Smart Dust : Dispersed, Un-tethered Geospatial Monitoring

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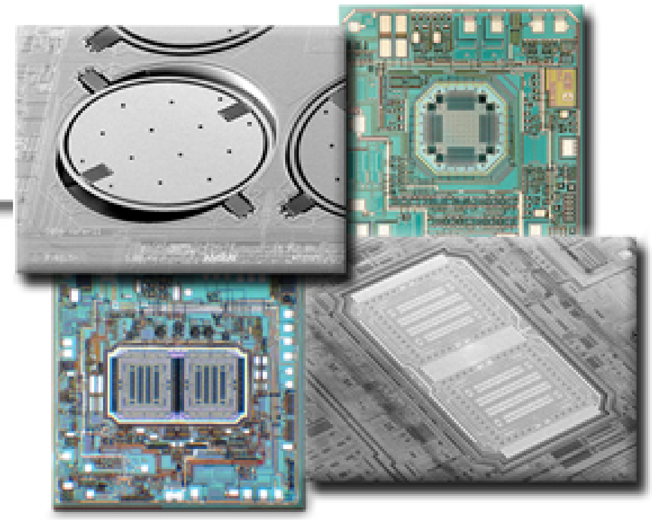
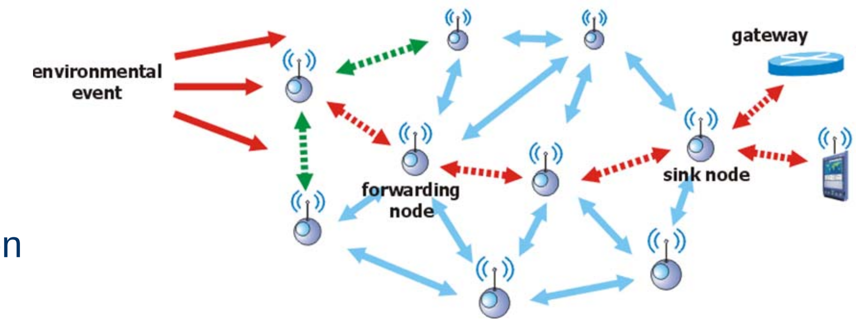
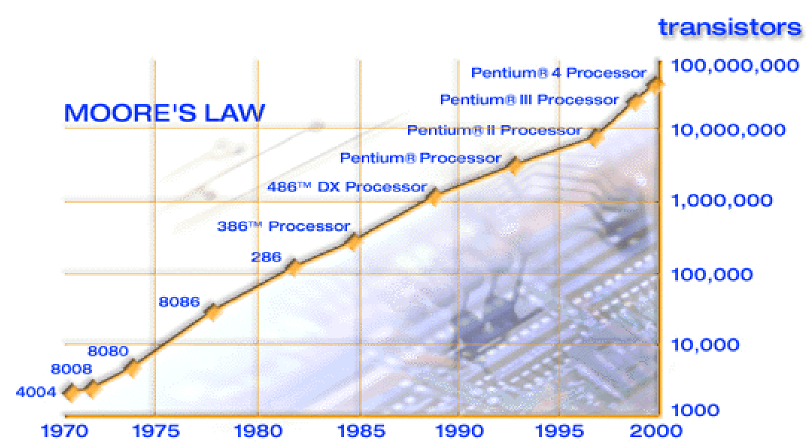
Drivers and Trends



Sensing, Communication and Computation

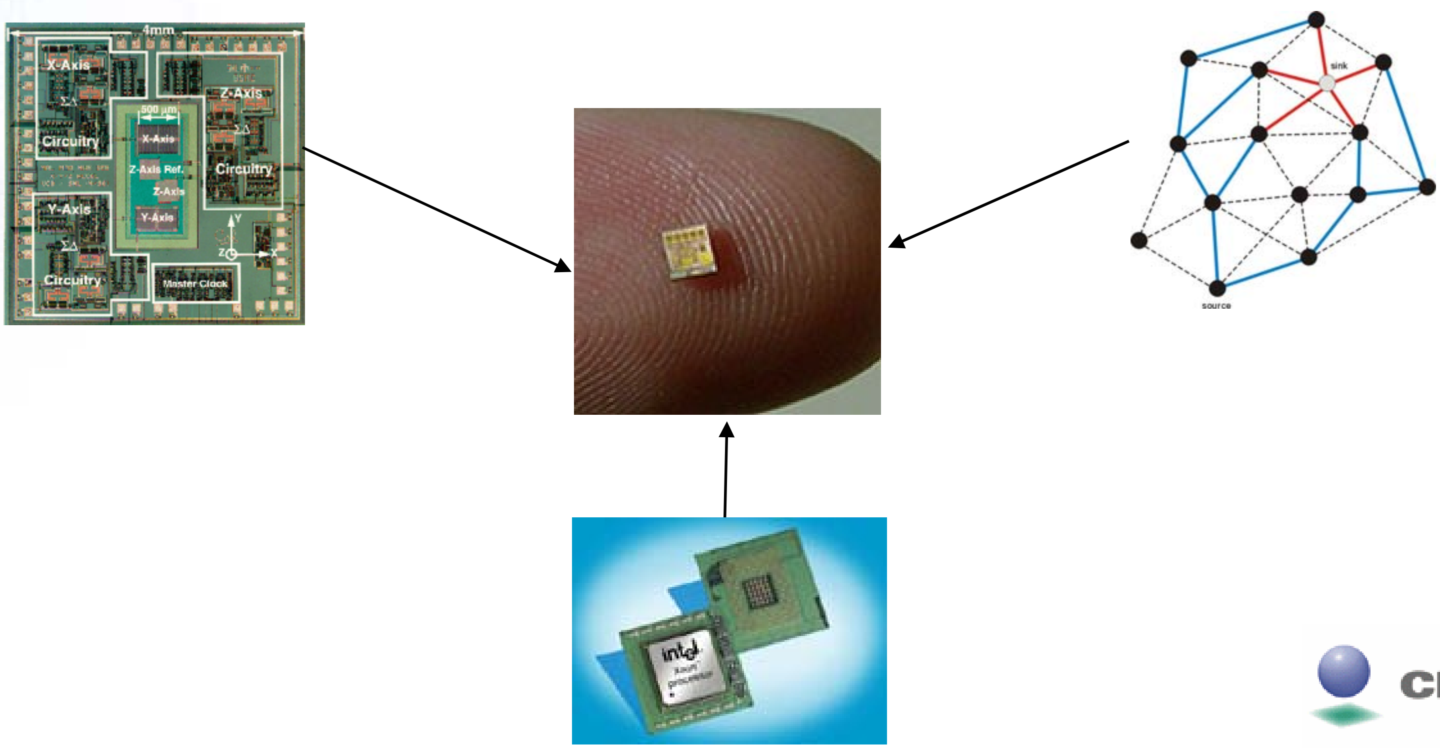
- MEMS (Micro-Electro-Mechanical-Systems) Technology
  - Ability to *machine* structures in silicon
  - Driving size and cost of sensors down
    - Gyroscopes now 3 in^3 (was 1,000 prior)
- Wireless Mesh Networks
  - Low power fault tolerant wireless communication
  - Information is no longer tethered
  - Setup and teardown is minimal
- Moore's Law
  - Exponential growth in number of transistors
    - Transistors/in^2 doubles every 18 months
  - Will continue through 2010, most likely till 2020





