Demand Response (DR)
Enabling Technology Development (ETD)
PIER Program

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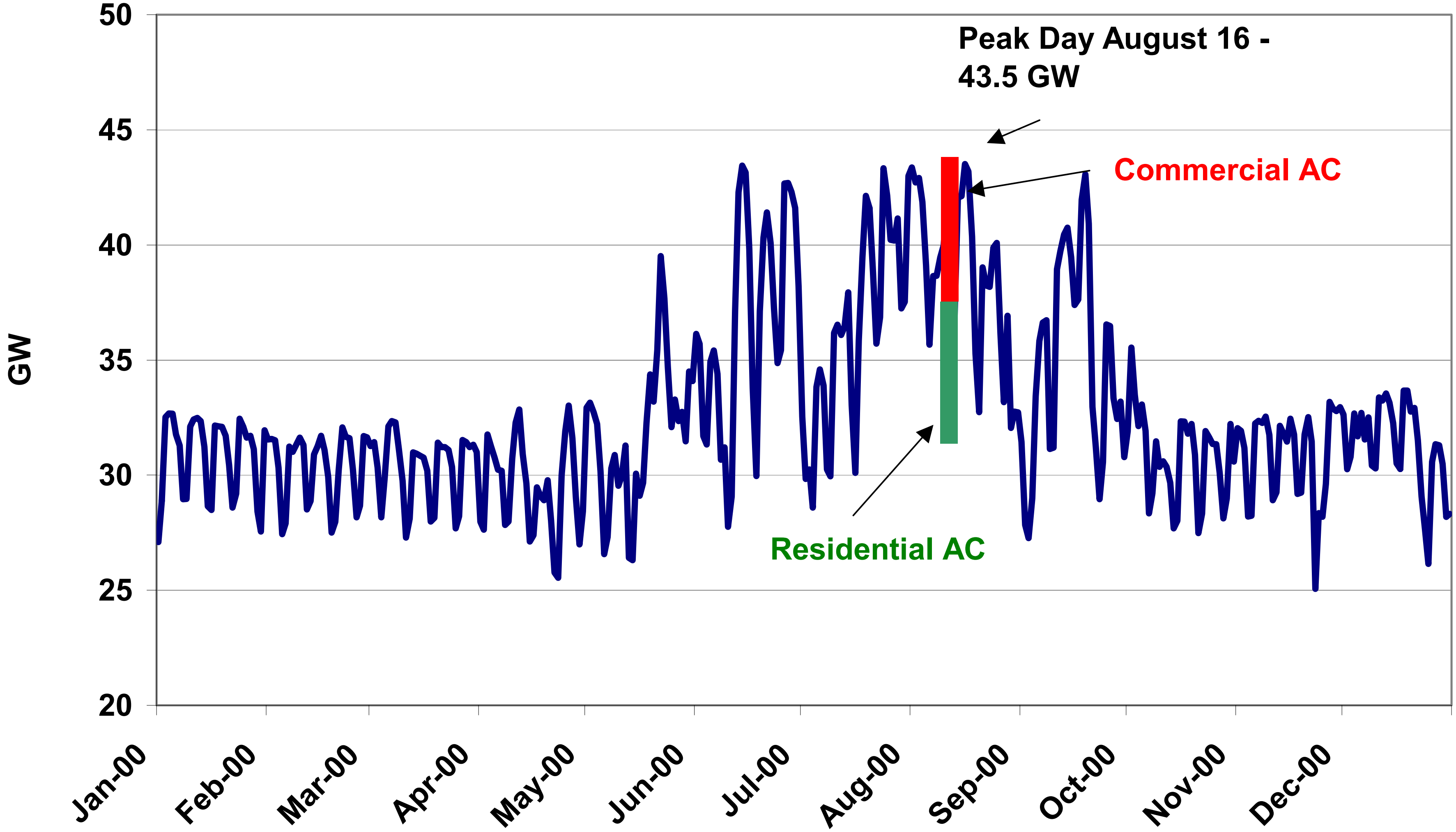
Purpose

- Summarize PIER's DR R&D program and present one project task that may be immediately useful for energy efficiency
- Specifically describe technologies being developed under the DR ETD project and how they could be used to facilitate cost-effective performance monitoring

Cal ISO Daily Peak Loads

January 1, 2000 - December 31, 2000



Options

- Supply-side solutions to provide for peak demand or system emergencies cost up to 10x more than some demand-side solutions
- In 2000-1, less than 5% "automated" load reduction could have avoided blackouts
- Air conditioning is the low-hanging fruit
- A real-time control and communications infrastructure is required to support an automated demand response (DR) system

Demand Response Definition

- **Demand response (DR) is the action taken to reduce load when:**
  - Contingencies (emergencies & congestion) occur that threaten supply-demand balance, and/or
  - Market conditions occur that raise supply costs
- **DR typically involves peak-load reductions**
  - DR strategies are different from energy efficiency, i.e., transient vs. permanent

