Synthetic Insects

Kris Pister

Professor EECS, UC Berkeley
Founder & Chief Technologist, Dust Networks

Outline

The past

Micro-robots → Smart Dust

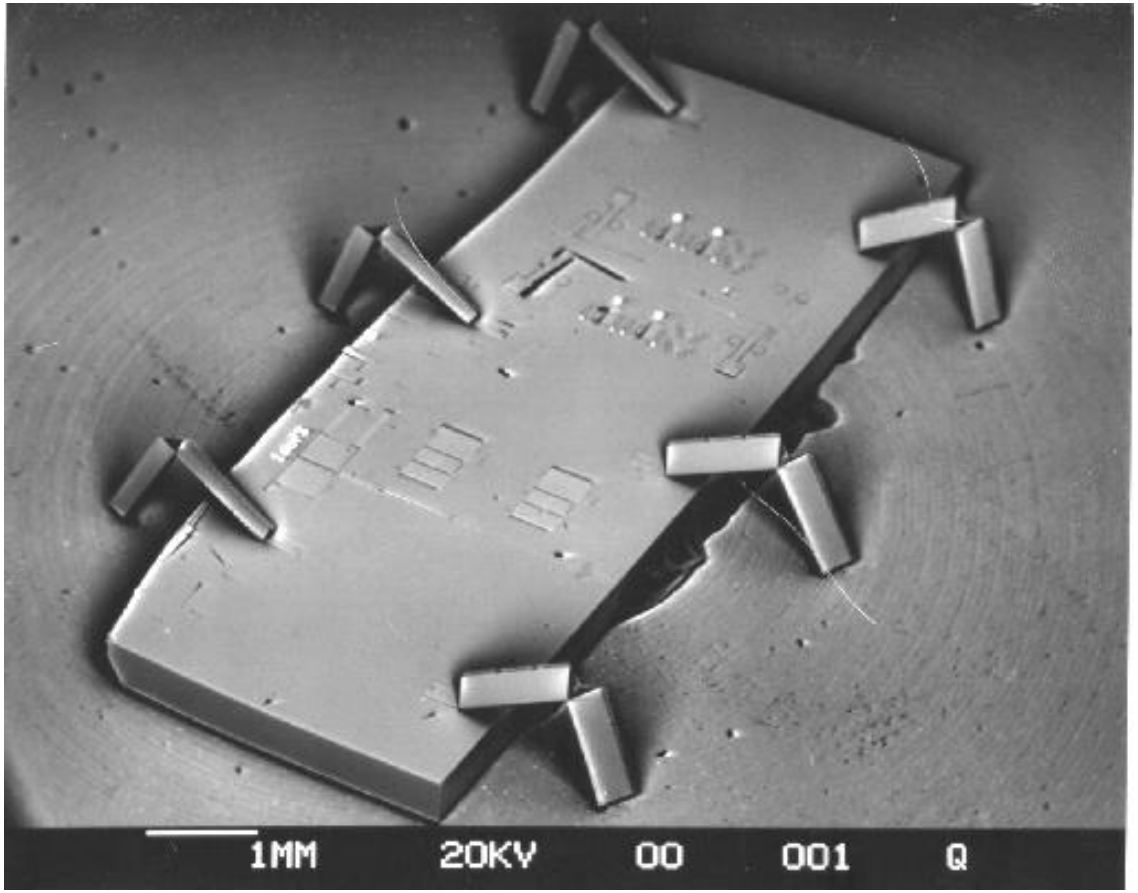
The present

Smart Dust → IoT

The future

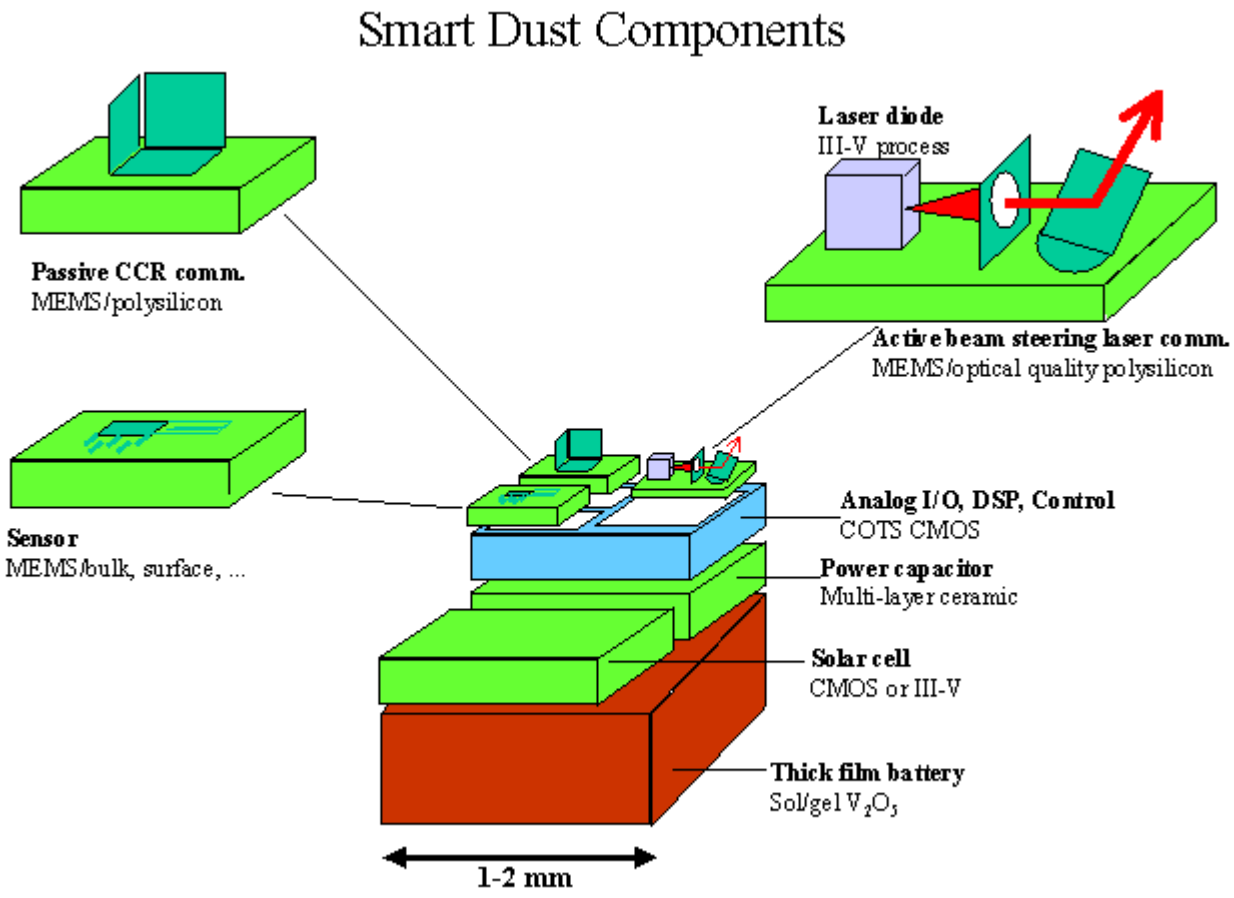
IoT → Micro-robots

Micro Robots, 1995



Goal: Make silicon chips that walk. (Richard Yeh)