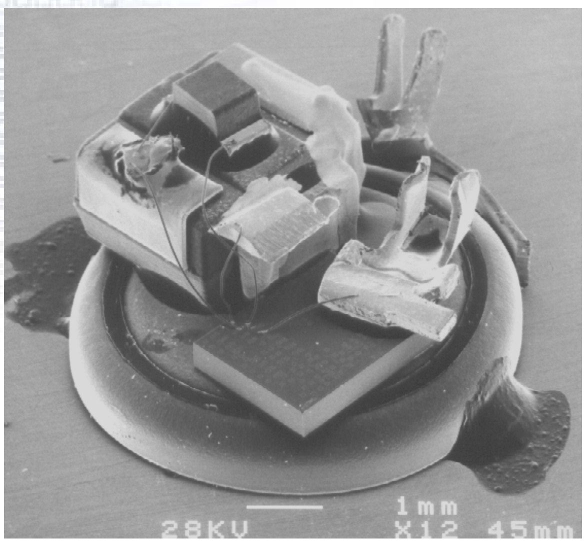
Implications

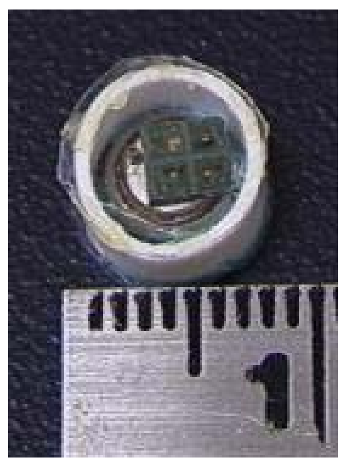
- Integration of these core technologies allows for:
  - Cheap, un-tethered **information** (not just *data*)
  - Easily deployable solutions
  - Ubiquitous information



What is Smart Dust?

- Integration of sensing, computation and networking
  - Create small, low power un-tethered package - *mote*
- Term *Smart Dust* coined by Dr. Kris Pister/UCB in 1994
  - As Moore's law continues, size will continue to shrink ⟶ dust





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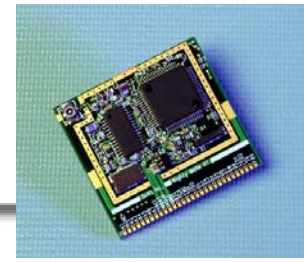
Wireless Mesh Network

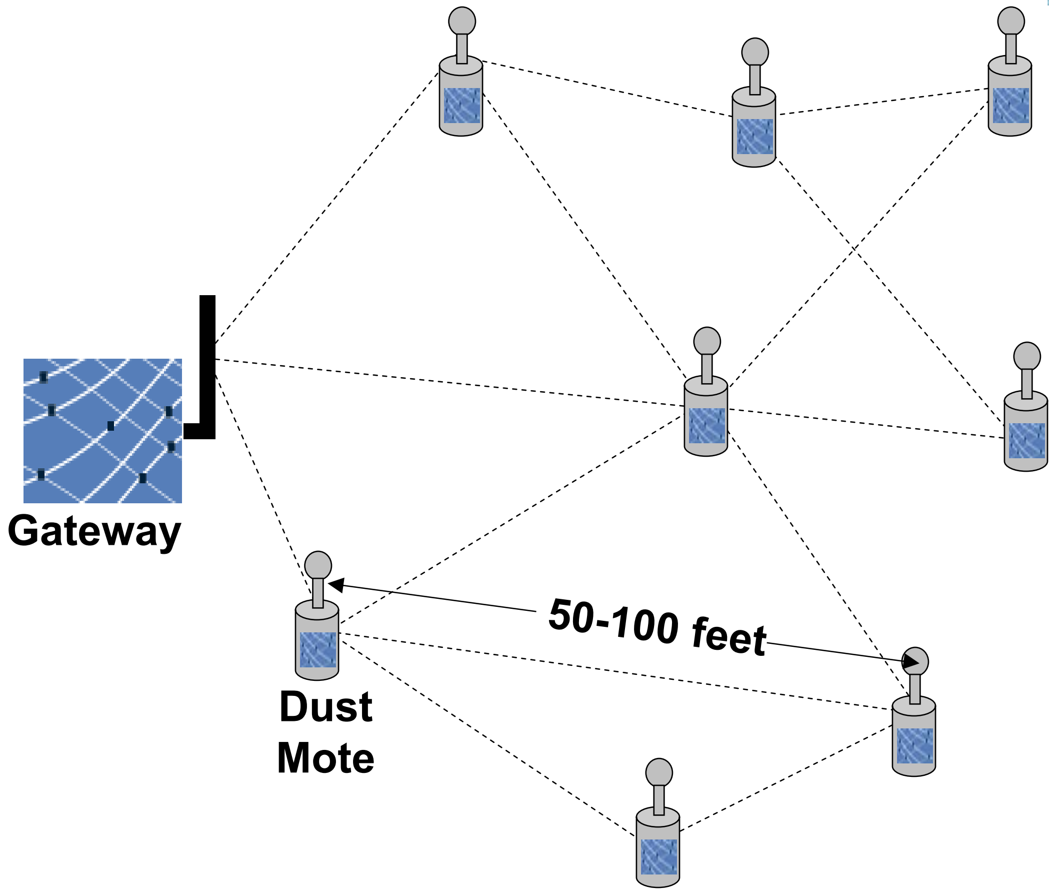


Self configuring mesh: motes automatically establish links with nearby neighbors, <u>each mote is a router</u>

Peer-to-peer : each mote has a transmitter and receiver to both send and receive data