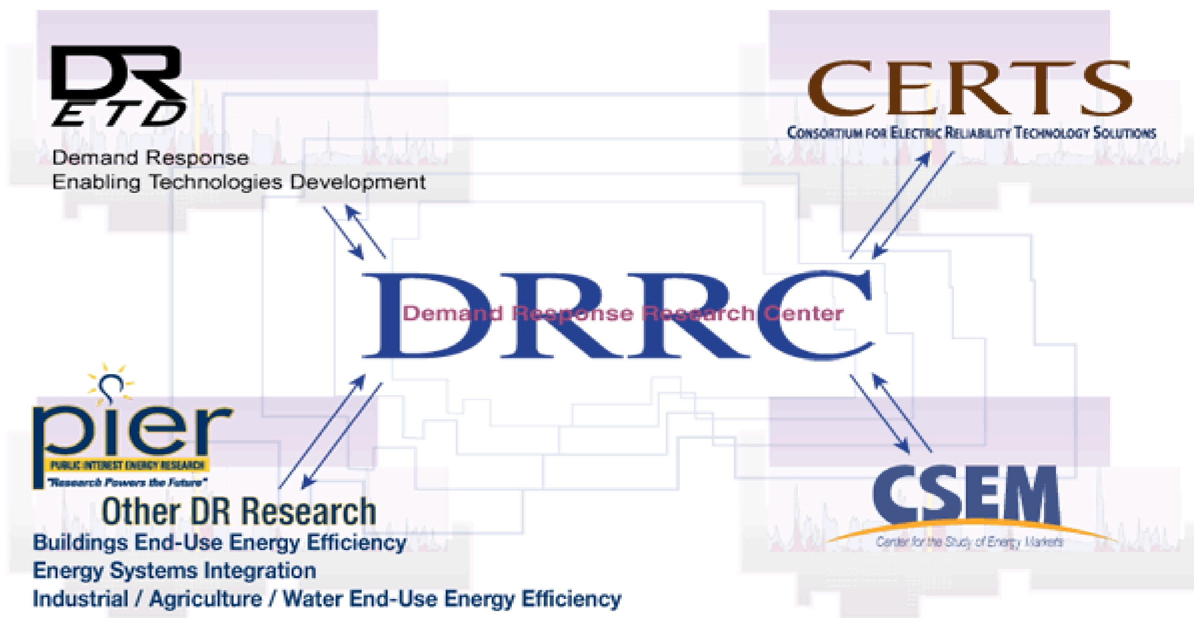
Demand Response R&D Vision

- Create a **real-time, automated DR infrastructure** that is simple to use and can adaptively respond to changing contingency and market conditions
- A DR infrastructure must **coexist with legacy systems, allow for future technology and tariff improvements**, and have near-, medium-, and long-term benefits to California ratepayers

Policy Objectives

- **Energy Action Plan (EAP II)**
  - "Implement a voluntary dynamic pricing system to reduce peak demand by as much as 1,500 to 2,000 megawatts by 2007."
- **Integrated Energy Policy Report (IEPR)**
  - Loading order has DR in second priority
  - 5% peak reduction by 2007
  - Dynamic tariffs for large customers
  - AMI for smaller customers w/ large loads

Current Program Organization



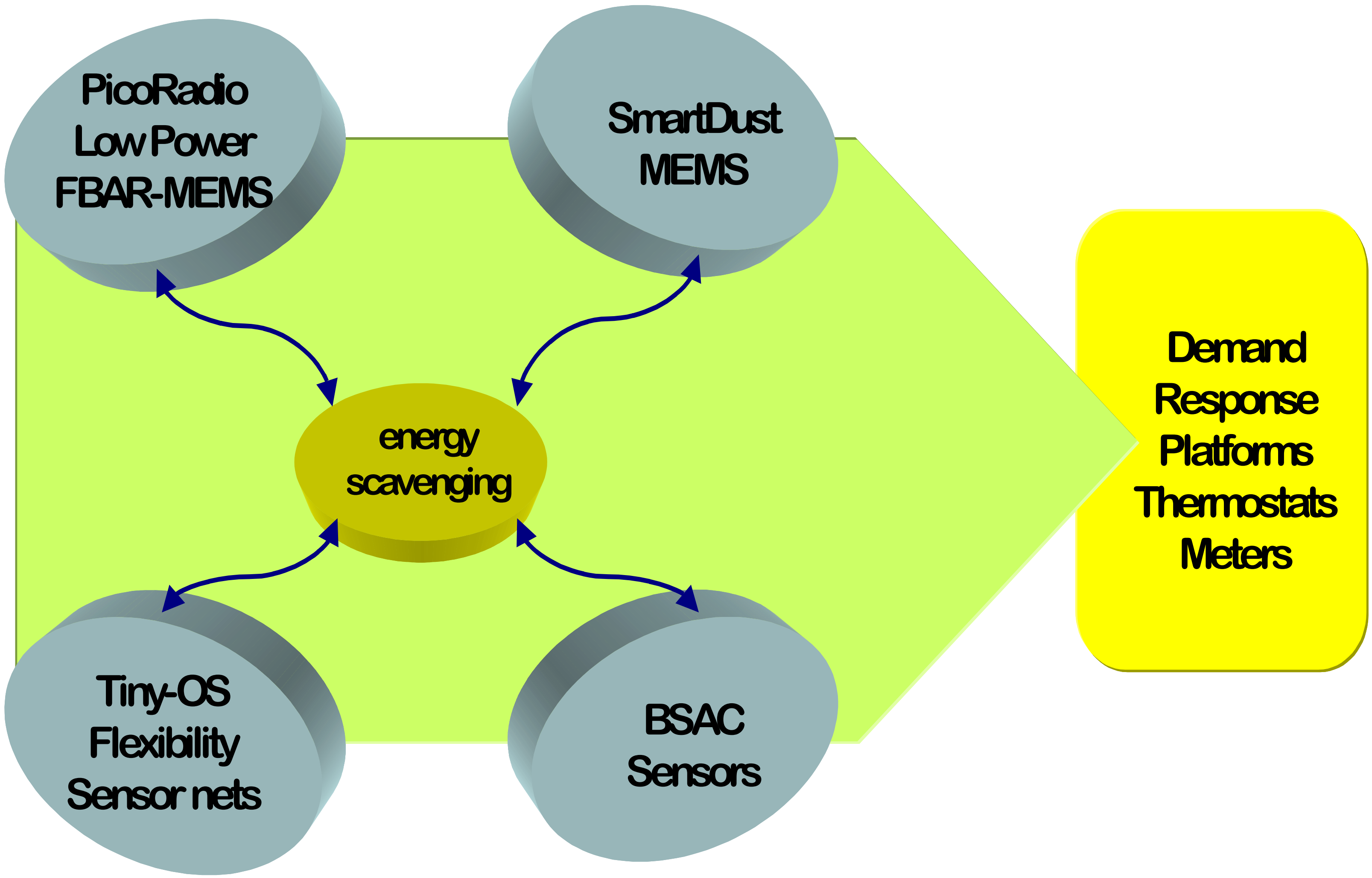
DR ETD Project Overview

- **Mid- to long-term R&D (3-8 year objectives)**
  - To help achieve a DR Infrastructure in California
- **Enabling technologies R&D – not product development**
- **Disruptive technologies – 10x10 improvements and cost**
- **Multi-disciplinary & collaborative research**
  - Promote new ideas – out of the box thinking
- **Leverage DoD, DoE, NSF, Intel, and other funding**
  - Get more value from the PIER funding

UC Berkeley R&D

- **Work based on technologies developed for military and other applications**
  - Smart Dust (highly integrated control platform)
  - Tiny OS (ad hoc self organizing networks)
  - Pico radio (low-cost, low-power wireless)
  - Energy Scavenging (avoid batteries)
- **Funding applies technologies to DR**

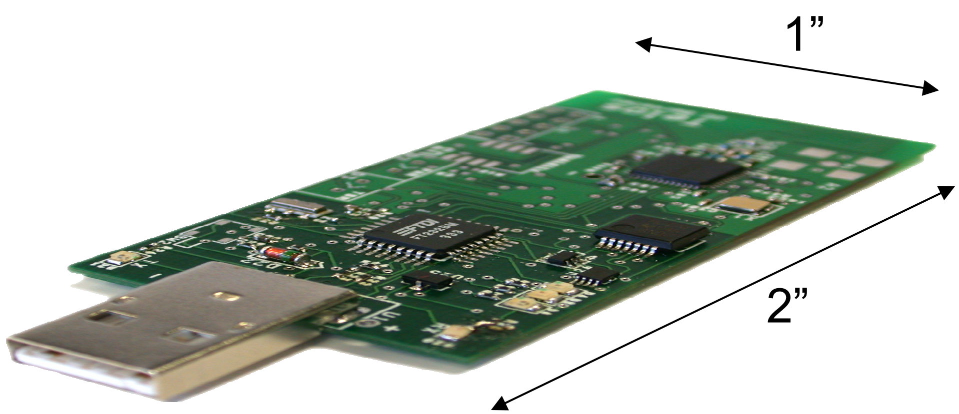
Integration of earlier UCB research (often funded by NSF/DARPA)



Let's now look at some of the technical details...

