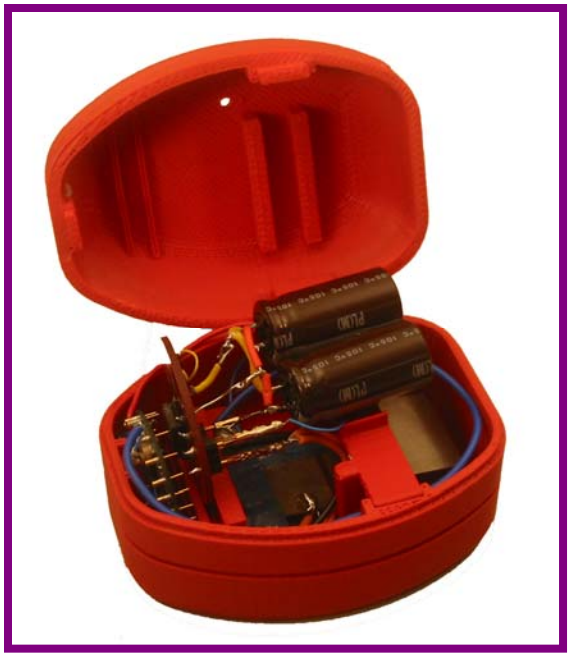
The way forward

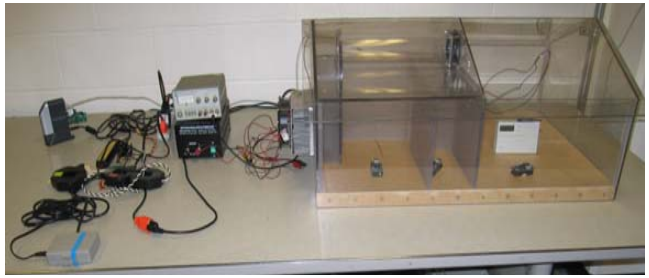
- Make DR technologies significantly less expensive and thus more appealing to customers (integrated/seamless)
- Accelerate innovations in the electricity sector by integrating technologies into “packages” that don’t exist in marketplace
- Package technology in forms/footprints that meet energy/DR requirements

Earlier successes

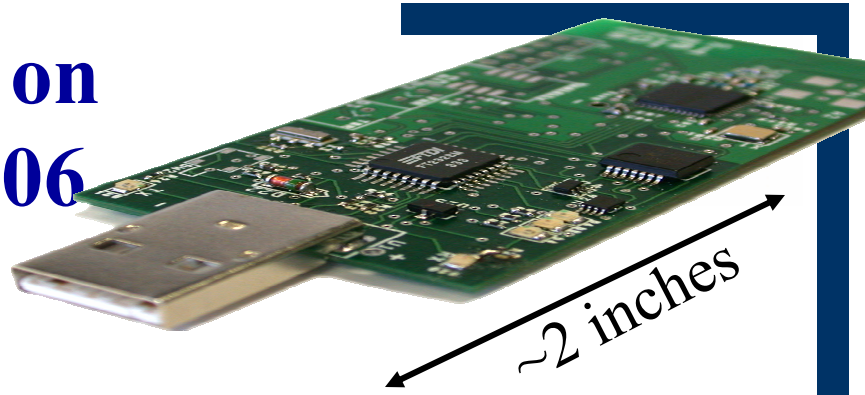
- **So far, the DR-ETD project has proven that microcomputers, cheaper radios, TinyOS, MEMS sensors, energy scavenging and WSNs are the enabling technology for a DR responsive system**
- **Enabling technology for**
  - New Meter
  - New Thermostat
  - New TempNode
    - Example of TempNode from 2004/5 publications



