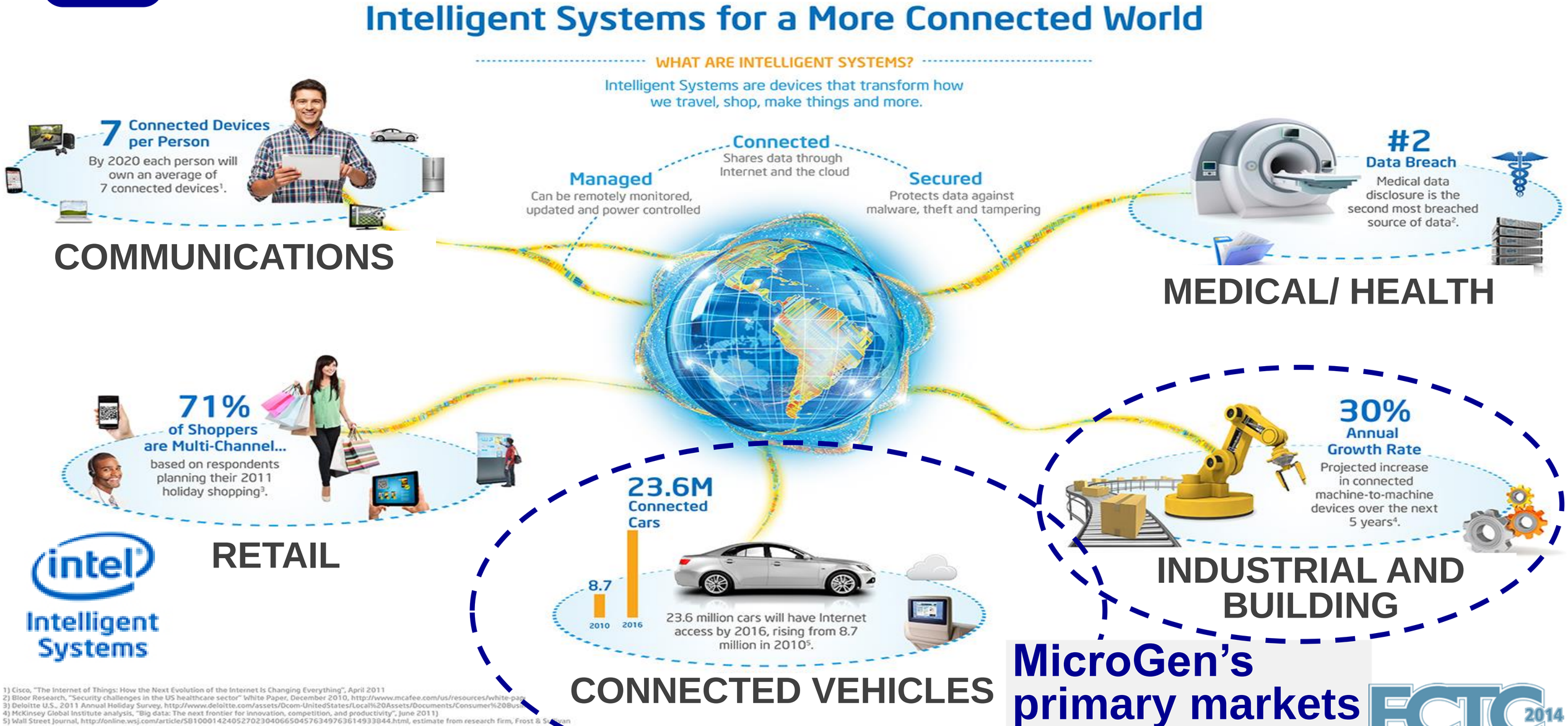
Robert Andosca, Ph.D.
Co-founder, President and CEO

