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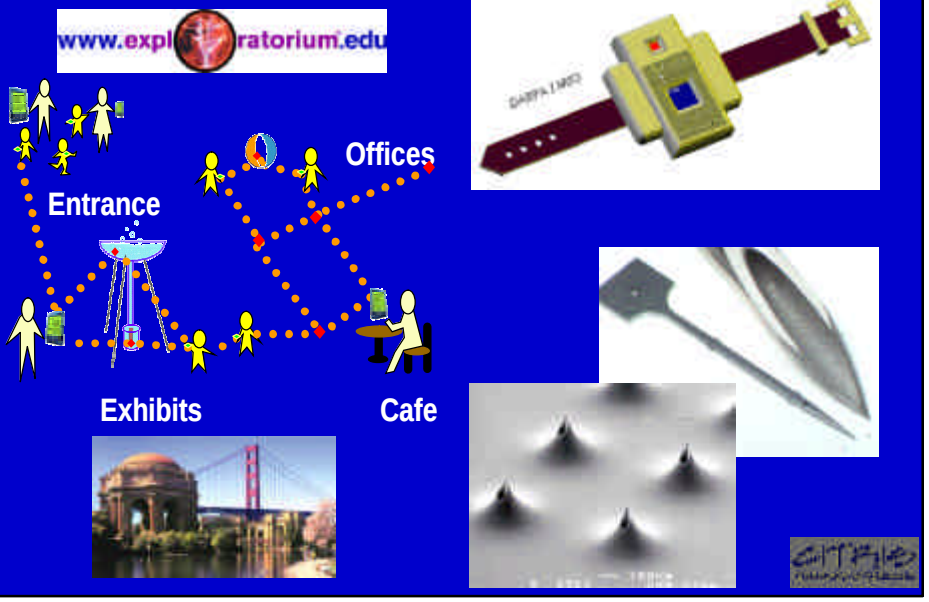
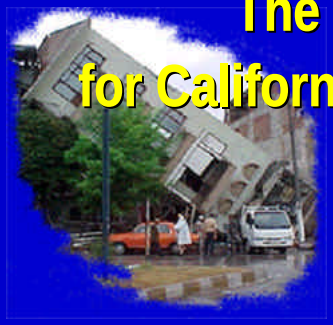
Wireless Measurement, Diagnosis, and Cure



The Best Technology for California's Biggest Challenges



- Education
- Land and Environment
- Seismic Safety & Response

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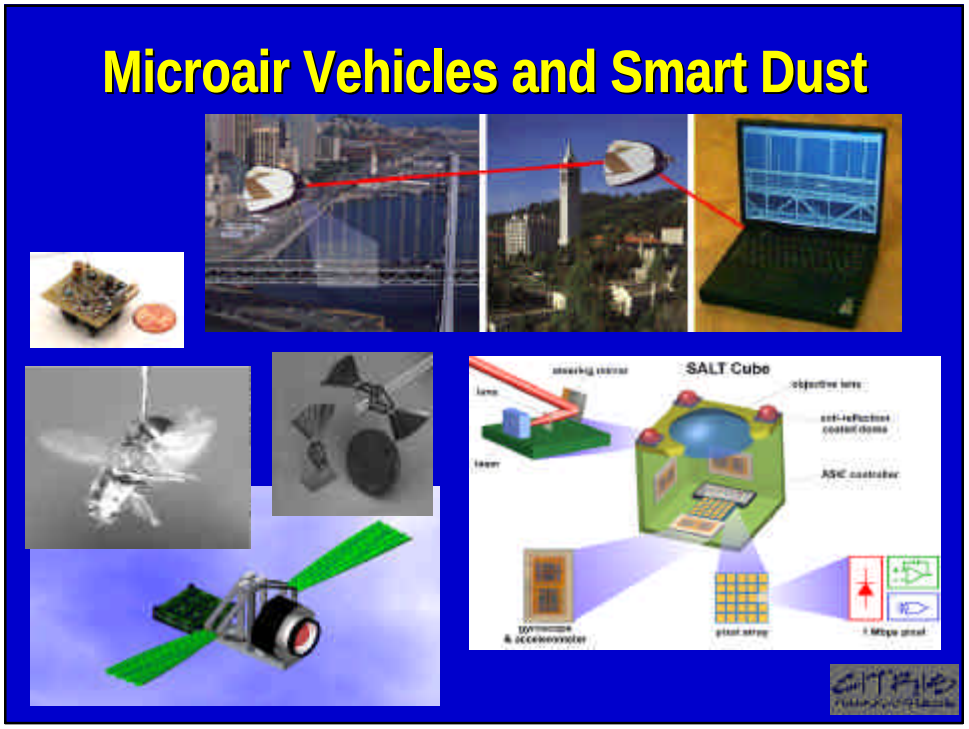
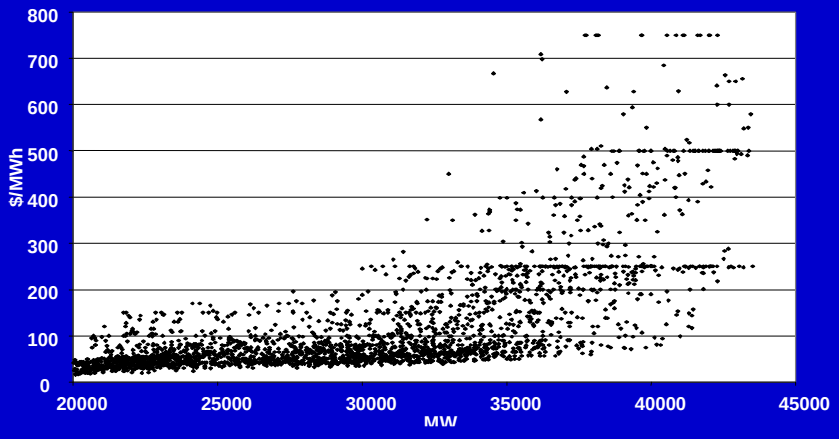


