

Lecture 1

Motivation

ME-426 – Micro/Nanomechanical Devices

Prof. Guillermo Villanueva

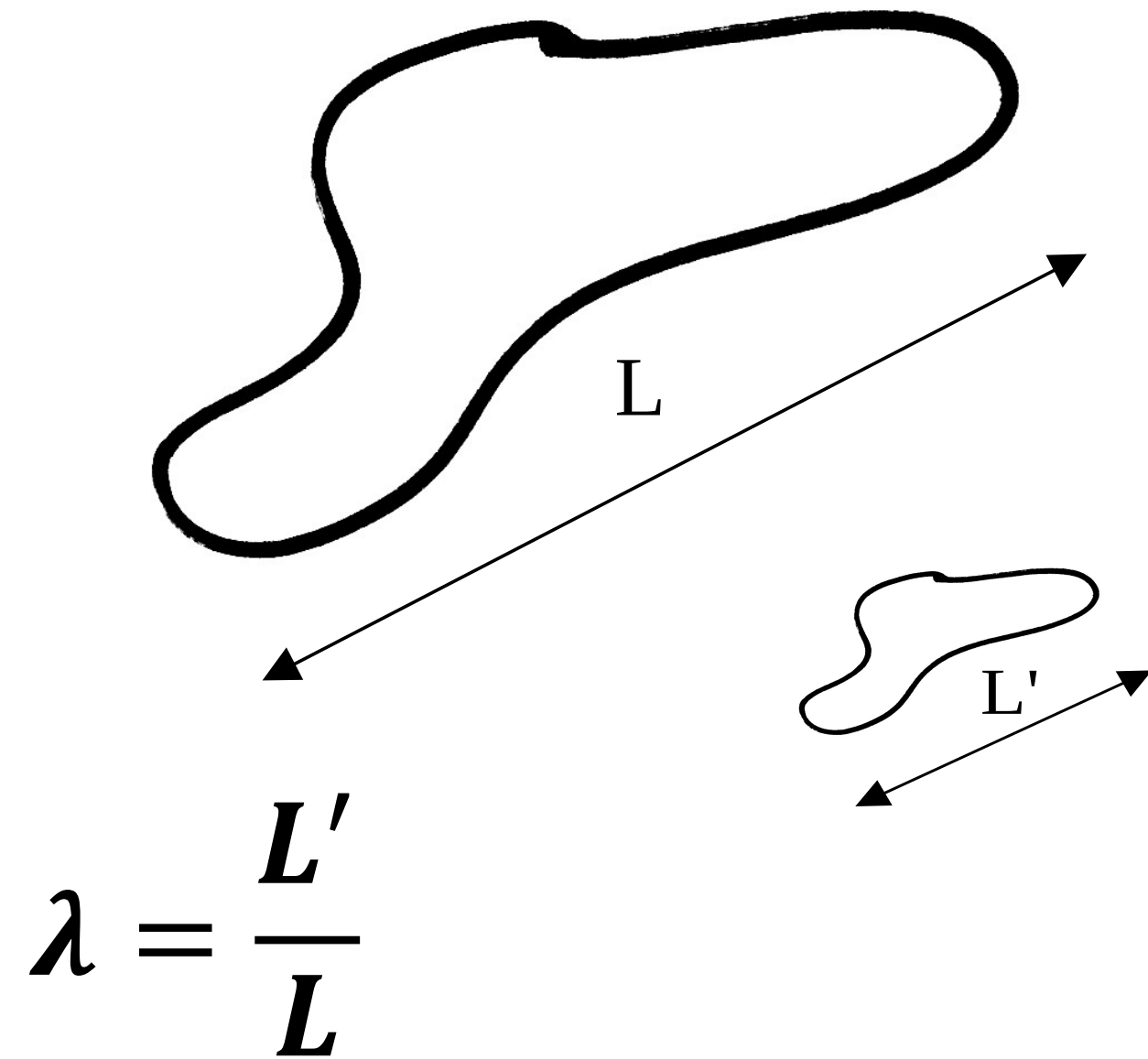
EPFL Welcome!!!