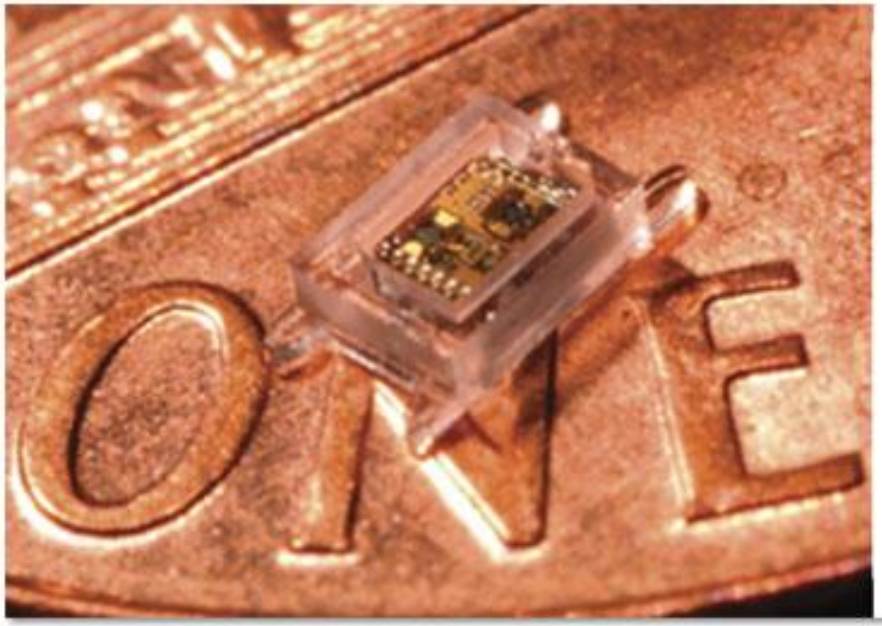
Smart Dust, 1997

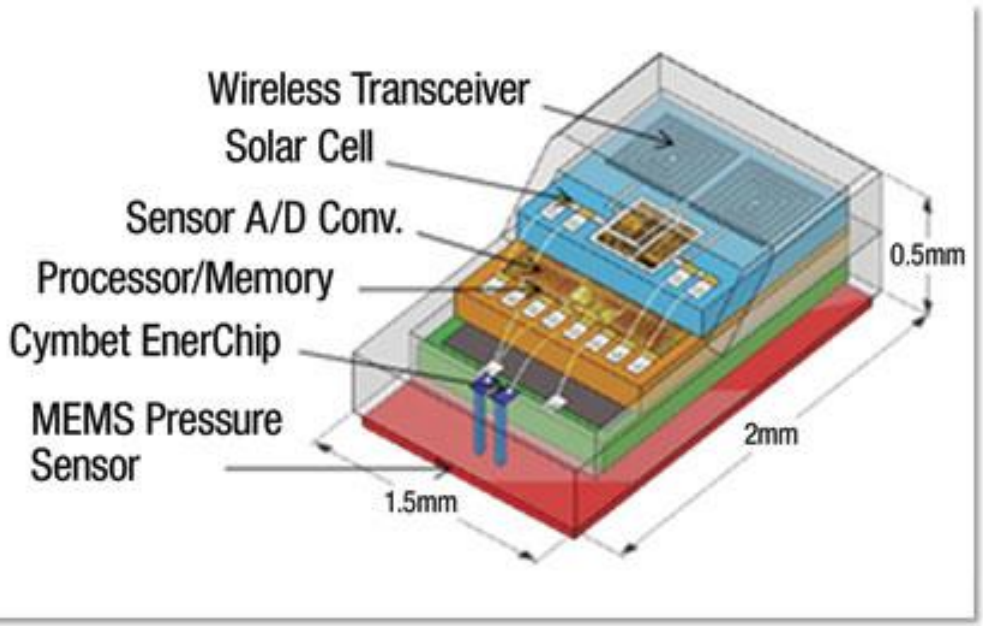


Smart Dust, 2001

U. Michigan, 2010

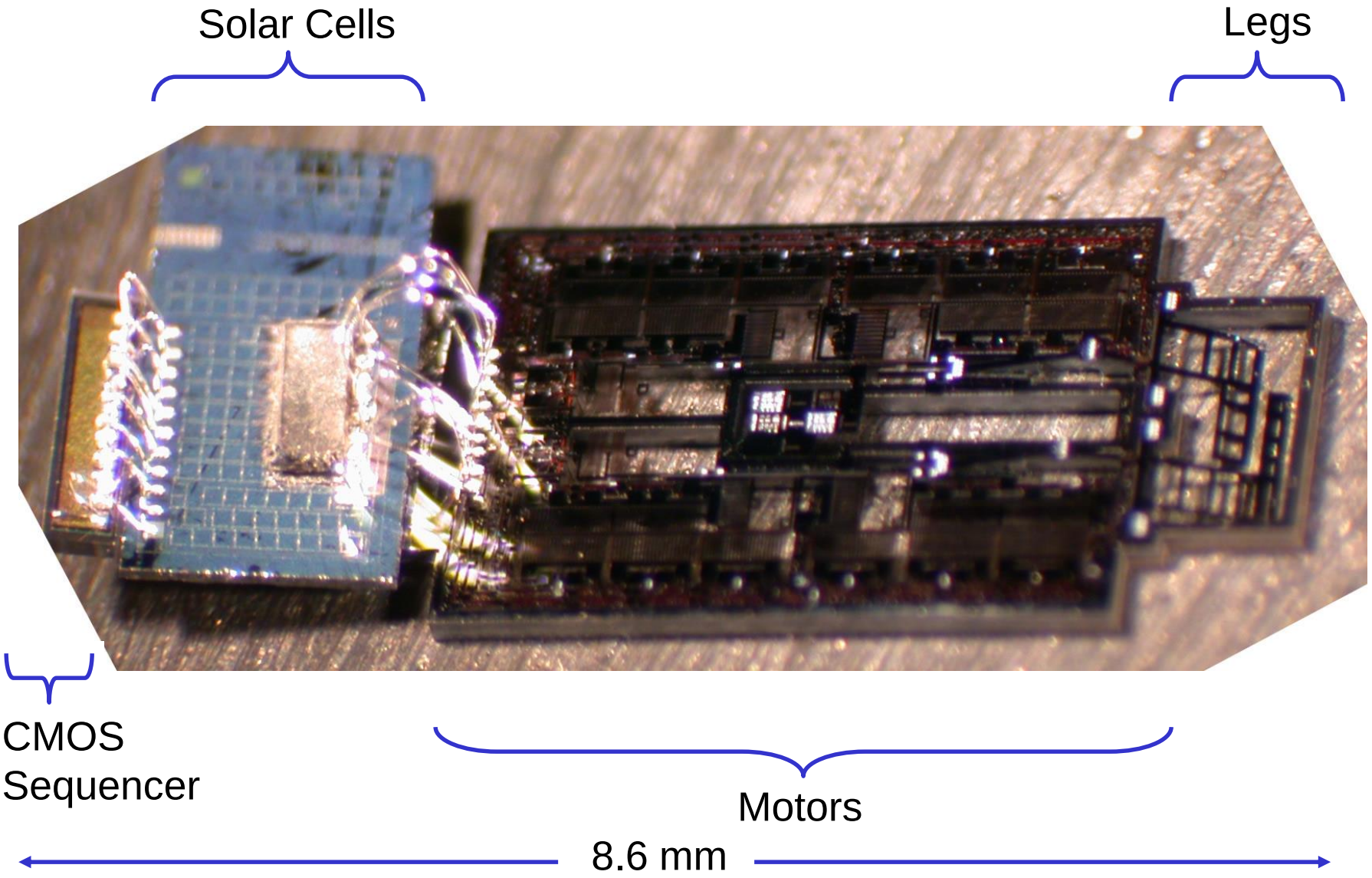
- Wireless intra-ocular pressure sensor
- $2mm^3$!

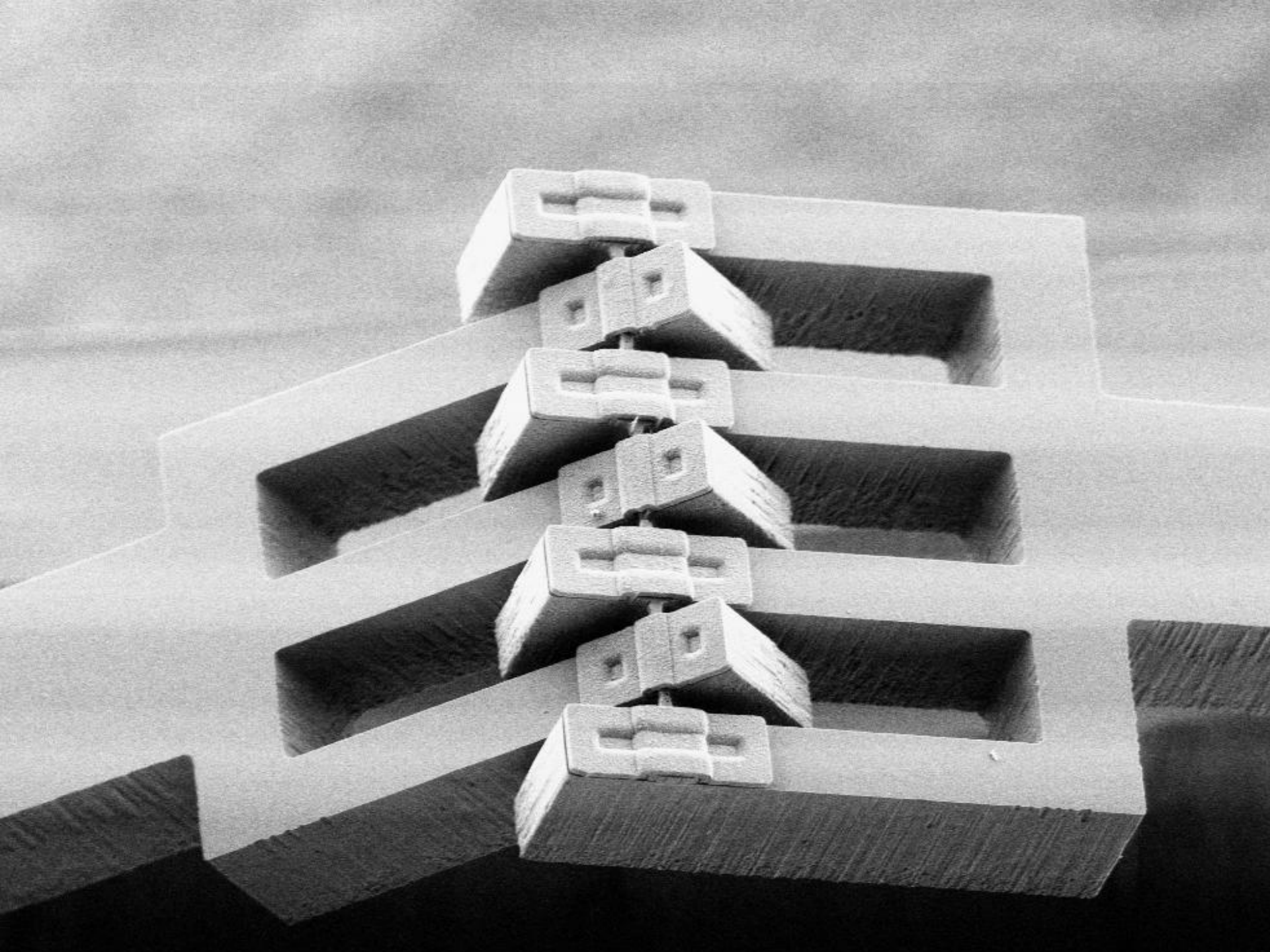


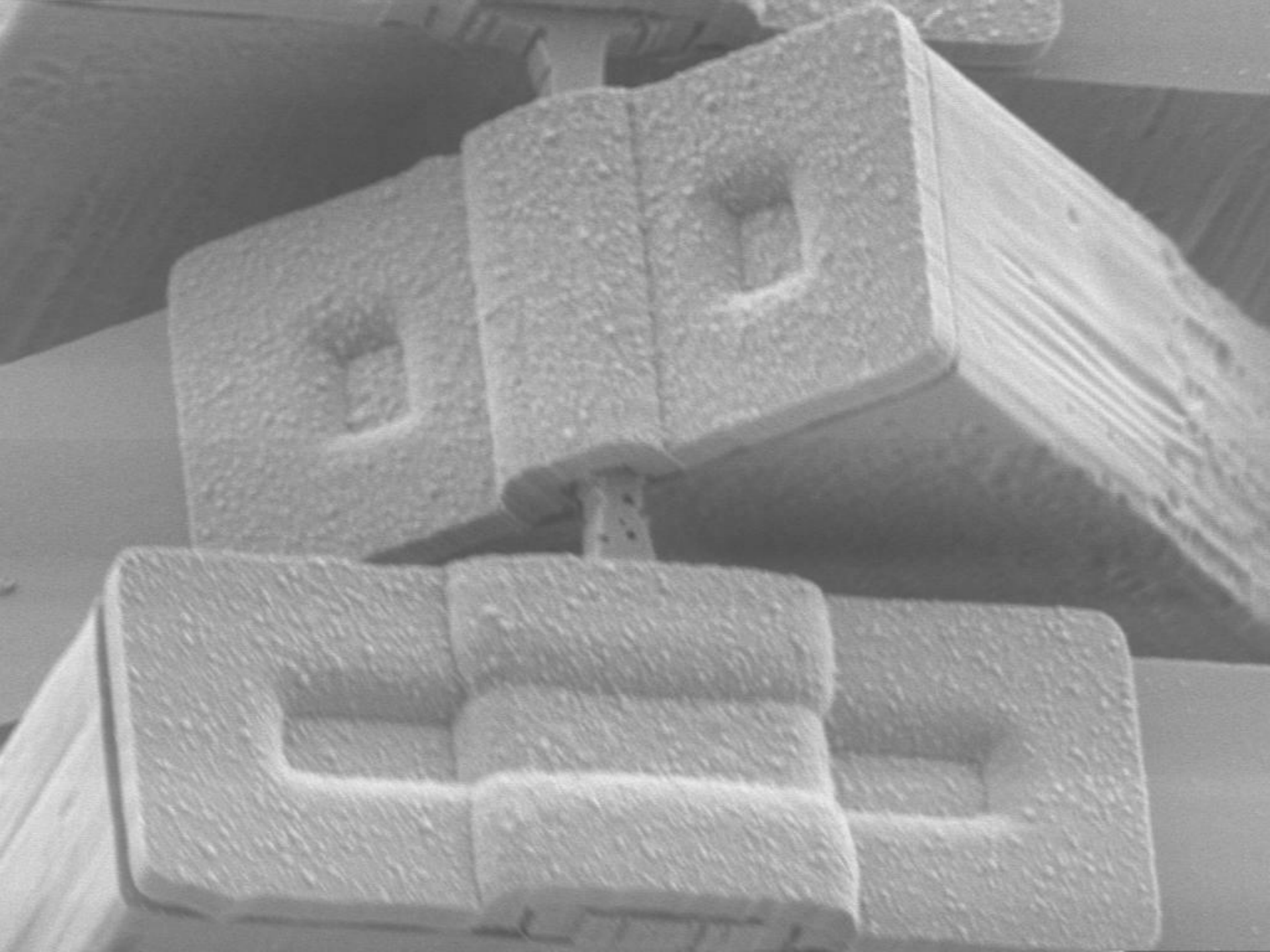


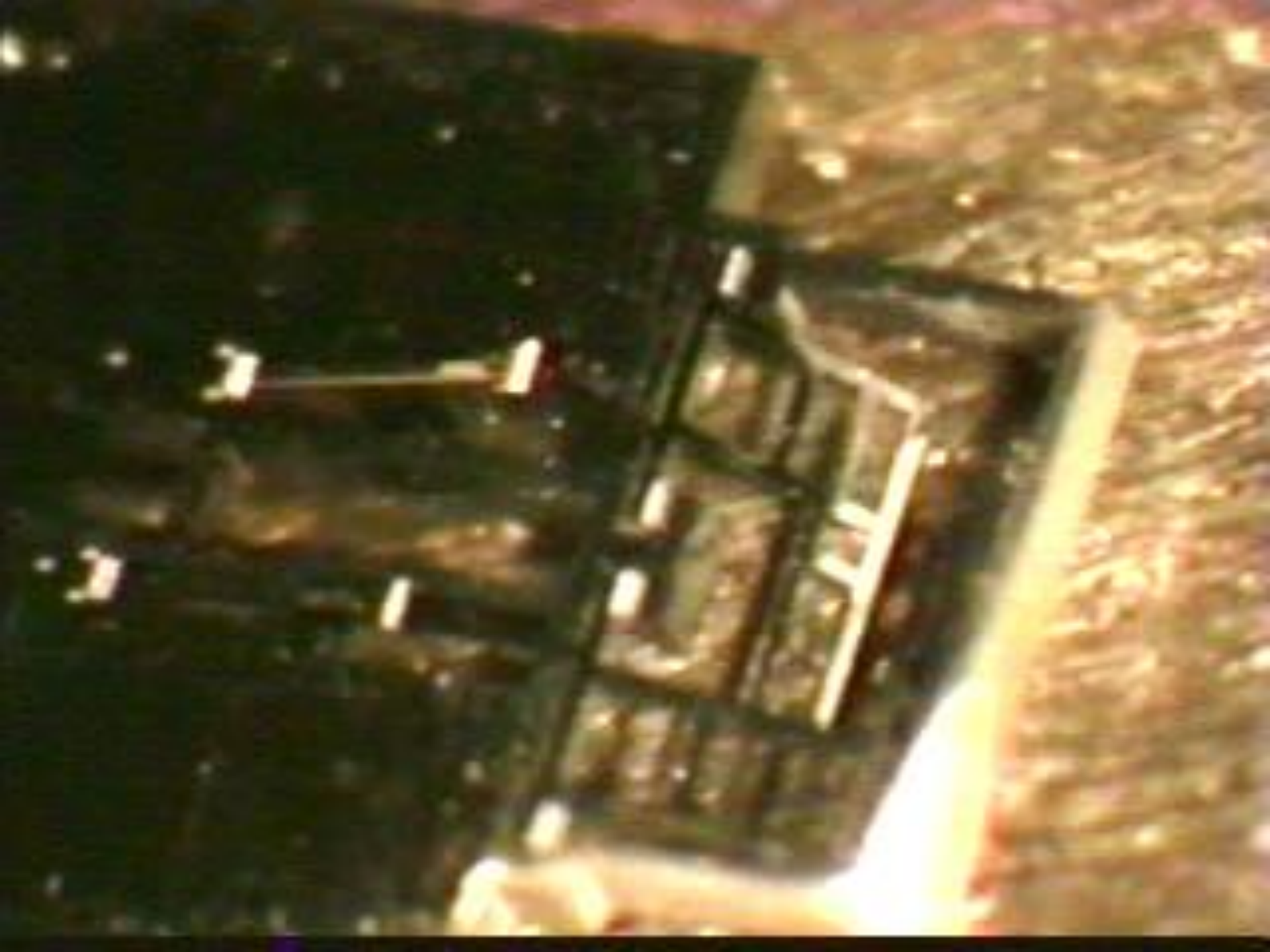
Autonomous Microrobot (2003)

