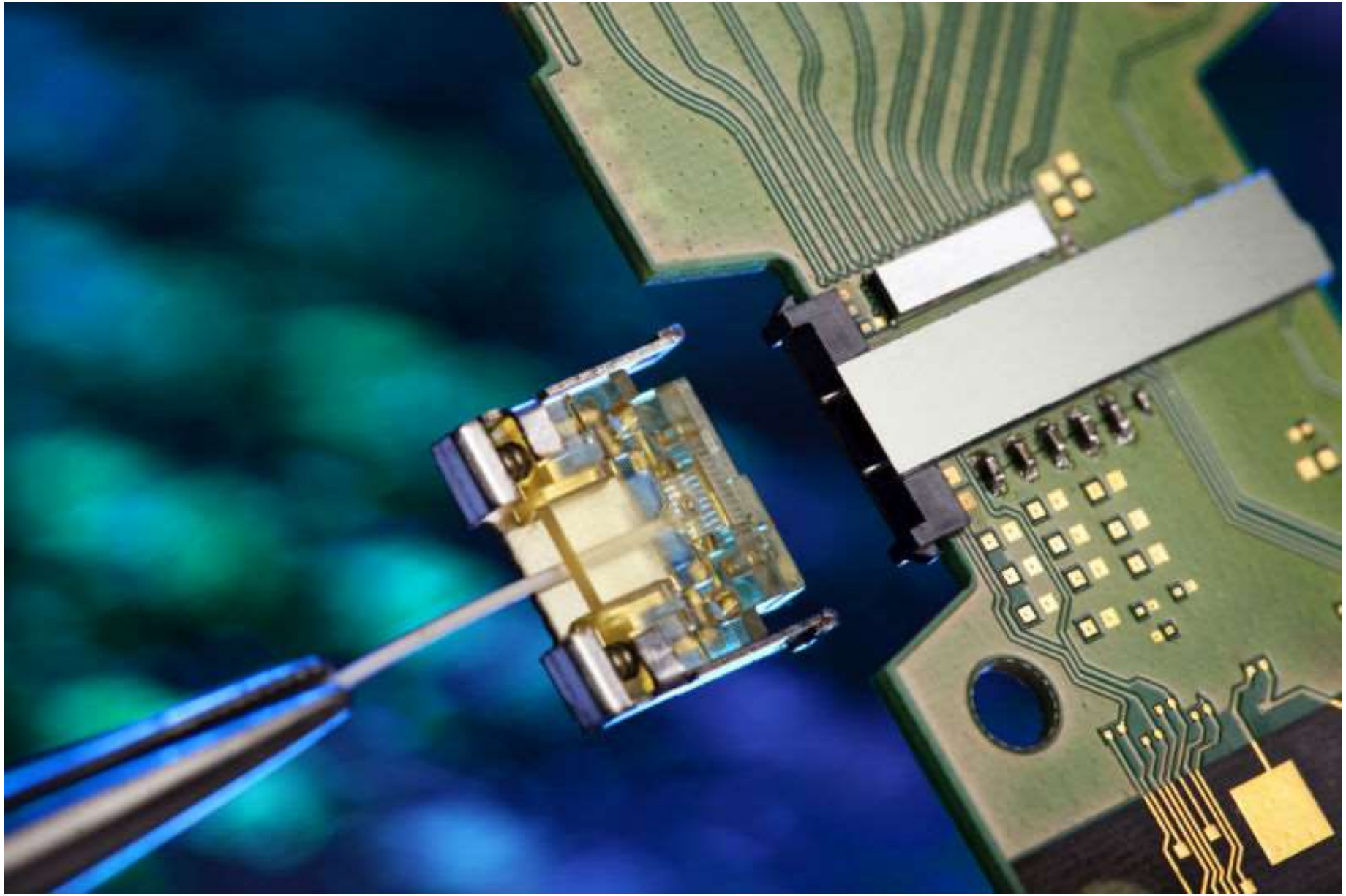
Evolution of classical optical theories

- Light is an electromagnetic wave phenomenon.
- Nevertheless it is possible to describe many optical phenomena using *scalar* wave theory. This approximate way is called **Wave Optics**
- When light wave propagates through and around objects *much larger than the wavelength* of the light, we can describe it by rays. This is called **Ray Optics**

Modern theory of optical phenomena

- There are certain optical phenomena that are characteristically *quantum mechanical in nature* and cannot be explained classically.

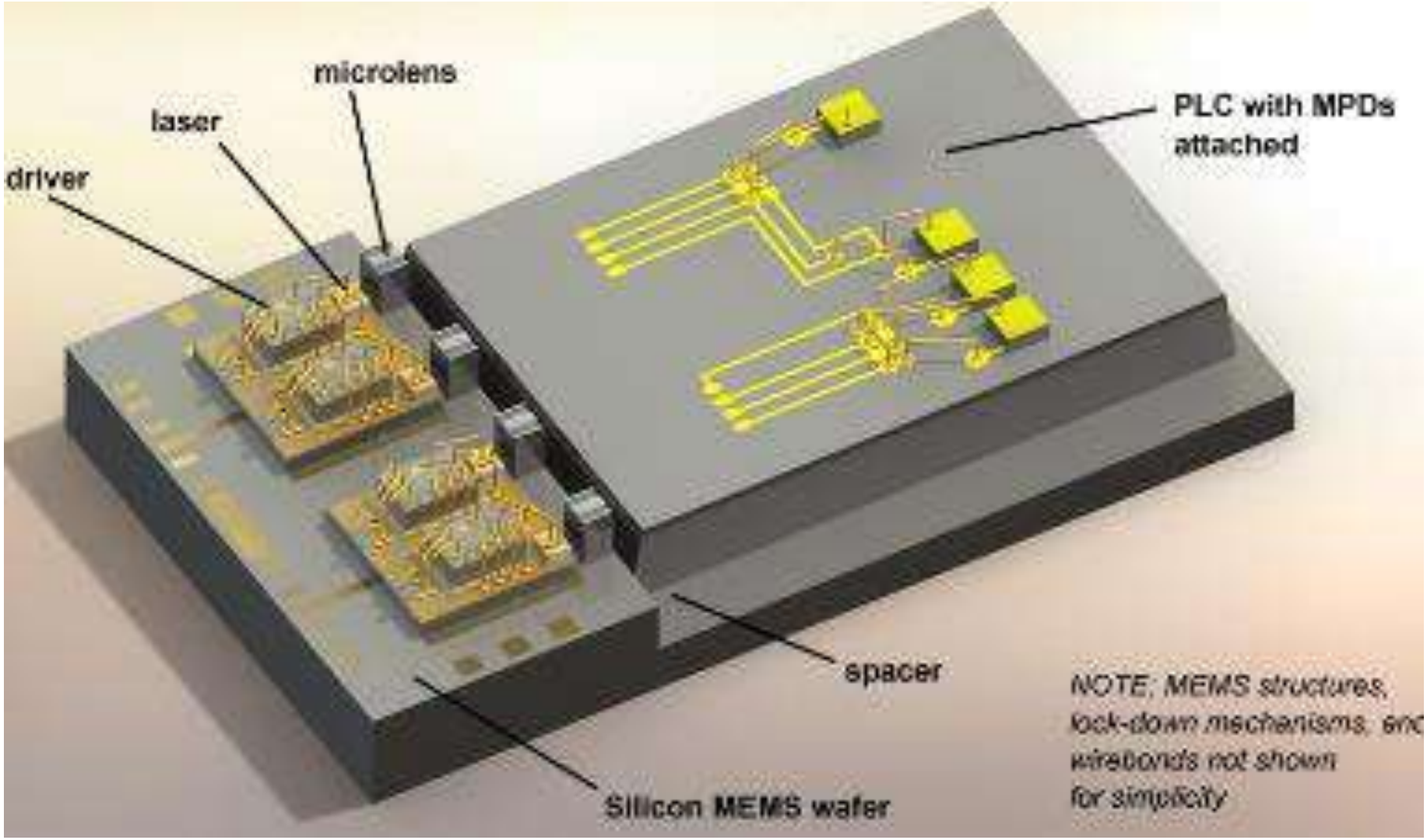
- These phenomena are described by Quantum Electrodynamics. For *optical* phenomena, this theory is referred to as **Quantum Optics**.

