



Programmable Communicating Thermostats for Demand Response in California

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BMI Lunch Seminar
September 24, 2007



PCT Research at UC Berkeley

- PIER-funded research team:
 - PI's: D. Auslander, R. White, P. Wright
- Since 2006: support regulators and industry stakeholders by researching key technical and safety issues:
 - Strawman "minimum functionality" PCT concept and bill of materials
 - Proof-of-Concept demonstration
 - Research technical implementation issues for PCT interfaces and advise industry working group
 - Measurement tool for RDS (one-way comm.) reliability
 - Simulate aggregate effects of PCT's on electricity grid

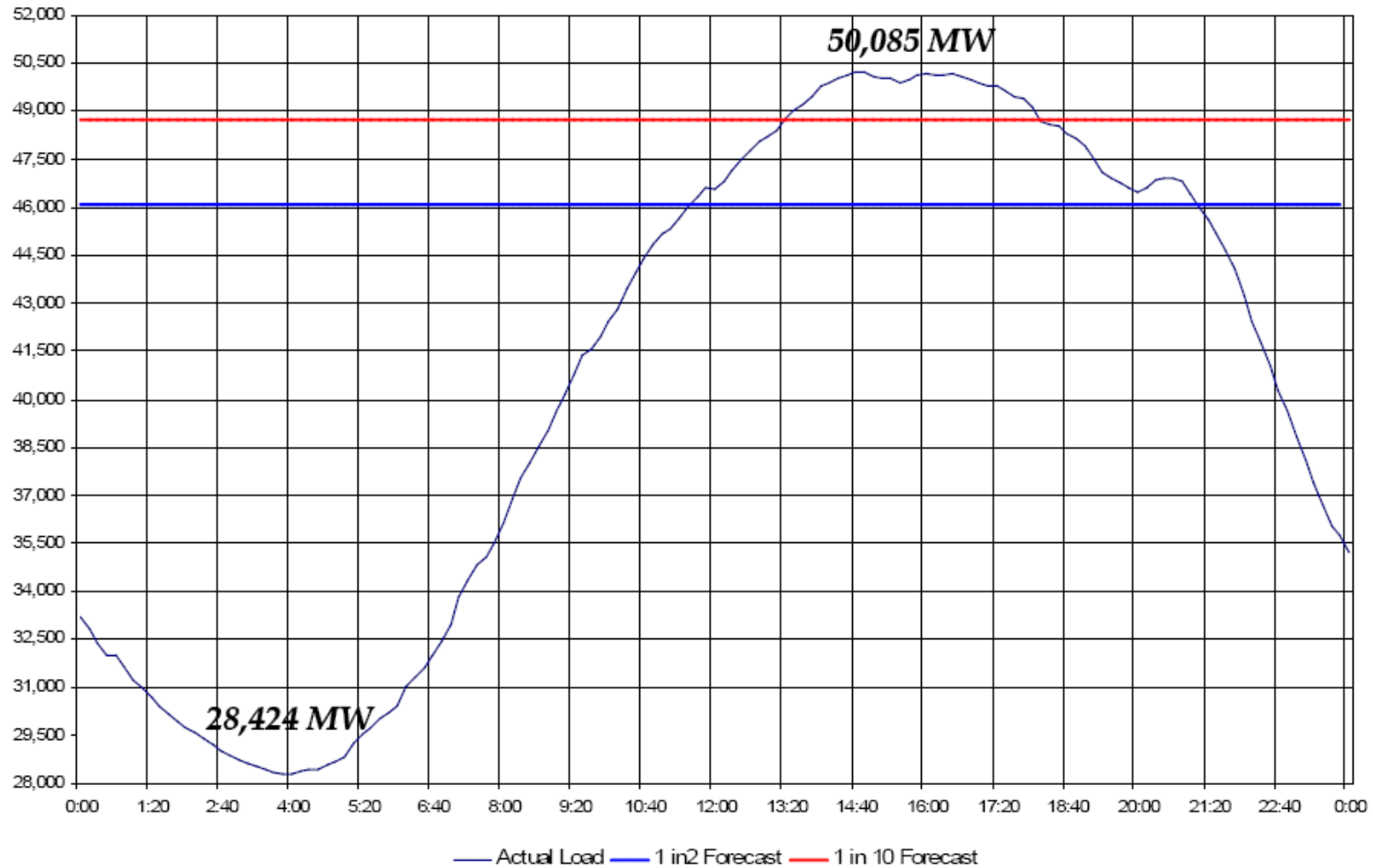


big picture background

(why we research demand response)



