

**"I never said
we'd replace
the dog."**



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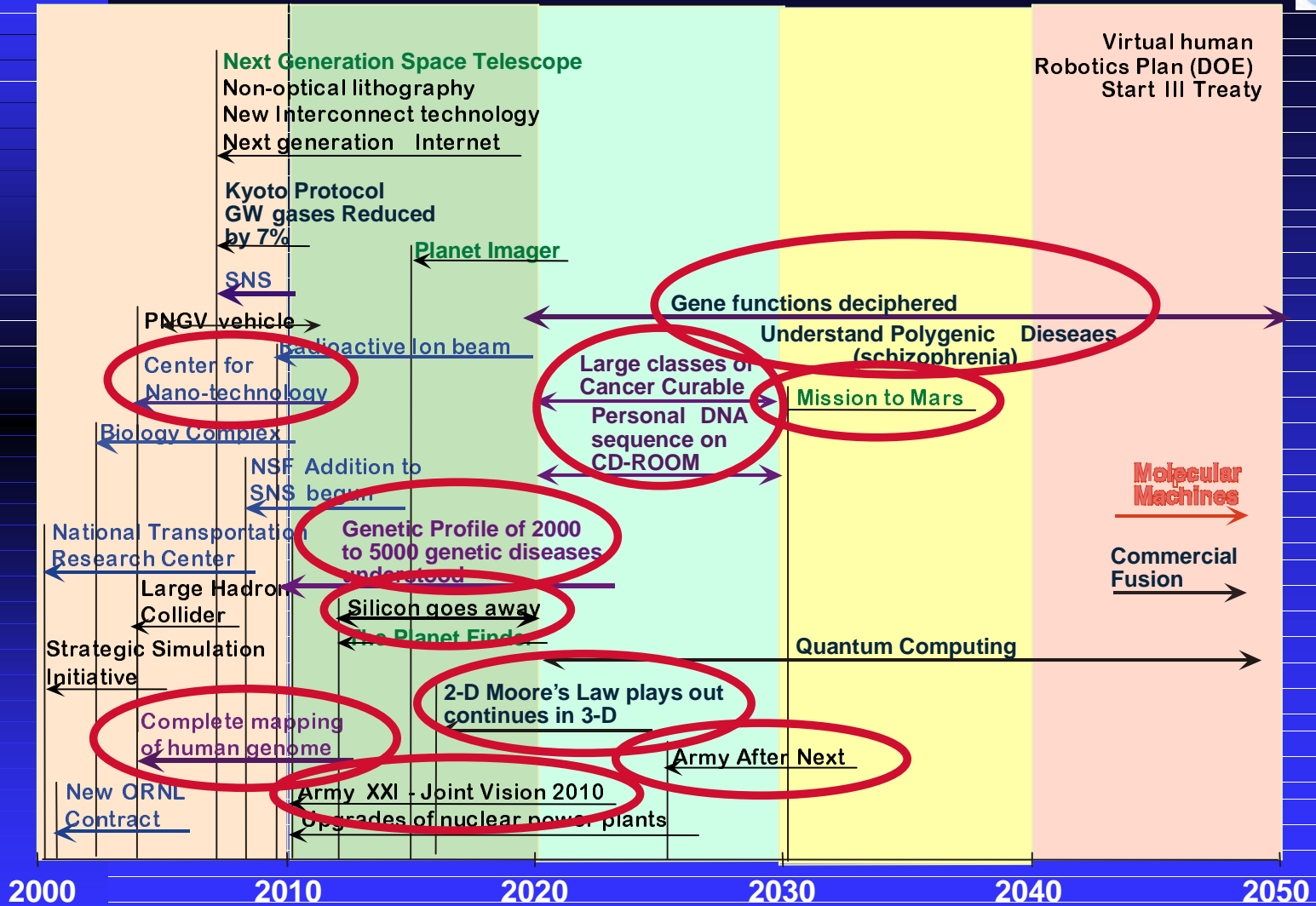


Things I'll talk about...

➡ The future and what to expect

➡ The present and what to pursue

TECHNOLOGY TIMELINE





**Much of the future involves biotechnology
so
in order to take advantage of this**

**I see these as HOT areas now and in the
near future....**

- ➡ Analog and mixed-mode IC design
- ➡ Wireless IC design
- ➡ Integrated sensors and MEMS
- ➡ Intellectual property law



Why integrated circuits?