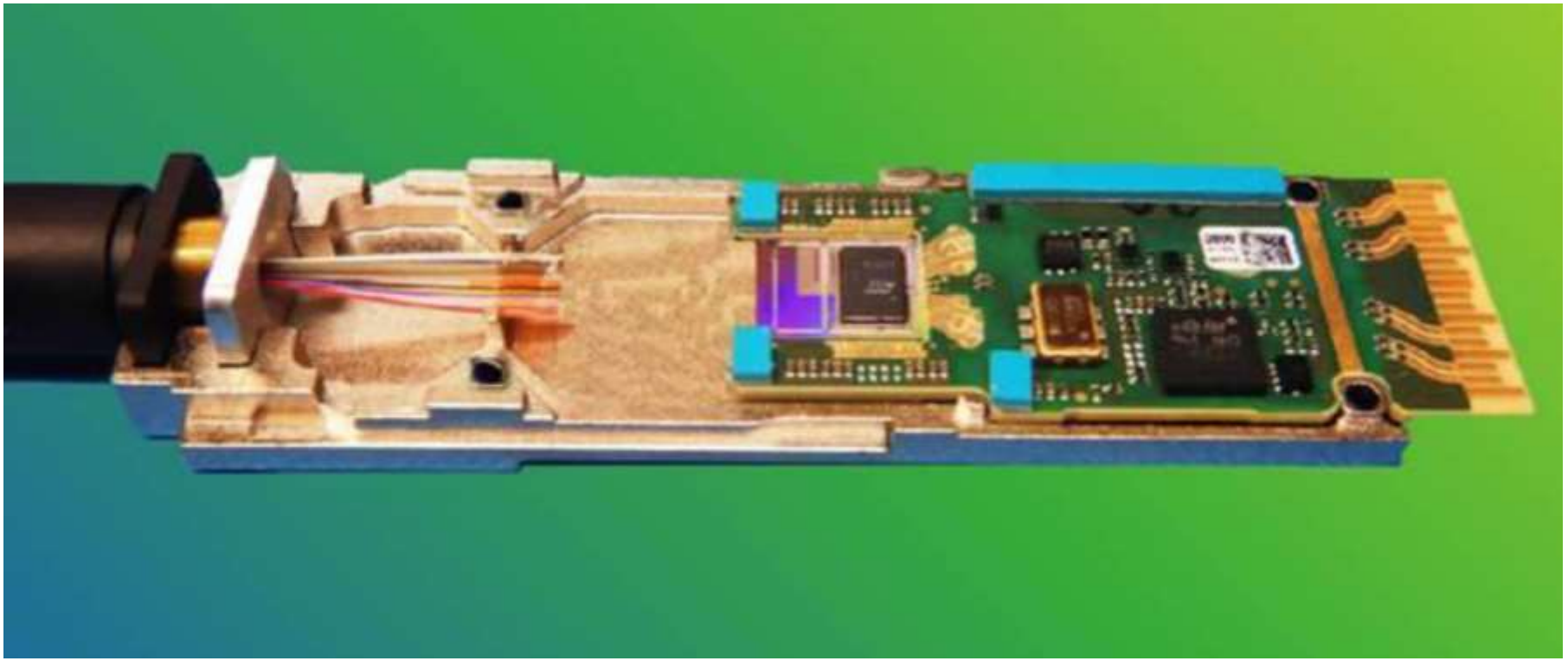


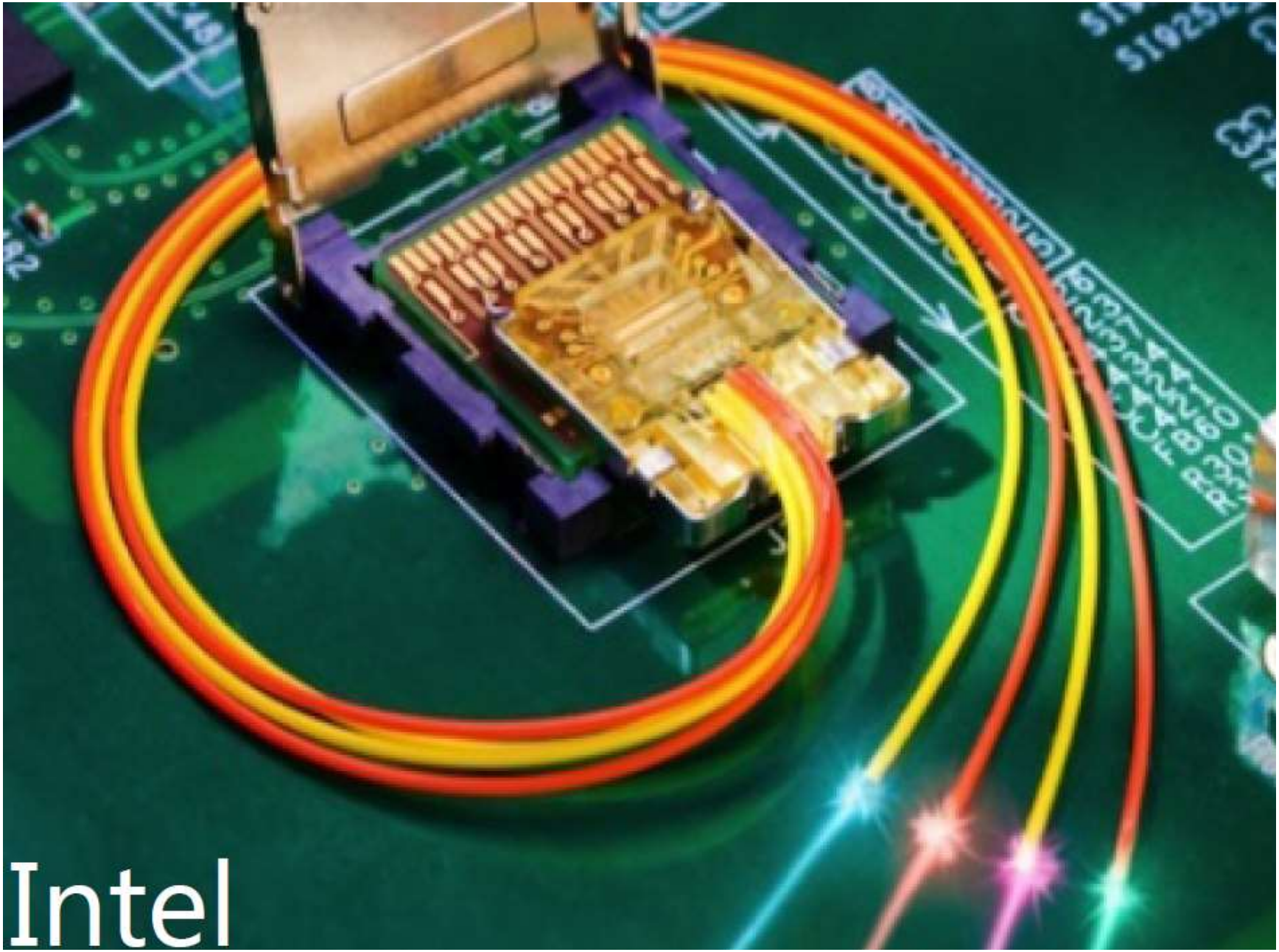
A new Eco-system with New Mentality

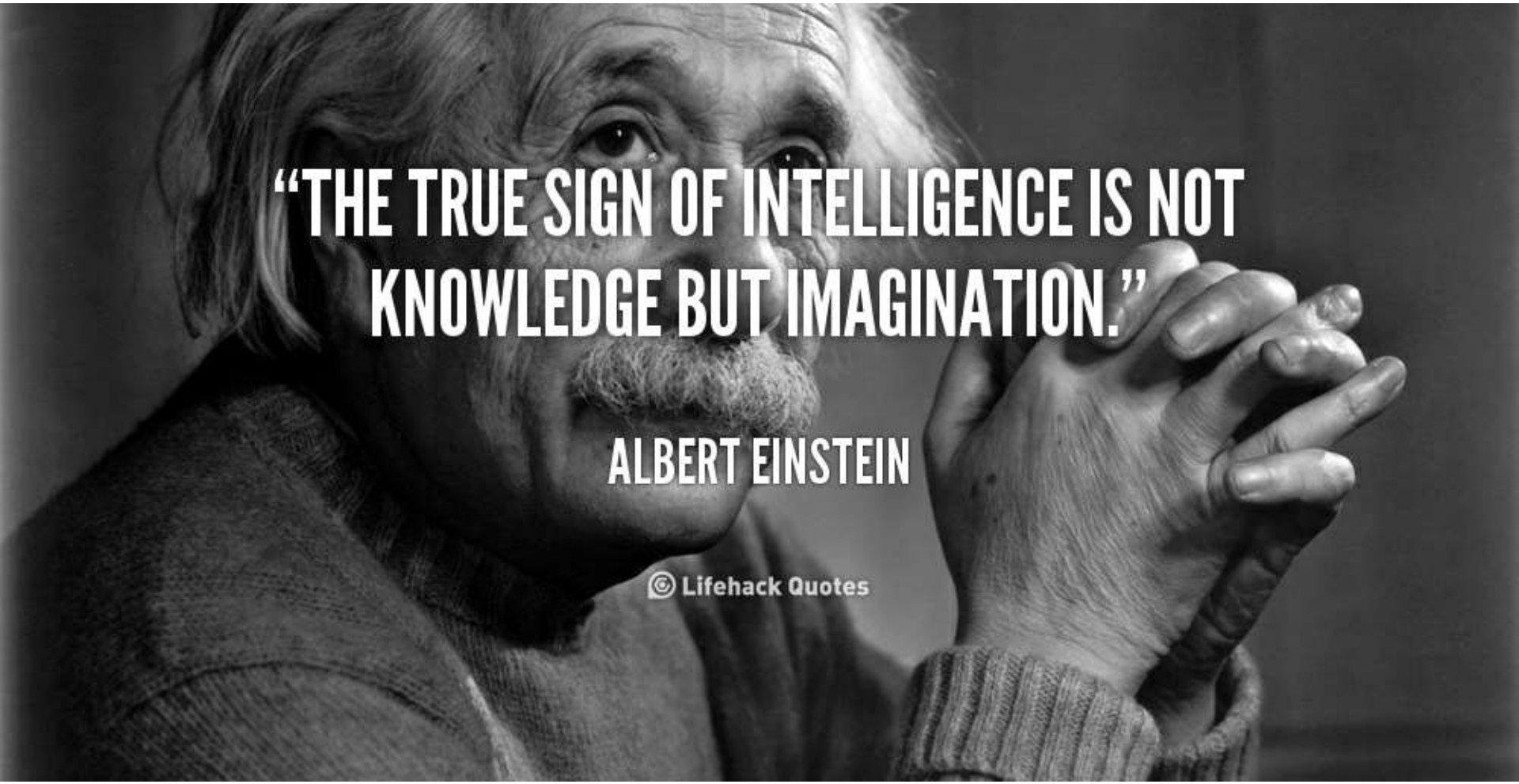
A step function **change** is required:

- **S**ize
- **P**ower