Phase 1 created special DR technology: TinyOS on Nodes (called 'Motes')

CPU	
Bus Speed	8 MHz
RAM	2 Kb
Program Space	60 Kb
External Flash	512 Kb
Serial Communications	DIO,SPI,I2C,UART
Current (active w/ radio on)	19 mA
Current (sleep)	2.4 µA
Voltage	2.0-3.6V
Radio	
Frequency	2400-2483 MHz
Data rate	250 kbps
Output Power	-25 to 0 dBm
Antenna	Microstrip Inverted-F
Humidity Sensor	
Humidity Accuracy	3.5% RH
Temperature Accuracy	0.5 °C
Electromechanical	
Battery	2xAA, 2/3A



Ultra Low Power Node {called 'Telos'}

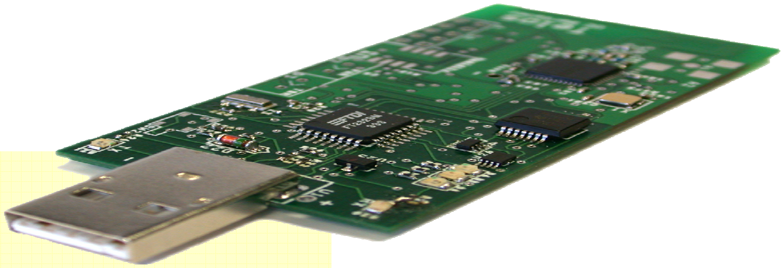
16-bit microcontroller has a sub 1mA sleep state and can rapidly wakeup from sleep in under 6ms.

Telos operates down to 1.8V to extract as much energy as possible from the battery source.

However!! For further cost reduction we need much lower power radios

Why is low power necessary? - Size and cost of our "motes" are today dominated by:

- 1) transmission energy
- 2) power supply

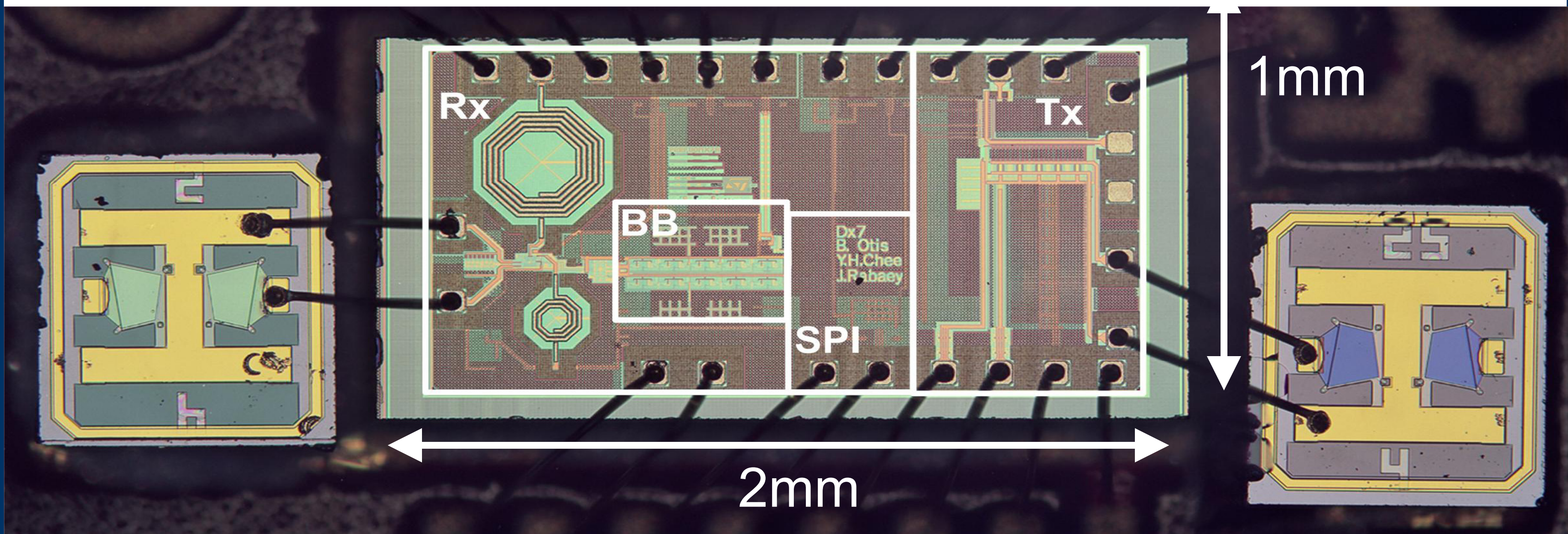


Power consumption determines sensor node volume.

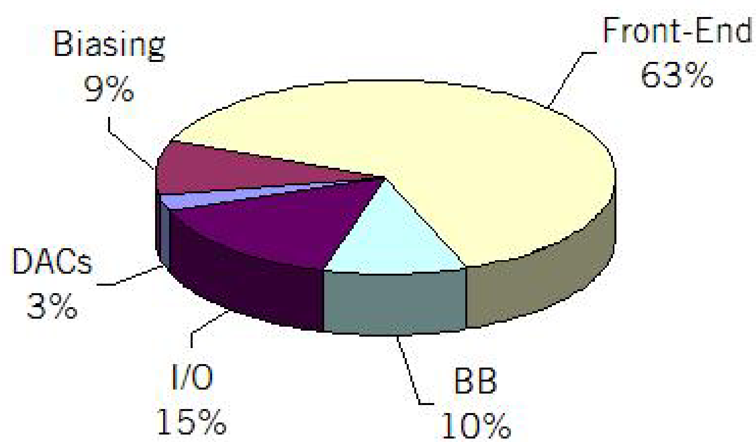
(Similarly, in some consumer products and toys, you might need several bigger 9 volt batteries, rather than one or two AA, or even smaller AAA, batteries,)