Seth Hollar, Anita Flynn, Sarah Bergbreiter

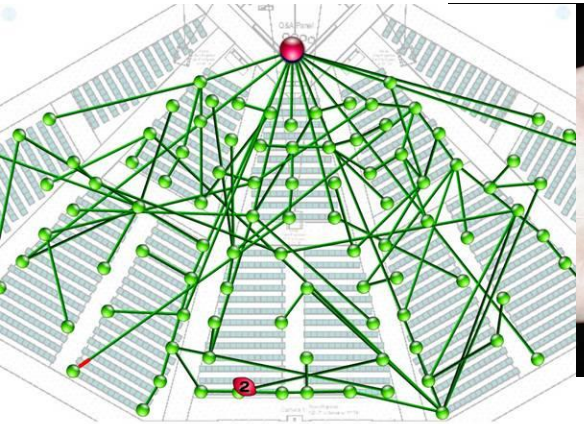


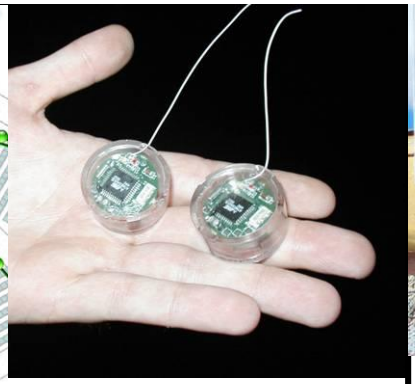






COTS Dust – 2001



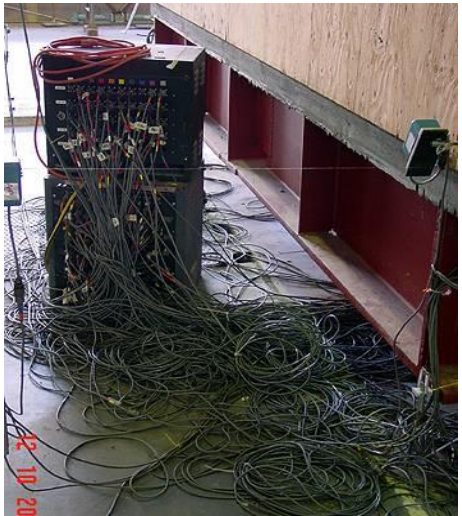


Intel Developers Forum, live demo 800 motes, 8 level dynamic network,

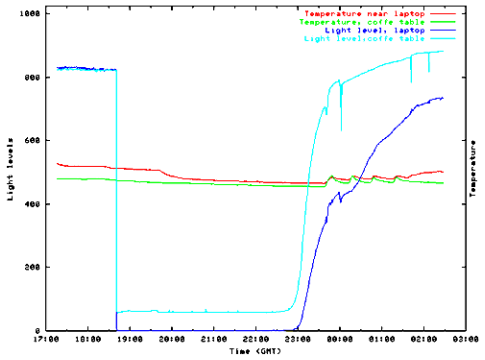
Motes dropped from UAV, detect vehicles, log and report direction and velocity

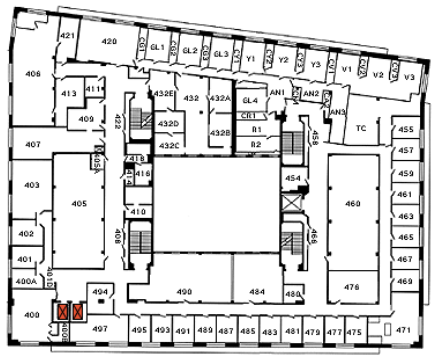
Seismic testing demo: real-time data acquisition, $200 vs. $5,000 per node

vs.

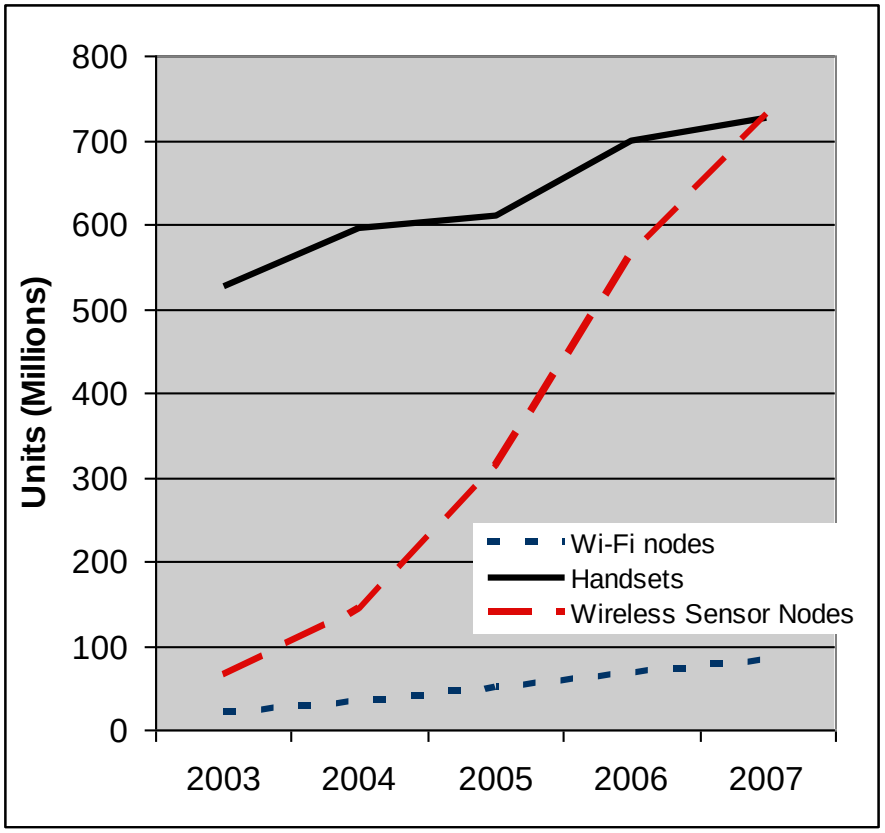


50 temperature sensors for HVAC deployed in 3 hours. $100 vs. $800 per node.





IoT Hype, 2003



Source: InStat/MDR 11/2003 (Wireless); Wireless Data Research Group 2003; InStat/MDR 7/2004 (Handsets)

Predicted $8.1B market for Wireless Sensor Networks by 2007

2000--2010 IoT frenzy

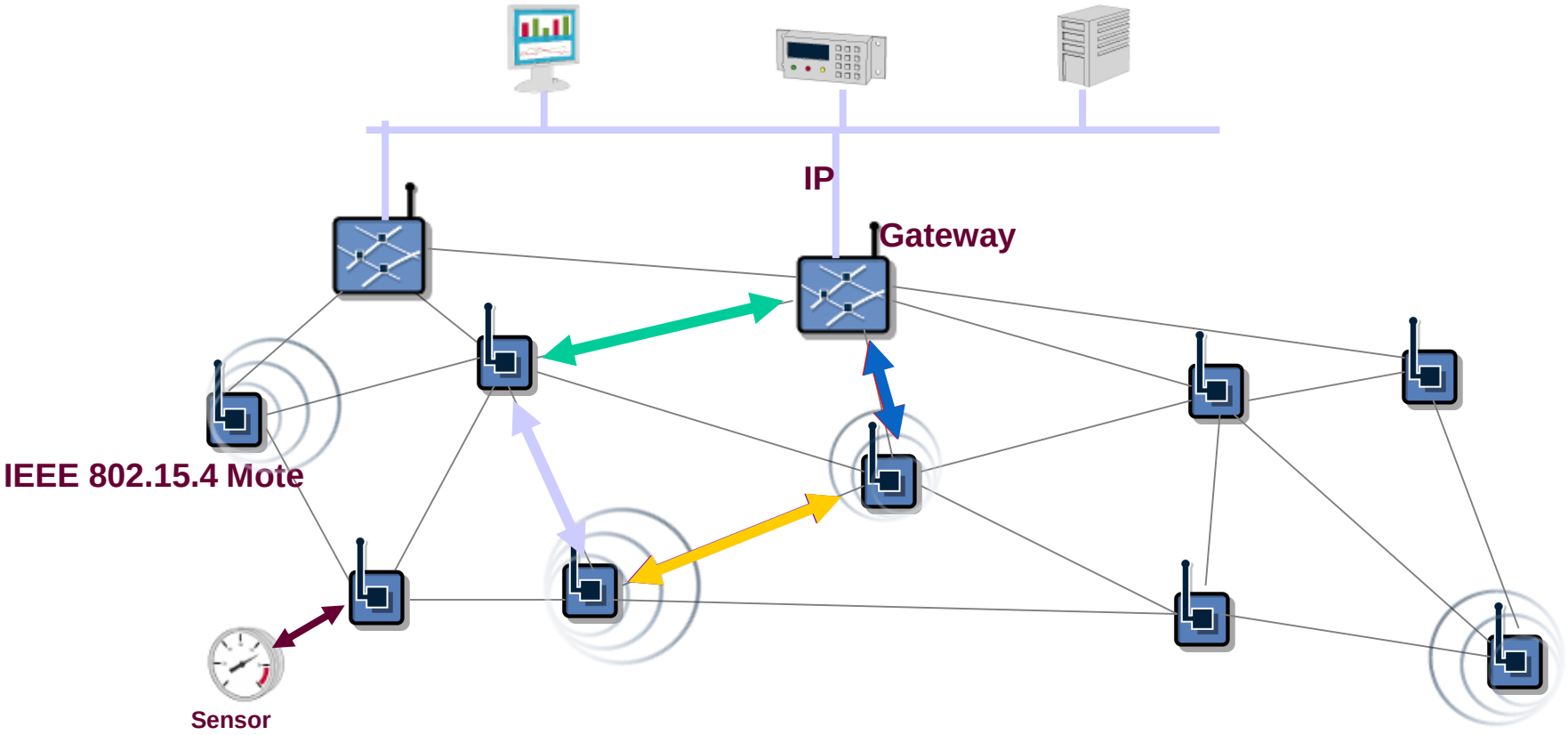
- ~100 startups
- ~$1B in venture capital
- Almost no success stories

Building a *reliable* low-power wireless sensor network is **hard**.