- **C**ost
- **B**andwidth handing

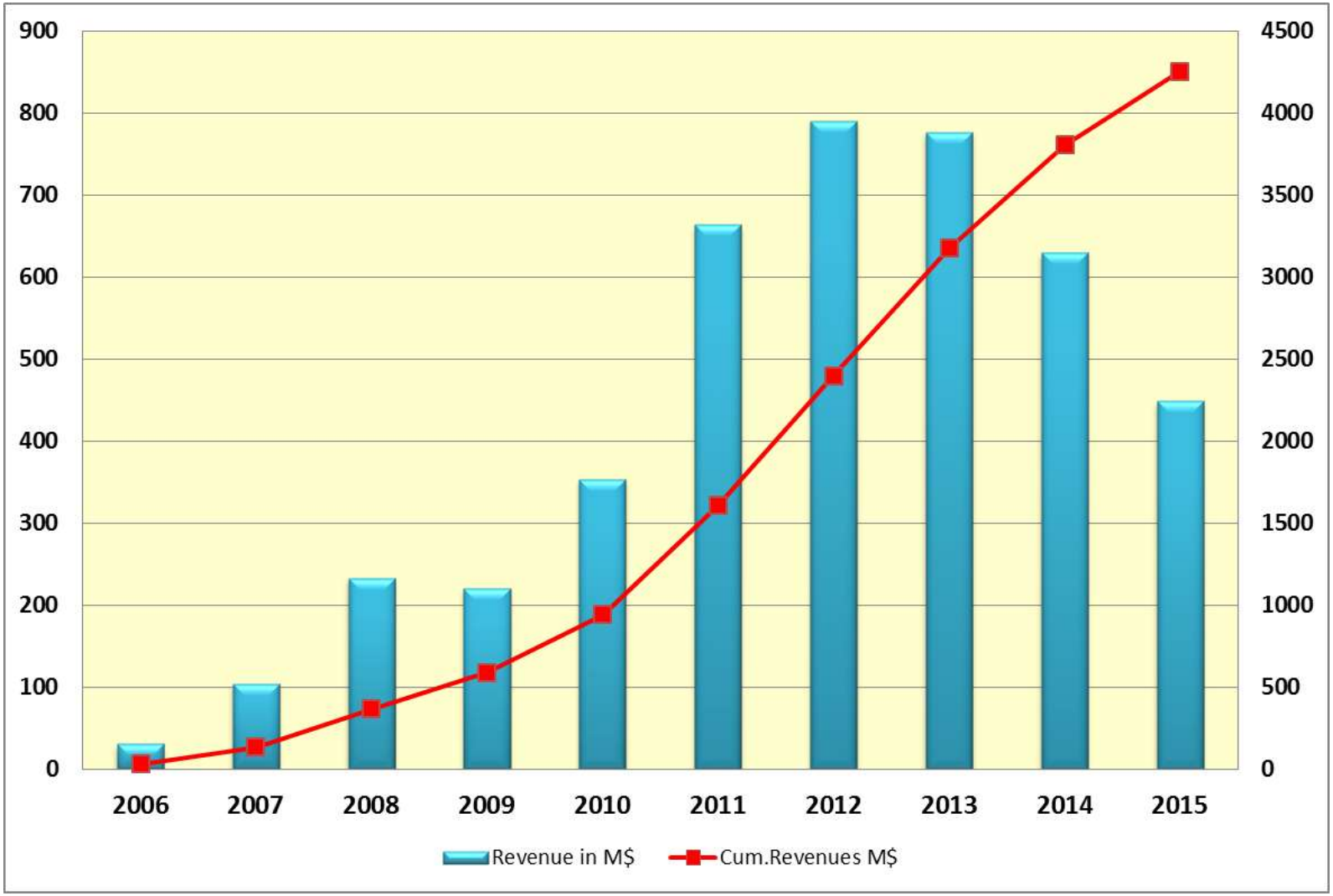

microlens
laser
driver
PLC with MPDs
attached
spacer
Silicon MEMS wafer
NOTE: MEMS structures,
lock-down mechanisms, and
wirebonds not shown
for simplicity