DR Applications running on "motes" made in 2003-2006



2003



2004/5

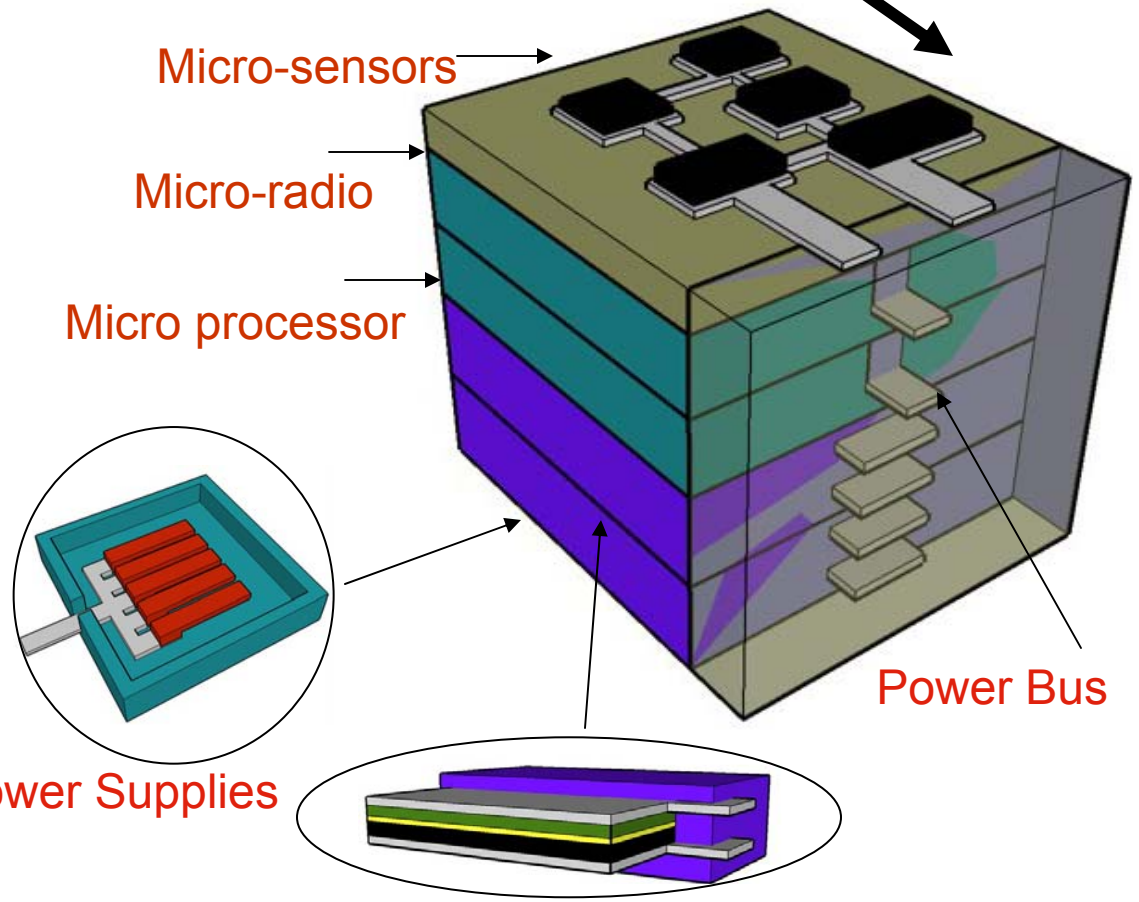
2006

2006 field deployments of REM multi-agent system with sense and actuation utilizing multi-hop wsn.

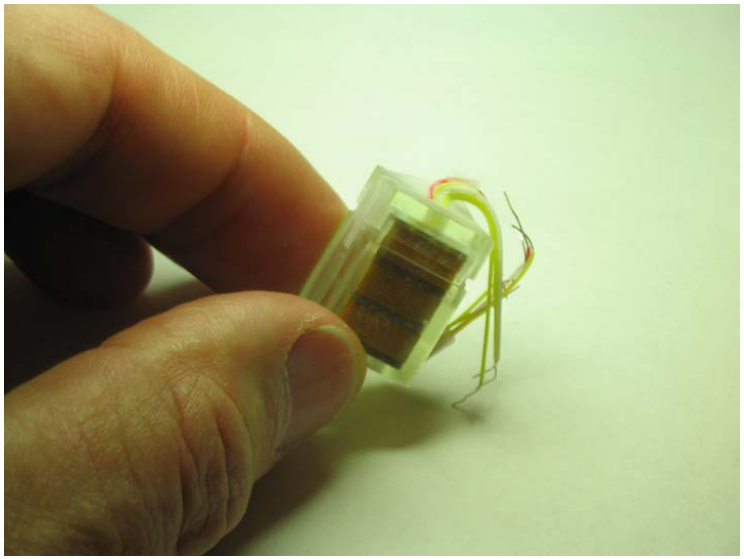
The way forward: Micro-integration by the millions = "super cheap"