Dust Networks

- Founded July 2002
- Focused on reliability, power consumption
- Developed TSMP
  - Time Synchronized Mesh Protocol
  - >99.9% reliability
  - Lowest power per delivered packet

Mesh Networking



- Time Synchronized for **low power** & **scalability**
  - **All nodes run on batteries, for 5-10 years**
- Channel Hopping and full mesh for **reliability**
  - **99.999% "best effort" packet delivery**

Emerson Process offerings, 2007

We Offer The Widest Portfolio Of Wireless Products In The Industry

Shipping Now

Shipping in 2008

Pressure

Temperature

Level

Flow

Vibration

Density / Viscosity

Multi-point Temperature

Gas Specific Gravity

Gas & Liquid Analysis

Oil & Gas Remote Control

Device 'Stranded Diagnostics'

Field Device Communicator

Discrete

Radar Level

Wireless Gateway

Level Switch

Valve Positioners

Asset Management Software

Middle East Desert Sand Storms

-48 ˚F with a wind chill of -70 ˚F Wireless Transmitter on the North Slope of Alaska

In Alaska, measures leak detection of pipeline running under a road mile from nearest device/gateway.

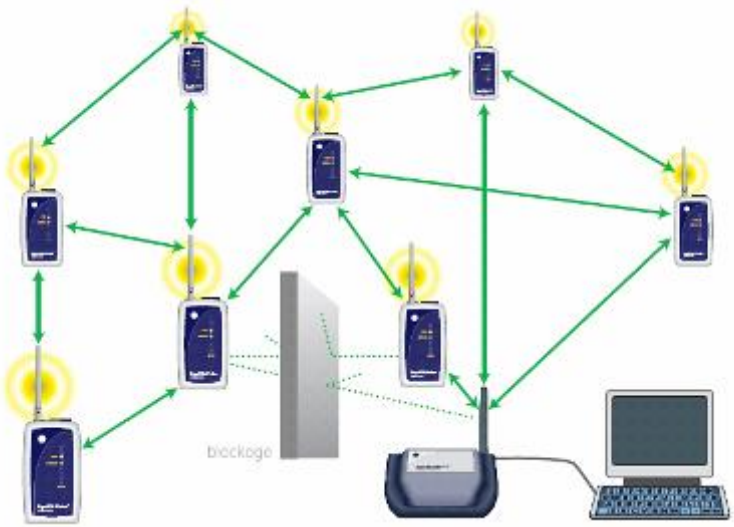
Rotating filter with DP transmitter going down in the steel tank and is sometimes immersed.

FPSO – Floating Platform, Storage and Offloading

Pharmaceutical Process Monitoring - GE

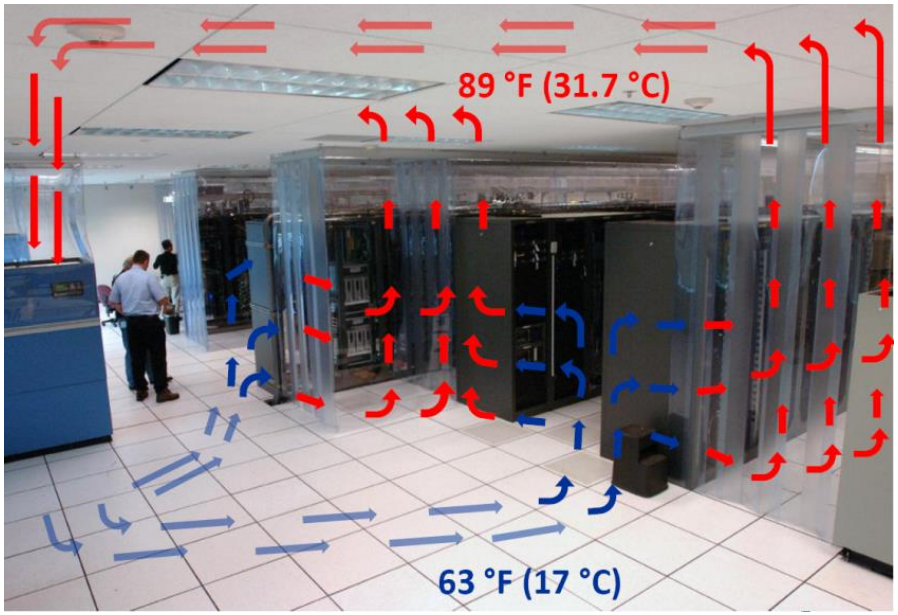
GE Sensing

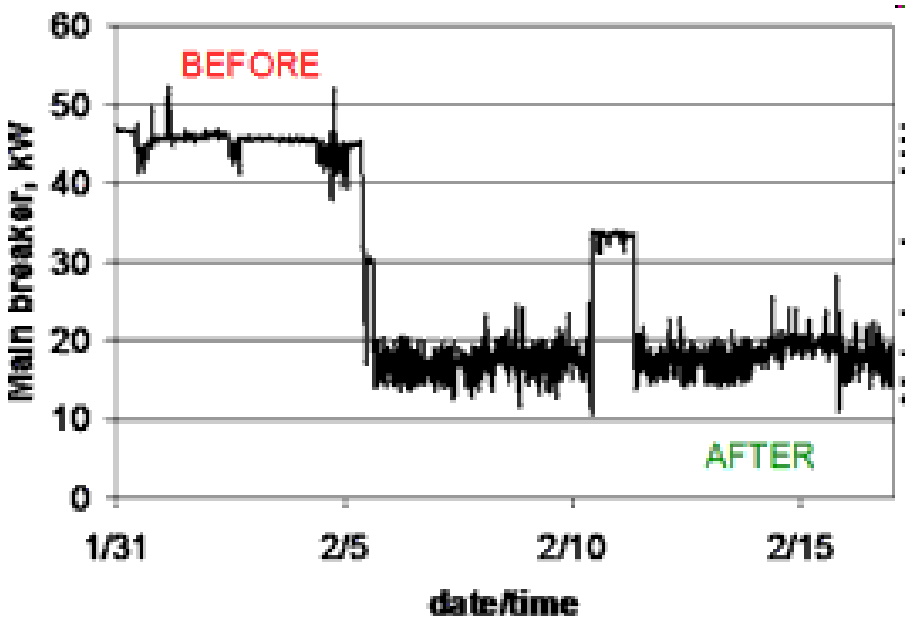
RF ValProbe™



Smart Building: Vigilent

- HVAC optimization to conserve energy
- Wireless temperature sensing
- Improved control algorithm
- No new motors/valves/control points





Smart Cities: Streetline Networks

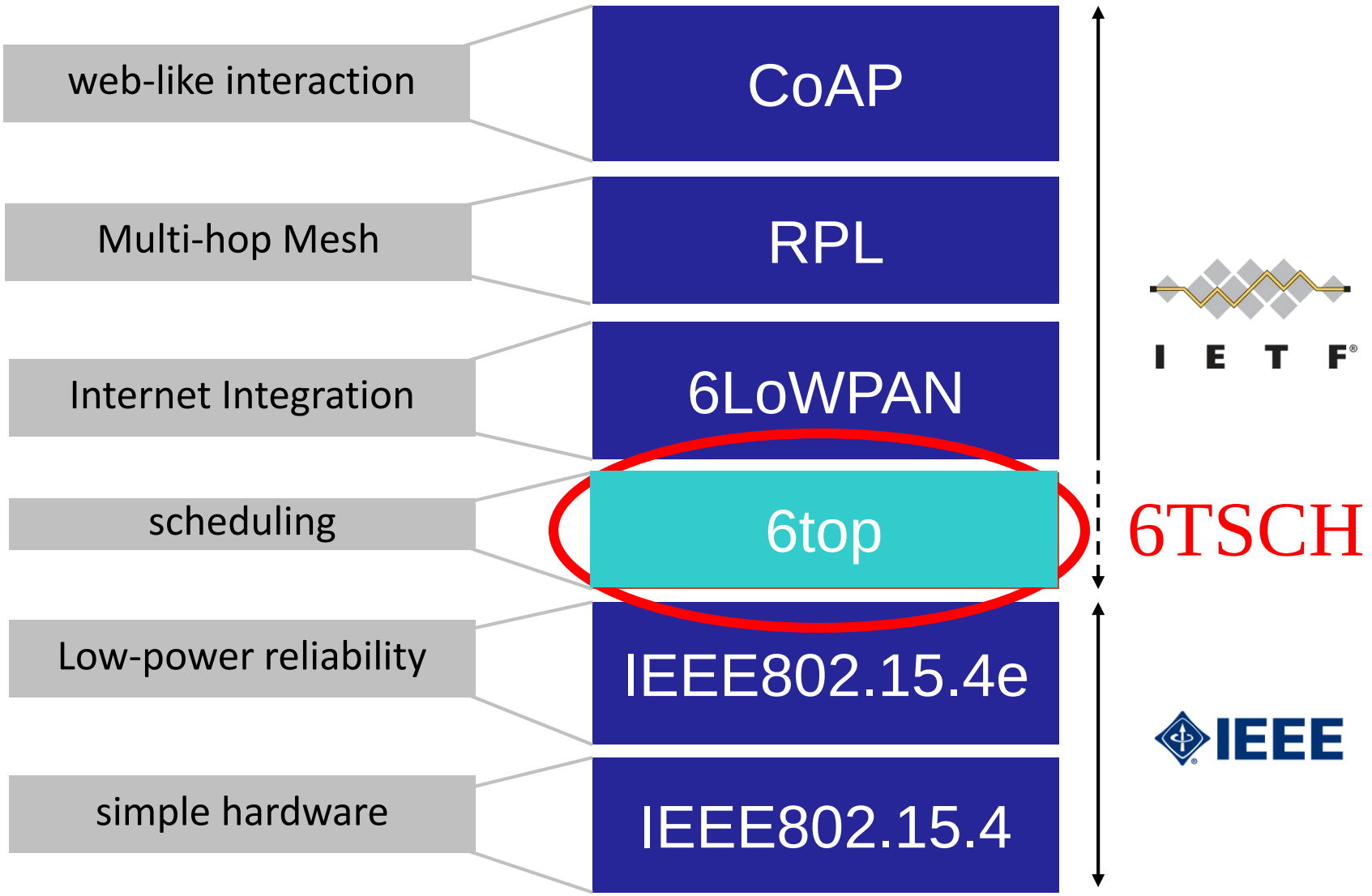
Smart City: Parking, Streetline Networks

STREETLINE

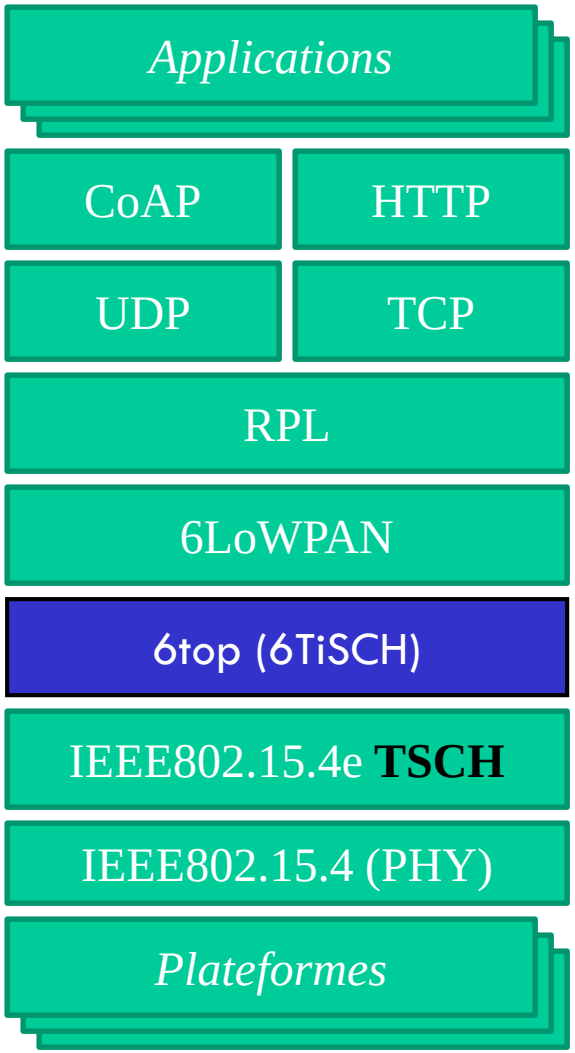
Find parking, pay, avoid ticket, find car