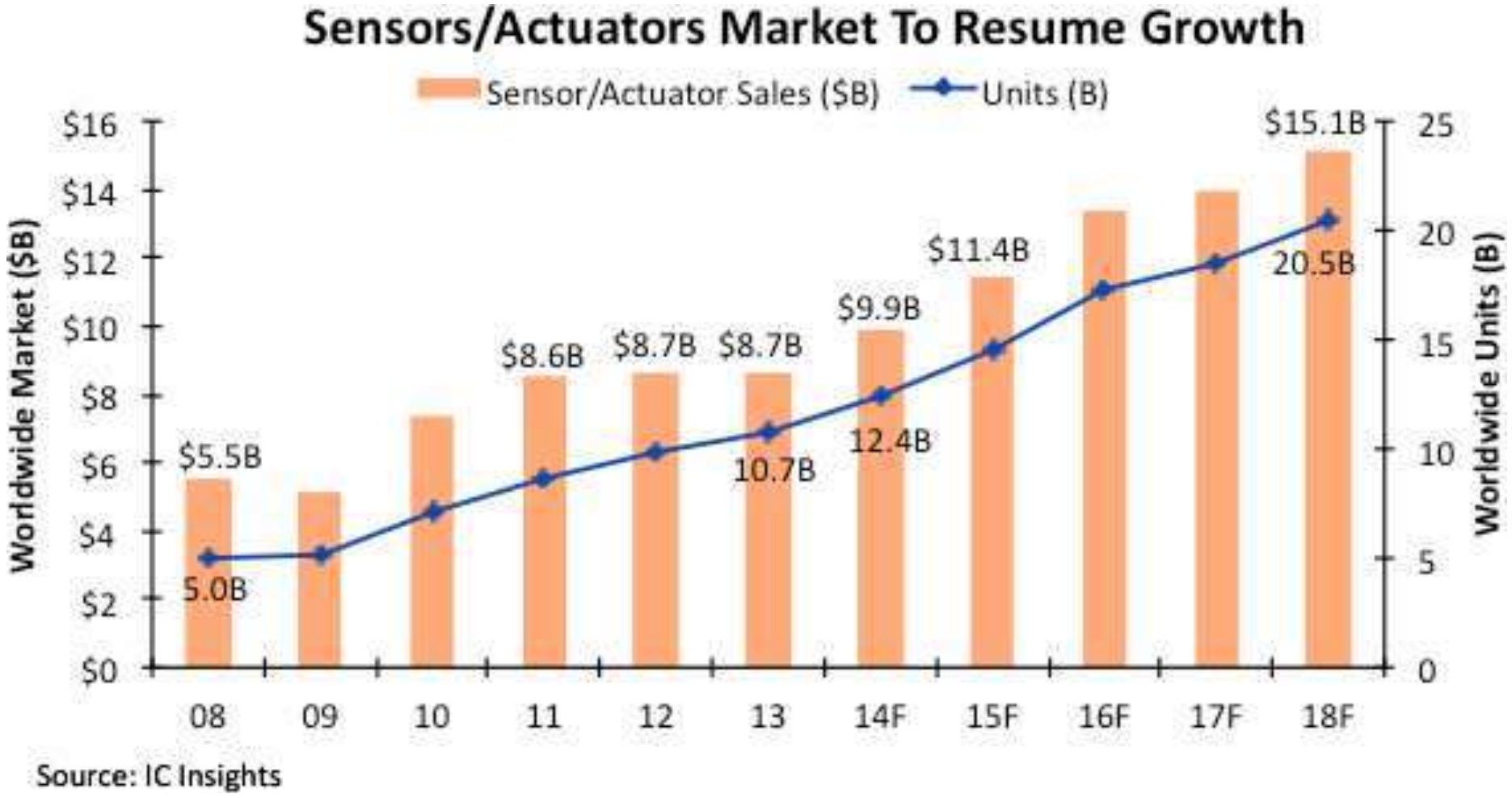

Intel


“THE TRUE SIGN OF INTELLIGENCE IS NOT KNOWLEDGE BUT IMAGINATION.”
ALBERT EINSTEIN
Lifehack Quotes

ST MEMS Sales
10 Years History



Source: IHS - Device: Sensors & Actuators



Source: IC Insights

Leading in MEMS & Micro-actuators

Number 1 - MEMS & Micro-actuators

Motion Sensors

Number 1 - Motion MEMS

Fluidic MEMS

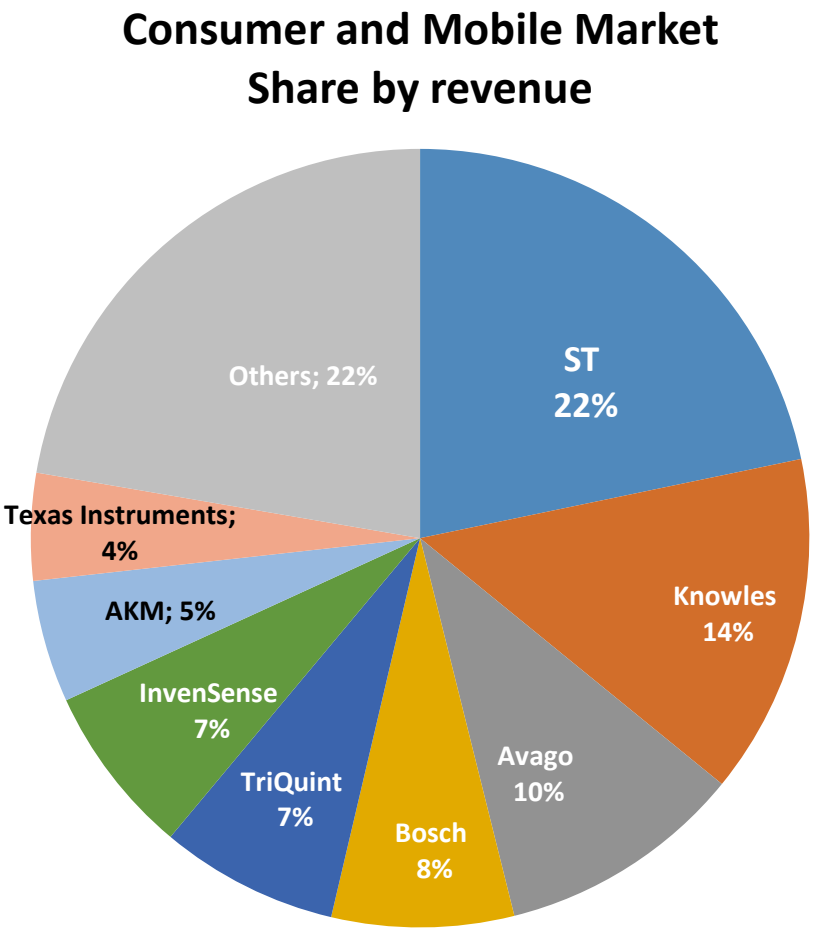
Number 1 – Fluidic MEMS (for printing)