Multi-hopping: data is passed from mote to mote along the network

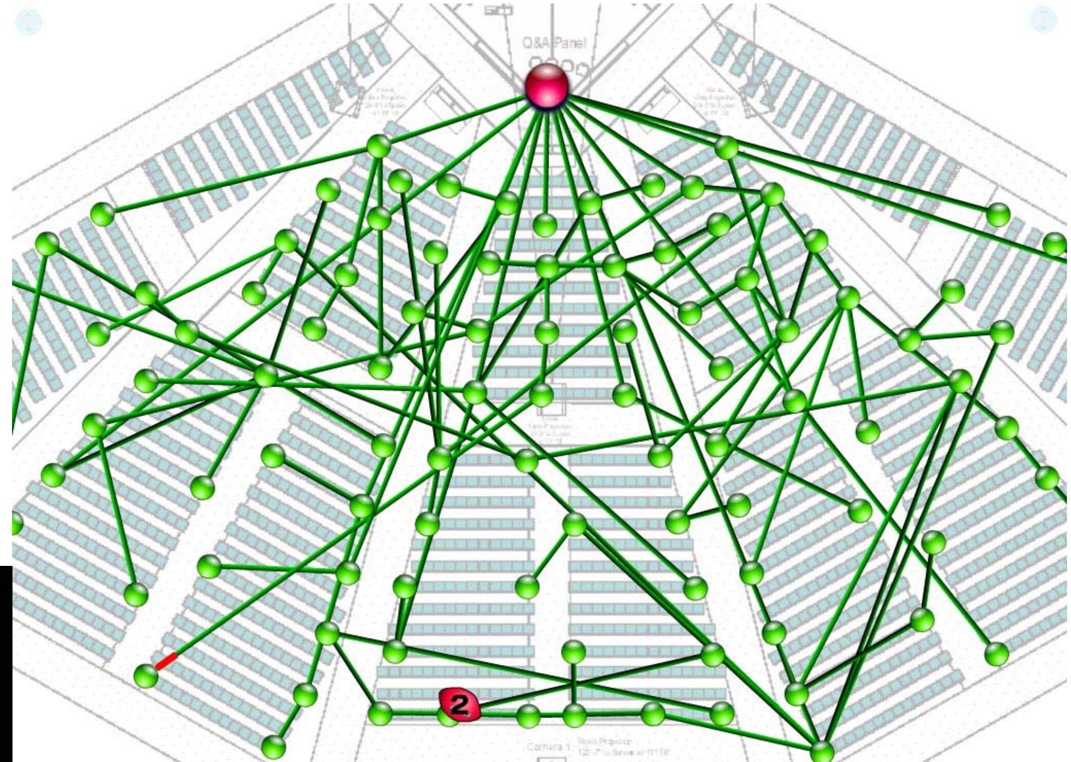
Self healing: network automatically re-routes around broken links

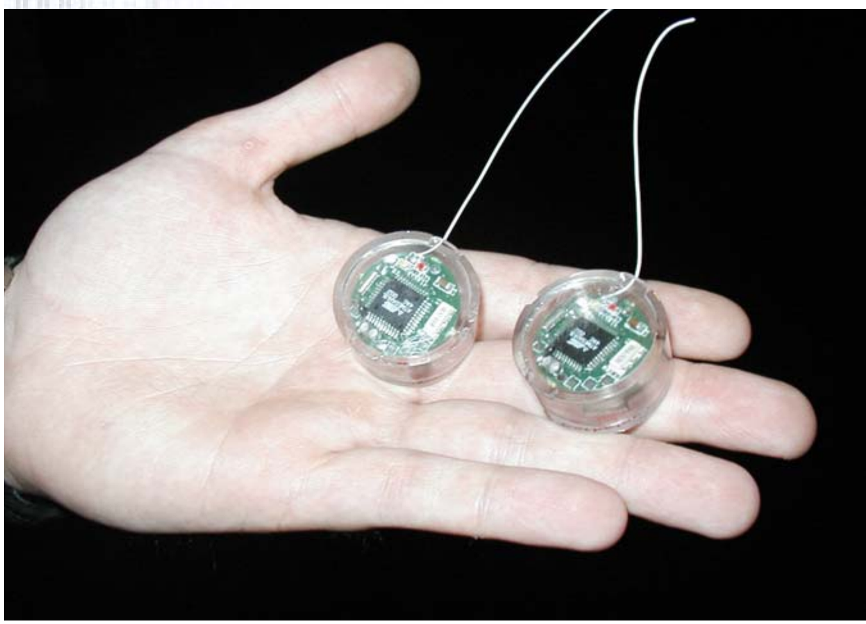


Wireless Monitoring and Control Network

800 node demo at 2001 Intel Developers Forum

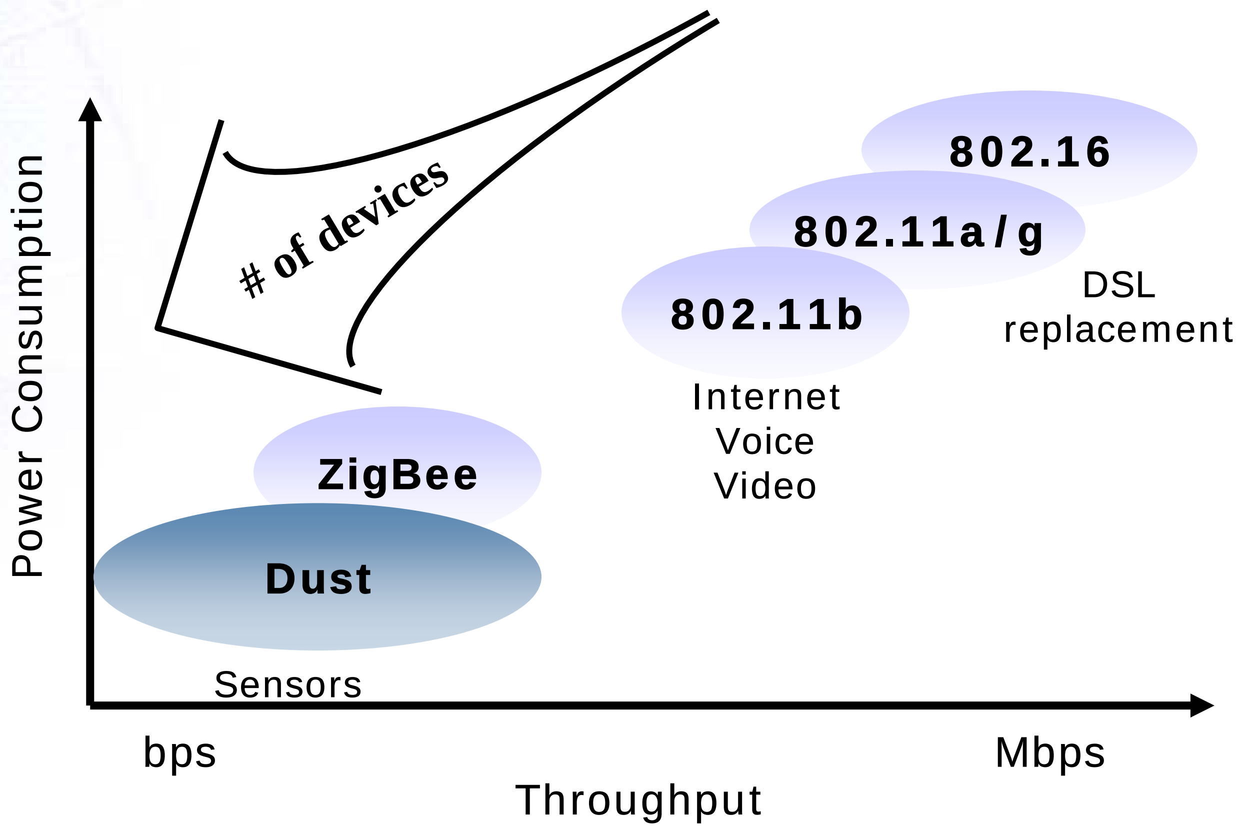
Self-configuring
Self-healing
Scalable
Dynamic