STREETLINE

A decade of standards



OpenWSN.berkeley.edu

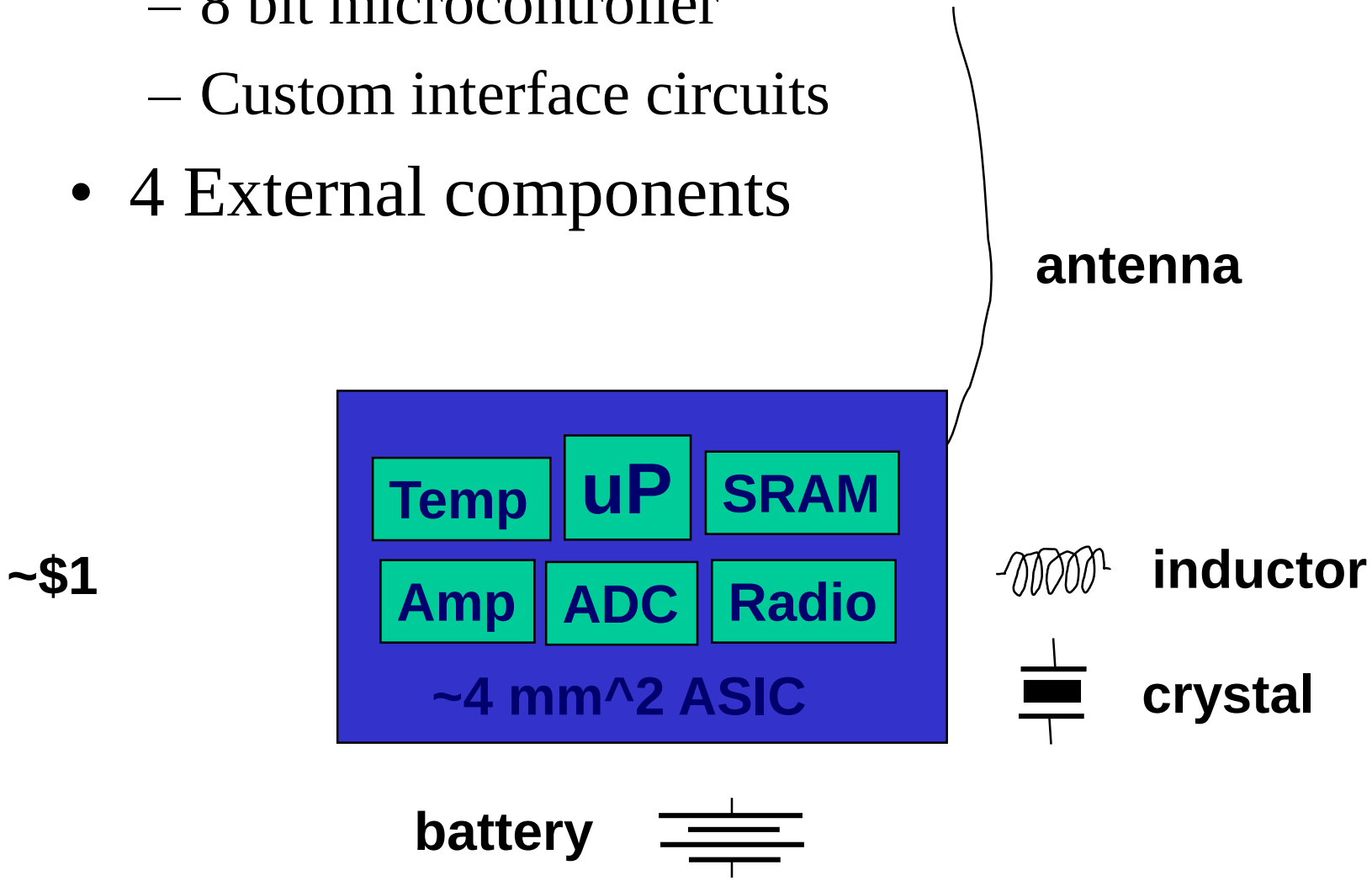


OpenWSN is

- Cloud-based Wiki and ticketing
- Source code on GitHub
- Ported to 10 platforms

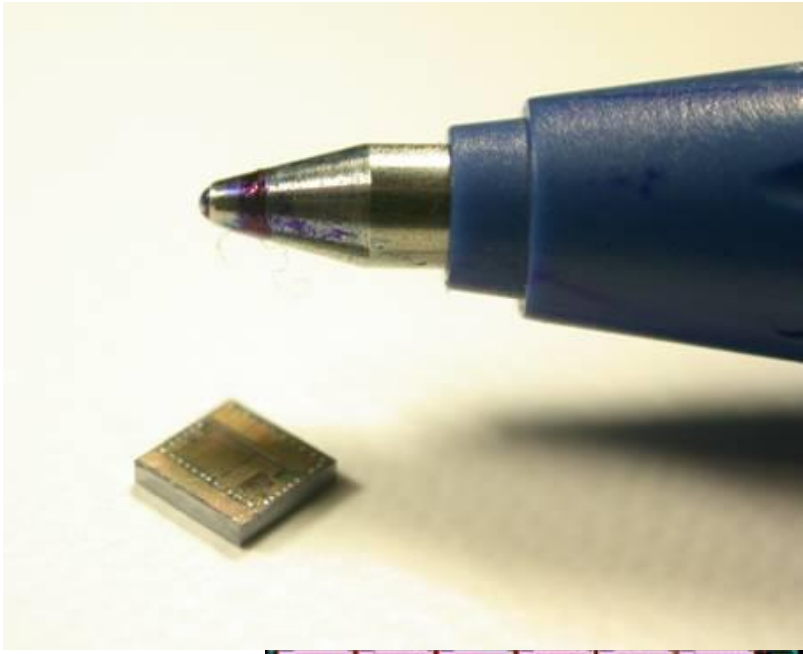
UCB RF Mote on a Chip (1999)

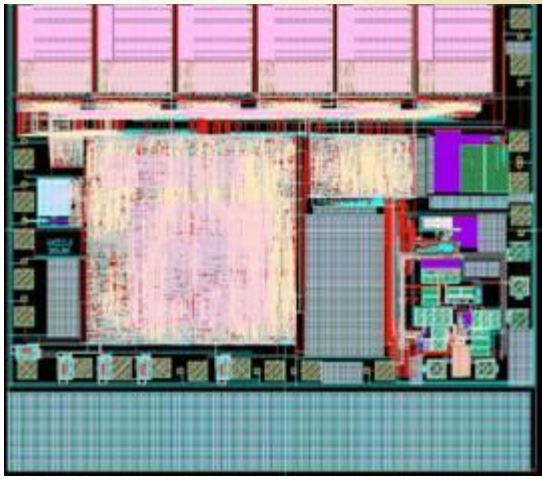
- CMOS ASIC
  - 8 bit microcontroller
  - Custom interface circuits
- 4 External components



2002 UCB Hardware Results

- 2 chips fabbed in 0.25um CMOS
  - "Mote on a chip" worked, missing radio RX (Jason Hill)
  - 900 MHz transceiver worked
- Records set for low power CMOS
  - ADC (Mike Scott)
    - 8 bits, 100kS/s
    - 2uA@1V
  - Microprocessor (Brett Warneke)
    - 8 bits, 1MIP
    - 10uA@1V
  - 900 MHz radio (Al Molnar)
    - 20kbps, "bits in, bits out"
    - 0.4mA @ 3V



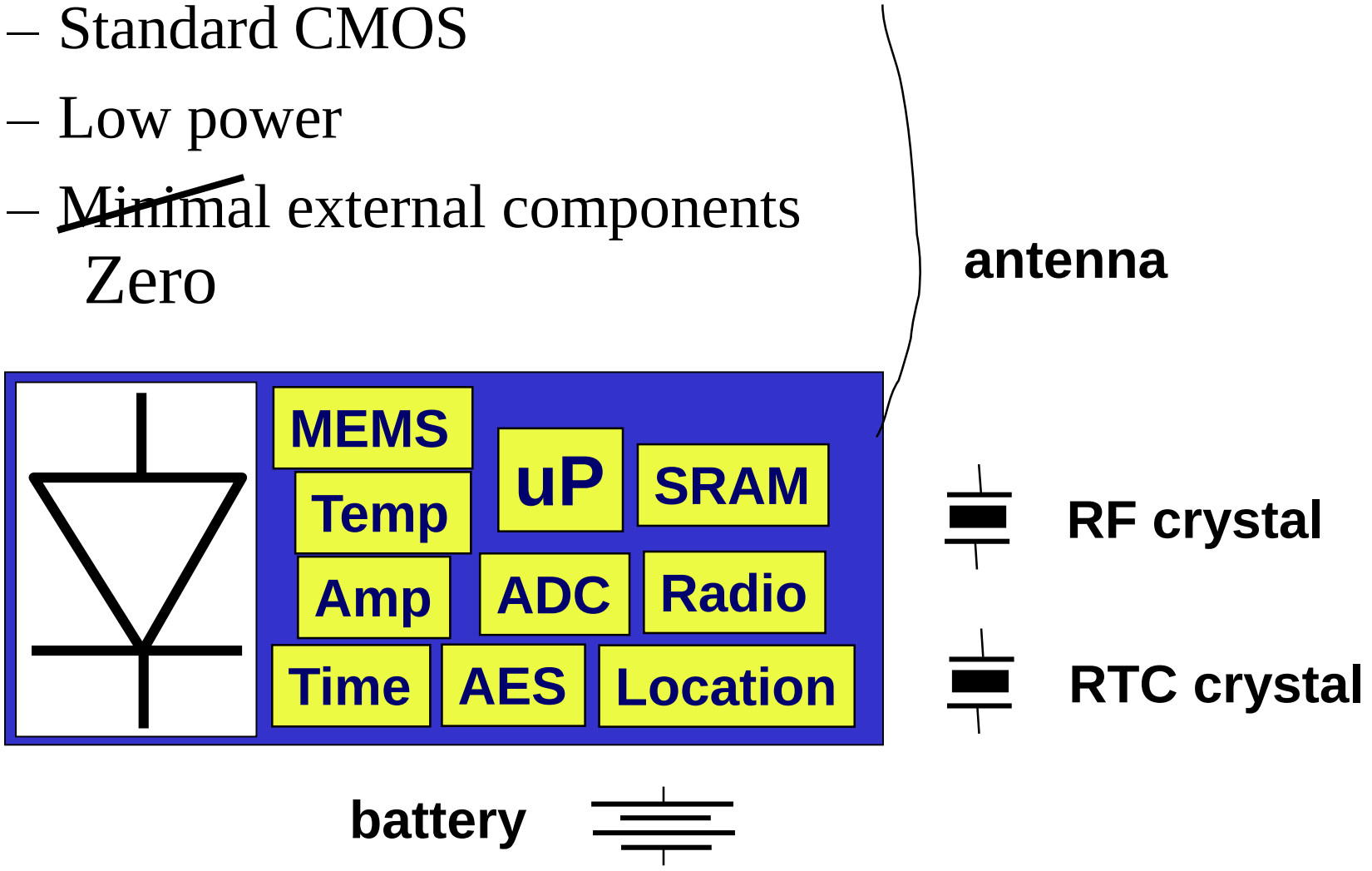


Vendors selling single-chip motes

- Atmel
- Freescale
- Linear (Dust)
- Silicon Labs (Ember)
- ST
- TI

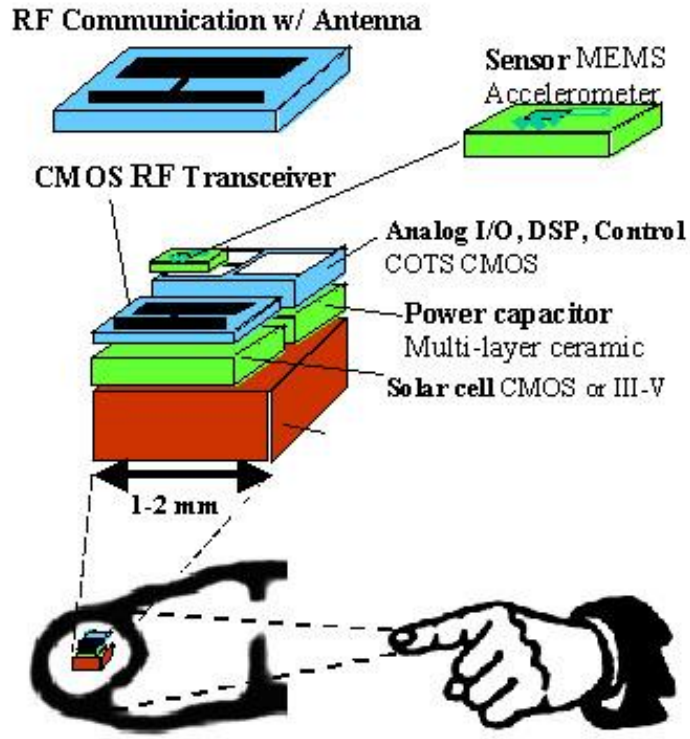
Single-chip mote, take 2

- Goals:
  - Standard CMOS
  - Low power
  - ~~Minimal~~ external components
    Zero