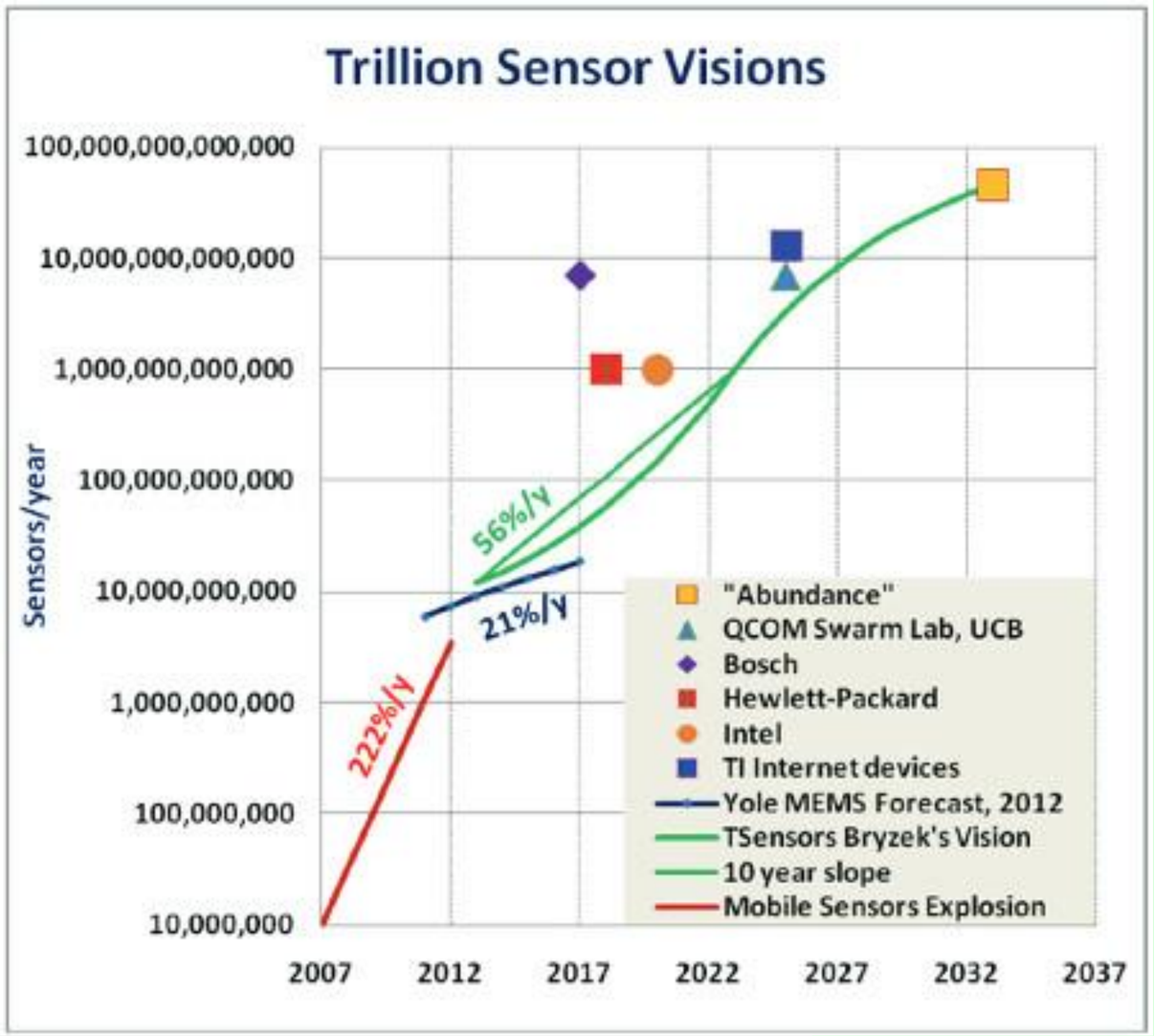
‘Internet of Things’ → Wireless sensors !!



MicroGen’s primary markets

1) Cisco, “The Internet of Things: How the Next Evolution of the Internet Is Changing Everything”, April 2011
2) Bloor Research, “Security challenges in the US healthcare sector” White Paper, December 2010, http://www.mcafee.com/us/resources/white-pap
3) Deloitte U.S., 2011 Annual Holiday Survey, http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Consumer%20Bus
4) McKinsey Global Institute analysis, “Big data: The next frontier for innovation, competition, and productivity”, June 2011)
5) Wall Street Journal, http://online.wsj.com/article/SB10001424052702304066504576349763614933844.html, estimate from research firm, Frost & Sullivan

IoT problem: Battery life !!!