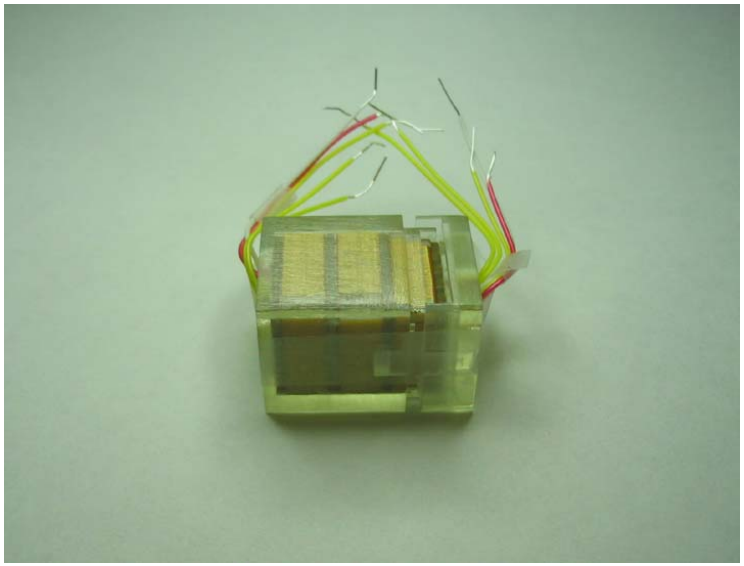
Software applications **run on the** **Hardware platforms**

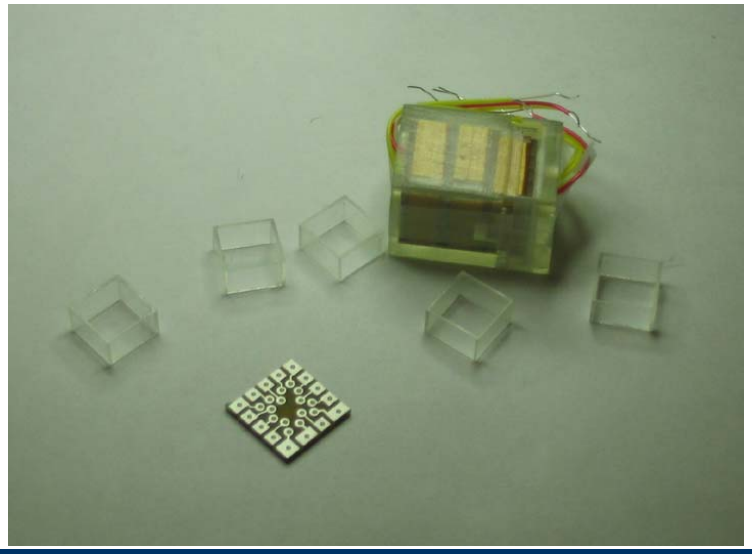
- **Control logic**
- **Learning algorithms**
- **Automation**
- **Distributed throughout all computers in the system**