Analog and Mixed- Mode Design

Why is analog and mixed-mode design hot???



- ☞ The world is, in general, analog.
- ☞ Nature hasn't supplied 32-bit parallel buses from which to extract data.
- ☞ As chip sizes shrink and processing speeds increase, those analog courses become more important.
- ☞ Every circuit is actually an analog circuit...



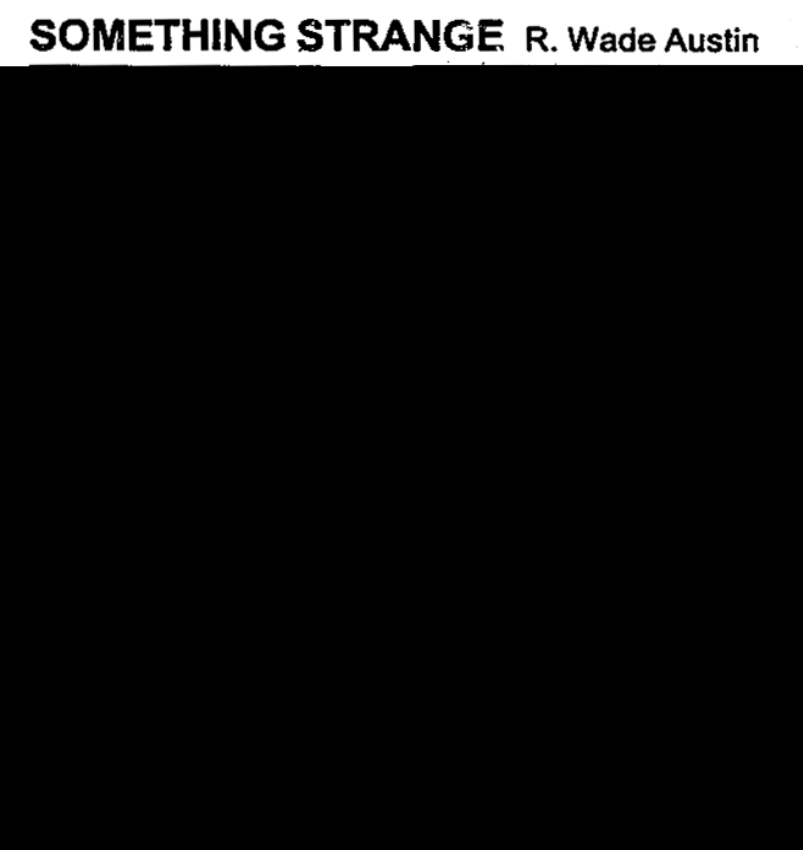
What do analog designers do?

- Amplifiers
- Analog-digital converters
- Digital-analog converters
- Communication circuits
- Transistor device design
- Fabrication process design
- Testing



.....and jobs are
plentiful.....

.....but respect is not.....





Wireless



The TRADITIONAL approach to instrumentation interfacing has been to employ long, heavy cables to interconnect sensors and controllers

- ➔ Cable is bulky, costly, and imperfect
- ➔ Cable is expensive to install and maintain:
 - ❖ \$200 [office] to \$2000 per ft [nuclear plant]
 - ❖ CERN Heavy Ion Experiment delay-line ASIC saved ***1 Million meters*** of cable
 - ❖ \$3M savings *paid for the chip development*

The integration of sensors with the wireless technology is still in its infancy...