For an eventual 1cm^3 node, running at a 1% Duty Cycle, we will need $P_{transceiver}$ <500microwatts

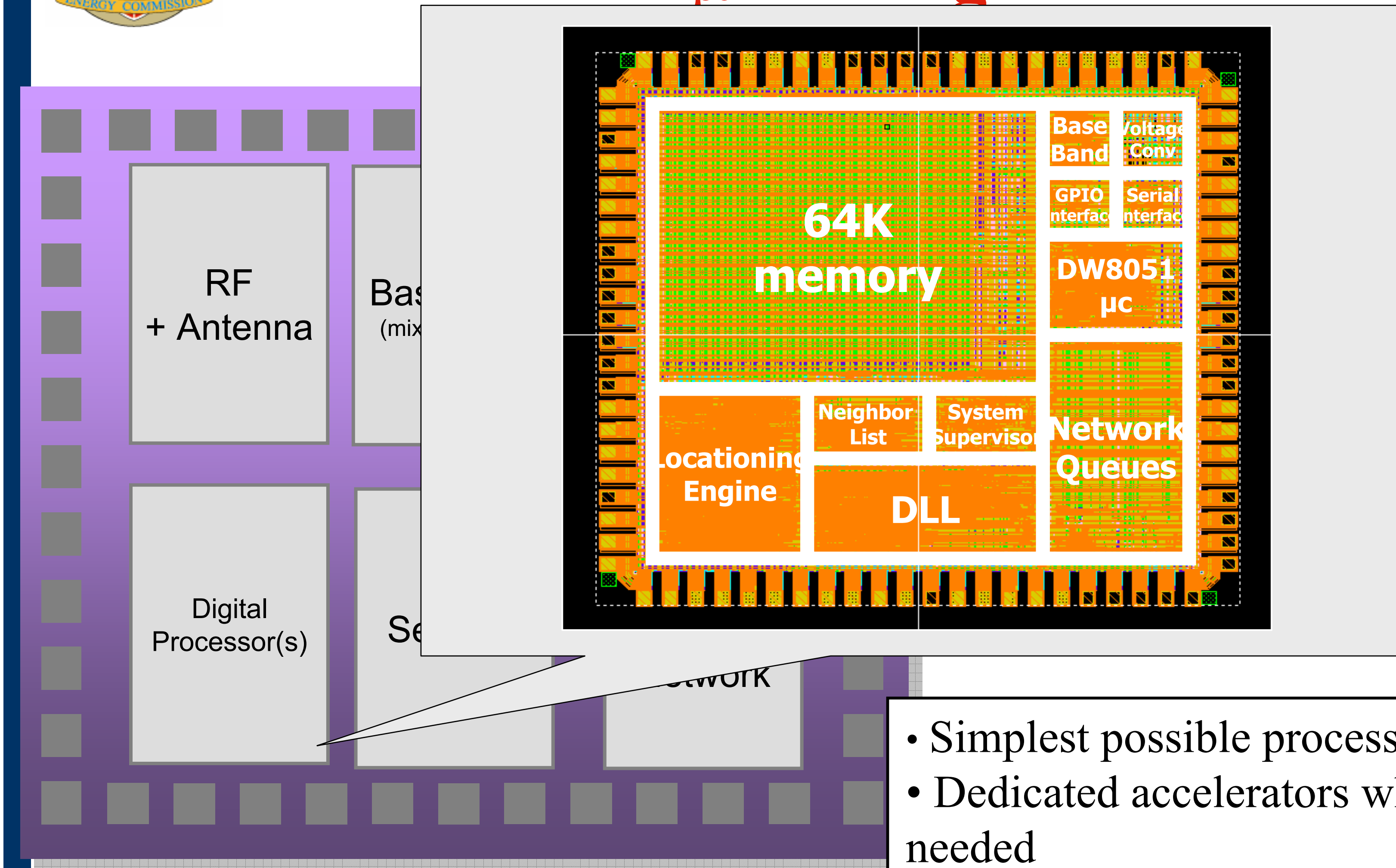
Smaller, Cheaper Radio Components



- No External Components (inductors, crystals, capacitors)
- 0.13mm CMOS
- Full digital SPI control of analog/RF blocks



Even Smaller Radios in Progress: A sub-100 µW Integrated Node

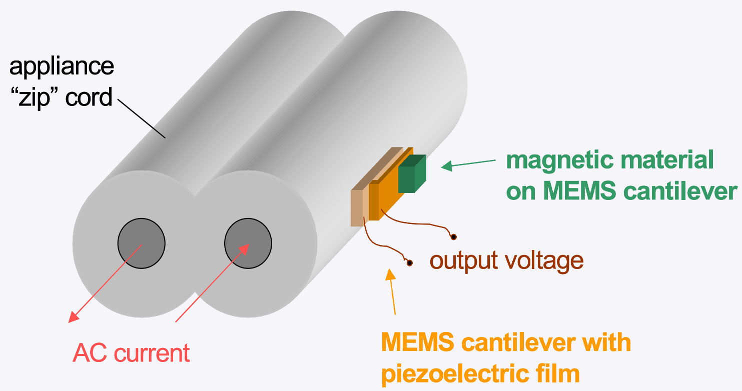


- Simplest possible processor
- Dedicated accelerators when needed
- Aggressive power management
- Minimizing supply voltage

Courtesy: Mike Sheets

MEMS version (Micro Electrical Mechanical Systems) for Phase 2 DR

Proximity Measurement

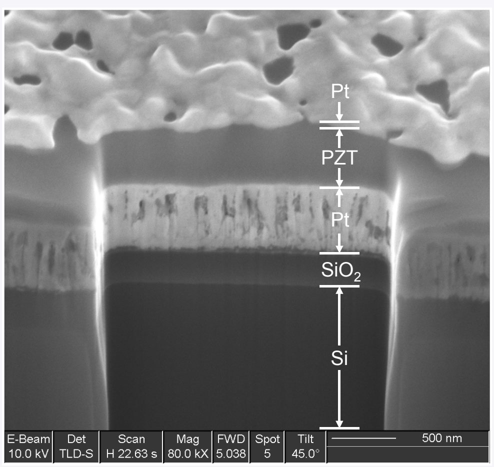


MEMS Advantage

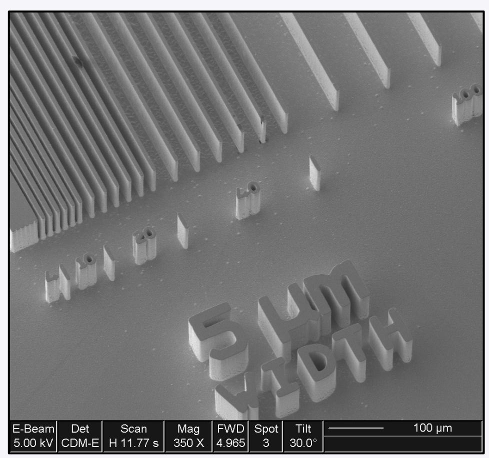
Smaller = cheaper !