The Inelasticity of California's Electrical Supply



Power-exchange market price for electricity versus load
(California, Summer 2000)

How to Address the Inelasticity of the Supply

- Spread demand over time (or reduce peak)
  - Make cost of energy
    - visible to end-user
    - function of load curve (e.g. hourly pricing)
  - "demand-response" approach
- Reduce average demand (demand side)
  - Eliminate wasteful consumption
  - Improve efficiency of equipment and appliances
- Improve efficiency of generation and distribution network (supply side)

Enabled by Information!

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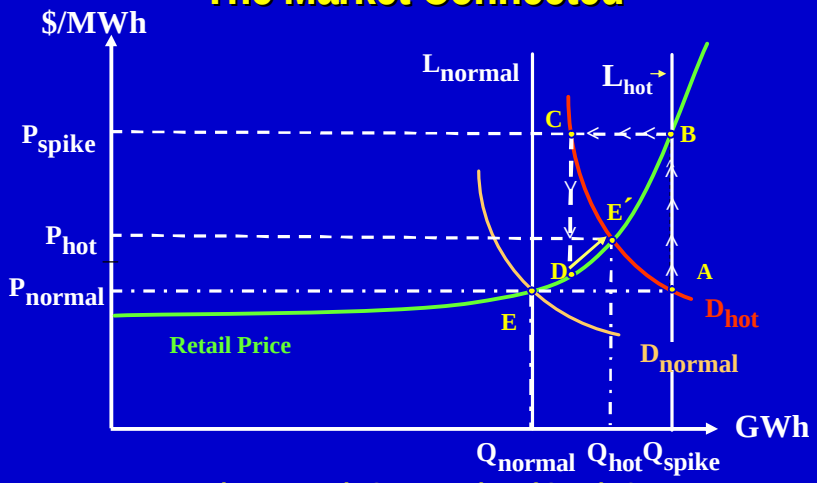
The Market Connected



Demand Response in Steep Portion of Supply Curve
Yields Lower Wholesale Prices [Braithwait-Frauqi01]

"As little as a 1 percent load reduction due to demand response can lead to a 10 percent reduction in wholesale prices, while a 5 percent load response can cut the wholesale price in half"

A Three-Phase Approach

- **Phase 1: Passive Monitoring**
  - The availability of cheap, connected (wired or wireless) sensors makes it possible for the end-user to monitor energy-usage of buildings and individual appliances and act there-on.
  - Primary feedback on usage
  - Monitor health of the system (30% inefficiency!)
- **Phase 2: Quasi-Active Monitoring and Control**
  - Combining the monitoring information with instantaneous feedback on the cost of usage closes the feedback loop between end-user and supplier.
- **Phase 3: Active Energy-Management through Feedback and Control—Smart Buildings and Intelligent Appliances**
  - Adding instantaneous and distributed control functionality to the sensoring and monitoring functions increases energy efficiency and user comfort