Wireless Networks for Sensors

Network and computations designed to meet the low power, low throughput requirements of wireless sensor networks



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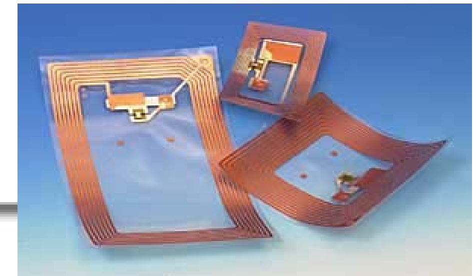
Energy and Lifetime

- 1 mAh ~= 1 micro*Amp*month (µAm)
- Lithium coin cell: 220 µAm (CR2032, $0.16)
- AA alkaline ~ 2000 µAm

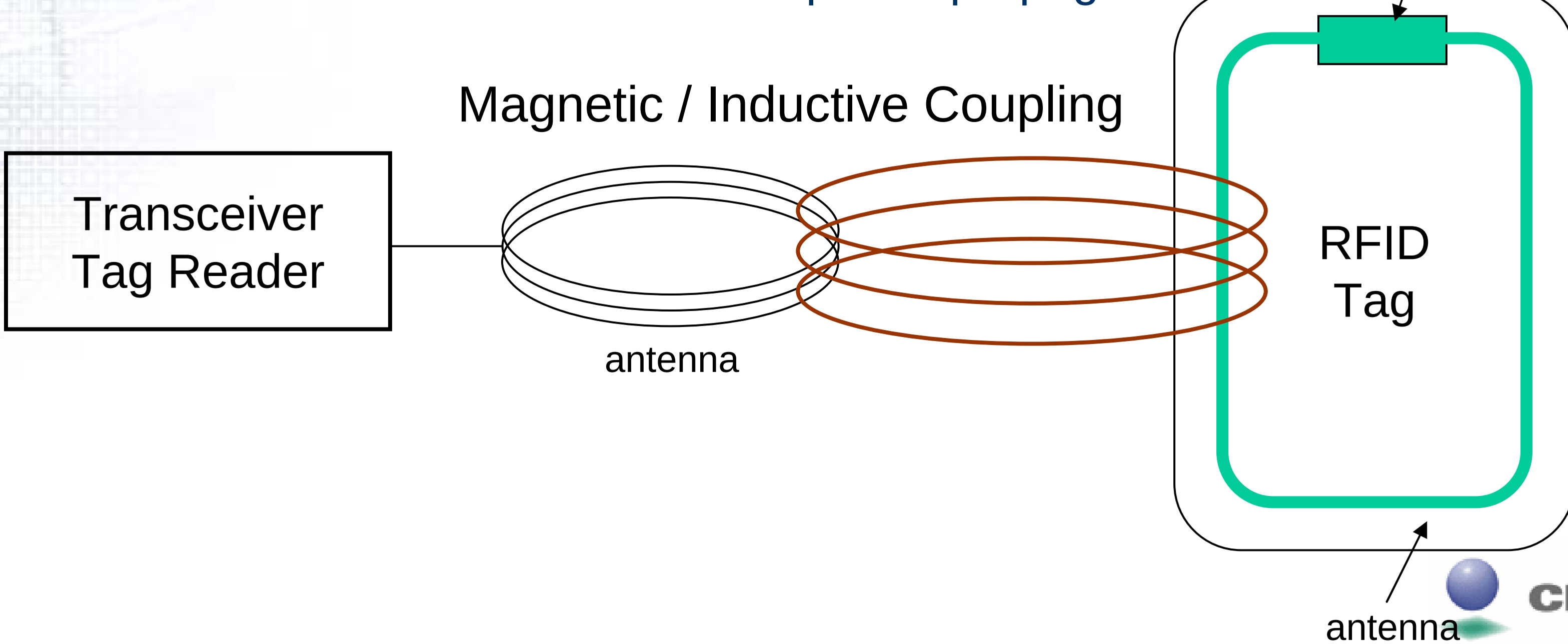
- 100kS/s sensor acquisition: 2µA
- 1 MIPS custom processor: 10µA
- 100 kbps, 10-50 m radio: 300µA

- 1 month to 1 year at 100% duty
- 10 year lifetime w/ coin cell → 1% duty
  - Sample, think, listen, talk, forward … every second!
- Energy Harvesting – infinite lifetime
  - Solar, vibration, thermal, etc.

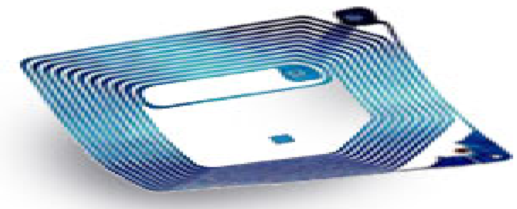
Smart Dust vs. RFID



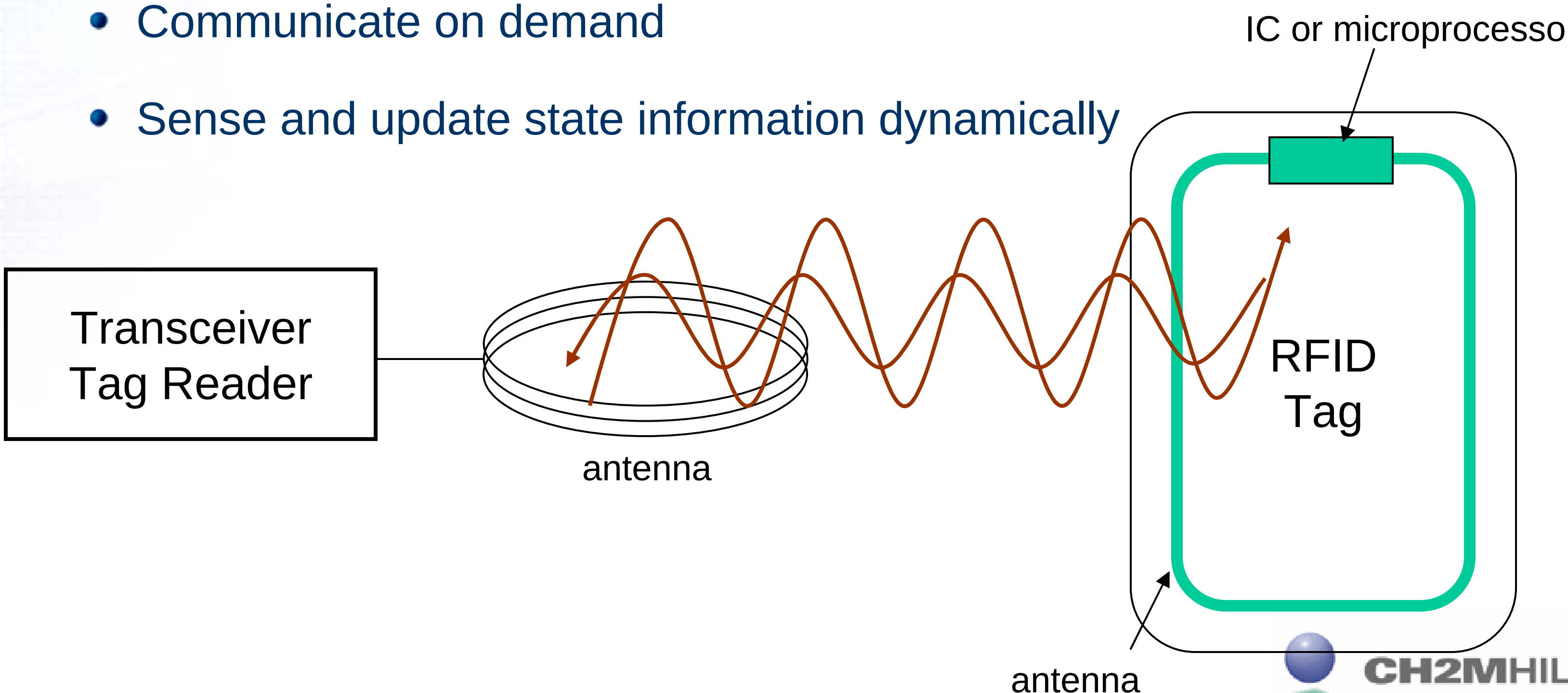
- Radio Frequency Identification - RFID
- RFID Components
  - Transceiver – Tag Reader (always powered)
  - Transponder – RFID tag (typically un-powered)
  - Antenna – used for data and power propagation