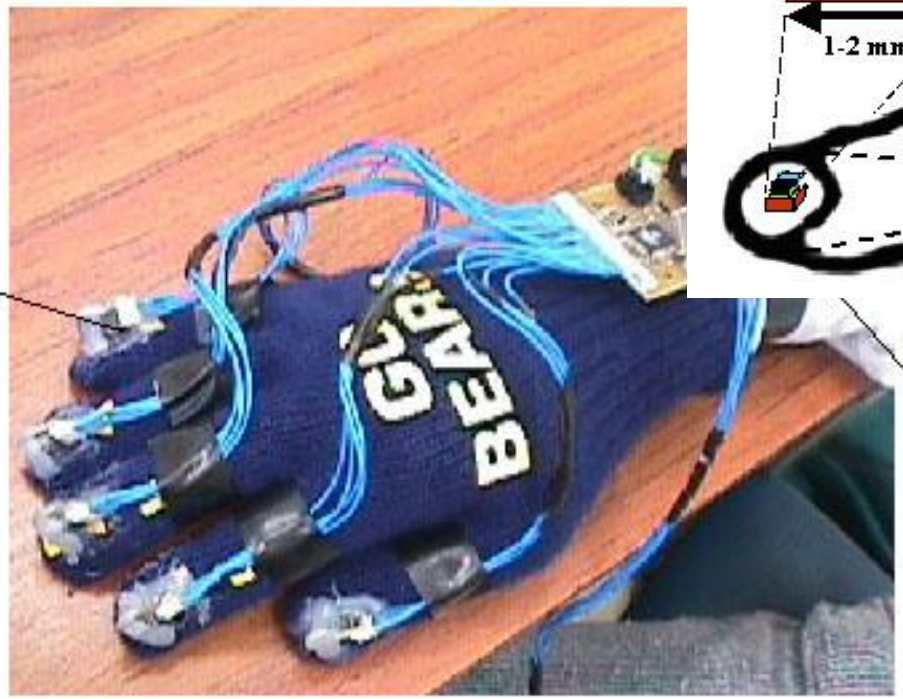


Acceleration Sensing Glove, 1999

- Accelerometers on fingertips
- Wireless on wrist
- Basic keyboard, mouse motions
- Mouse, keyboard, sign language