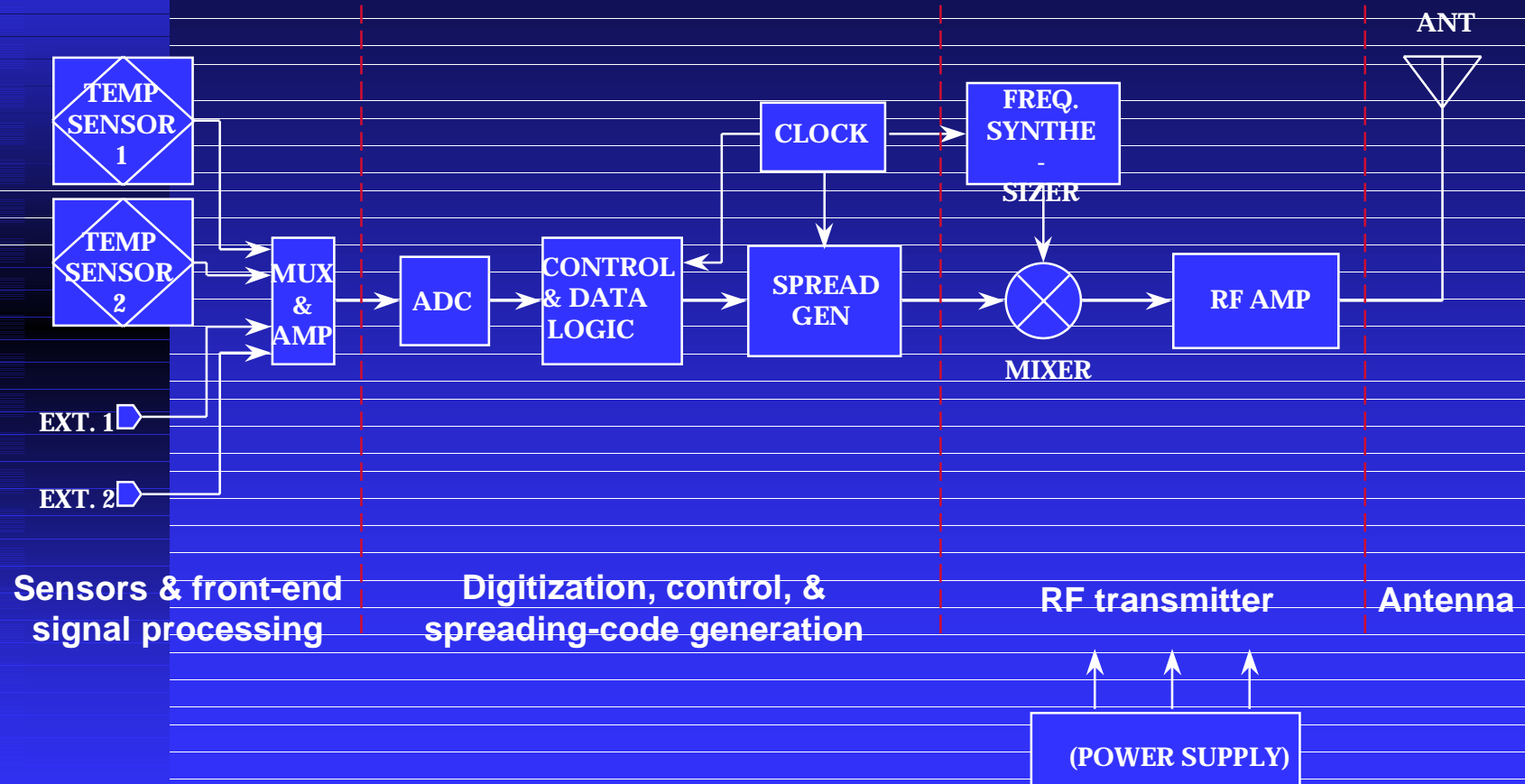


- ➡ High-quality wireless sensors do not exist today on the commercial market
- ➡ Premium -grade analog sensor integration will be more difficult than just “plug and play” - good understanding of device physics is required
- ➡ Low-noise, high resolution, and high reliability sensor integration also requires special transmission techniques (*spread spectrum*)



INTELLIGENT WIRELESS SENSOR

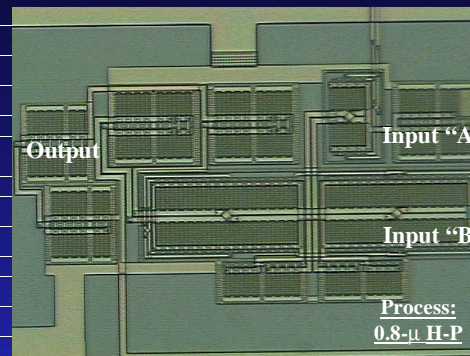
Multiple-sensor proof-of-principle device