Environmental Sensors

Number 2 - Pressure sensors

MEMS microphones

Number 5 - MEMS Microphones

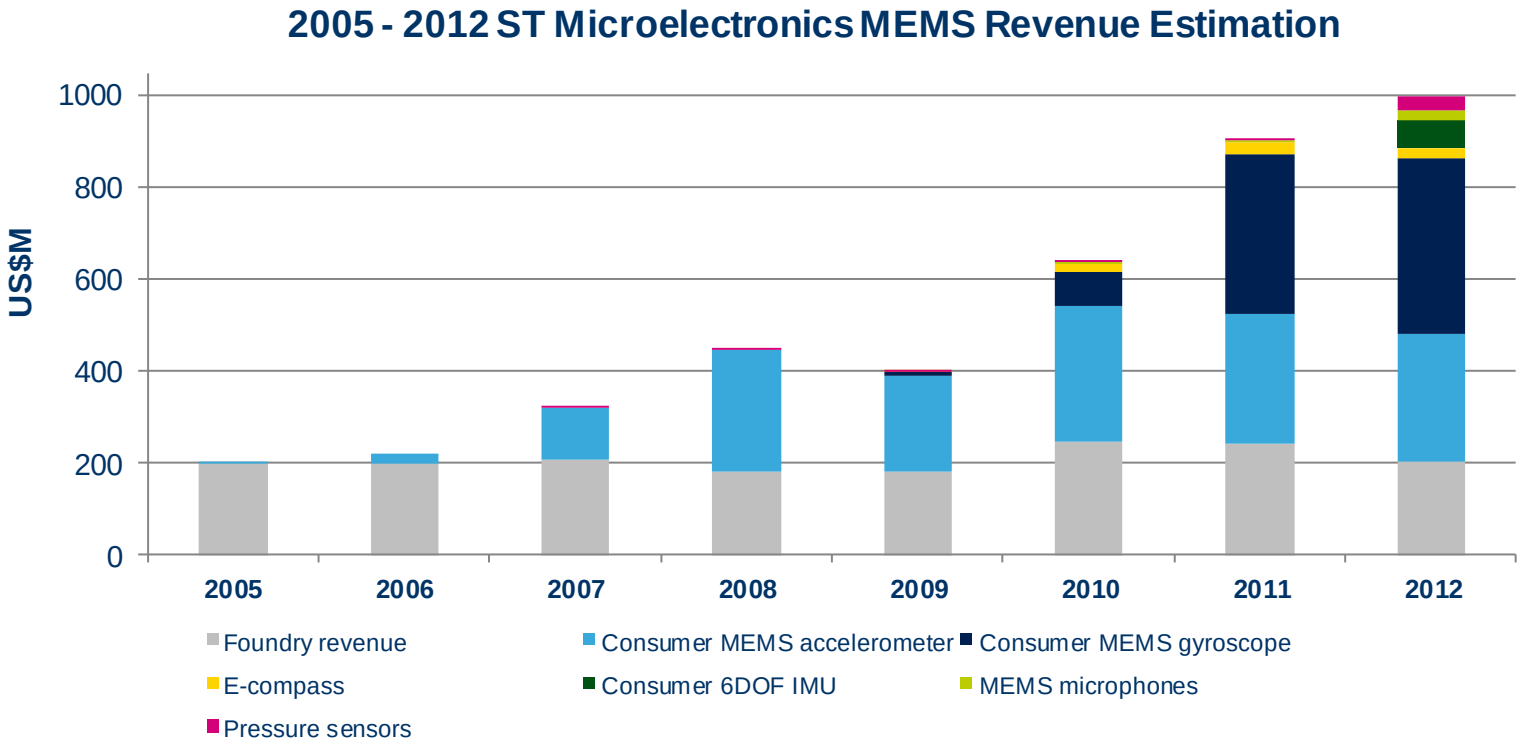


Source: IHS MEMS Market Tracker - Consumer and Mobile - H2 2013, ST

Silicon is not only a semiconductor

	Si	C	SiC	SiN	Fe	W	Steel	Mo	Al
Yield Strength (Gpa)	7	53	21	14	12.6	4	2.1	2.1	0.17
Knoop Hardness (Kg/mm^2)	850	7000	2480	3486	400	485	660	275	130
Young Modulus (100 Gpa)	1.9	10.3	7	3.8	1.96	4.1	2	3.43	0.7
Density (g/cm^3)	2.3	3.5	3.2	3.1	7.8	19.3	7.9	10.3	2.7
Thermal Conductivity (W/cm K)	1.57	20	3.5	0.19	0.8	1.78	0.32	1.38	2.36
Thermal Expansion (ppm/K)	2.33	1	3.3	0.8	12	4.5	17.3	5	25

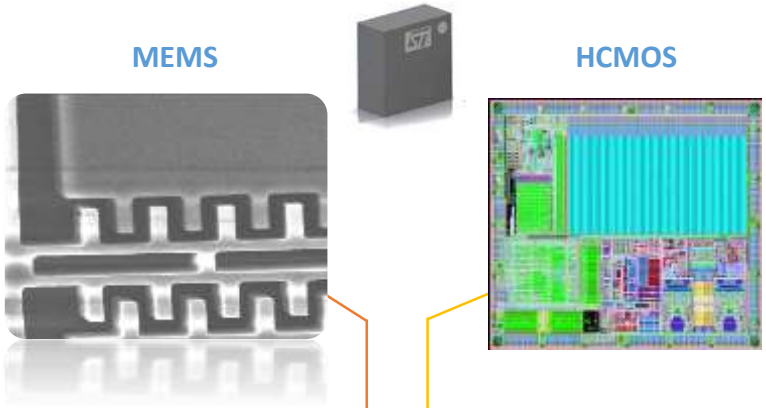
Leading the global MEMS World with a Rainbow of Products

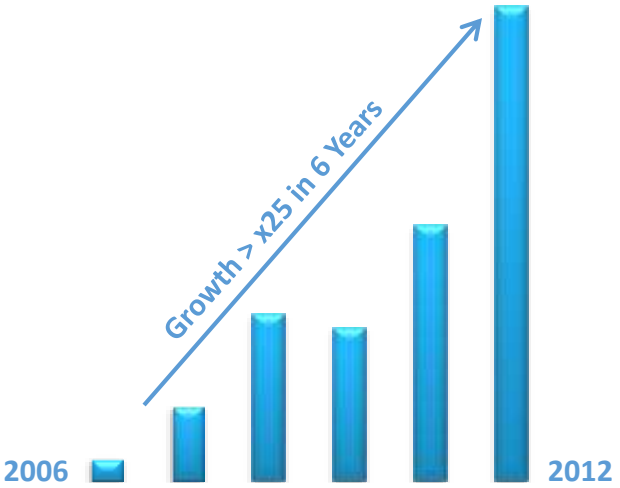


First MEMS company to reach $1,000M!

Source: Yole développement, Feb. 2013

Building Value in Europe with MEMS





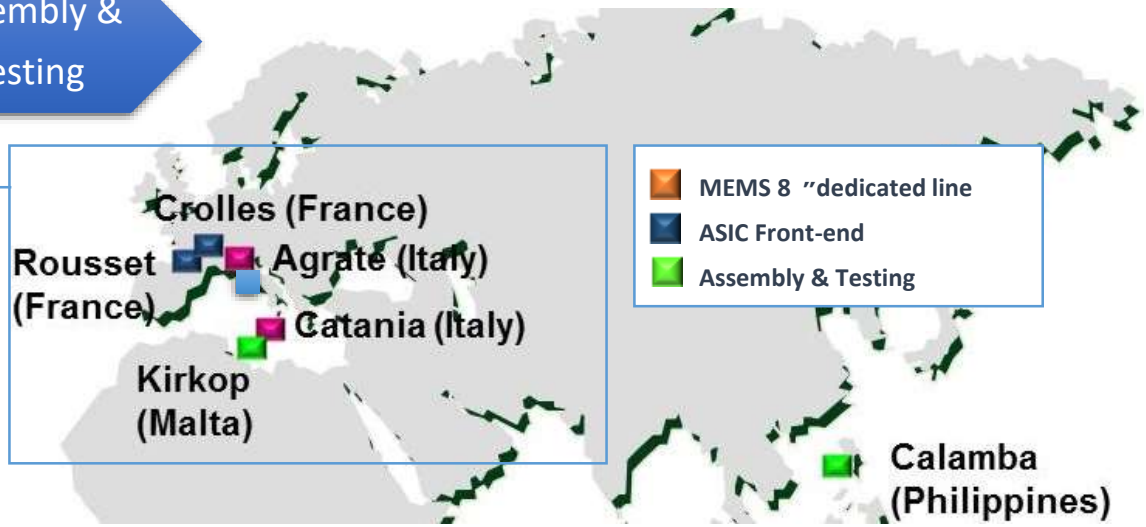
Agrate (Italy)