- Scaling Laws
- Examples of application

Scaling laws

EPFL Scaling laws

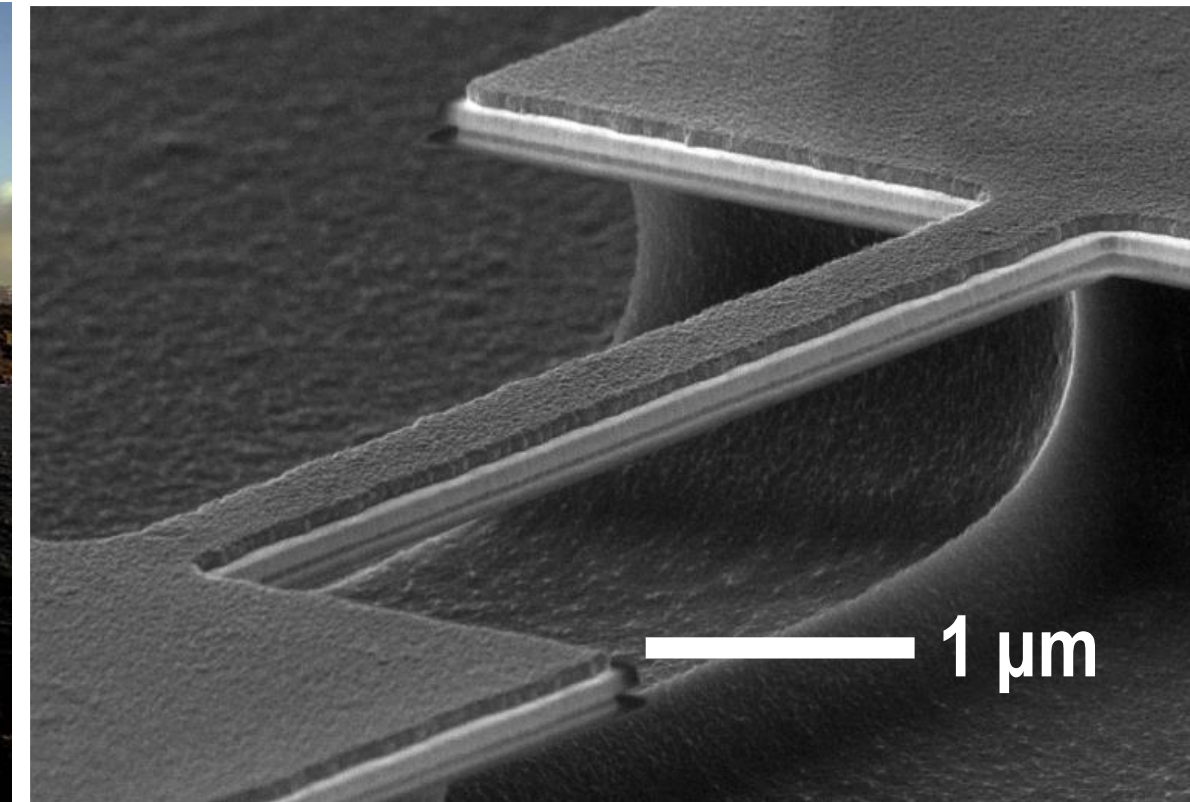
- Mechanics and physics laws are the same as the macro scales, it is the relative importance of the forces that are modified



Magnitude	Scaling factor
length (L)	λ
area (A)	λ^2
volume (V), mass (m)	λ^3
surface to volume ratio	λ^{-1}
stiffness (k)	λ
resonance frequency (f_0)	λ^{-1}
mass responsivity ($\mathfrak{R}$)	λ^{-4}
thermal time constant (τ)	λ

EPFL Scaling laws

- Overview – Mo



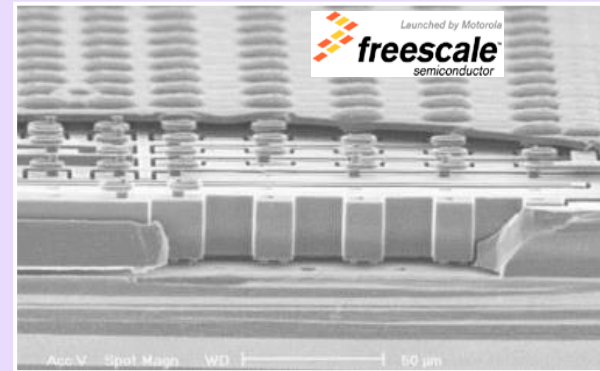
Magnitude	Macroscopic	NEMS	Ratio
length (L)	$\sim 5 \text{ km}$	$\sim 5 \text{ }\mu\text{m}$	10^{-9}
mass (m)	$\sim 4 \cdot 10^8 \text{ kg}$	$\sim 0.5 \text{ pg}$	10^{-24}
surface to volume ratio	$\sim 0.1 \text{ m}^{-1}$	$\sim 10^7 \text{ m}^{-1}$	10^8
stiffness (k)	$\sim 10^6 \text{ N/m}$	$\sim 10^{-1} \text{ N/m}$	10^{-7}
resonance frequency (f_0)	$\sim 1 \text{ Hz}$	$\sim 10 \text{ MHz}$	10^7
thermal time constant (τ)	$\sim 30 \text{ years}$	$\sim 10 \text{ }\mu\text{s}$	10^{-16}