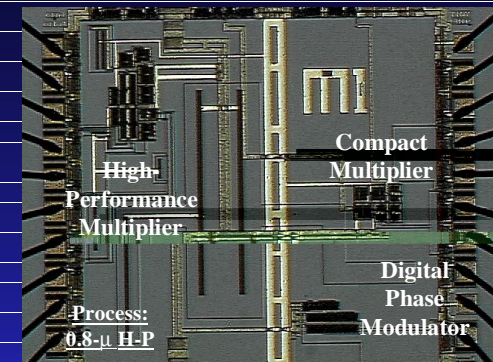


Advanced Wireless or Reduced Wiring Sensors

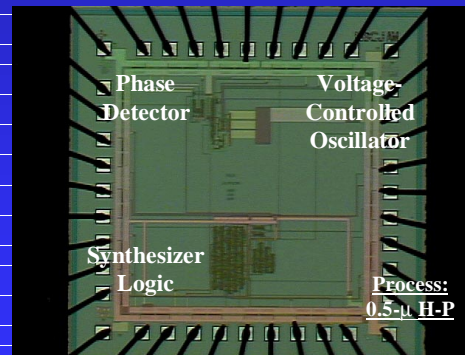
- ✦ Multiple low-power intelligent sensors will provide efficient plant status assessment
- ✦ Adaptive spread-spectrum modulation assures high data integrity and security.
- ✦ Advanced bi-directional sensor networking features include:
 - ◆ Power supply and data transmission sharing common conduit
 - ◆ Sensor polling/verification and remote calibration/reconfiguration.
 - ◆ Robust, “smart” dataflow architecture.
 - ◆ Dynamic device/system data bandwidth management accommodates varying network traffic levels and rates.
 - ◆ Automatic response to facility damage, altered equipment configurations, emergency situations.