Crolles (France)

Cornaredo (Italy)

Malta & Philippines

Design → High Value Front-end → Assembly & Testing



Key success factors:

- Technology: Pioneering R&D
- Manufacturing: Internal high-volume capability
- WW Technical Support Network

Leading in MEMS & Micro-actuators

Number 1 - MEMS & Micro-actuators

Motion Sensors

Number 1 - Motion MEMS

Fluidic MEMS

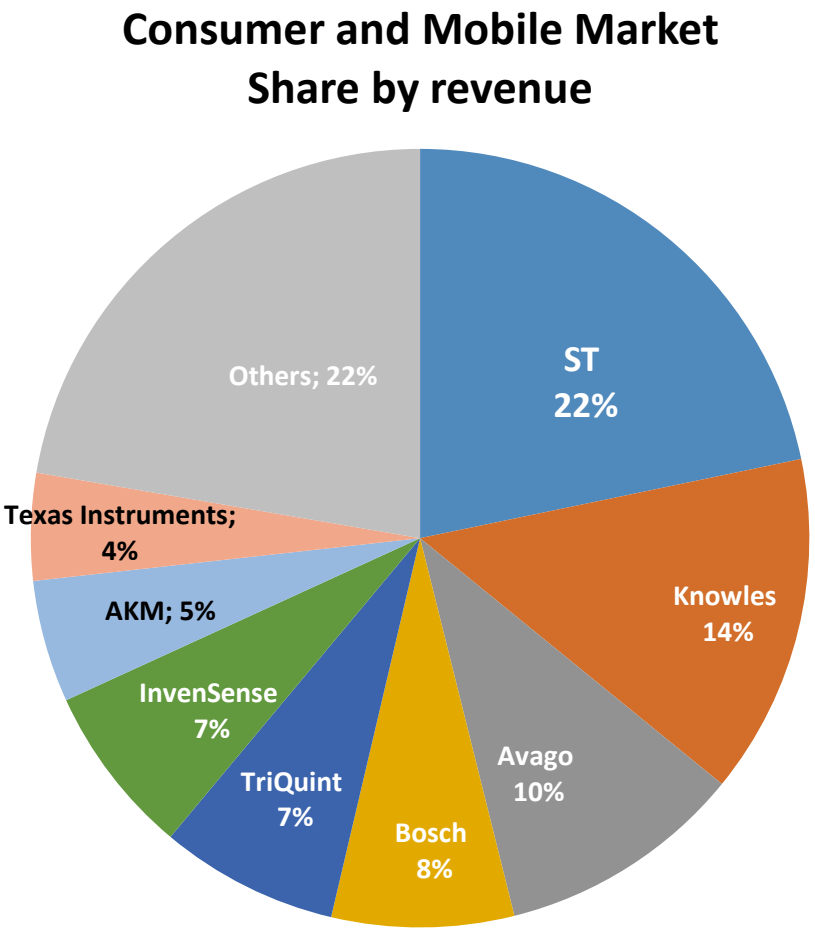
Number 1 – Fluidic MEMS (for printing)

Environmental Sensors

Number 2 - Pressure sensors

MEMS microphones

Number 5 - MEMS Microphones



Source: IHS MEMS Market Tracker - Consumer and Mobile H2 2013, ST

Smart Home

Smart Lighting Control

Wireless Sensors Network
(Pressure, Humidity, Temperature, CO_2)

Photovoltaic Panels

Zero Power Stand-by

Very-large band PLM
(500Mbps Powerline Modem)

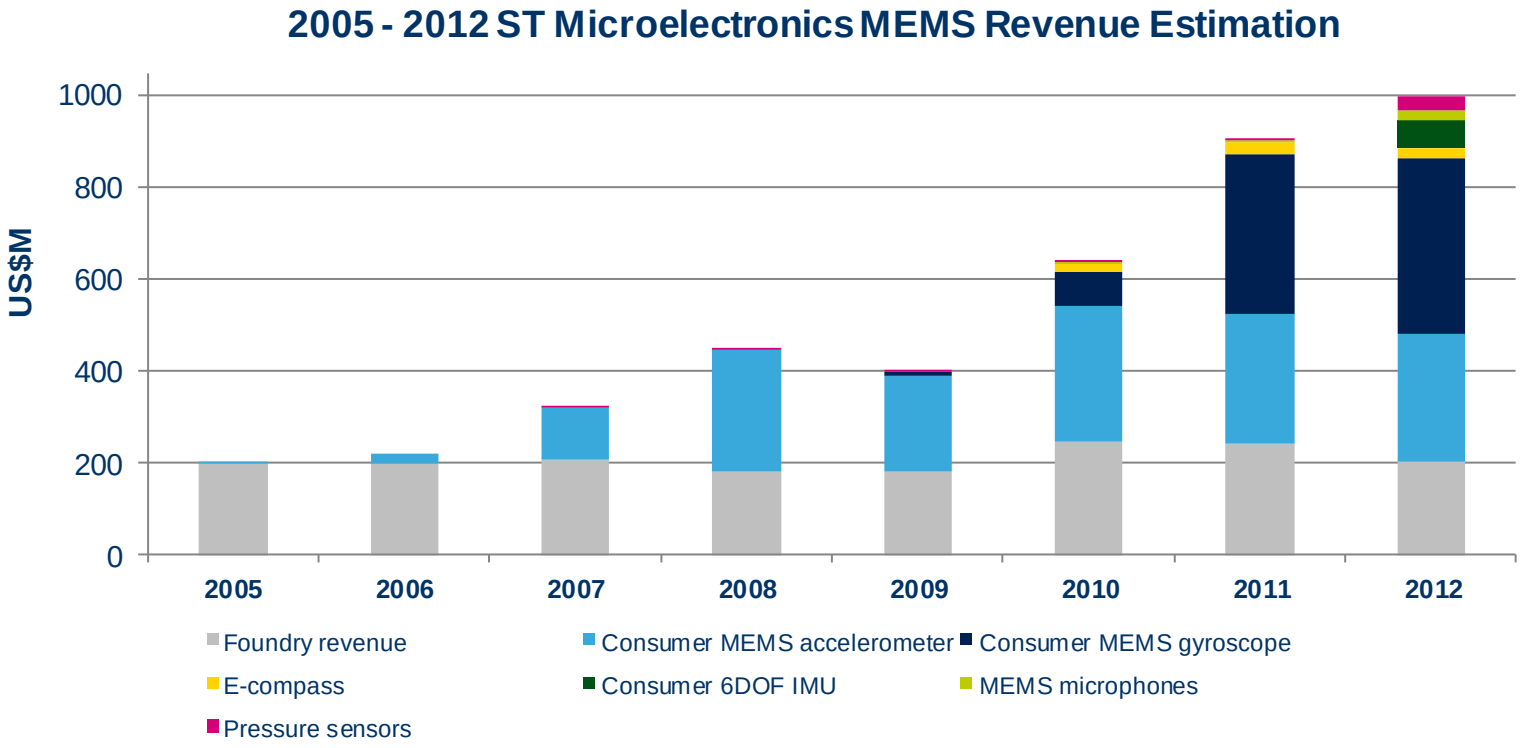
Smart Gas and Water Meters

Smart Energy Meter

Smart Plug
(Remote Appliance Control and Monitoring)