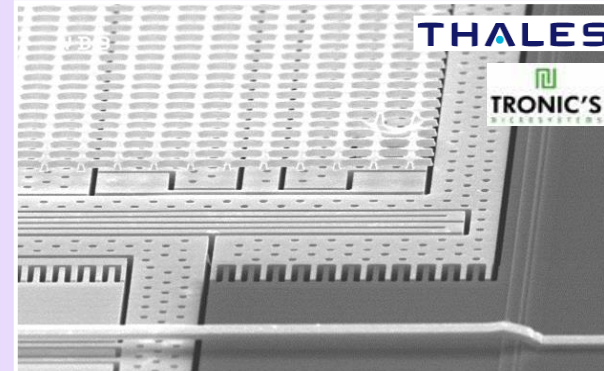
Examples of Devices

EPFL Different MEMS products

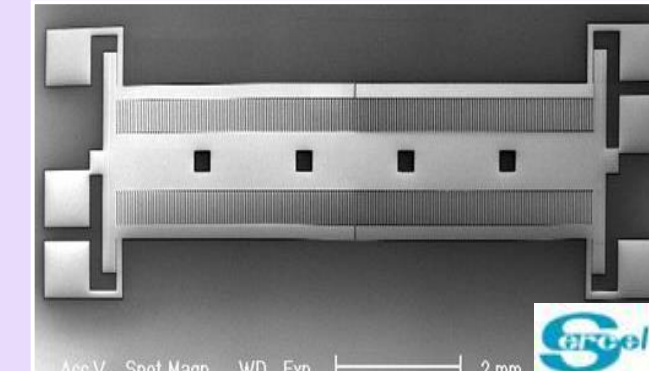
Inertial Sensors



Accelerometers



Gyroscopes

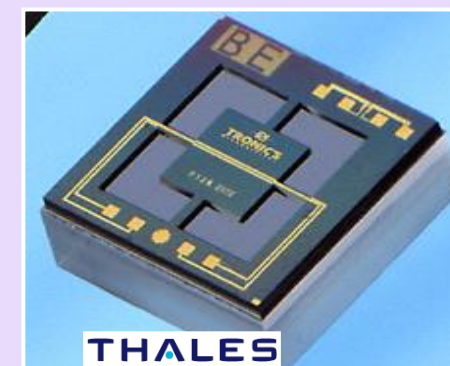


Geo-phone

Force/pressure sensors

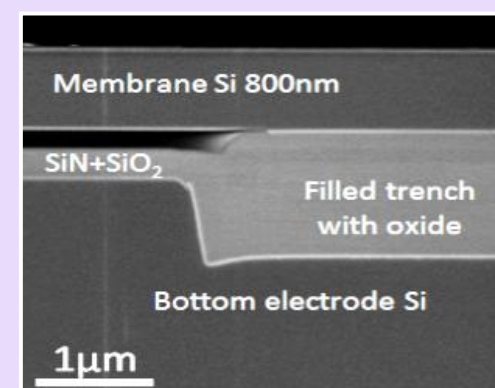


Pressure sensors

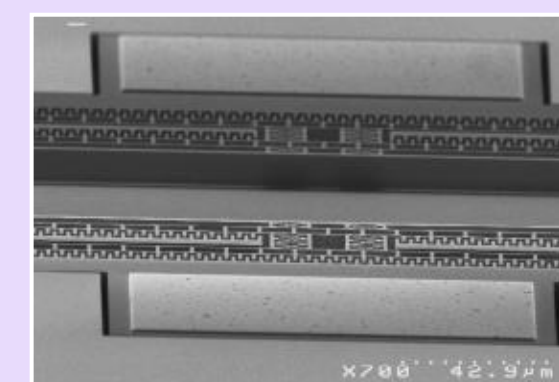


Force sensors

Acoustic sensors



MUT



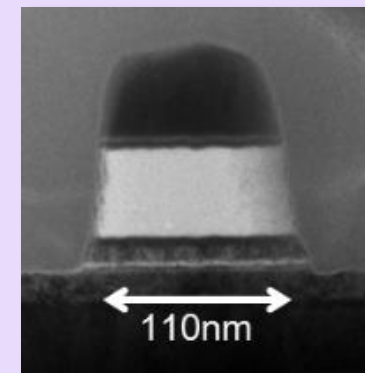
Microphones

- Courtesy of J. Arcamone

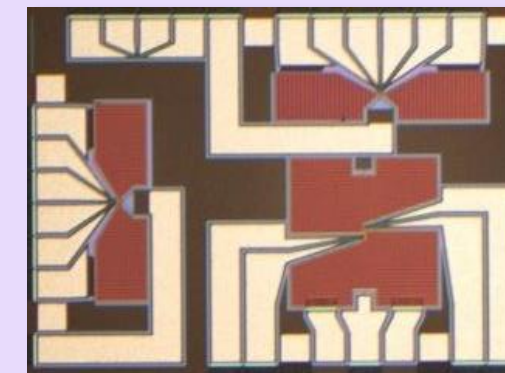
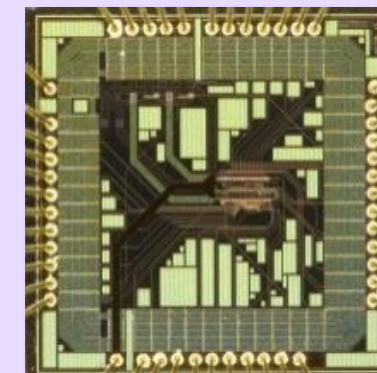
EPFL Different MEMS products