Source: T-Sensor Summit, Stanford University, Oct 23-25 2013

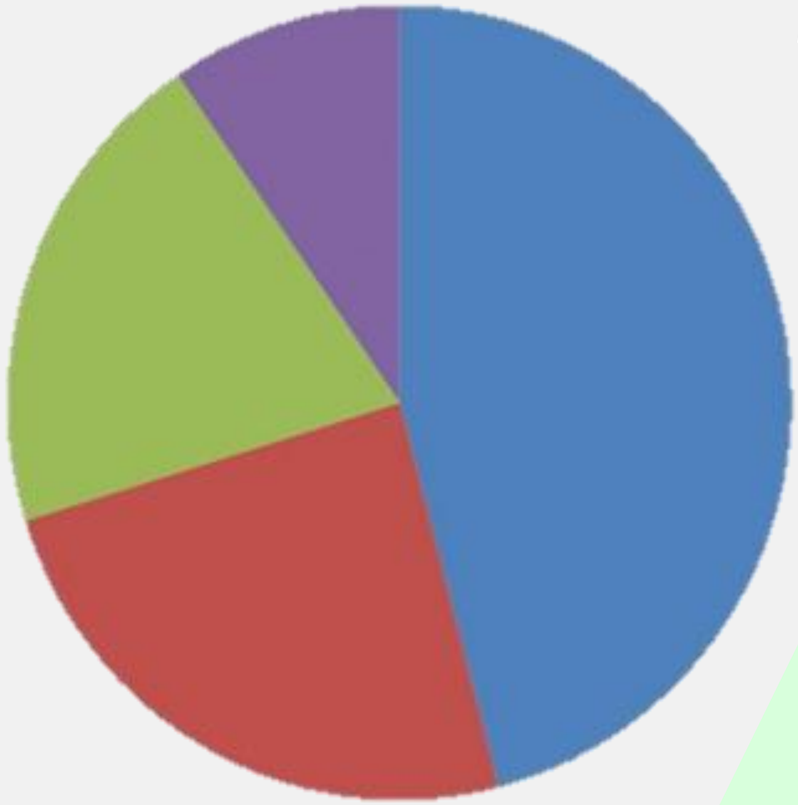
"Energy is a challenge. To power trillions of sensors requires energy and per unit it will have to be reduced from today's levels.

It will need to be derived from light, vibration, thermal energy scavengers."

– Janusz Brysek, Ph.D.
Chairperson Trillion Sensor Summit and VP MEMS/Sensors Fairchild Semiconductor

Source: EE Times, Nov 11, 2013

IoT alternative EH power sources



Energy harvesting (EH) types:

- 24% Vibration – piezoelectric
- 20% Vibration – induction
- 10% Solar
- 46% Thermal

Currently $$$

Source: IDTechEx (January 2014)

Current IoT power sources comparison

Induction vibration – large  and high cost

- ✓ Magnetic $\vec{B}$-fields do not scale well: 10X size reduction → 10^4 $\vec{B}$-field reduction
- ✓ Difficult to fabricate at micro-scale
  - ✧ e.g. coils are costly to make and low permeability ρ of thin-film magnetic

Thermal energy generators – large  and high cost

- ✓ Non-standard materials – MicroPelt built dedicated fab
- ✓ Requires large cooling fins and heat sinks

Small-scale solar – moderately small  and low cost

- ✓ Low power generation indoors
  - ✧ e.g. SolChip and Panasonic are 5 and 60 μW DC with indoor lighting, respectively

Piezoelectric vibration – small and low cost

- ✓ MicroGen uses standard piezo-MEMS fabrication techniques
- ✓ 100-1000 μW DC currently, where 100 μW will power most wireless sensors