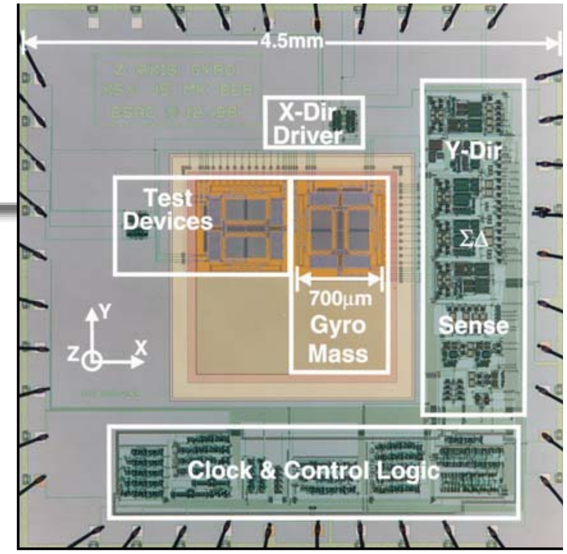
RFID versus Smart Dust



- RFID is typically passive
  - Needs a Tag Reader to activate
  - Does not typically store/update state information
- Smart Dust is active
  - Communicate on demand
  - Sense and update state information dynamically



Available Sensors

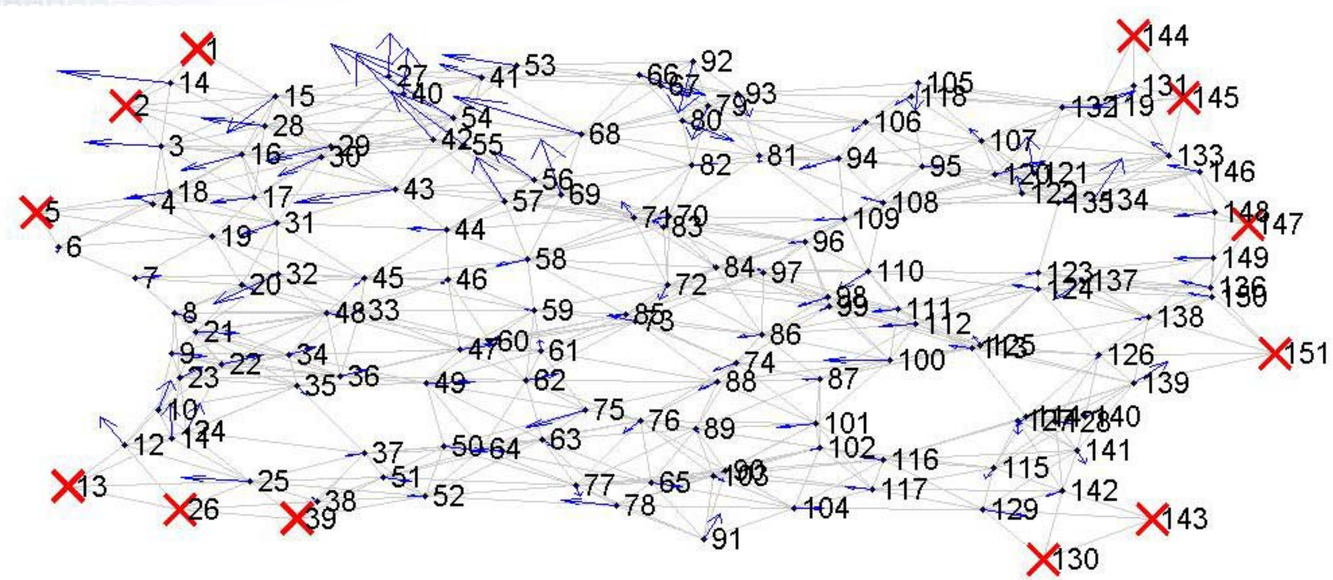


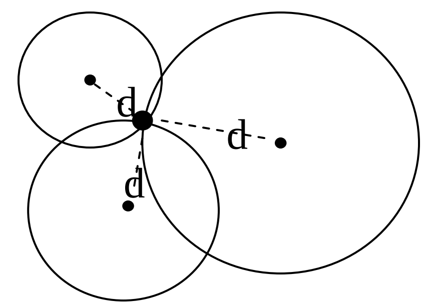
- Demonstrated sensors integrated with Smart Dust
  - Temperature, light, humidity, pressure, air flow
  - Acceleration, vibration, tilt, rotation. sound
  - **GPS – enables spatial aspects**
  - Gases (CO, CO2)
  - Passive Infra-red, contact/touch
- Available
  - Images, low-res video
  - Gases (VOCs, Organophosphates, NOx…)
  - Radiation

Demonstrated Actuators
- Motor controllers
- 110 VAC relays
- Audio speaker
- RS232: LCD, …

Mote Localization

- Determine mote location based on anchors
  - Use GPS on anchor motes
  - Triangulate distances for non-anchored motes
    - Two dimensional: 3 distances
    - Three dimensional: 4 distances