- Courtesy of J. Arcamone

Magnetic sensors



TMR

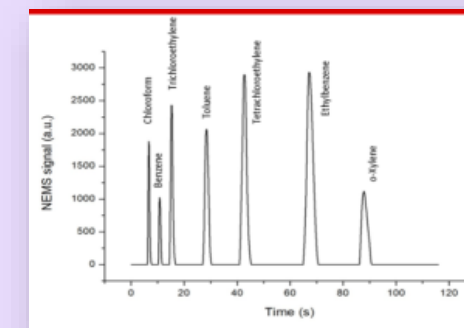


3-axes compass

Gas sensors



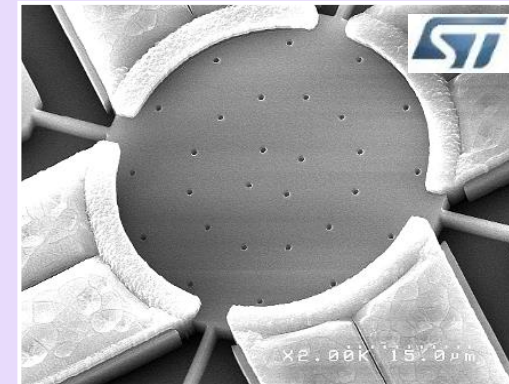
NEMS-based + μ GC gas sensor



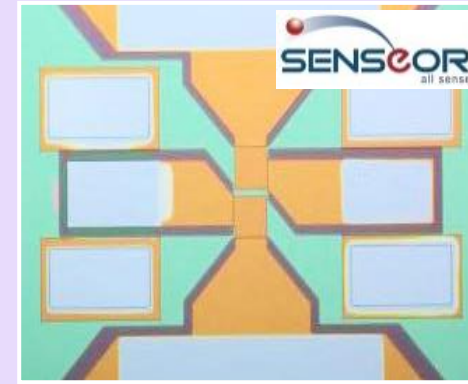
Humidity

EPFL Different MEMS products

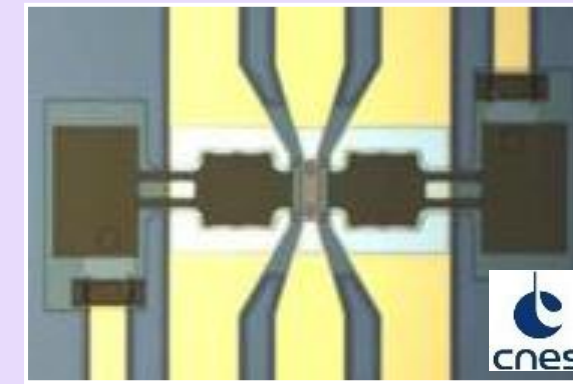
RF-MEMS



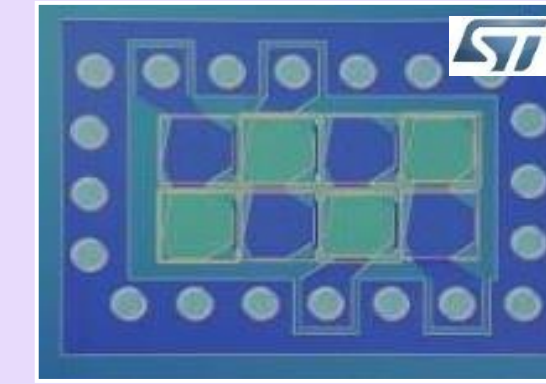
Q=58000 @ 97MHz
High Q resonators (Si and HBAR)



Q=24000 @ 4.2 GHz



35V / 40GHz
Micro-switches



BAW filters

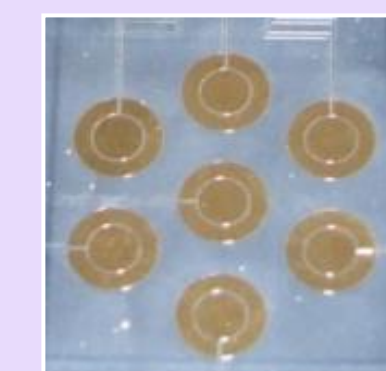
MEMS actuators



Micro-valves



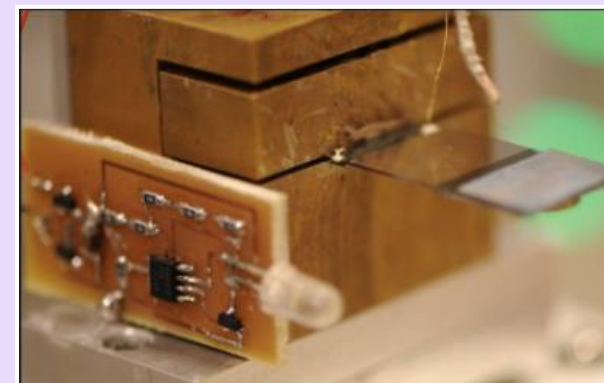
10 diopters @ 10V
PZT self focussing lens