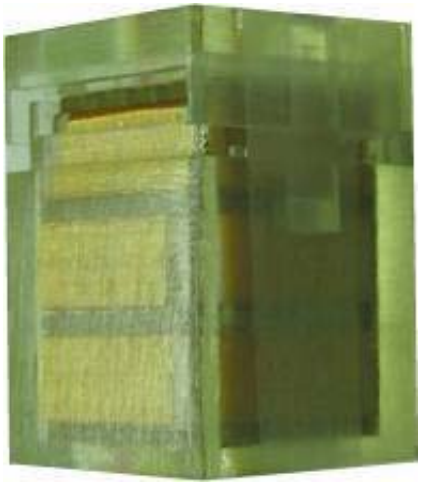


Beginning Micro-integration:
PicoCube January 2007

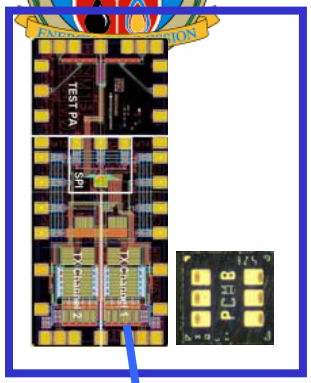




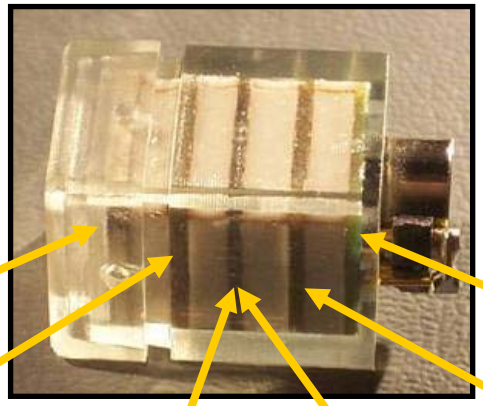




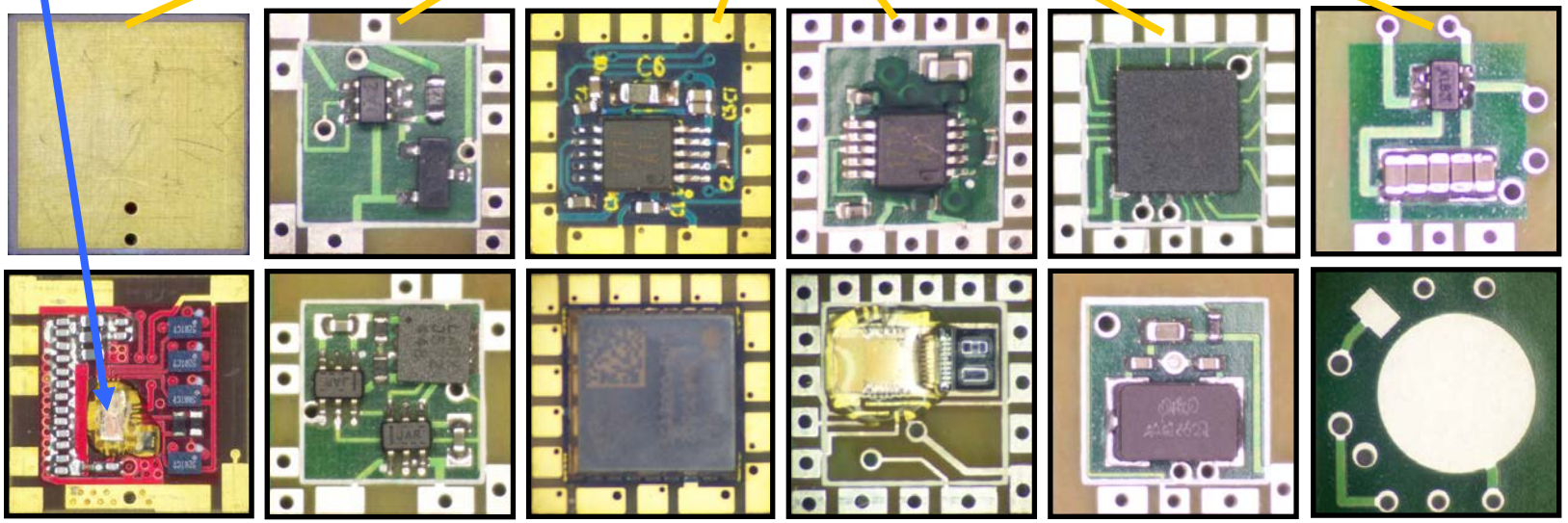
Micro-integration



radio
COB
die



- Stacked PCBs
- 1cm square



radio board
top/bottom