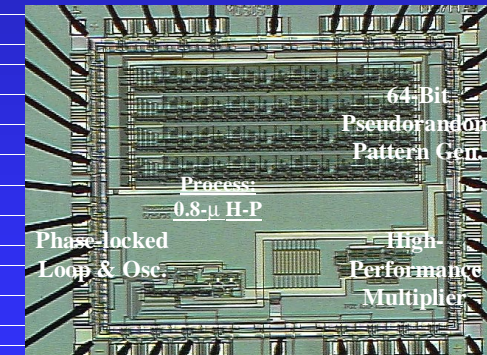
High-Performance Multiplier/Modulator



Multiplier/Modulator Prototype Chip



High-Speed (1-GHz) Phase-locked Loop



Integrated Wireless Test Chip

Our first fully integrated wireless data- acquisition chip

☞ Two
thermometers

☞ Two
uncommitted
inputs

☞ 10-bit ADC

☞ Control logic

☞ Spread-
spectrum radio-
frequency
transmitter

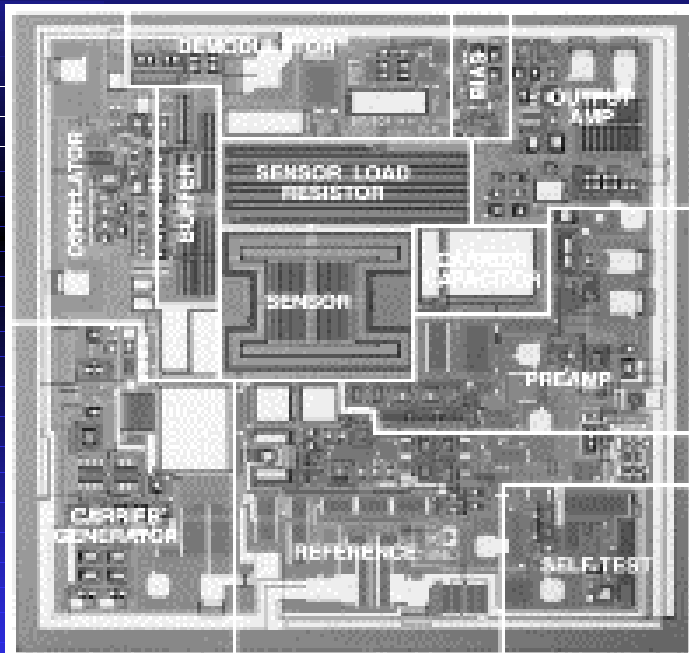




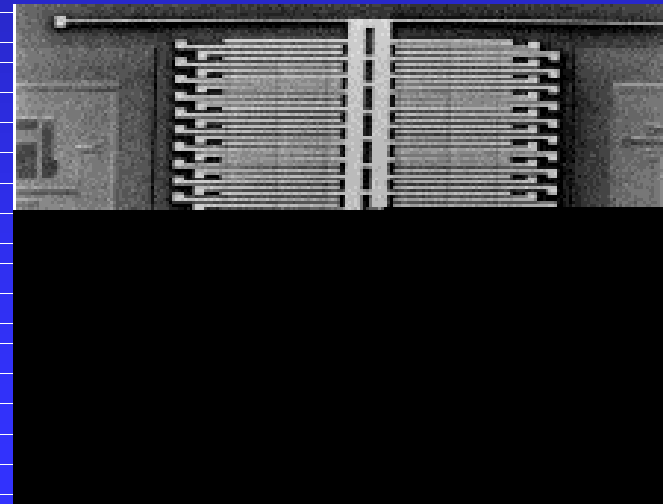
Integrated Sensors and MEMS



Integrated sensors (systems-on-a-chip) are already here..



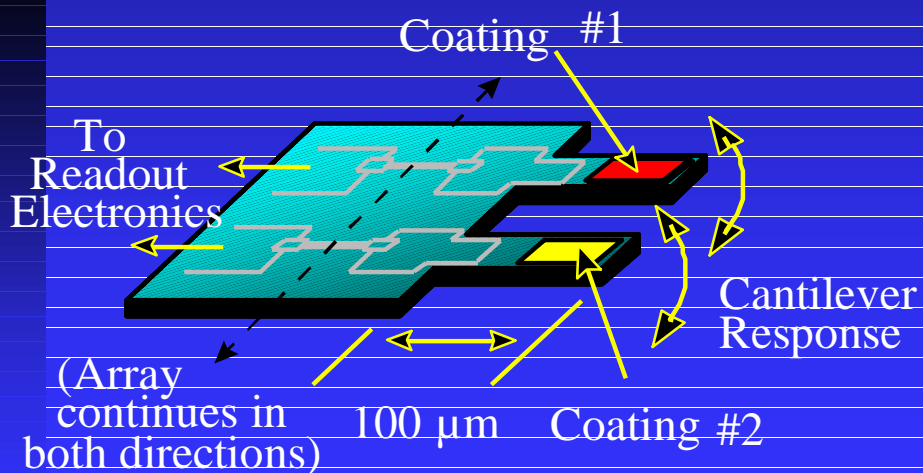
Analog Devices' ADXL-50, the industry's first surface micromachined accelerometer, includes signal conditioning on chip.



Electrically Readable Cantilevers R&D at ORNL



- ✦ ORNL presently has several patents issued and pending and over a dozen disclosures on the technology
- ✦ Utilizing *arrays* of microcantilevers on a *single chip* with *customized coatings* to produce application-specific programmable sensors
- ✦ Researching the limits of electronic readout of microcantilevers
- ✦ Researching different chemical coatings for selective sensing (chemical & biological)