PMUTs

Energy harvesting

200μW/cm³ @ 200 Hz

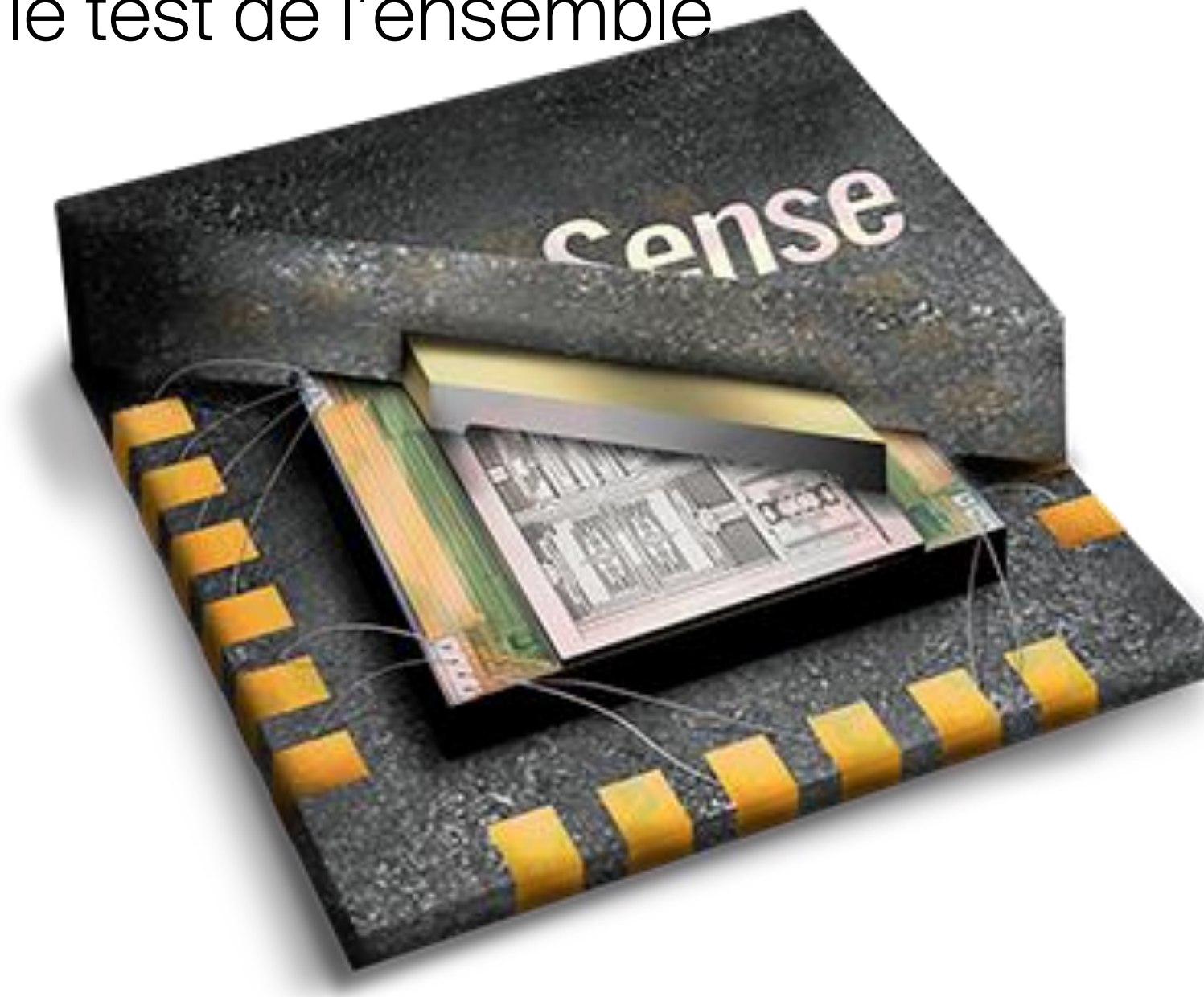


AIN

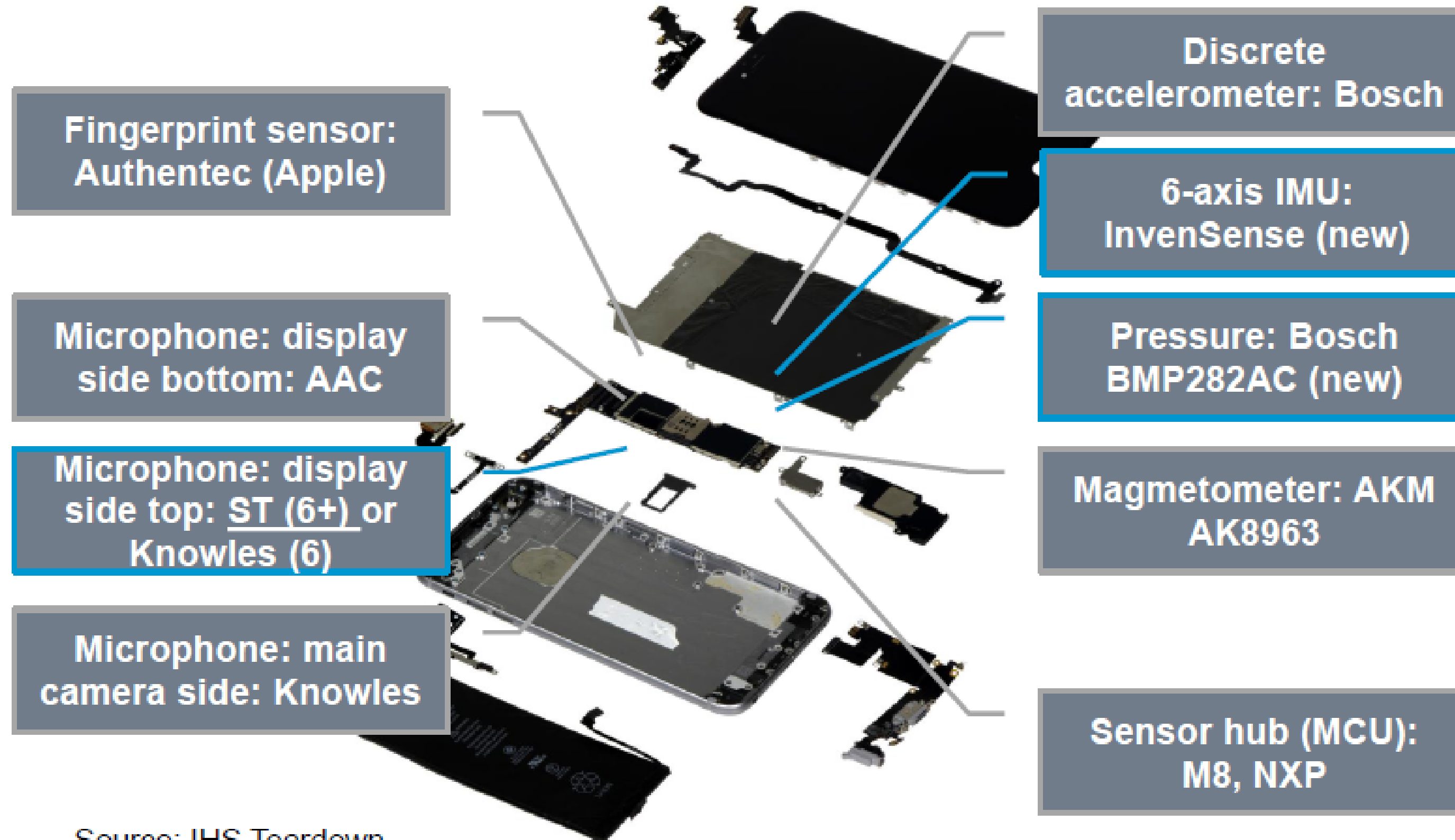
- Courtesy of J. Arcamone

EPFL What is a MEMS product

- A chip, an ASIC and a package
 - Prix d'un MEMS pour les marchés « Consumer » : environ 1US\$
- Environ 1/3 du coût pour la puce MEMS, 1/3 pour l'ASIC, 1/3 pour la mise en boîtier, le boîtier lui-même et le test de l'ensemble