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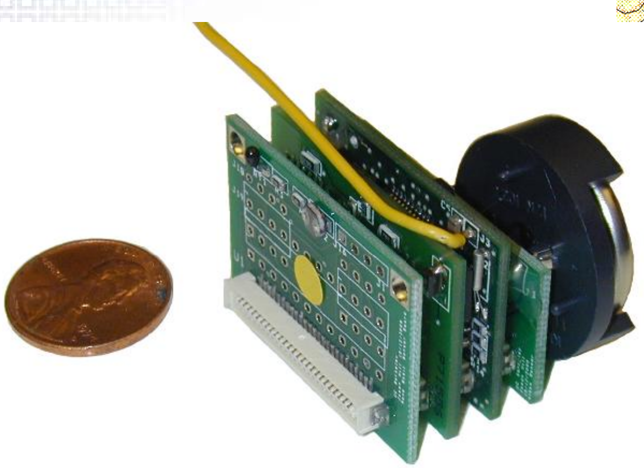
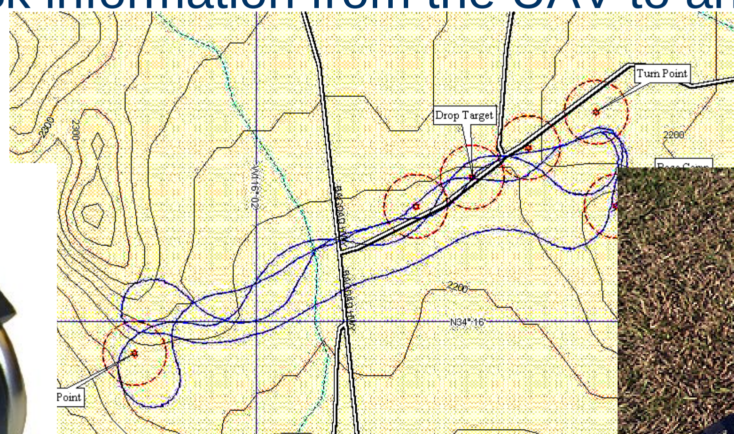
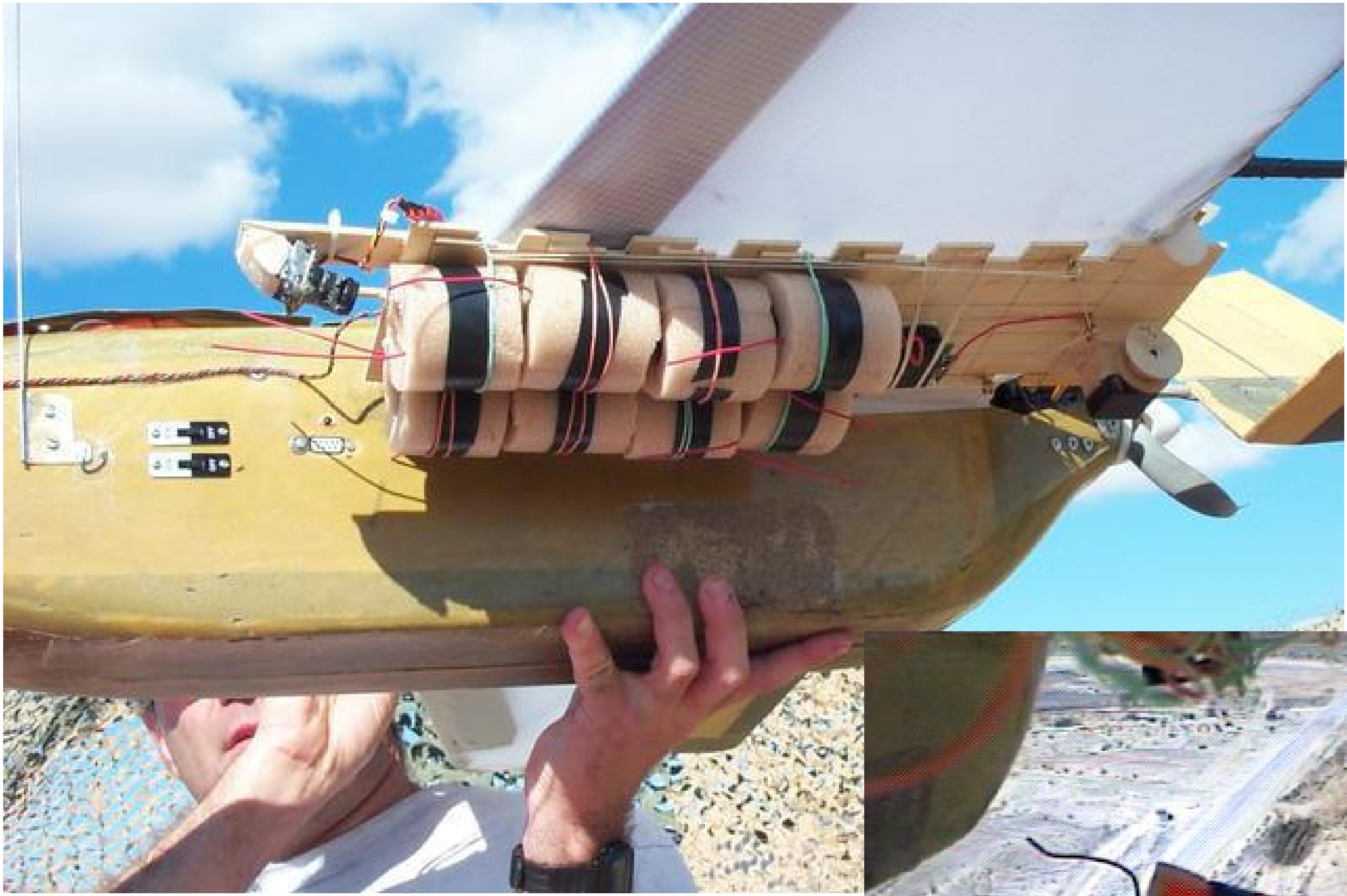
29 Palms Sensorweb Experiment

- Goals
  - Deploy a sensor network onto a road from an unmanned aerial vehicle (UAV)
  - Detect and track vehicles passing through the network (magnetometer)
  - Transfer vehicle track information from the ground network to the UAV
  - Transfer vehicle track information from the UAV to an observer at the base camp.