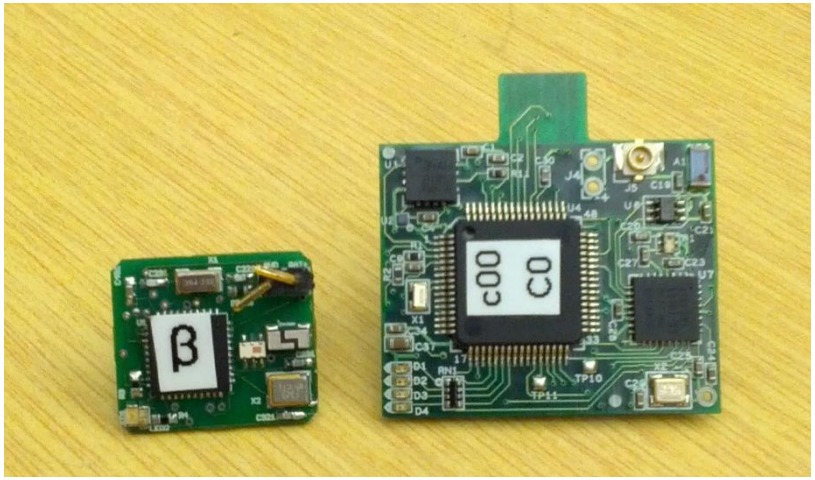
Finger accelerometer

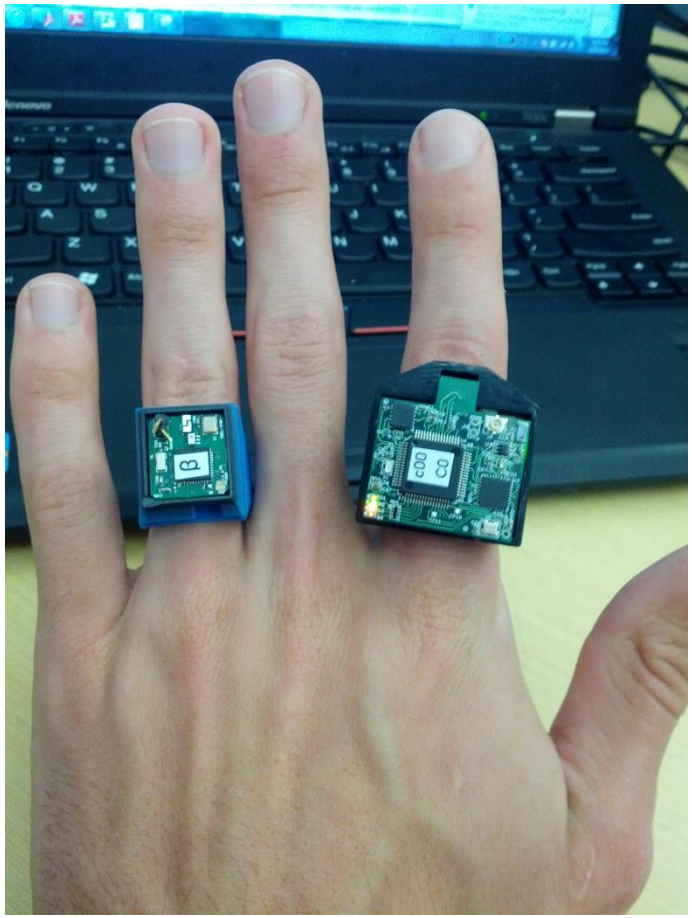


Wrist controller, RF transmitter and battery pack

GINA

- 9 axis inertial measurement
- Ring form factor
  - Ring GINA

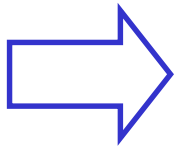


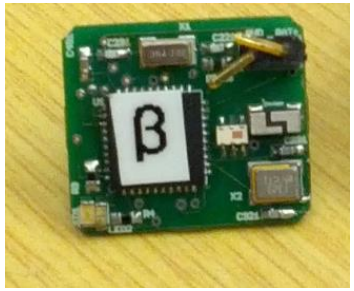


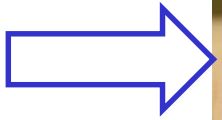
Mehta, Greenspun, Chraim

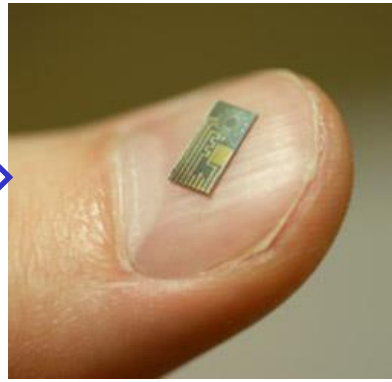
Progression

- Single chip mote
- Finger tip accelerometers
- Virtual keyboard

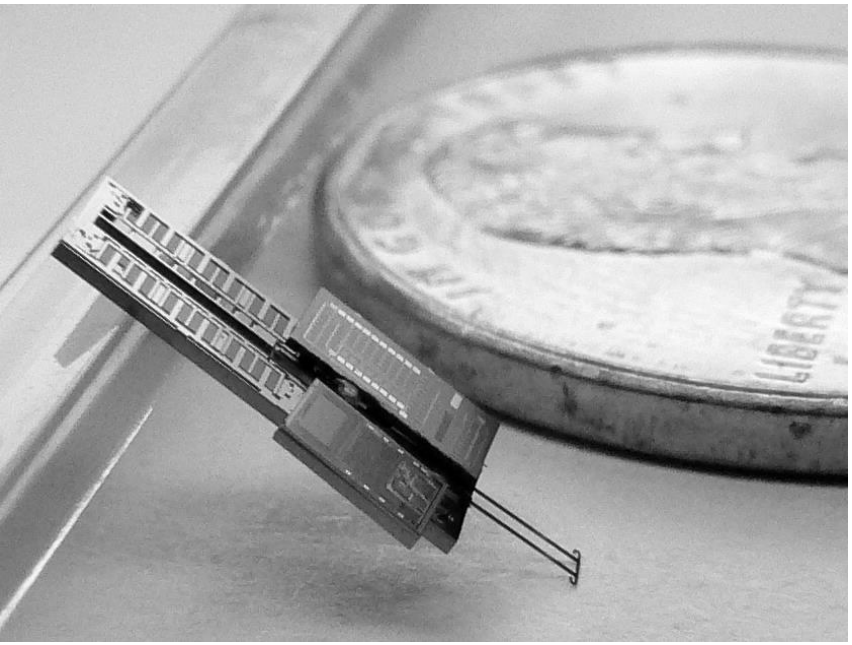


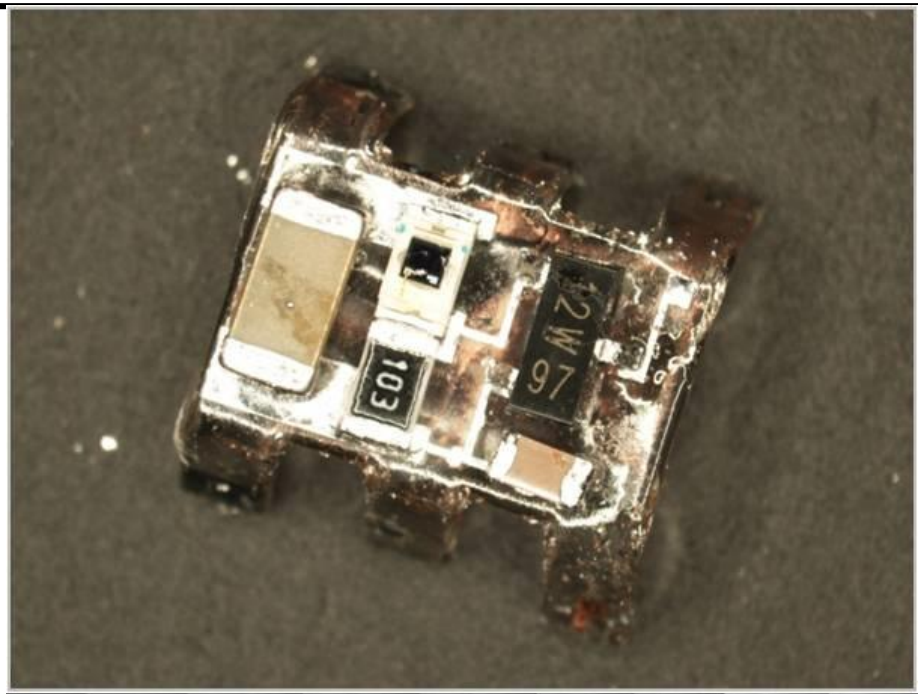


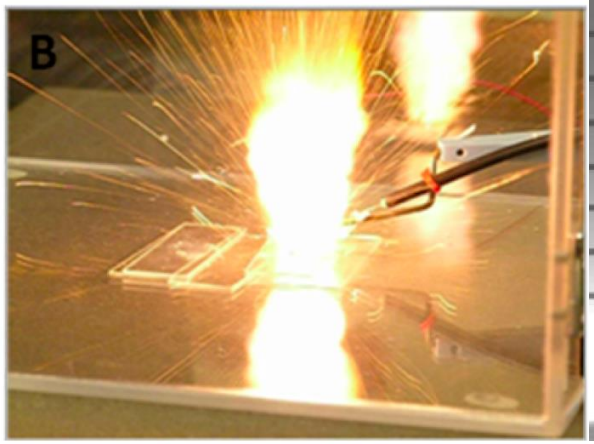


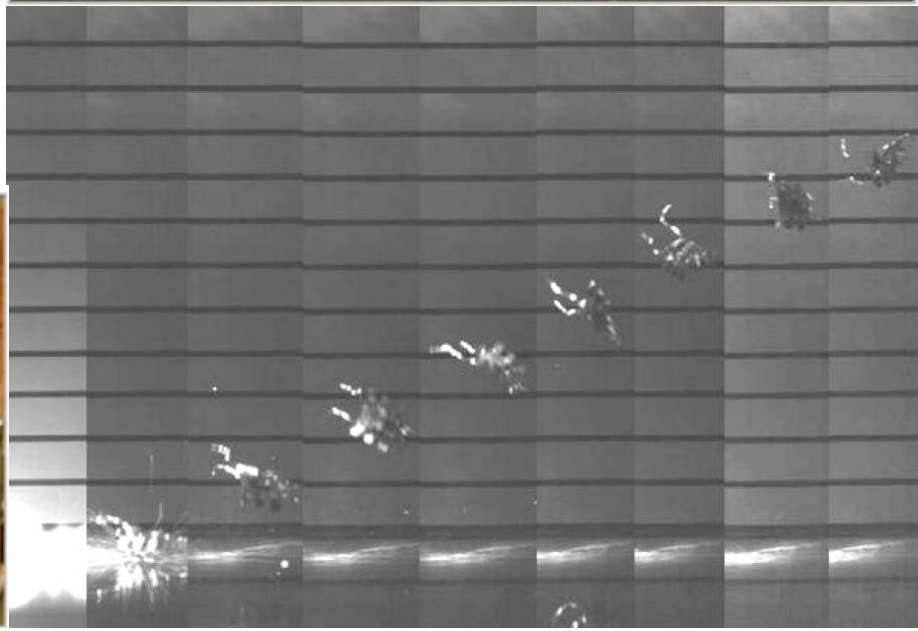


Sarah Bergbreiter, UMD

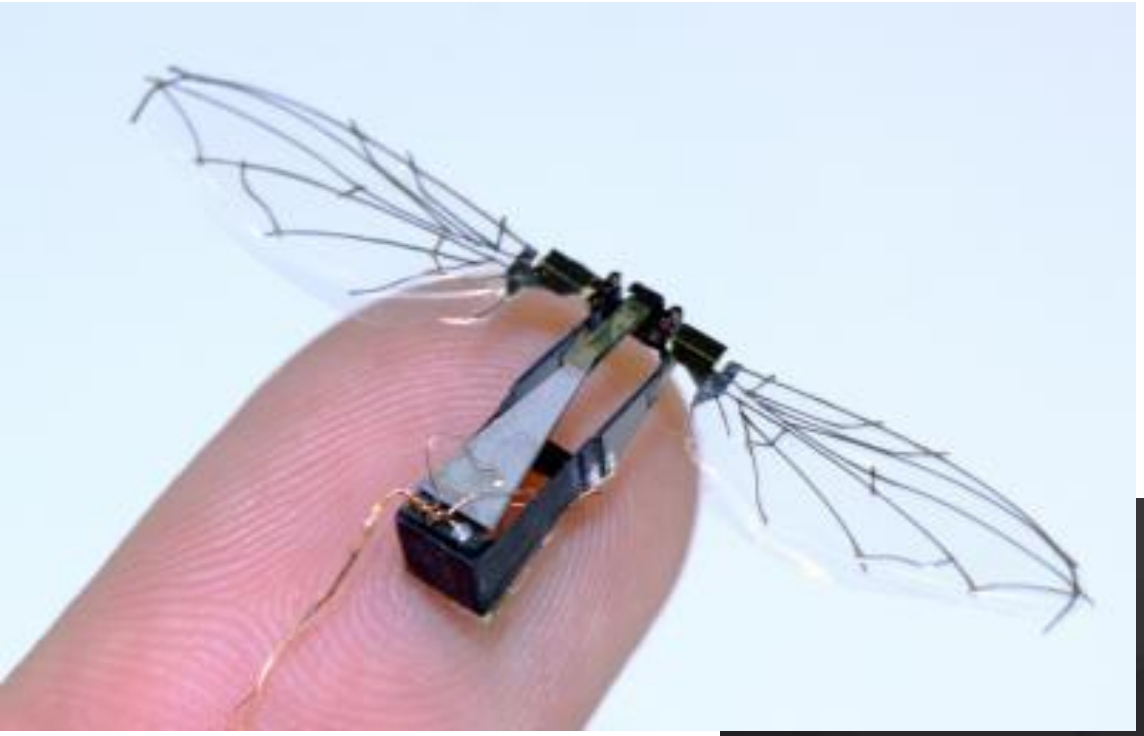




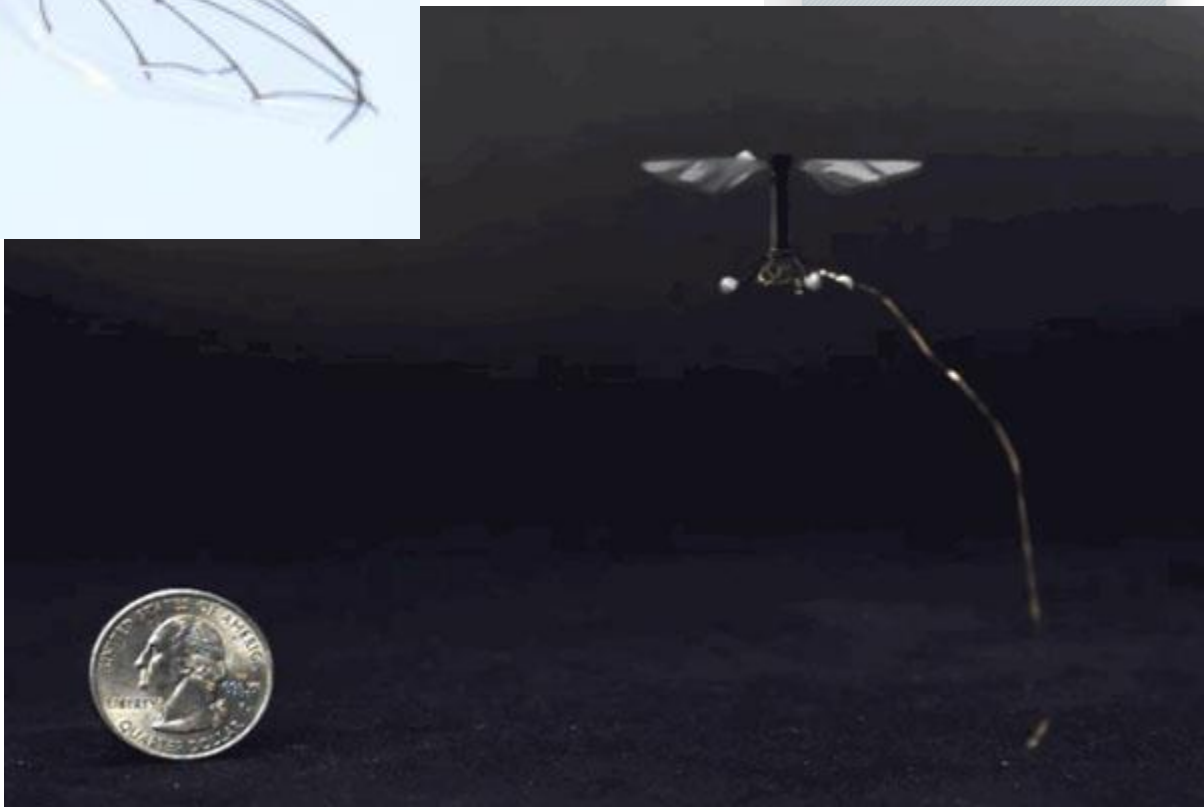