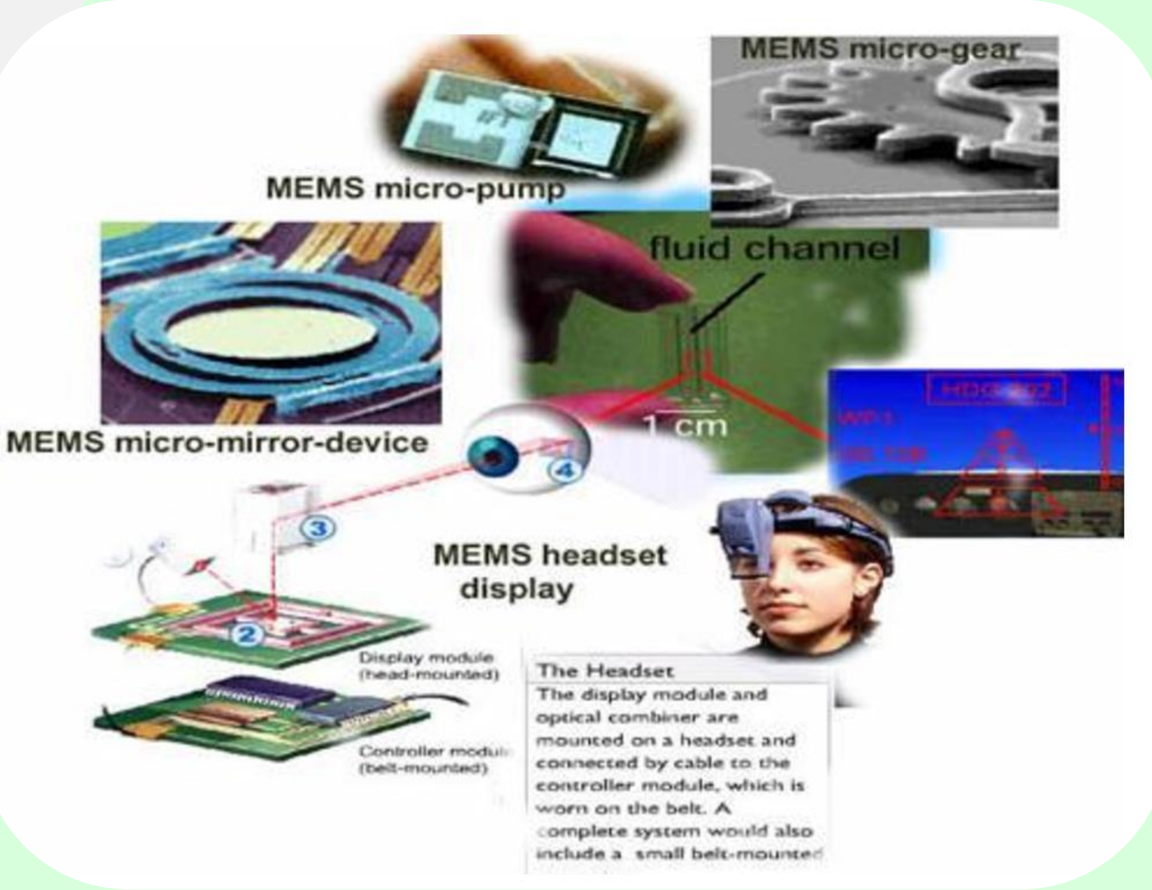
Perpetuum’s Induction Vibration EH

Large device, several hundred $ each

What is MEMS?

Micro Electro Mechanical Systems

- ✓ Uses the same fabrication techniques as computer chips
- ✓ Typically have an electrically actuated moving component (but not always)