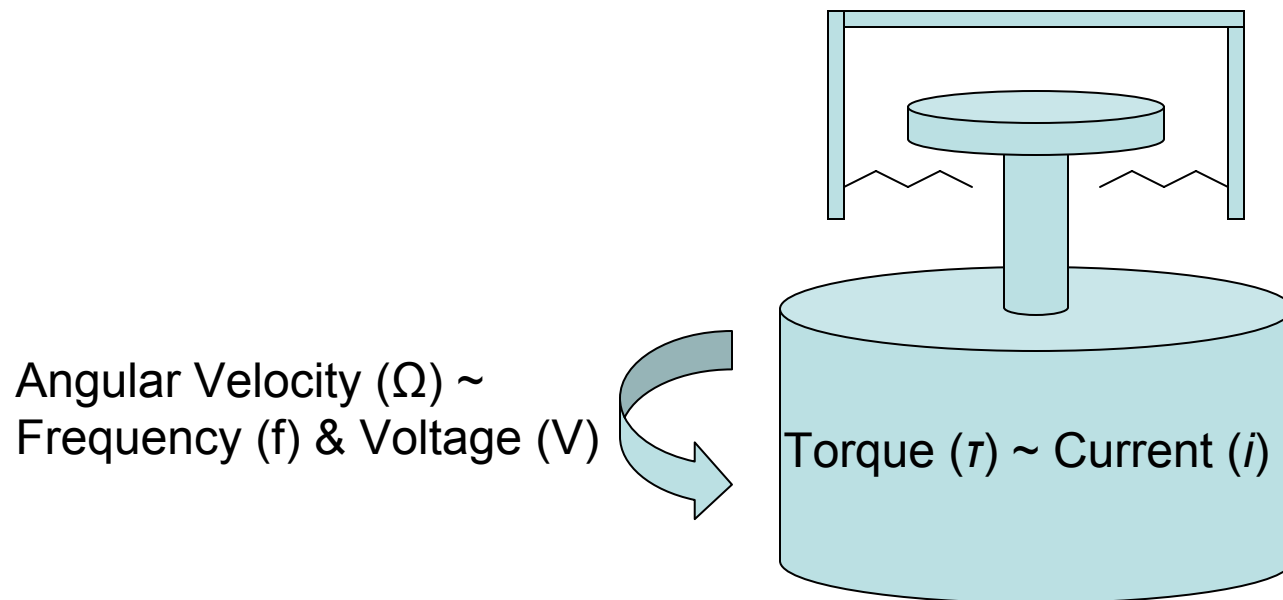
CAISO Load Curve July 24, 2006





Why Demand **MUST** = Supply

Viscous Damping (D) \sim Resistance (R)