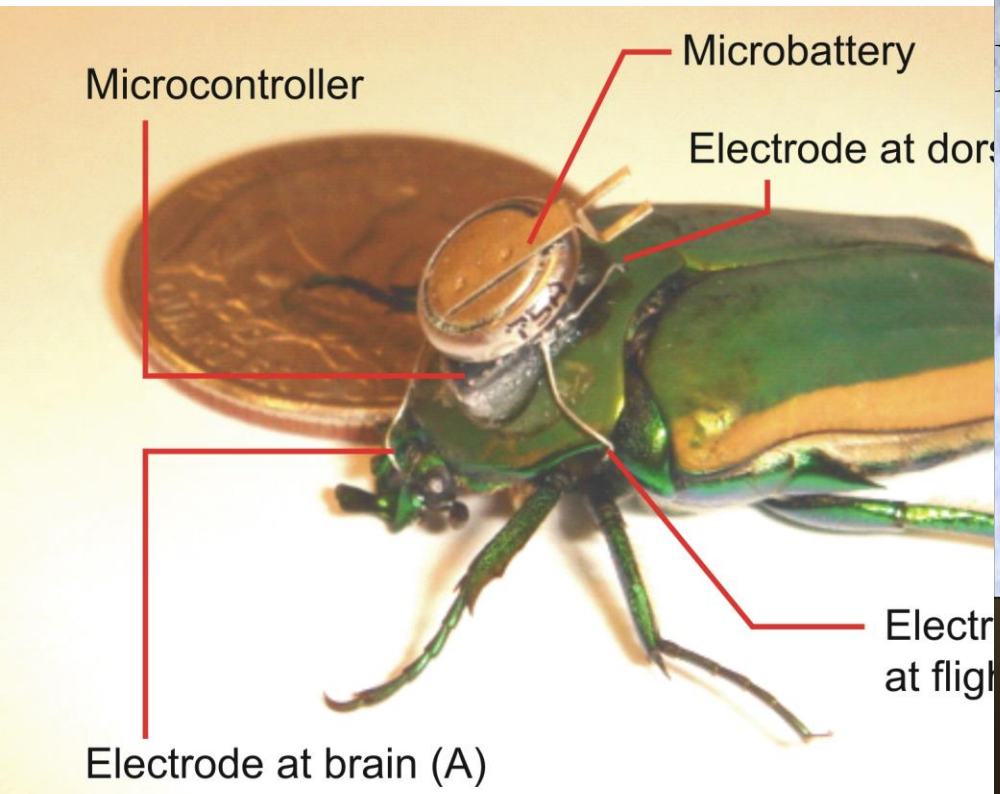
Rob Wood, Harvard

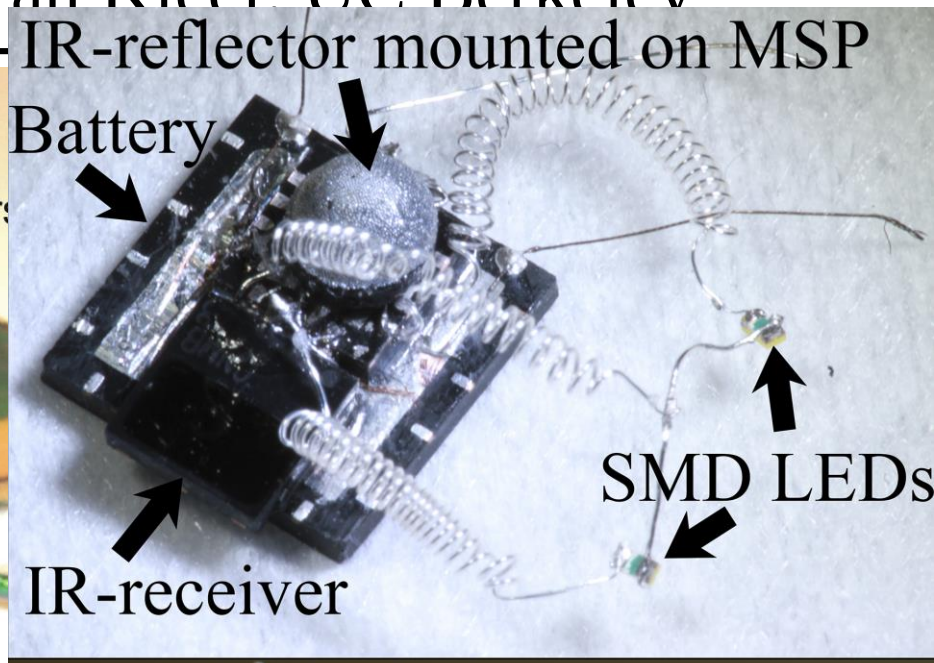


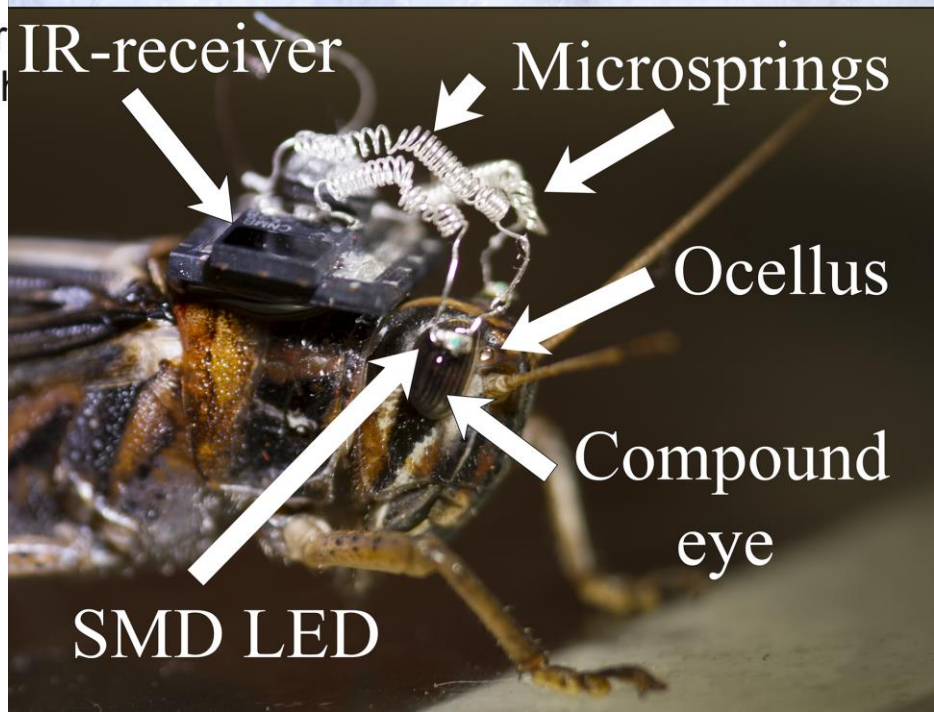
HARVARD
MICROROBOTICS
LABORATORY



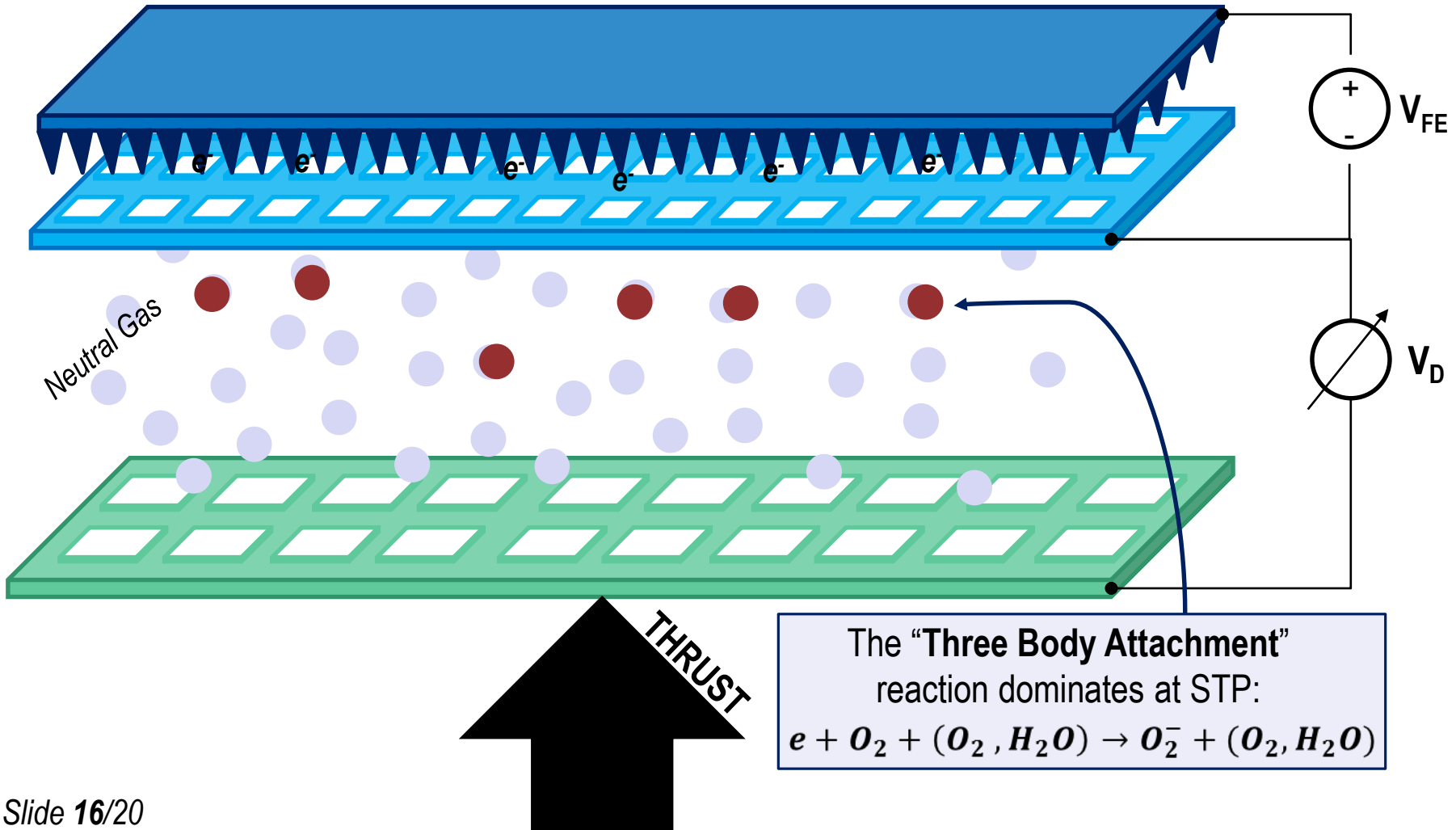
Michel Maharbiz, Josh Van Kleef, UC Berkeley





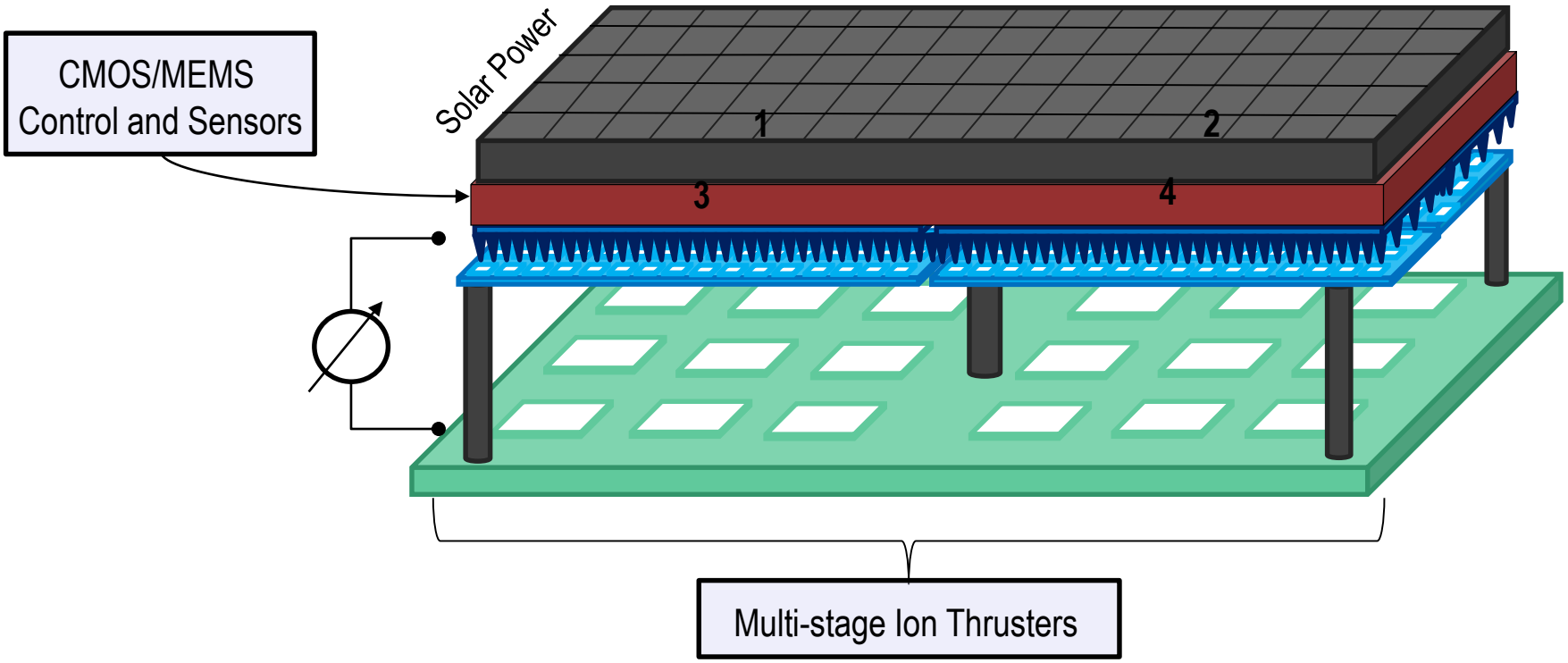


The MEMS Ionocraft



The Future Vision

"Quadcoptor"-esque design, with individual thruster control from either field emission voltage or cathode-anode distance actuation.



Delayed Gratification

Nodal CAD For MEMS

Wireless Sensor Networks

μ-robots

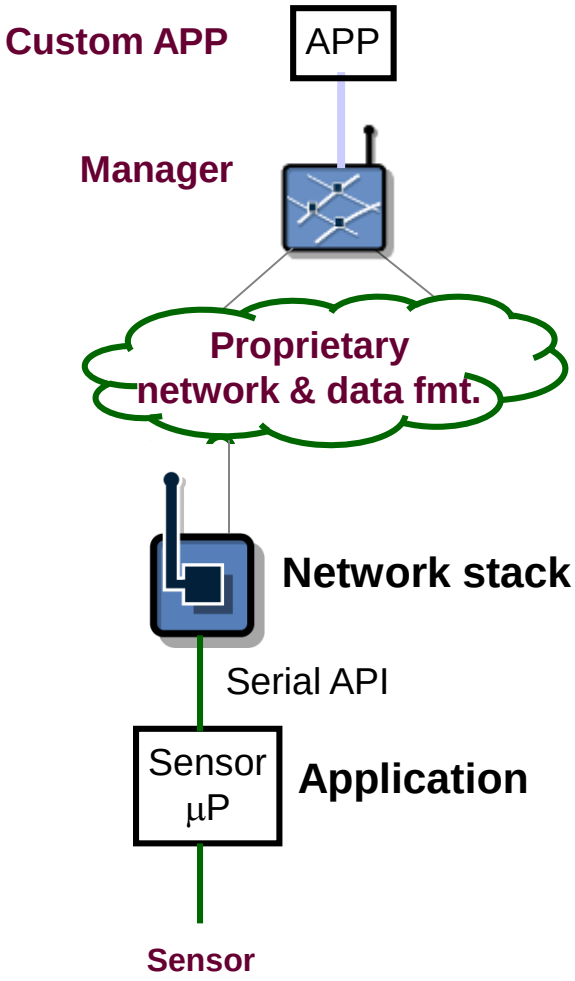
1989

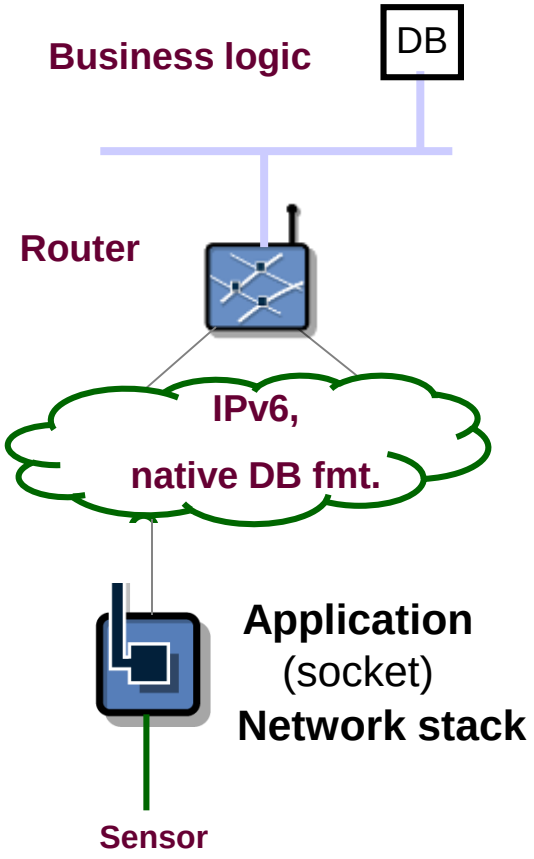
How hard can it be?

XeF_2

This time for sure!

Evolving information flow in WSN





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