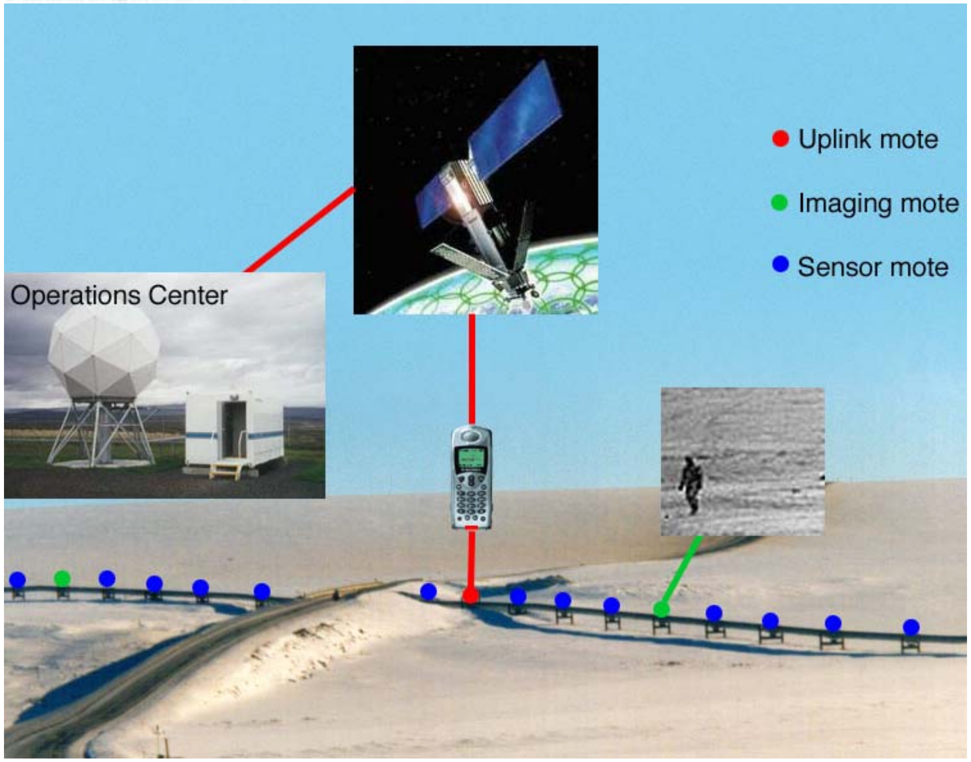
- 8 packaged motes loaded on plane

  - **Last 2 of six being dropped**

Infrastructure Protection

Performance

- Detect activity by motion, sound, magnetic field sensors
- Send alarms to Op Center via cell phone or satellite phone
- Provide images of area on alarm



Spatial Aspects

- Pre-defined linear network
- Use radio time of flight calculations
- Immediate localization of event

Sustainability

- Real-time mote health reporting
  - Battery, sensor, radio
- Network management
  - Notification of potential single-point failures (motes, links)
- Environment a challenge

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Seismic Structural Monitoring

Goal: 100 sensors on three floors

Traditional Infrastructure

Mote Infrastructure

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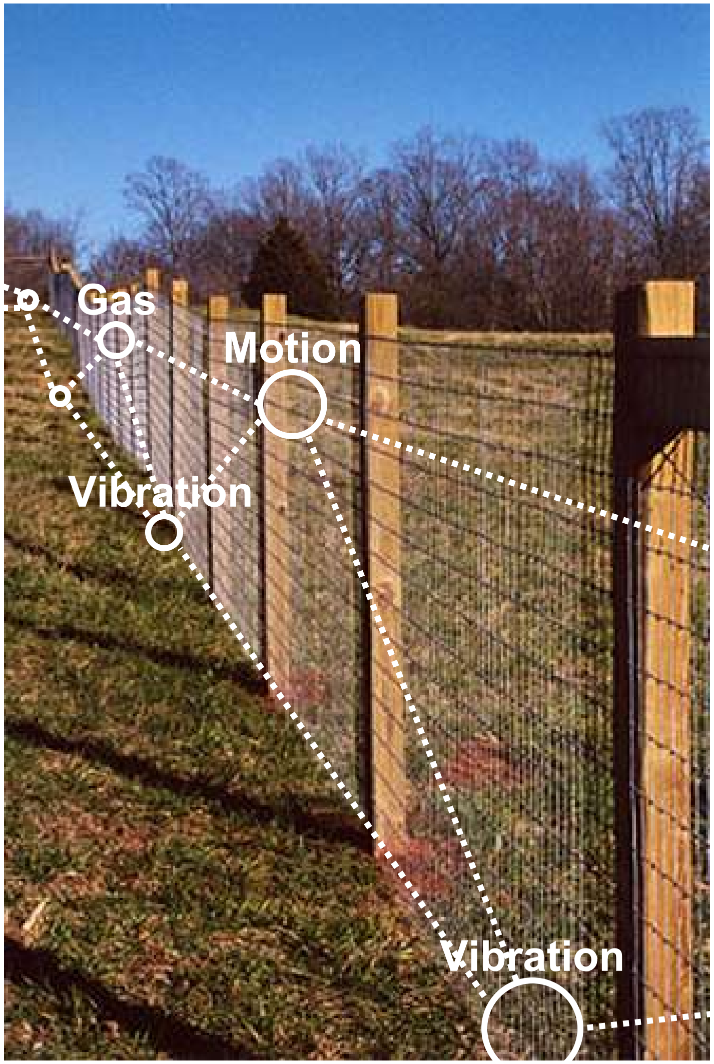
Unattended Perimeter Security

The Problem: **Cheaply monitor infrastructure perimeter**

Sensing of Interest: **Motion, vibration, gas emissions.**

What Smart Dust Provides

- Dramatically reduced installation time and cost
- Reliable, self-healing monitoring
- Unattended operation for years
- Quick repurposing of network to serve new security priorities



Application Footprint

- Where does smart dust make the most sense?
  - Low cost installation/deployment
  - Dynamic – need to set-up and tear down quickly and cheaply
  - Un-tethered – the need to function without wires
  - Low power – ability to run for an extended period of time
  - Passing of information, not just raw data

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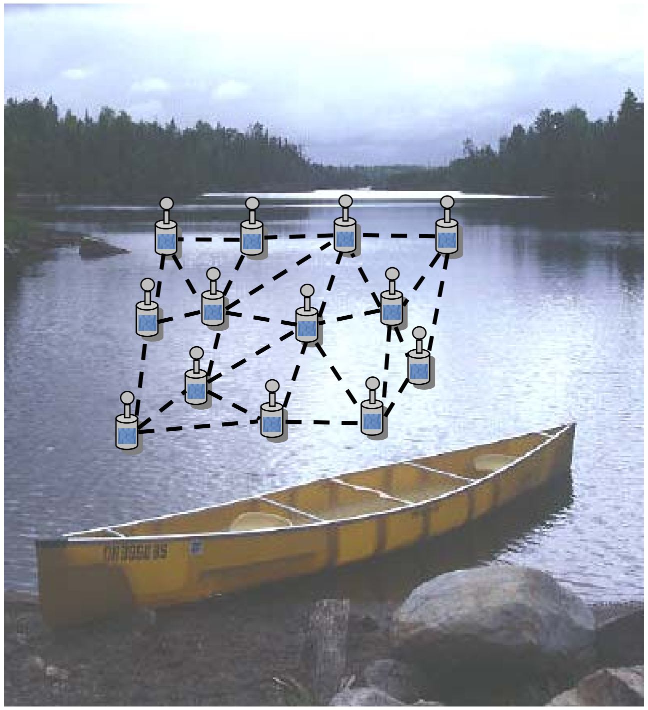
What's Next

Applications

- Leverage un-tethered sensing with localization
  - Wetlands monitoring
  - Site remediation monitoring
  - Spatially link information streams
- Challenges
  - Information Aggregation
    - Only disseminate meaningful information
    - Perimeter processing necessary