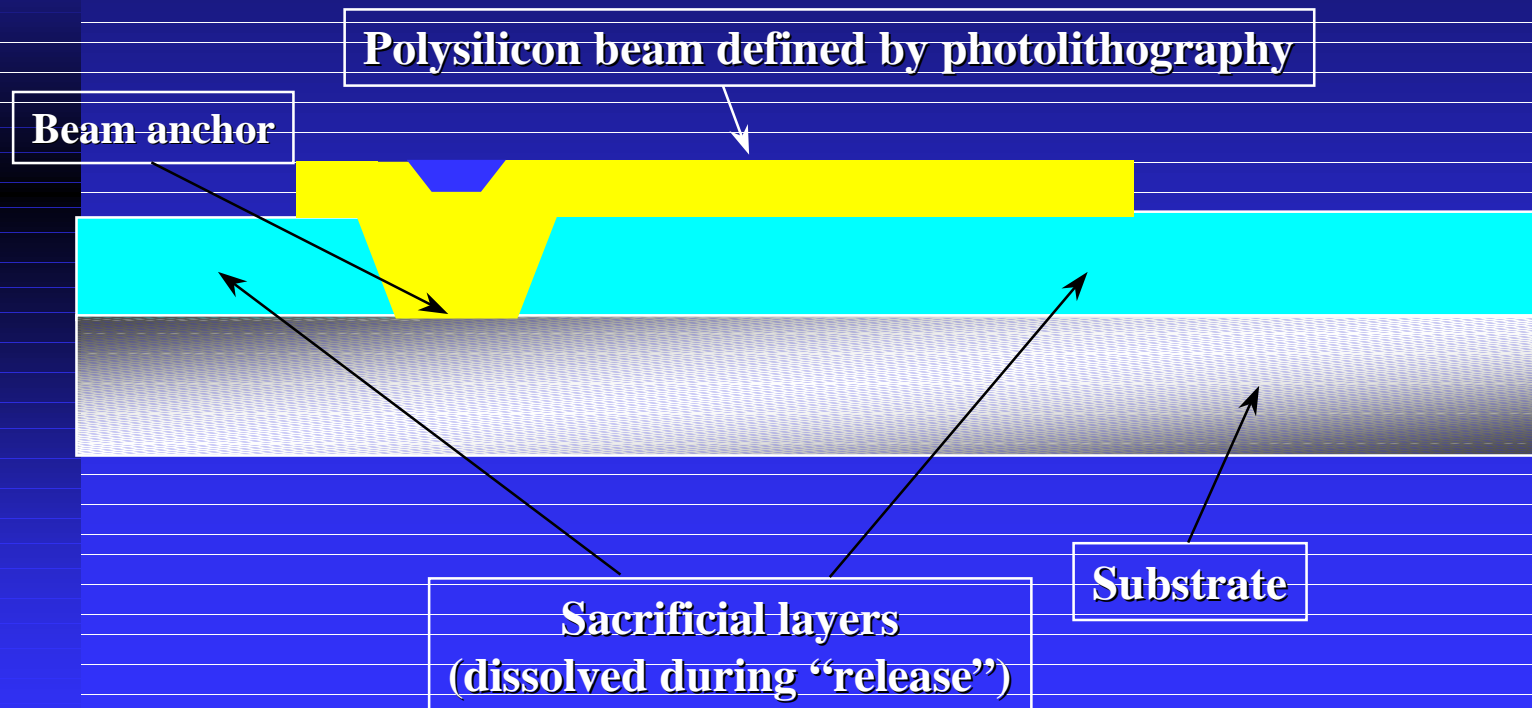


Original AFM
optically-read beams



Surface micromachined cantilever

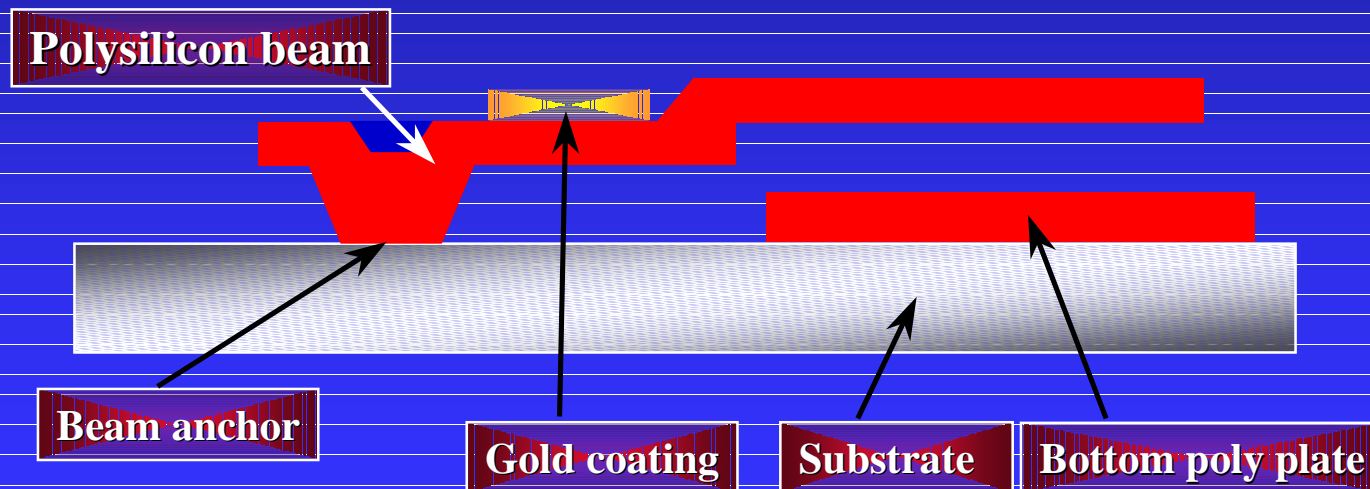
Cross section of a microcantilever



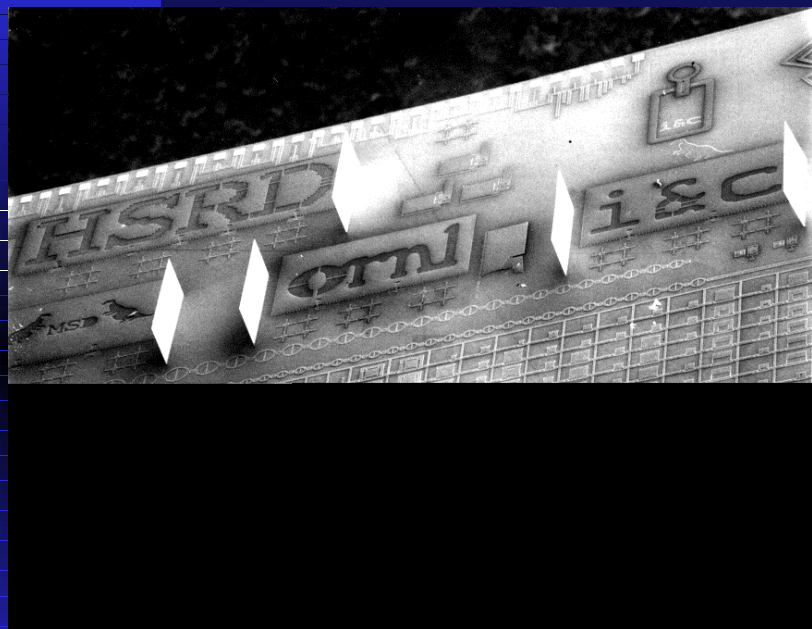


ORNL surface micromachined cantilever cross-section fabbed through MUMPS