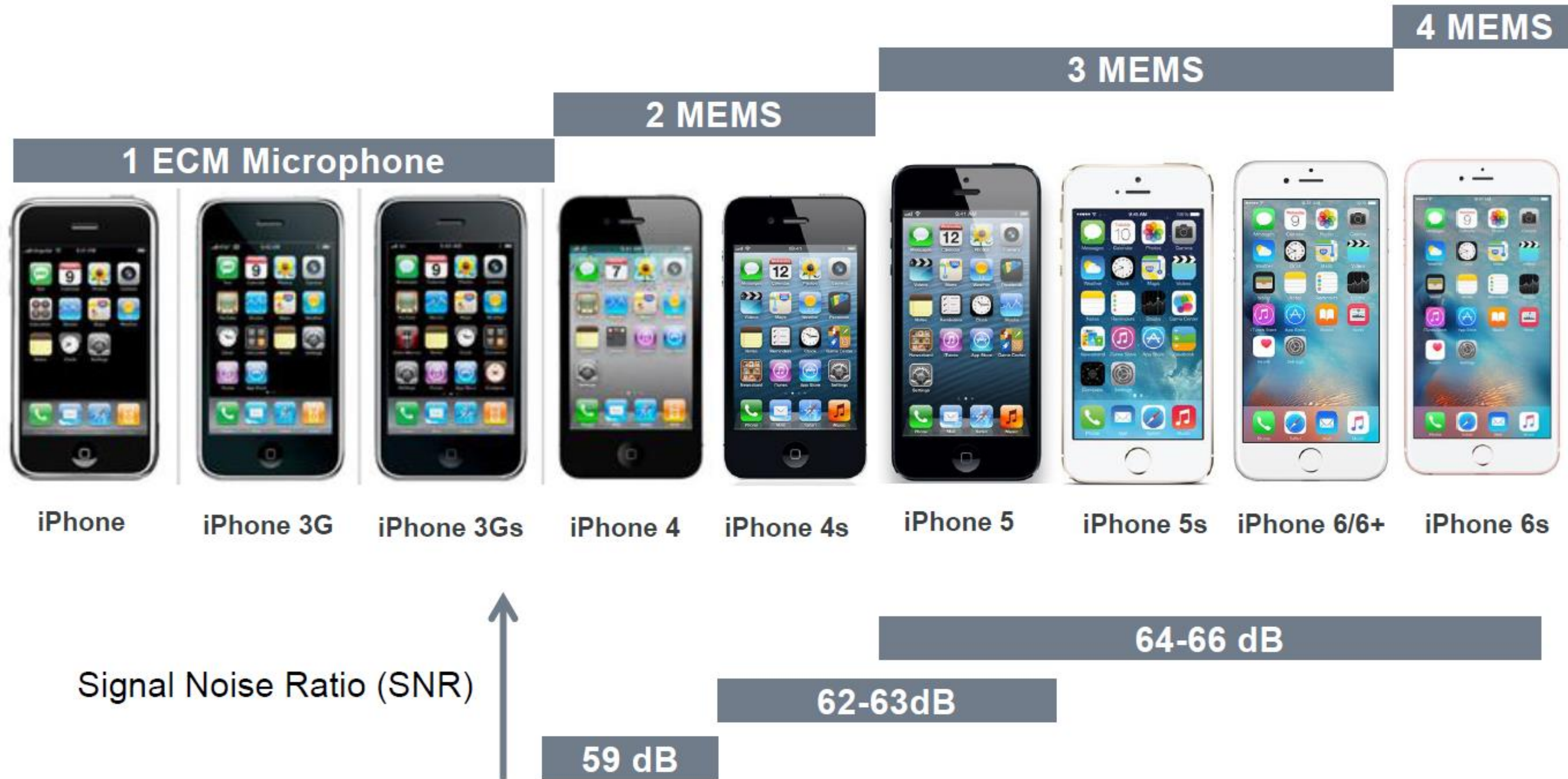


EPFL MEMS are everywhere



Source: IHS Teardown

EPFL MEMS are everywhere



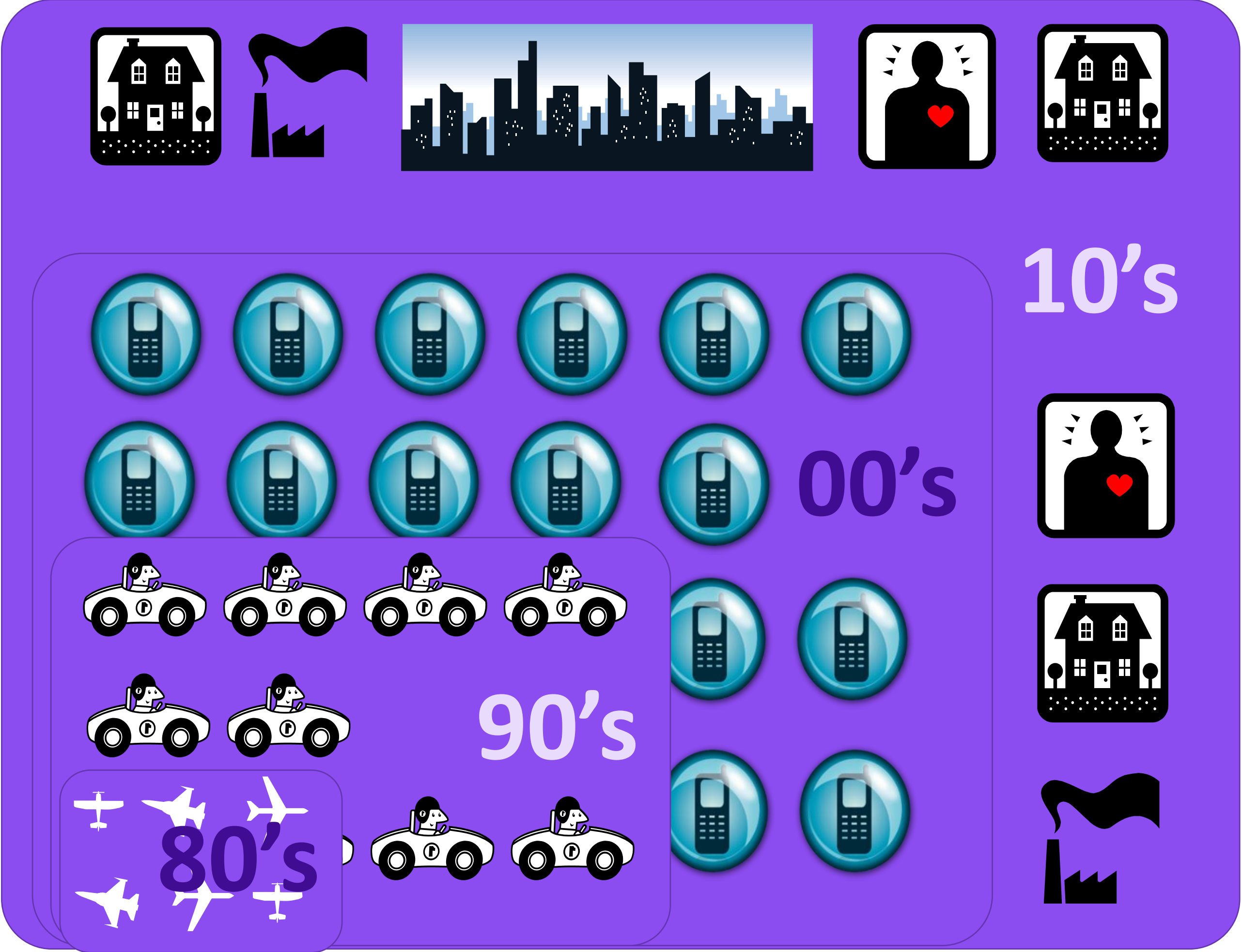
Source for pictures Apple