Photovoltaic Inverter1

Leading the global MEMS World with a Rainbow of Products



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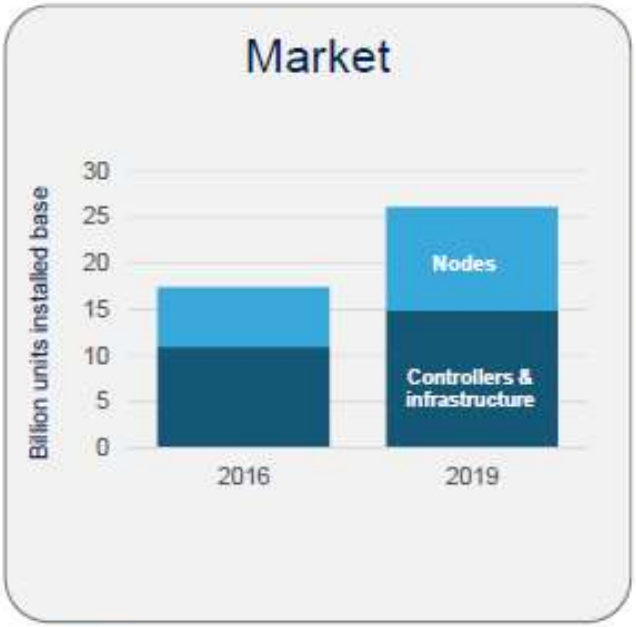
Smart Things

Making everyday things connected and more aware of their surroundings



Key Applications

Wearable

Smartphones

Tablets

Smart consumer

Key Enabling Products and Technologies

- MEMS
- Power and Smart Power technologies
- Ultra-low power radio for Bluetooth and subGHz
- CMOS

Market Leading positions

- MEMS sensors & micro-actuators
- Power supply ICs for AMOLED display

Key success factors

- Unique, full range of sensors & micro-actuators
- Free and easy-to-use software libraries for activity and gesture recognition
- Ecosystem of cloud partners for easy integration

Source: IHS

New Things to Augment Life: **SMART X**

Smart City

Reduce traffic congestion

Better use of resources

Improve security

Smart Car

Reduce emissions

Increase safety

Save fuel

Smart Home

Make entertainment more interactive and immersive

Increase comfort

Save energy

Smart Me Healthcare

Empower patients

Help physicians monitor and diagnose remotely

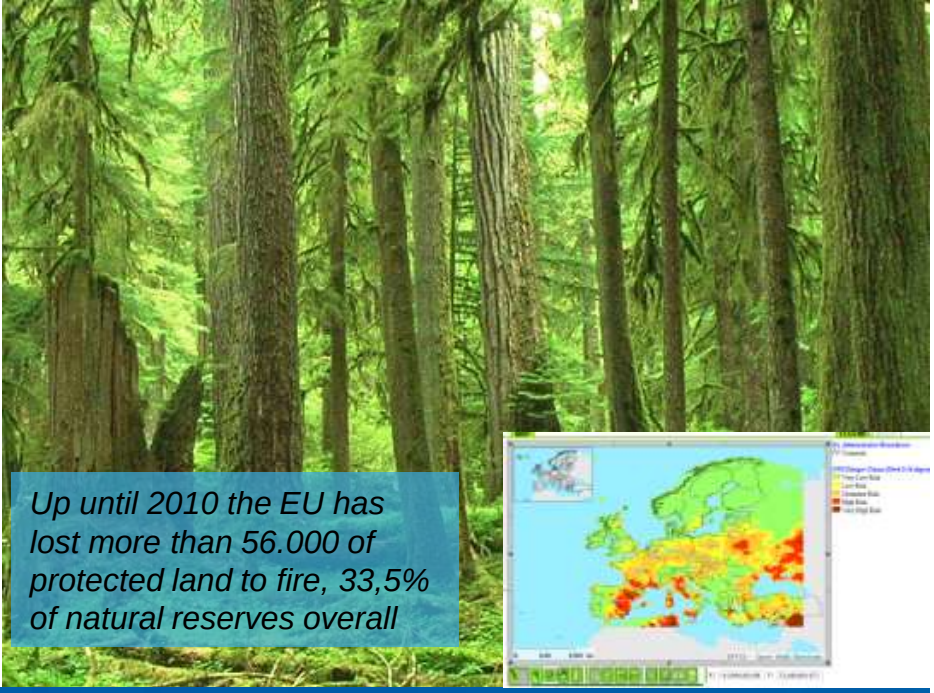
Smart Me Fitness & Wellness

Help to lead healthier lives

Optimize sports performance

Early warning of illness

Smart Environments



Up until 2010 the EU has lost more than 56.000 of protected land to fire, 33,5% of natural reserves overall

14 thousand slope rescues on Italian ski resorts only in 2010 mostly due to skiers collisions for excessive speed

- **Forest Fire Detection**
  Monitoring of smoke and fire detection, e.g. improve current facilities such as the European Forest Fire Information System
- **Air Pollution**
  CO2 emissions of factories, toxic gases generated in farms and biomass energy plants.
- **Landslide and Avalanche**
  Monitoring of soil moisture, vibrations and earth density to detect early signs of landslides in high risk areas
  Visual monitoring of snow levels and crack patterns to detect avalanche risk
- **Ski and sea resorts**
  Monitoring of skiers for falls, speed and erratic behaviors, off-limits trespassing, monitoring of skilifts
  Monitoring of swimmers to detect distress signs to aid lifeguard duty, beach littering detection

Motion MEMS Evolution

Low-noise
low-thickness

Optical Image Stabilization (OIS) For Smartphones

New Market penetration
Cost effectiveness

Recreational & Professional Drones

Addressing existing and new applications and markets

Wearable

Ultra-low power
For always-on wearable devices

2015

Virtual Reality
Augmented Reality

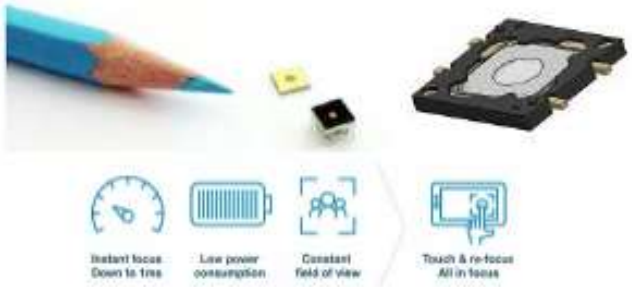
High accuracy

2016

MEMS Micro-actuators

Micro-mirrors

Thin-film Piezo-electric MEMS



3D scanning

- In production with multiple OEMs for Intel RealSense™ Depth Camera
- Opportunities for other micro-mirror applications

Camera Autofocus

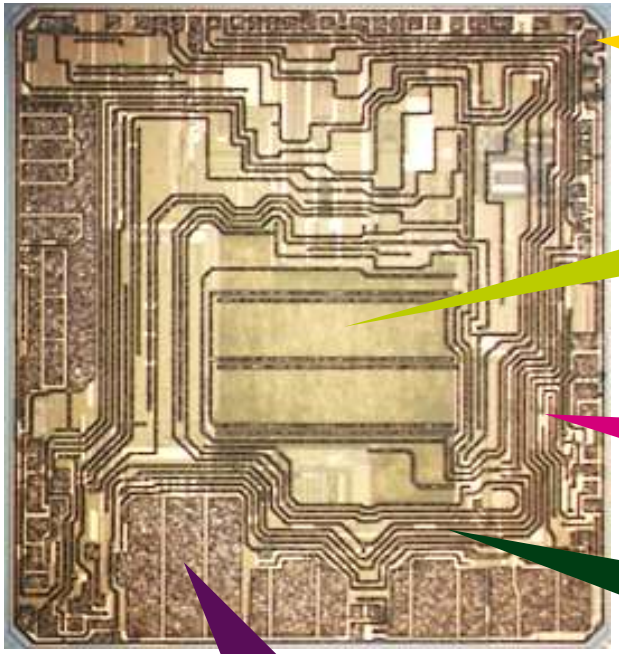
- Lower power consumption and higher speed versus Voice-Coil Motor (VCM) based solution
- Partnering with innovative lens maker PoLight for autofocus actuator in smartphones