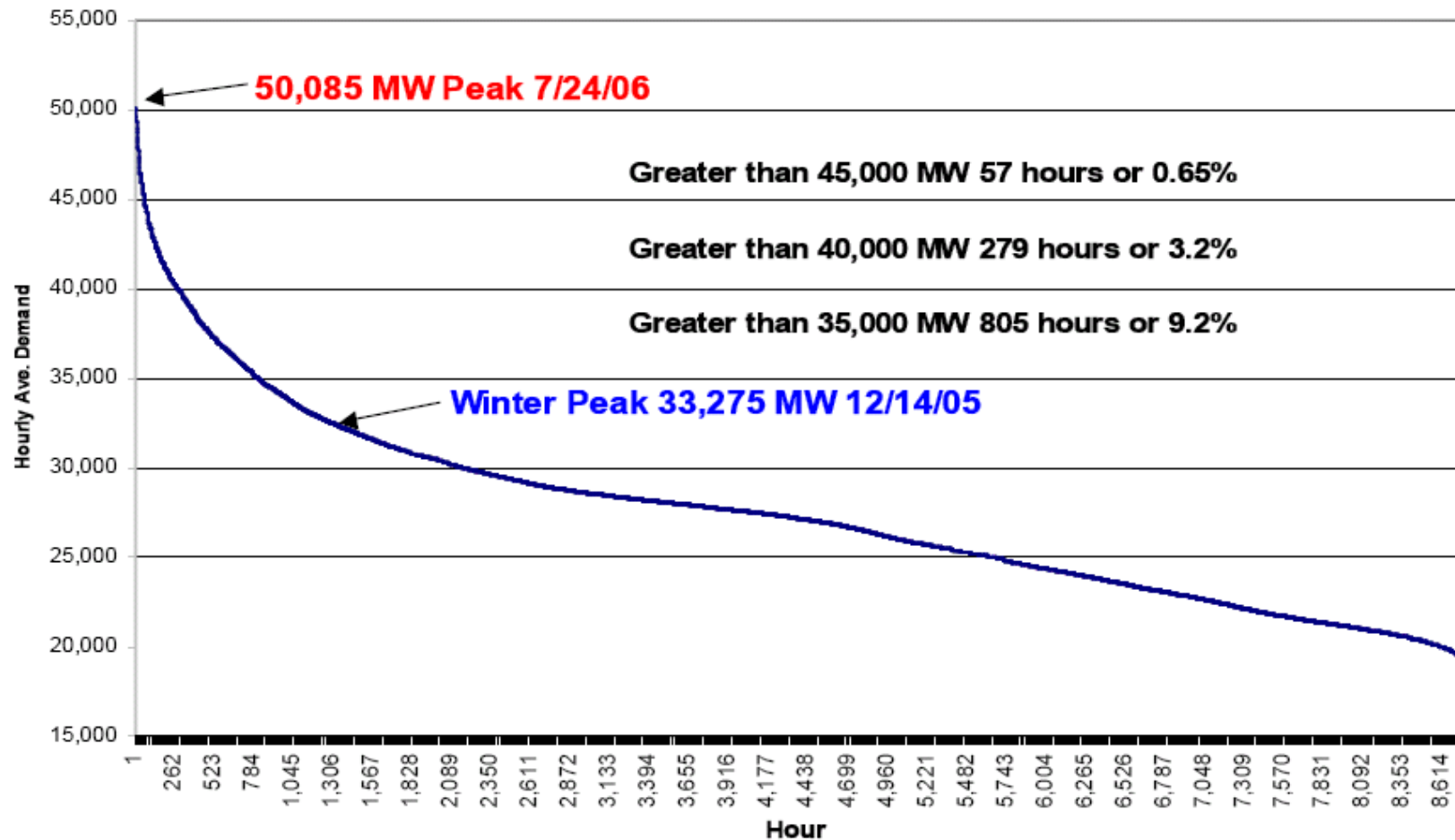
Mechanical: If you increase **DAMPING** without increasing the **TORQUE**, you lose angular velocity

Electrical: If you increase **RESISTANCE** without increasing the **CURRENT**, you get **UNDER-FREQUENCY** and **UNDER-VOLTAGE** problems