☞ We read the stress-induced movement by sensing the change in capacitance between the beam and lower plate



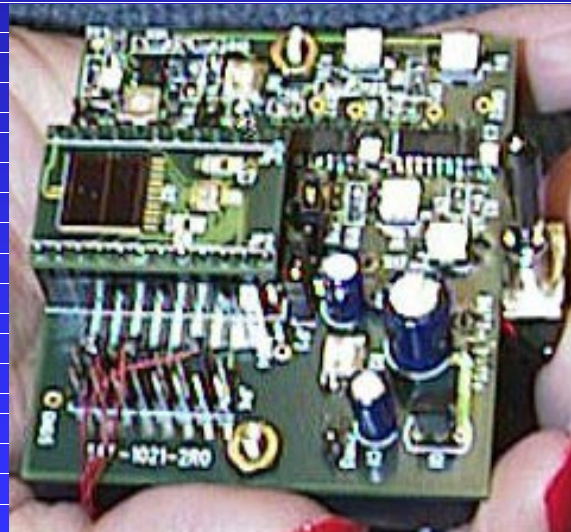
Micro-cantilever array chip





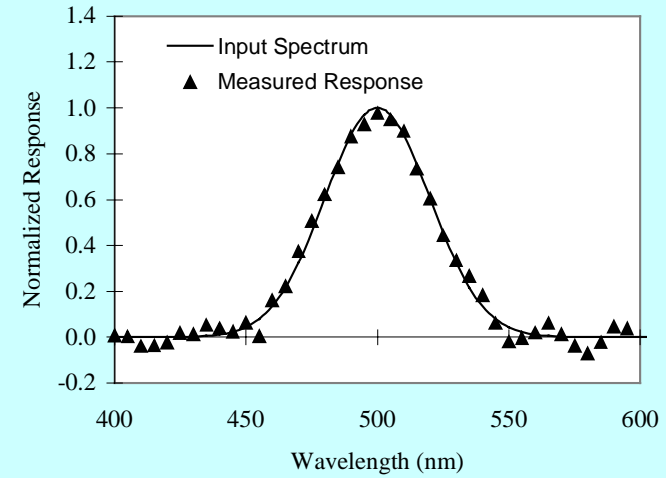
The result is a battery-operated remote sensor package

- ➔ We presently use 4 AA batteries
- ➔ Our plan is to shrink the whole shebang to use camera or hearing-aid batteries