Printing

High-speed inkjet print head for commercial and industrial applications

- High-viscosity materials
- Different printing materials

Challenges in modern Smart Power ASICs



ISOLATION & INTEGRATION SCHEMES
- **Junction Isolation**
- **Deep Trench Isolation**
- **SOI**

LOGIC CORES
- CMOS density

GREAT BENEFIT from **Litho Node Evolution**

ANALOG FEATURES
- Optimize Analog CMOS
- **Enrich basic Device Offer** (Active & Passive)

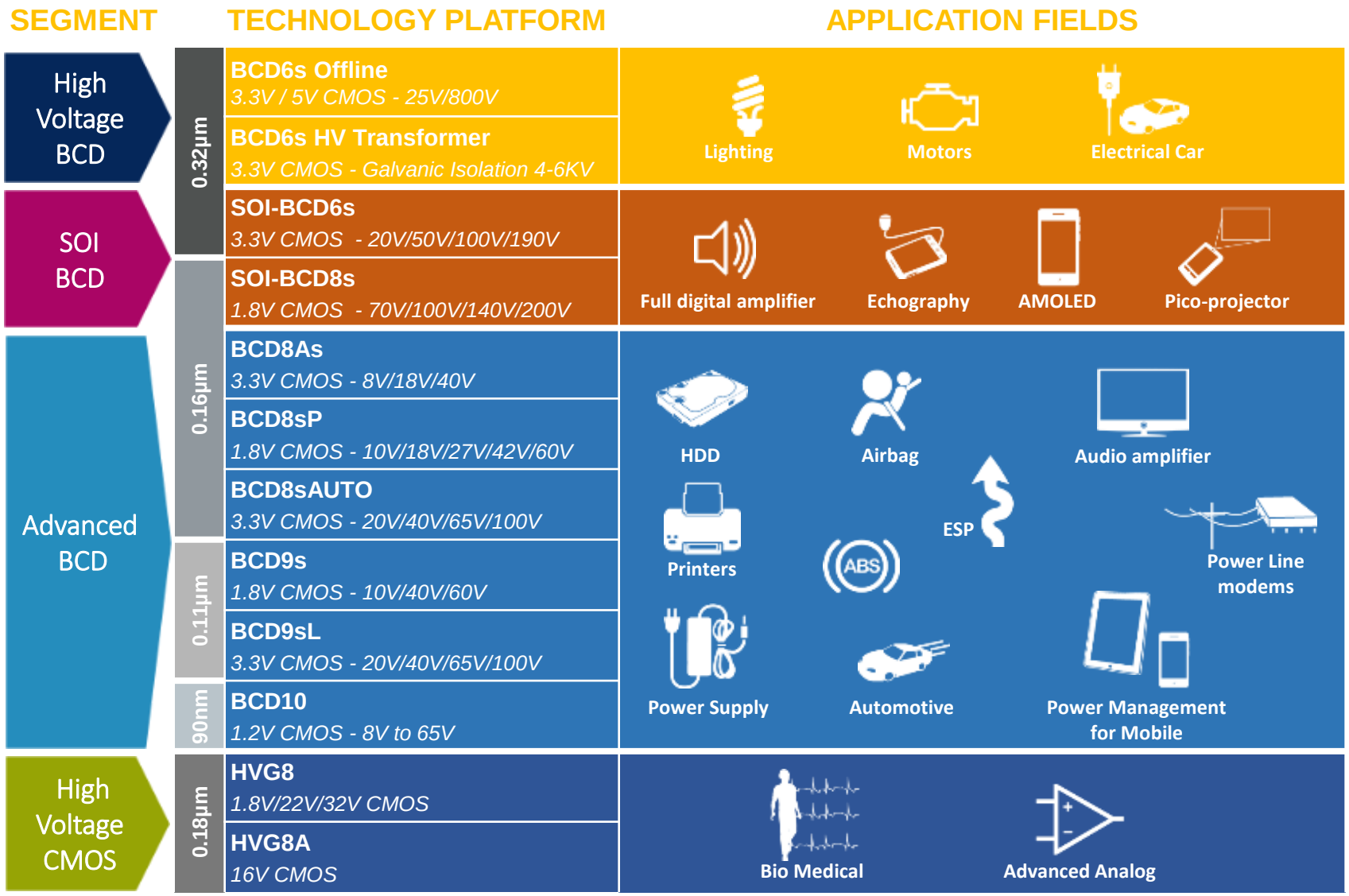
LARGE CURRENT ROUTING
- **Thick Copper Metallization**
- **Bonding over Active Areas**

POWER DEVICES
- Specific ON resistance
- Robustness

POOR IMPROVEMENT from **Geometry Scaling**

Innovative Architecture to **Optimize Performance**

BCD Technology Segmentation

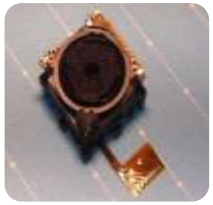


THE FIRST 100 BCD ICs

Beyond Motion MEMS

2012/13

High volume production of Dual Core Gyroscopes for Optical Image Stabilized Camera

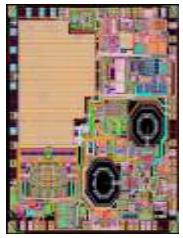


High volume production of Digital Microphones for many customers

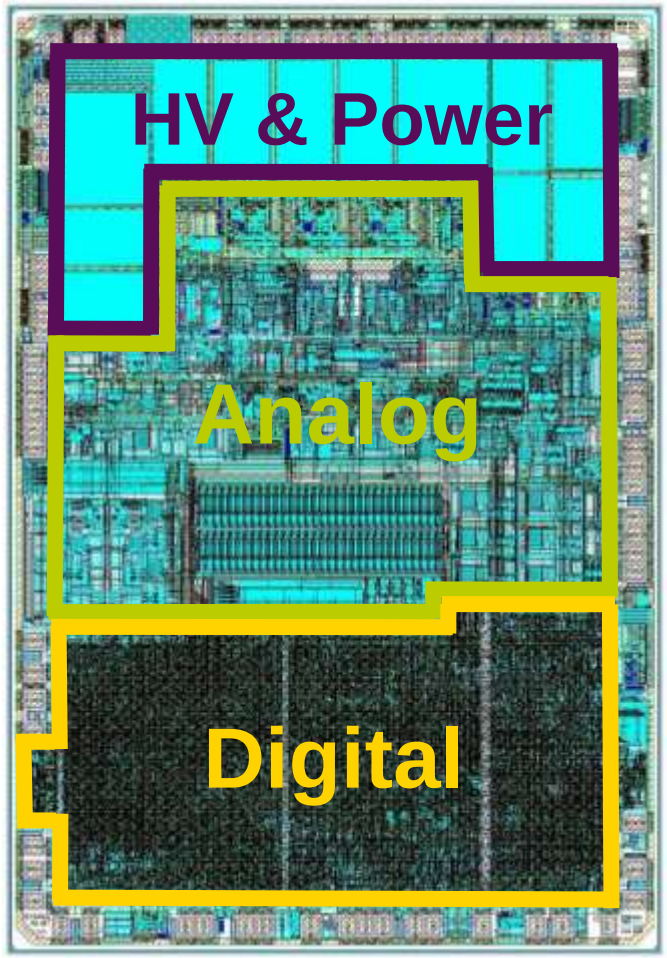
High volume production of Pressure Sensors

Production Start of Accelerometer for Vehicle Air Bag

Production Start of Low Power Sub-GHz Radio



Analog + Digital + Power & HV on one chip



High Voltage & Power section (DMOS) to drive external loads

Analog blocks to interface the external world to the digital systems

Digital core (CMOS) for signal processing