CAISO Load Duration Curve

Sept '05 to Sept '06



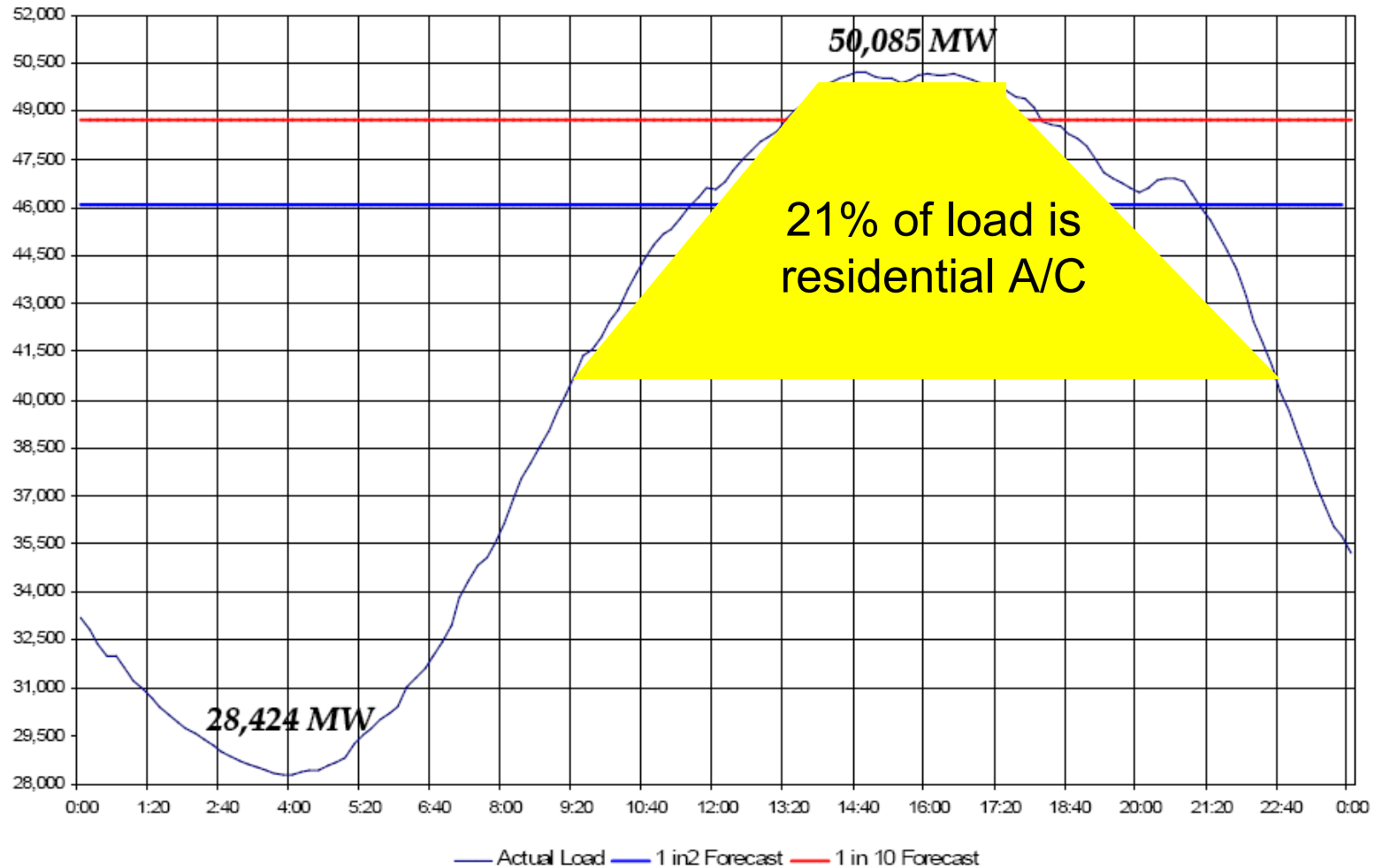


project background

(why the PCT team spent 2 years
researching thermostats)



CAISO Load Curve July 24, 2006





Programmable Communicating Thermostat

- PCT = Programmable
Thermostat +
Communication Interface
- Send signal to PCT to curtail load:
 - Price (voluntary)
 - Curtailment (mandatory)
- 1-way and 2-way comm. technologies:
radio, paging, telephone, Internet
- SCE Energy\$mart Program
demonstrated potential of PCT's to
curtail ~ 0.3 kW/ton (A/C size)