Arrays allow correction for position errors

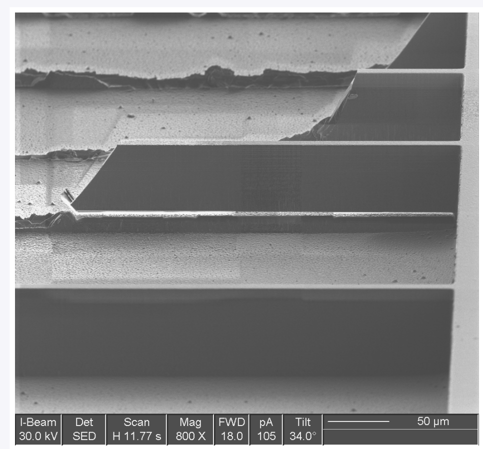
Microfab



thin films



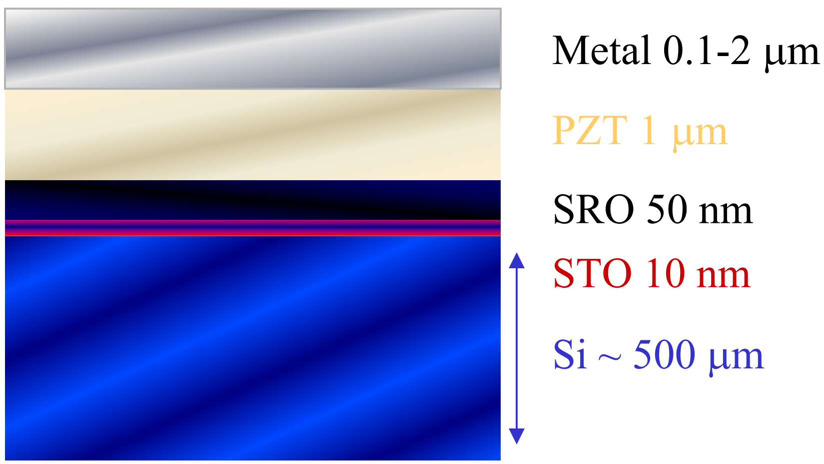
arrays of unreleased sensors



single cantilever released

Phase 2 DR research: MEMS scale

Piezoelectric and Elastic Layers



1. $SrTiO_3$ (STO) coated (10 nm) single crystal Silicon **[Motorola, Inc.]**

2. Deposition of $SrRuO_3$ (SRO) bottom electrode, and PZT with pulsed laser deposition.

3. Deposition of metallic elastic layer via e-beam evaporation/thermal evaporation

Elastic Layer Deposition Methods

*__Pt__- electron beam evaporation, Ti adhesion layer

*__Ni__- thermal evaporation

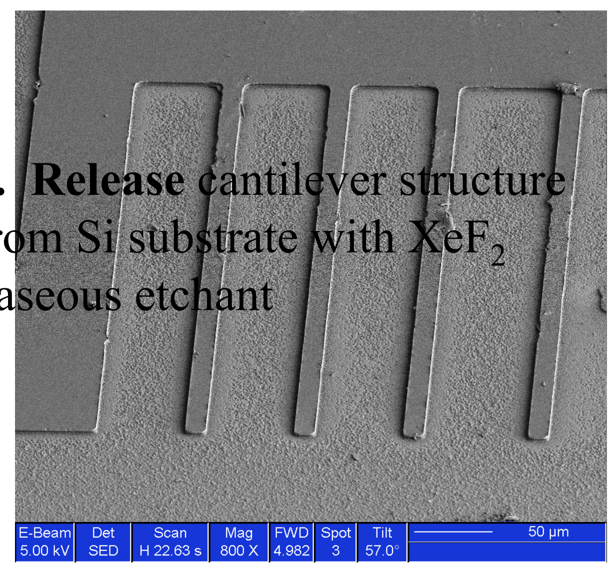
*__Au__- electron beam/thermal evaporation, Cr adhesion layer

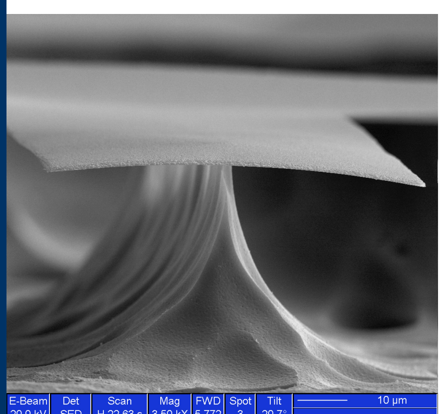
Phase 2 DR research: MEMS scale
Cantilever Array Structures

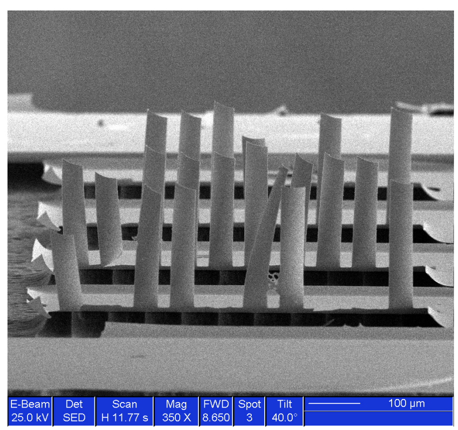
4. Definition of devices using photolithography