switch/power board
top/bottom

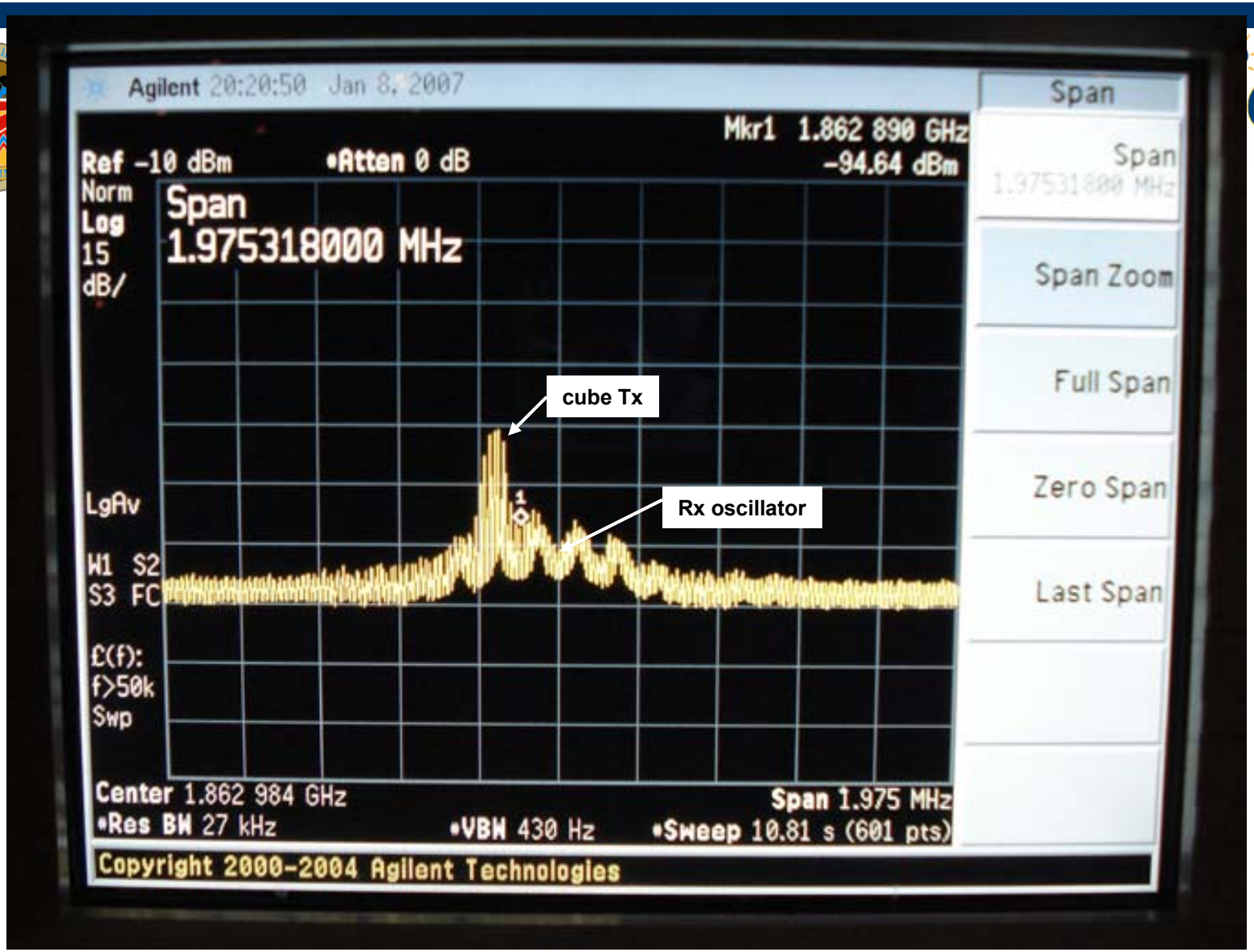
sensor board #2
top/bottom

sensor board #1
top/bottom

uC board
top/bottom

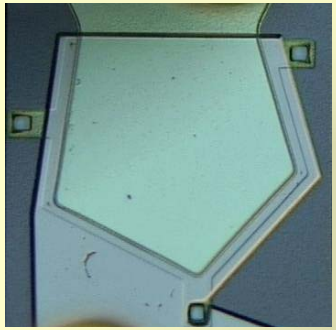
storage board
top/blank bottom

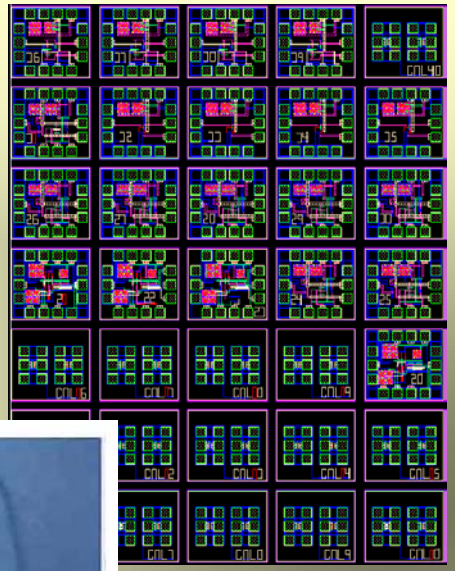
Graphic used for the hands-on part of the demo..