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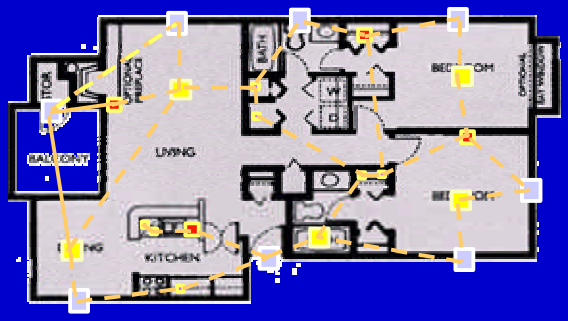
Smart Buildings



Dense wireless network of sensor, control, and actuator nodes

- Task/ambient conditioning systems allow conditioning in small, localized zones, to be individually controlled by building occupants and environmental conditions
- Joined projects between BWRC/BSAC, School of Architecture (CBE), Civil Engineering, and IEOR with Berkeley and Santa Cruz

Energy Consumption in Buildings (US 1997)

End Use	Residential	Commercial
Space heating	6.7	2.0
Space cooling	1.5	1.1
Water heating	2.7	0.9
Refrigerator/Freezer	1.7	0.6
Lighting	1.1	3.8
Cooking	0.6	-
Clothes dryers	0.6	-
Color TVs	0.8	-
Ventilation/Furnace fans	0.4	0.6
Office equipment	-	1.4
Miscellaneous	3.0	4.9
Total	19.0	15.2

(Units: quads per year = 1.05 EJ y^{-1})

Source: Interlaboratory Working Group, 2000

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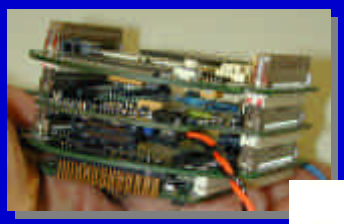
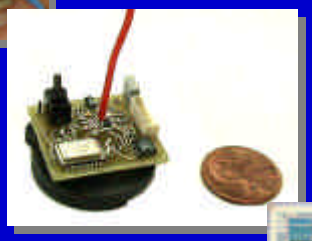
The CITRIS Roadmap



Today

Dynamic ad-hoc networks of ultra low-power wireless sensor, control, and actuator nodes

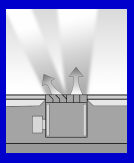


Where we are heading?

Integrated radio
+ sensor on–a-chip
(< 100 mW)

New Building Technologies

- Wireless Sensing and Control
  - Develop low cost, small wireless devices
  - Track temperature, humidity, illumination and occupancy,
- Underfloor Air Distribution
  - Thermal and energy performance
  - Occupant response
  - Technology transfer to design industry
- Task/Ambient Conditioning Systems



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A Proof-of-Concept:
A six month demonstration, already underway!

Leaders: Pister, Culler, Trent, Sastry, Rabaey

- "Easy":
  - Fully instrument a number of buildings on campus with networked light and temperature sensors in every room, and make the data available on a centralized web-site.
- "Medium":
  - Make a wireless power monitor with a standard 3-prong feedthrough receptacle so that people can monitor power consumption of electronic devices as a function of time.
  - Similar device, but passively coupled to high-power wiring to monitor total power consumption through breaker boxes. This would give us a much finer granularity of power-consumption details, and let us look at clusters of rooms, floors, etc.
  - Fully instrument the campus power distribution system
- "Hard":
  - Real-time monitoring and control of hundreds of power systems on campus. Enforce compliance with load reduction. Charge/reward departments according to their use during peak times.

Committed Support from Industry

"I believe we are now entering the Renaissance phase of the Information Age, where creativity and ideas are the new currency, and invention is a primary virtue, where technology truly has the power to transform lives, not just businesses, where technology can help us solve fundamental problems."

Carly Fiorina, CEO, Hewlett Packard Corporation

Founding Corporate Members of CITRIS

BROADVISION, ERICSSON, hp, IBM, Infineon, intel, MARVELL, Microsoft, NORTEL NETWORKS, ST, Sun microsystems

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