5. Etch heterostructure with Ar ion milling to expose Si substrate

6. Release cantilever structure from Si substrate with XeF_2 gaseous etchant

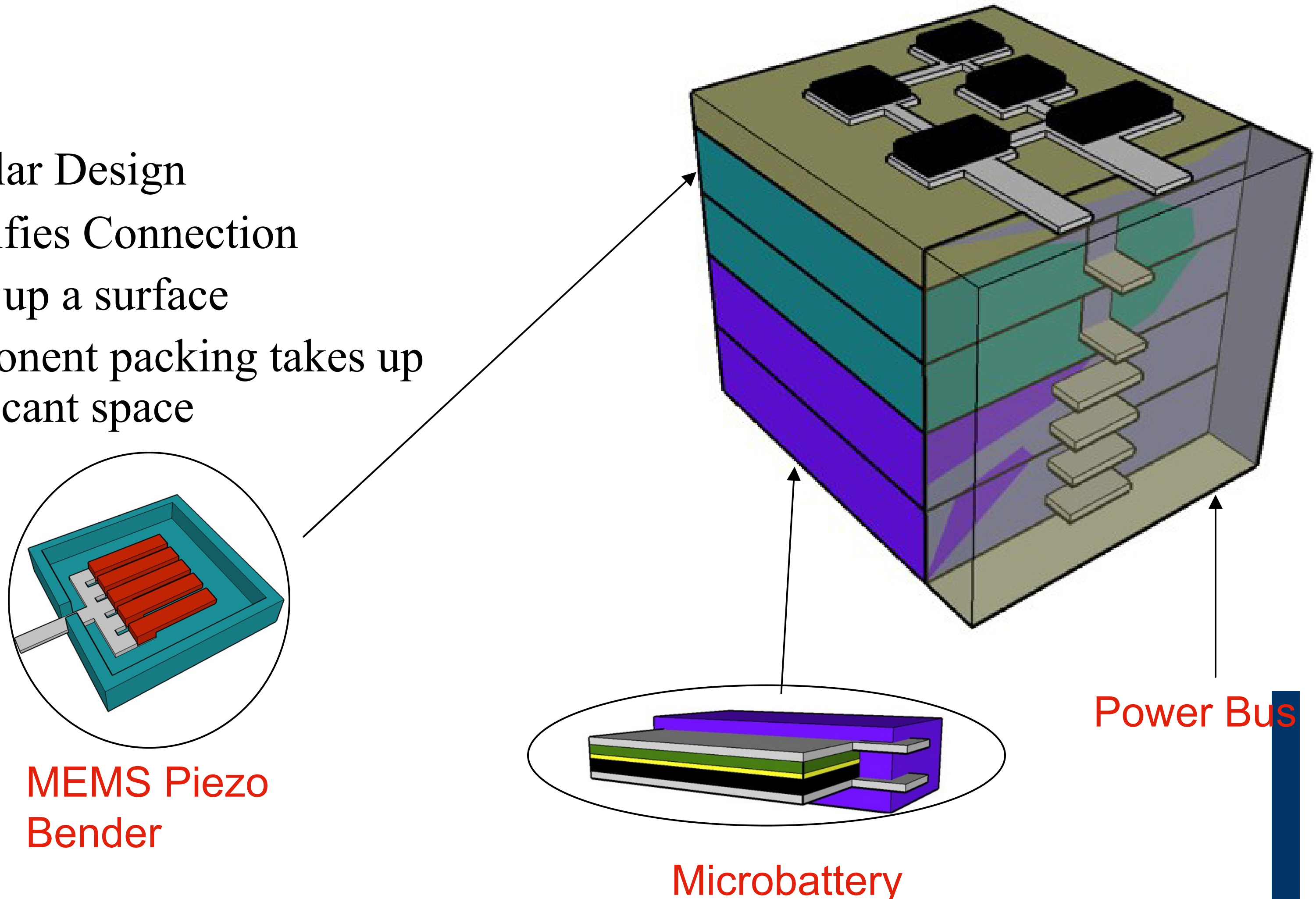






Making everything as small as possible to reduce cost

- ≥ 3 Separate Components
- 1 Bus
- Overall
  - + Modular Design
  - + Simplifies Connection
  - - Takes up a surface
  - - Component packing takes up significant space

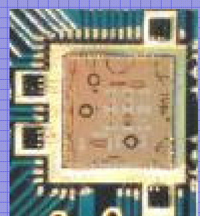


Challenges of Phase 2: Even lower power radios, integration with scavenging, and cost reduction

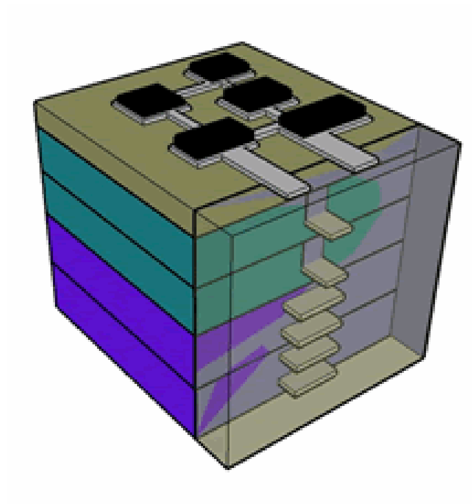
"Disappearing Computer"

B. Gates, *Economist* (2003)

Low Power Radio



Power Storage



"Picocube"

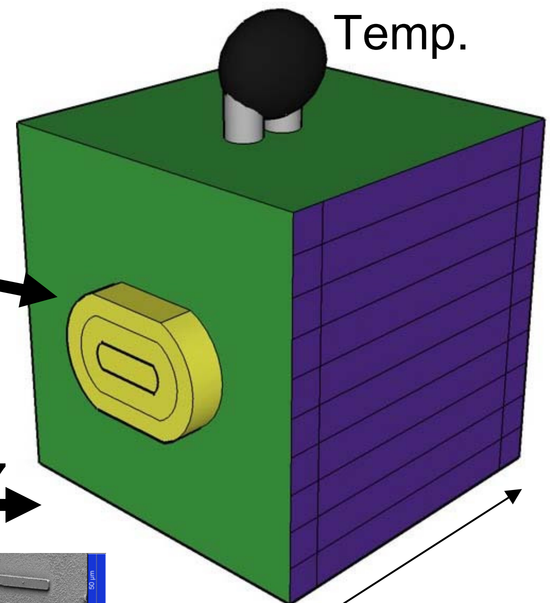
Sensor

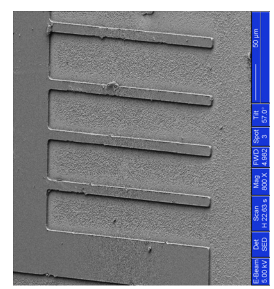
Renewable Power Supply

DR Core Technology Trend

10x10x10 →

Today's prototypes 2005 2006 2007





MEMS version in progress for 2007

Summary

- Low-cost wireless DR mesh networks can also be used for continuous monitoring
- MEMS-level (and eventually NEMS) will allow cost-effective ubiquitous sensing for commissioning & performance monitoring
- Energy scavenging power supplies will reduce O&M costs by increasing battery life beyond 20 years