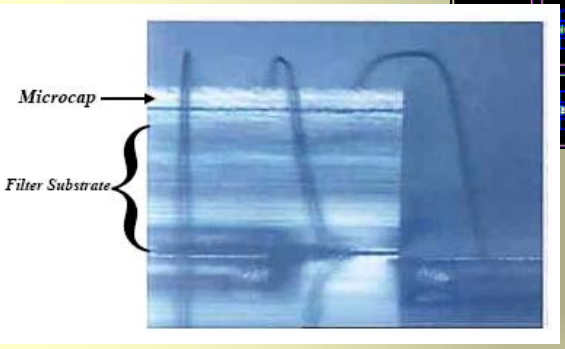
A spectrum analyzer snapshot showing the cube transmitter signal on top of the Rx oscillator signal.

Further Minimization/Packaging





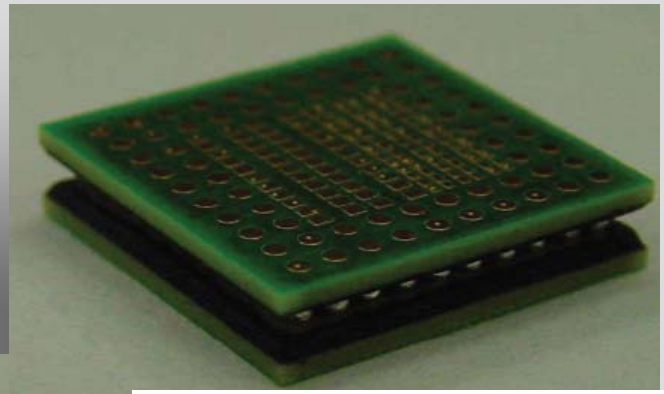
Micro-encapsulation allows co-design/packaging of FBAR resonators and CMOS circuitry