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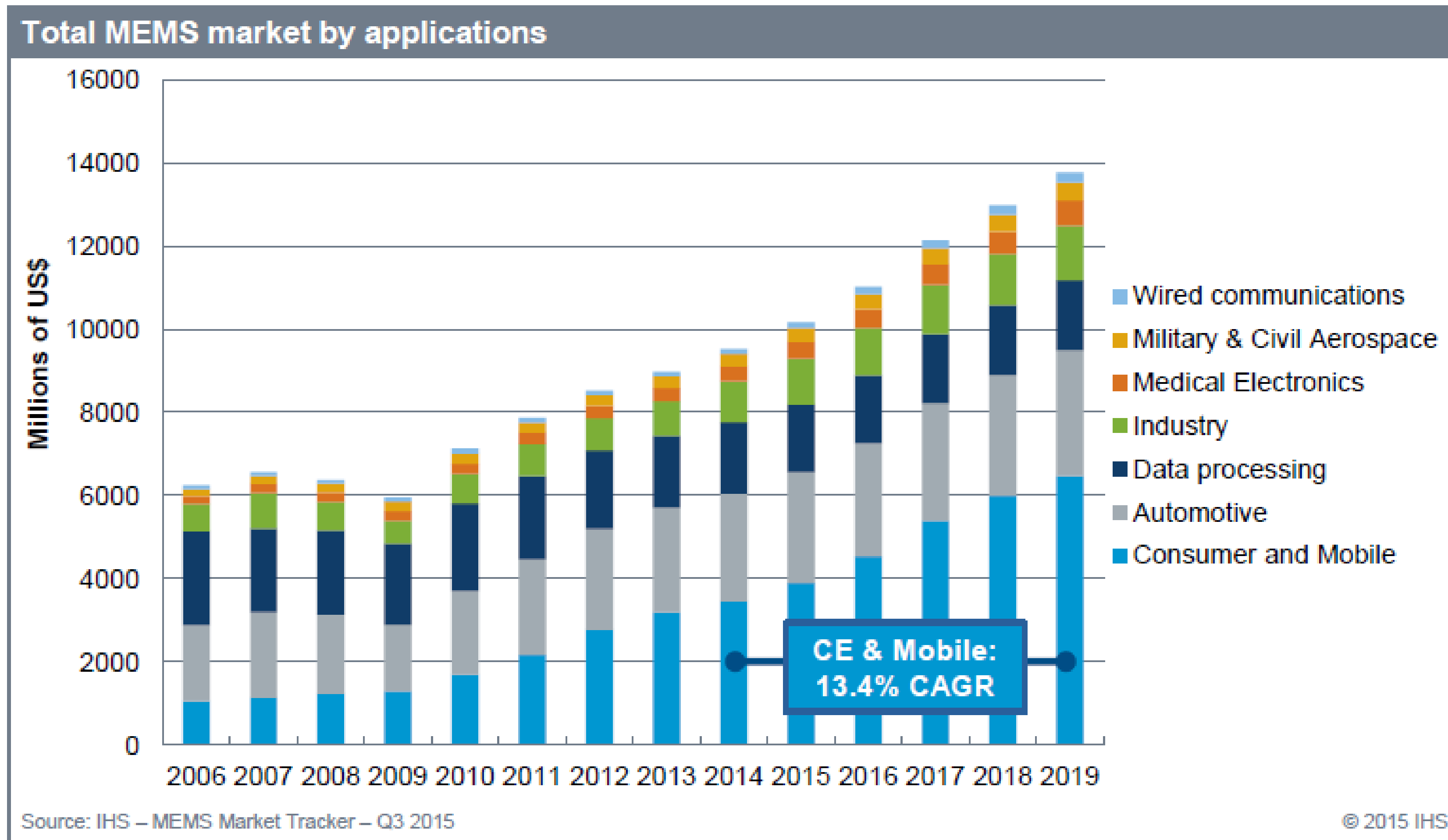
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MEMS Market



EPFL Revenue vs. Applications



EPFL Revenue Vs. Application