Backup Slides

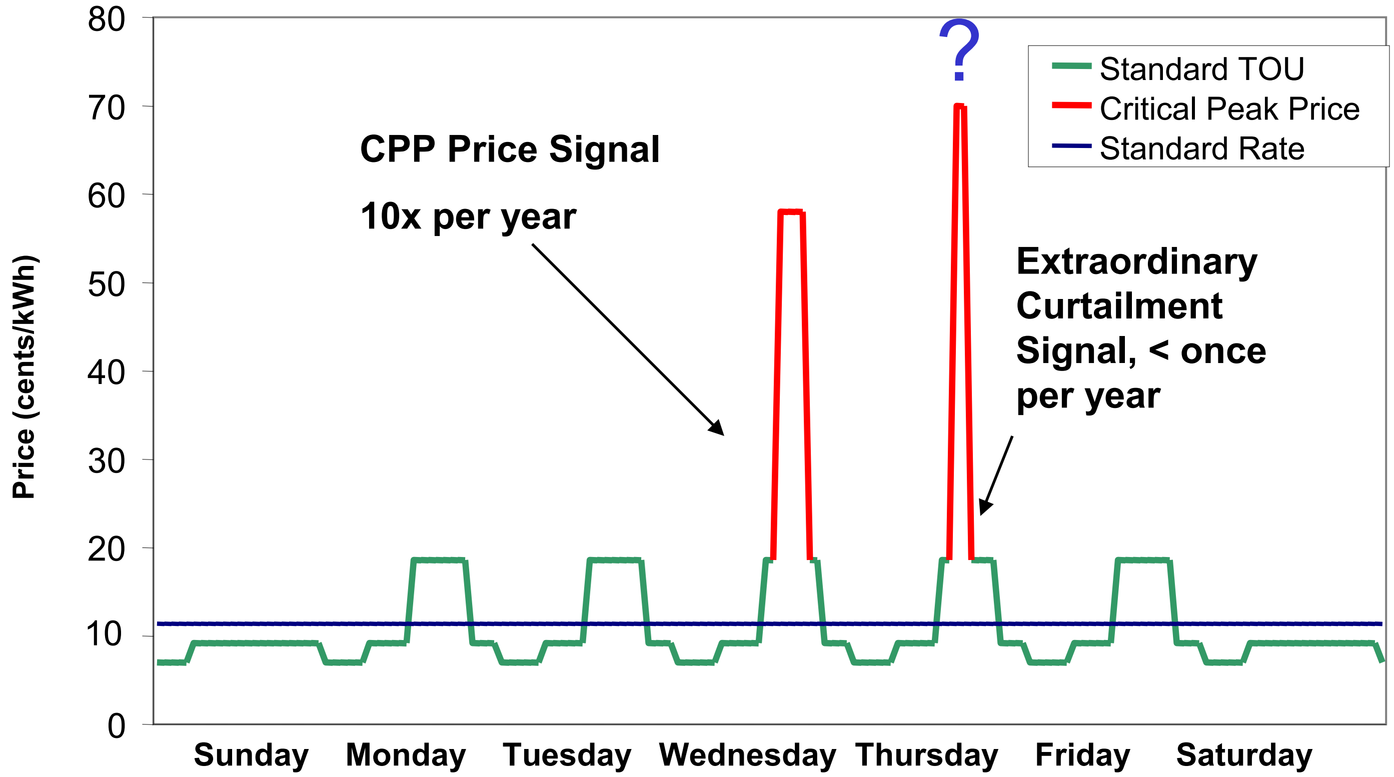
DR Regulatory Proceedings

- **OIR# R.02-06-001**
  - Joint Proceeding – CPUC and CEC
- **Working Groups**
  - WG# 2 > 200 kW (25-30,000 electric meters)
    - All have interval meters and TOU tariff
  - WG# 3, < 200 kW (~11 M electric meters)
    - 2,500 customers in a Statewide Pricing Pilot (SPP)
  - IOU Business Plans for Automated Meter Infrastructure (AMI)
- **Goal: ~ 1% per year = 5% 5 years after t=0**

Critical Peak Pricing (CPP): 2 Major Functions

- Economic
  - On 10 or fewer hot afternoons, CPP prices goes to $0.50 - $1.00 per kWh with 24 hour notice
  - Customer decides on how to respond to price
- Grid protection or reliability
  - < 1 time per year, local or system-wide problem
  - No advance notice, No over-ride of a/c
    - Thermostats, pool pumps, electric water heaters, etc.