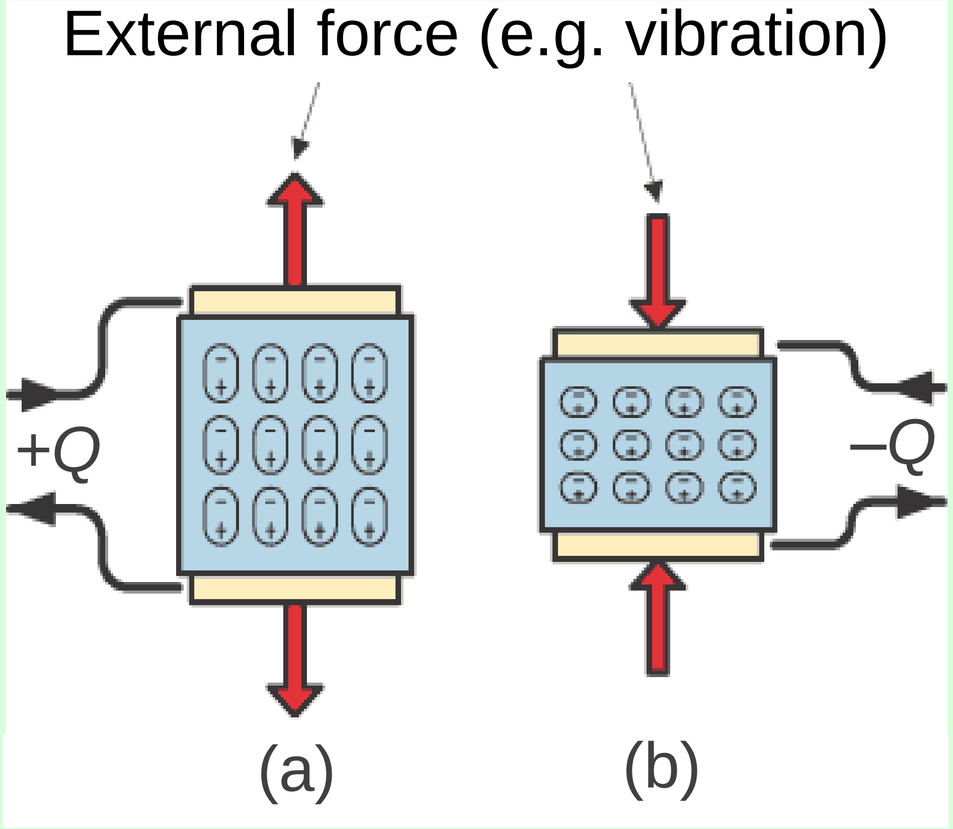


What is piezoelectricity?

Piezoelectricity – Discovered in 1885 by the Curie Brothers

Mechanically straining a piezoelectric crystal causes asymmetry inducing an internal electric $\vec{D}$-field pushing and pulling charge Q.

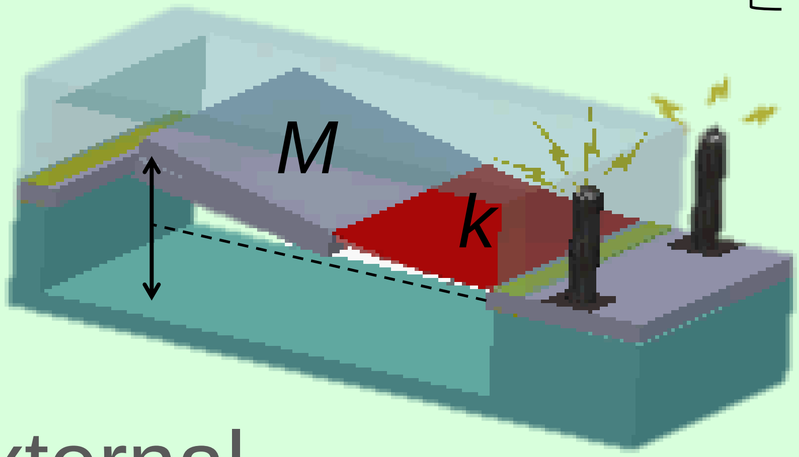
When the piezo-capacitor is electrically connected to ground charge Q is pushed and pulled from its electrodes creating alternating current (AC). This AC is then converted to DC electricity and stored.



How it works – “Resonant mode”

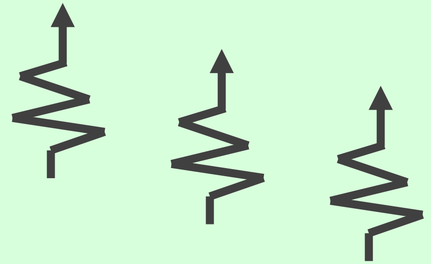
$$\text{Resonant frequency } f_1 \sim \left[\frac{k}{M}\right]^{\frac{1}{2}}$$