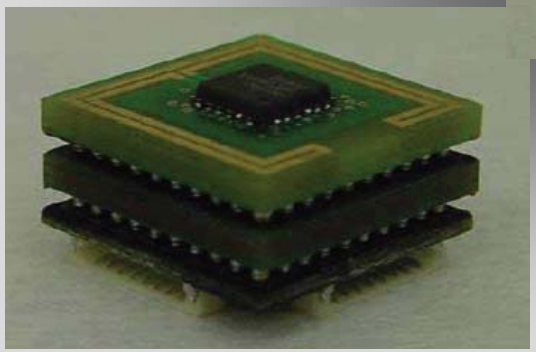


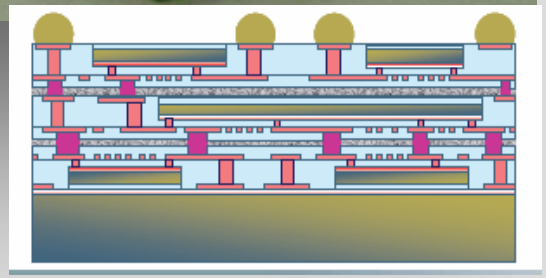
Joint project with Avago and UW

J. Richmond, M. Mark, N. Pletcher

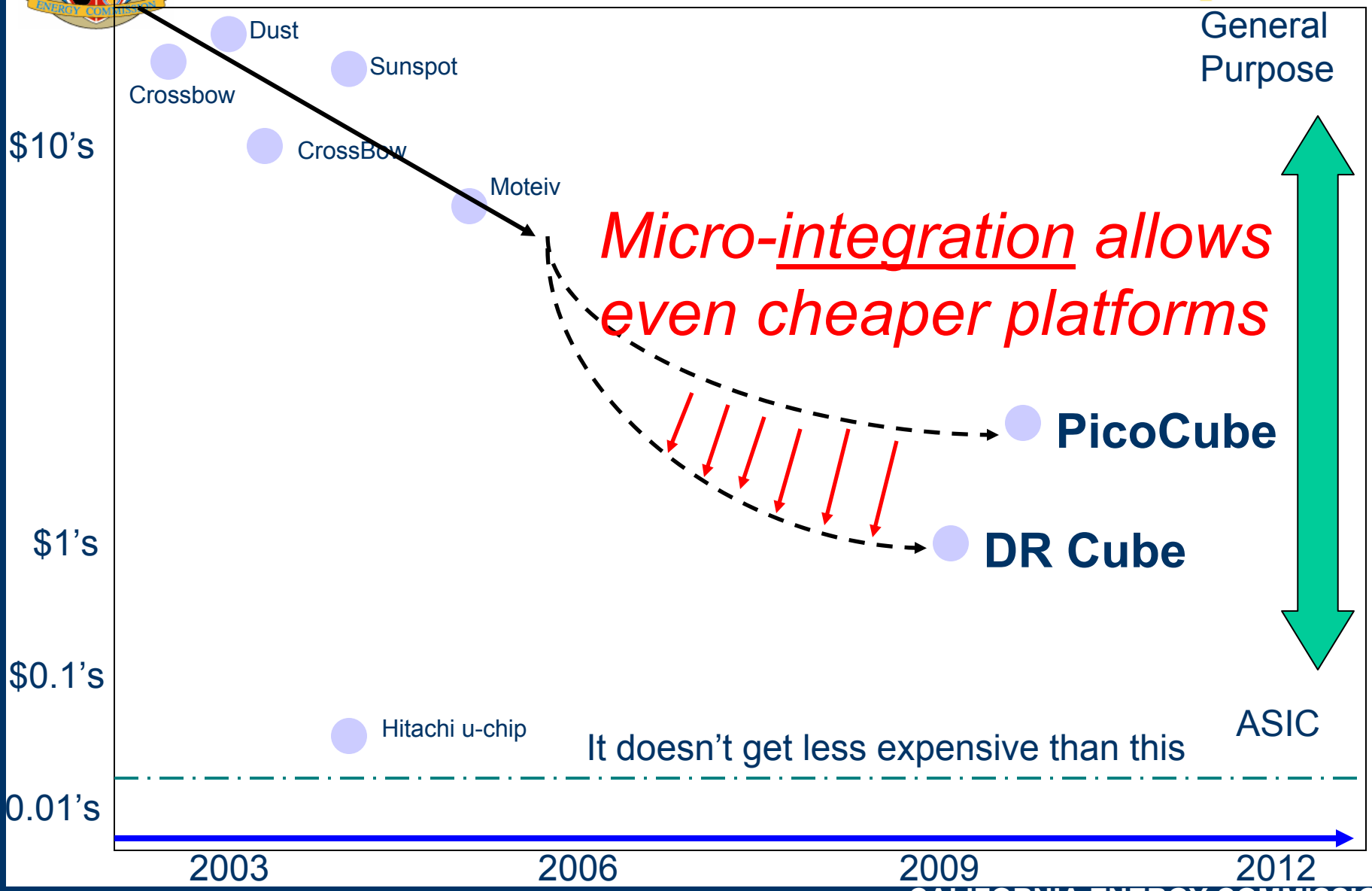
Exploring joint project with IMEC on 3D integration





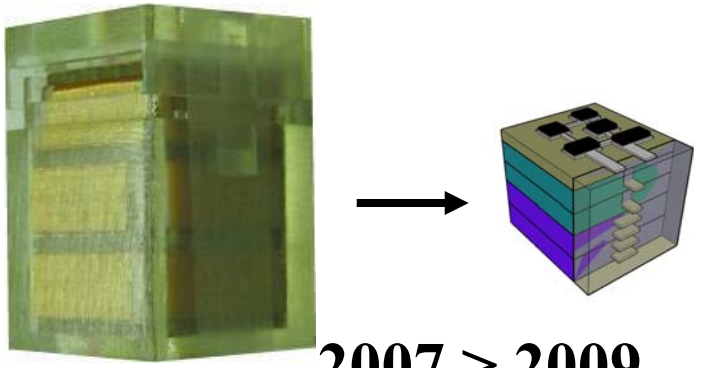


Pico Cube 2006 >> DR cube 2009



Summary: Micro-integration of Hardware, Software, & Applications

- **10x cost reduction, 10x capability increase**
- **Macro to micro UCB research**
  - Micro-computers
  - Micro-radios
  - Micro-sensors
  - Micro-power supplies
  - DR software applications
  - <$2 BOM per platform



2007 > 2009

- **Micro-integrated platform for meters, thermostats, temperature-nodes. Enables control and learning.**

The way forward

- So far, the DR-ETD project has proven that microcomputers, cheaper radios, TinyOS, MEMS sensors, energy scavenging and WSNs are the enabling technology for a DR responsive house
- Now we must make DR significantly less expensive and more appealing to customers (integrated/seamless)
- Accelerate innovations in the electricity sector by integrating technologies into “packages” that don’t exist in marketplace
- Package technology in forms/footprints that meet energy/DR requirements