Critical Peak Pricing (CPP) with additional curtailment option



Static vs. Dynamic Tariffs

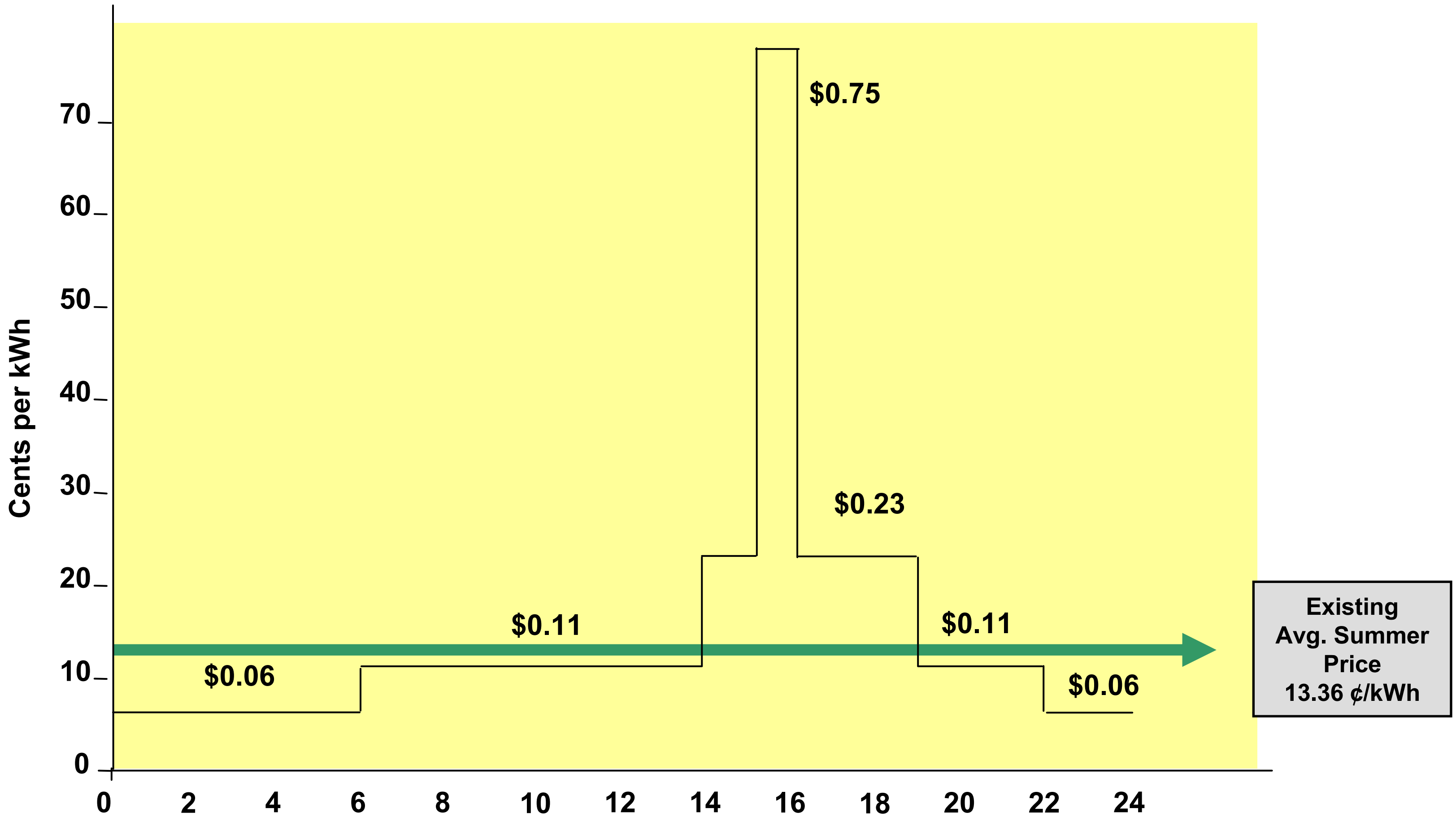
STATIC

- Flat (13¢/kwh)
- Inverted Tier
  - <250 kwh - 13¢/kwh
  - 250-750 kwh - 19¢/kwh
  - >750 kwh - 26¢/kwh
- TOU (Time of Use)
  - Night - 6¢/kwh
  - Shoulder - 11¢/kwh
  - Peak - 23¢/kwh

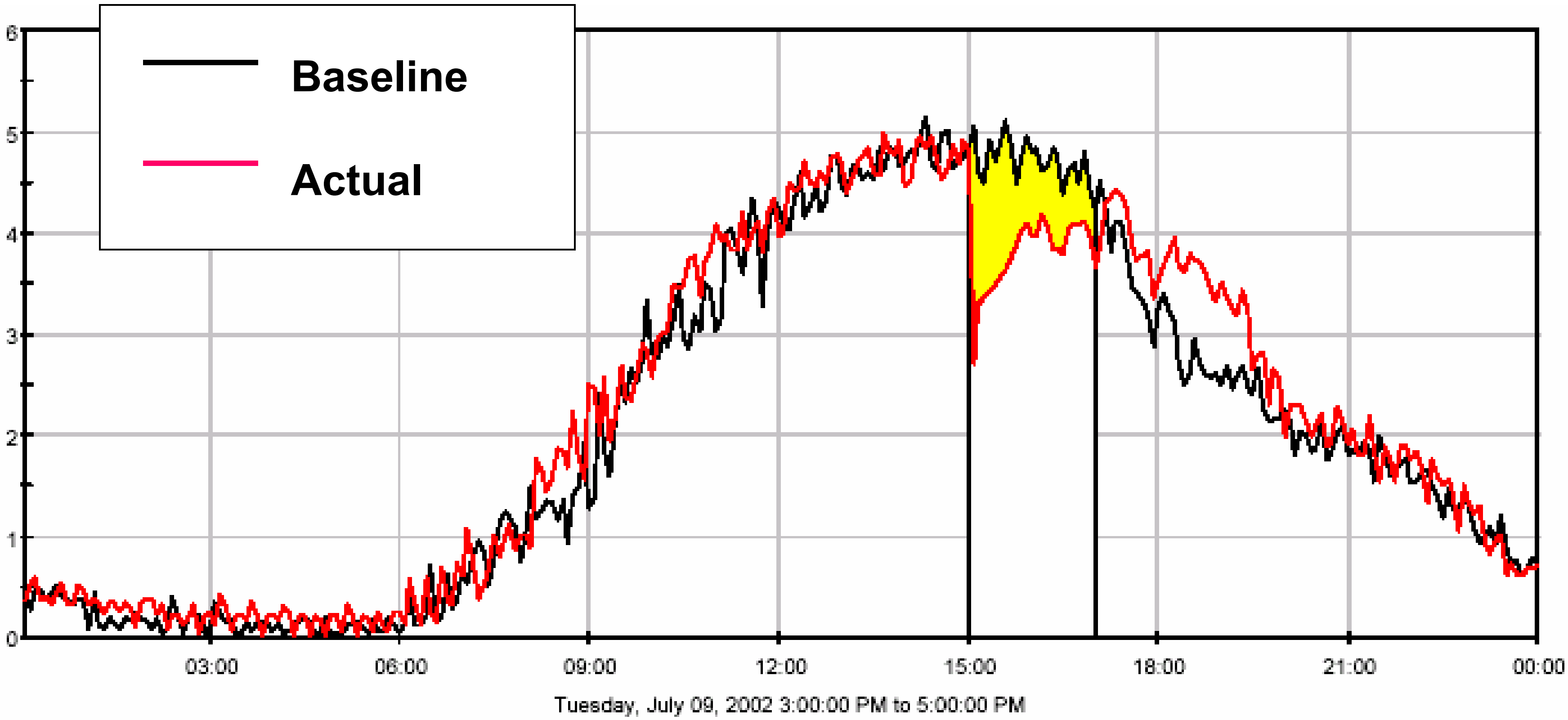
DYNAMIC

- CPP (Critical Peak Pricing)
  - 50 hours per year
  - 2-5 hours per event
  - ~5x (75¢/kwh), ~10x levels
- RTP (Real-time pricing)
  - Hourly 24x7
- Emergency
  - minimal notice

TOU with CPP Example



Example of Smart Thermostat Response for Small Commercial Customers. Thermostat Raised 4º F



Source: Program Impact Evaluation of the 2002 SCE Energy $mart Thermostat Program Final Report, RLW Analytics, 2/28/2003

Deployment Comparison Between AMI and Load Control Devices

System Initiative	Advanced Metering Infrastructure (AMI)	Load Control Devices (e.g., lights, thermostat, pool pumps, EMCS)
Market Process	Regulated	Unregulated
Owner	Utilities	End user (residential, C&I)
Primary Function	Provide electricity metering & monitoring	Control actions in response to signals: price (market) , reliability (contingency, system protection)
Supported Features	• Changing tariffs • New applications • Inc. upgrades • Net metering • Gas & water	• Default control/shed strategies • Manual override switch • Default programming option • Remote audit/support • Customer choice
Other Stakeholders	Regulators (rate case)	Utilities (system reliability, incentive programs)