Low cost wafer-level packaged **piezoelectric** MEMS vibration energy harvestor



BOLT™ *– Used for industrial and building applications*

external vibration

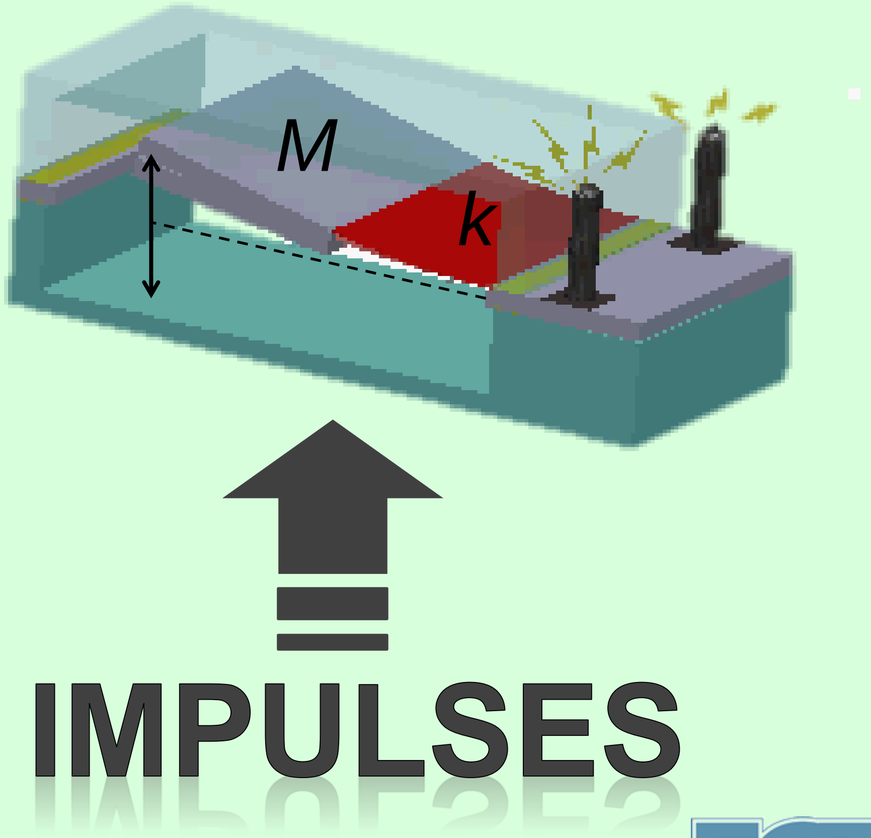


See video of simple operation

How it works – “Impulse mode”

Click here to view demo

A high quality factor *Q* oscillator will “ring” at its “natural” or resonant frequency when impulsed.