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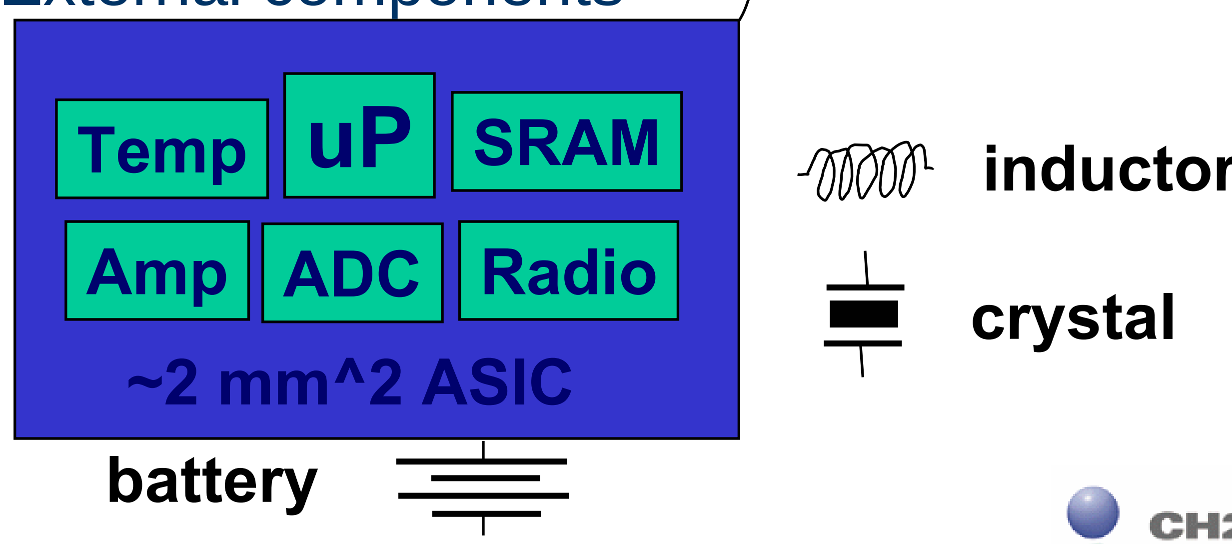
Technology

Smaller and Lower Cost Integrated Solution

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



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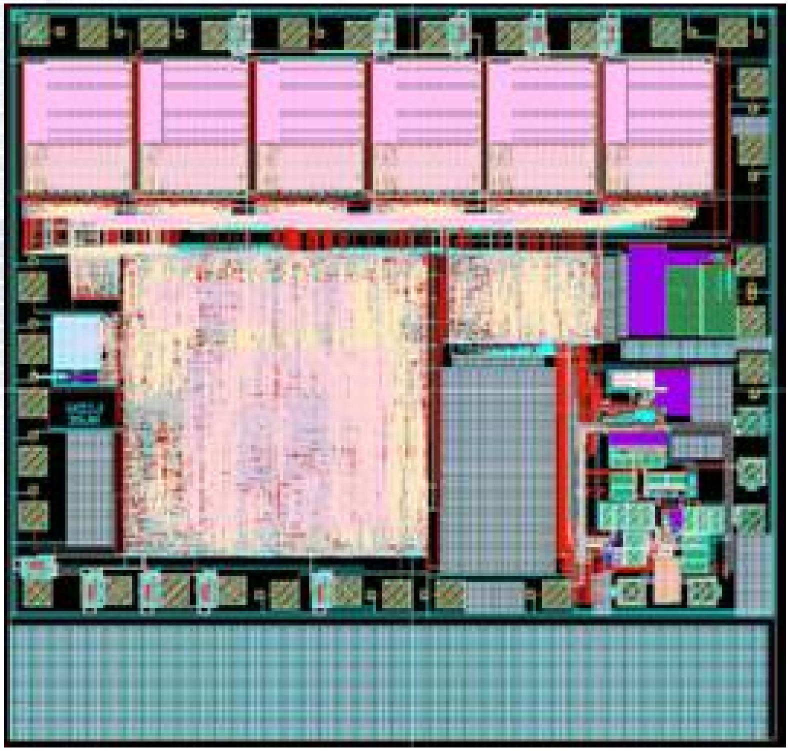
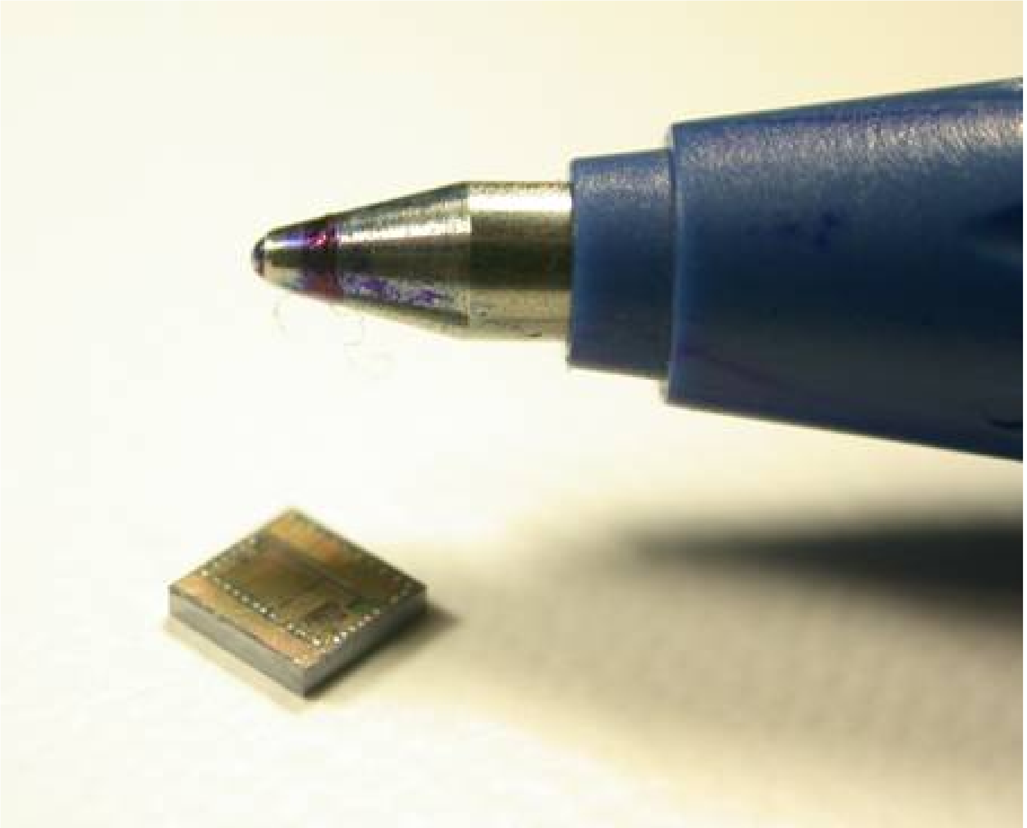
Single Chip Integration

- 8 bit microprocessor
- Analog to Digital Converter
- 900 MHz transmitter





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Summary

- Smart Dust
  - Integrated package that provides
    - Un-tethered sensing
    - Information gathering
    - Reliable low-power communication
  - As Moore’s law continues, devices will continue to shrink
  - Can spatially enable either through topology or assisted GPS

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Questions

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