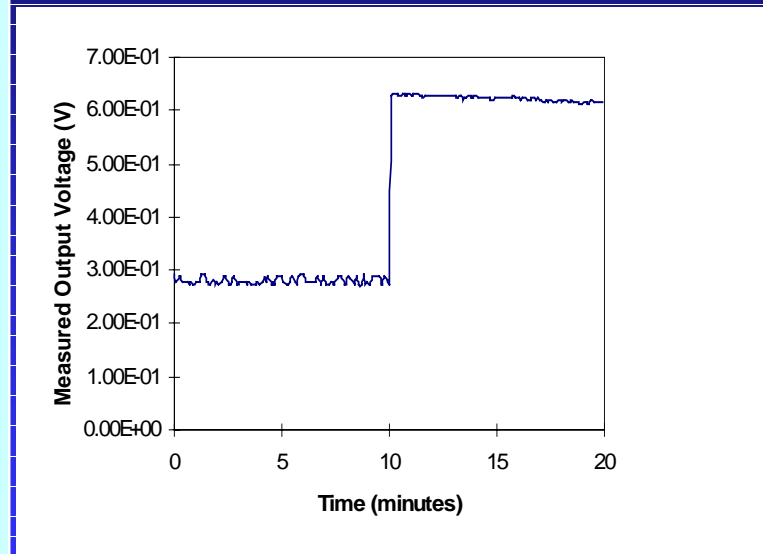
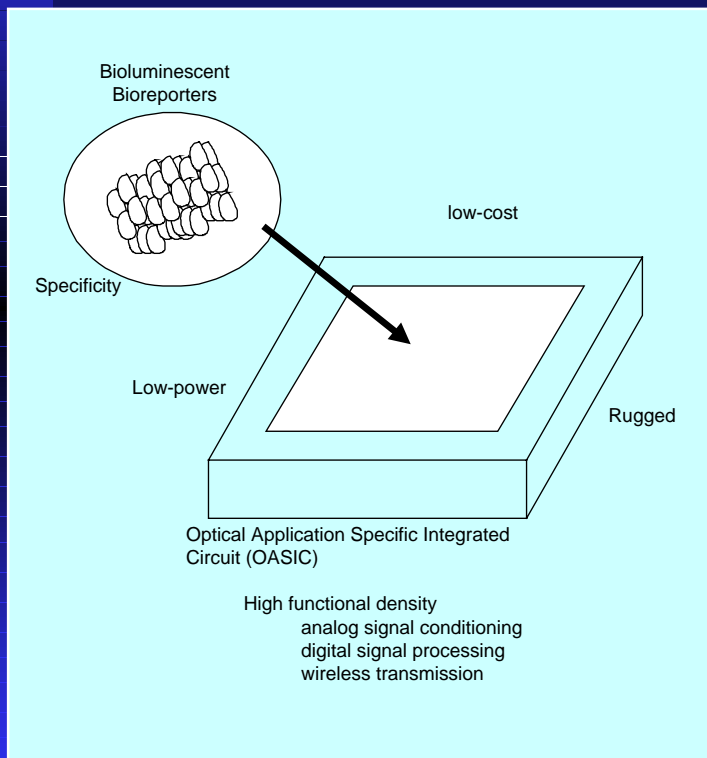




CMOS Photo-Spectrometer



Bioluminescent Bioreporter Integrated Circuits





Intellectual property law

- ➔ Patents become more and more important as the financial stakes get higher
- ➔ A patent is basically worthless until it's been defended against infringement
- ➔ Most of the patent lawyers I have dealt with have at least one technical degree



How to prepare...

- ➔ Get a Master's degree
- ➔ Learn to communicate effectively (spoken and written)
- ➔ Take E-M fields and analog courses
- ➔ Take semiconductor processing and elementary solid-state physics courses
- ➔ Do “hands-on” projects



Mild paranoia is a great asset!

- ☞ Don't let your skills get rusty!
 - ❖ Keep learning new things
 - ❖ Get another degree
- ☞ Change jobs (voluntarily)
- ☞ Pay attention to technology trends
- ☞ Don't ever be lulled into thinking change won't affect you; your career is about 40 years long (27 cycles of Moore's Law)



- The program involves UTEE and Instrumentation and Controls Division of ORNL
- The joint program offers training in many of the aforementioned areas
- Program participation is for M.S. and Ph.D. degrees



**“The fool believes everything,
but the wise man looks well to
his going.”**

Proverbs 14:15