VIBE*™ – *Used for Intelligent Tire Systems (ITS) tire mounted TPMS apps

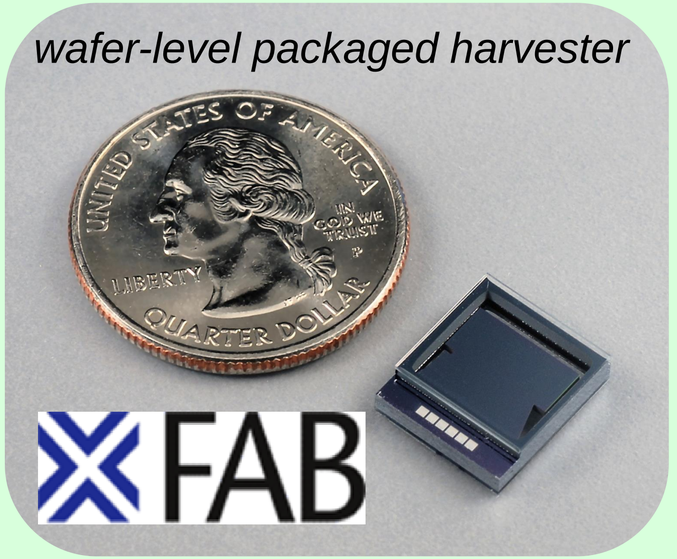
MicroGen's micro-power sources

Piezoelectric MEMS
Vibration Energy Harvesters
and Power Cells

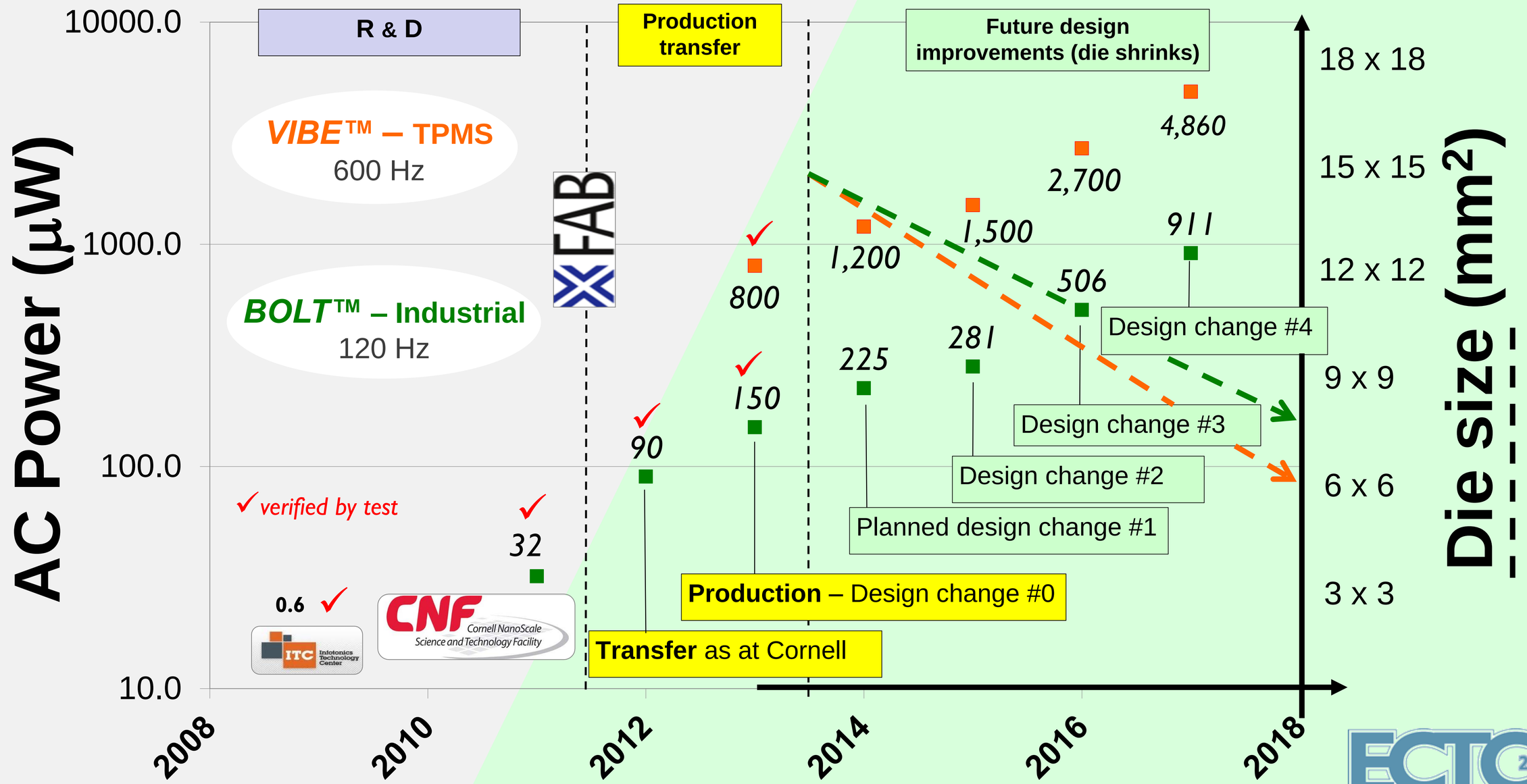
Superior power generation from small form-factors

Low cost, long life, high reliability and green energy

In volume production at X-FAB in Germany



Power/ chip size roadmap



Conclusion – Need for IoT applications

Assumption: A low cost, small wireless sensor node (including IC, sensor, and RF radio) **requires a low cost, small power source**

- ✓ Most current EH types are expensive
- ✓ Most current EH types are large

Bottom line:

- ✓ Need to develop more low cost, small EH sources
- ✓ Need more companies to produce such devices (need more investment $$$)

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