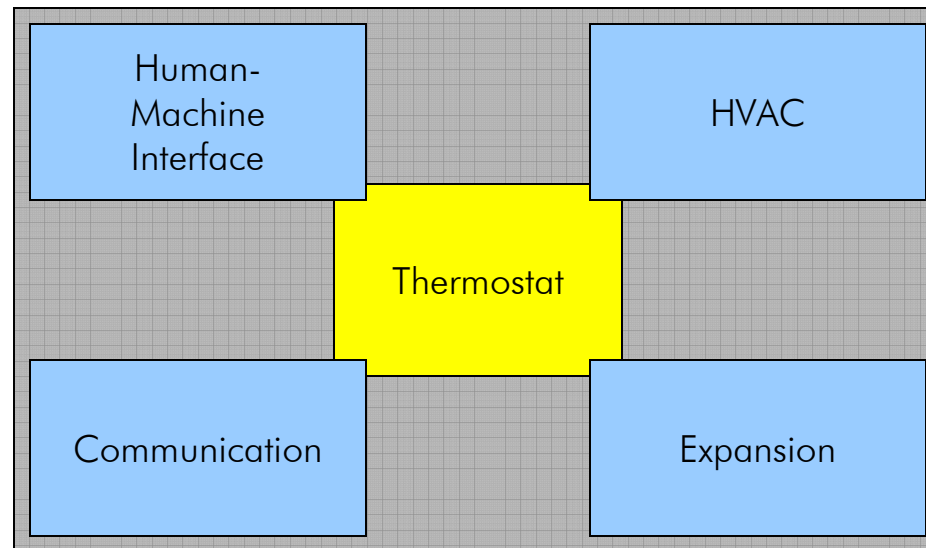
CEC's PCT Vision

- Mandate residential PCT's through 2008 Title 24 building standard
- Potential for several GW of curtailable load – "negawatts cheaper than megawatts"
- Prevent rotating blackouts, increasing public safety and equity
- Managing A/C at t-stat provides better comfort and communication to customer
- Statewide standards for "systems integration interfaces" to ensure compatibility & flexibility, reduce overall cost





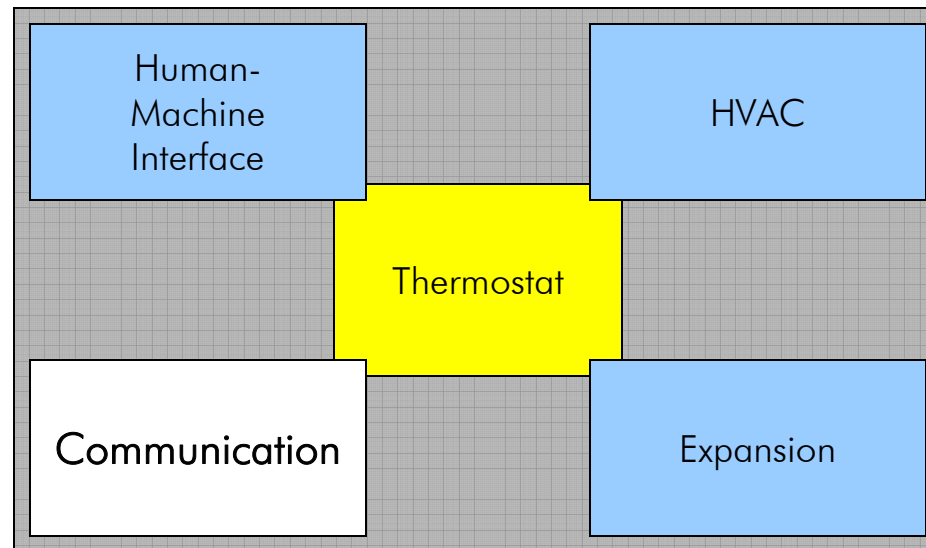
PCT System Interfaces





PCT System Interfaces

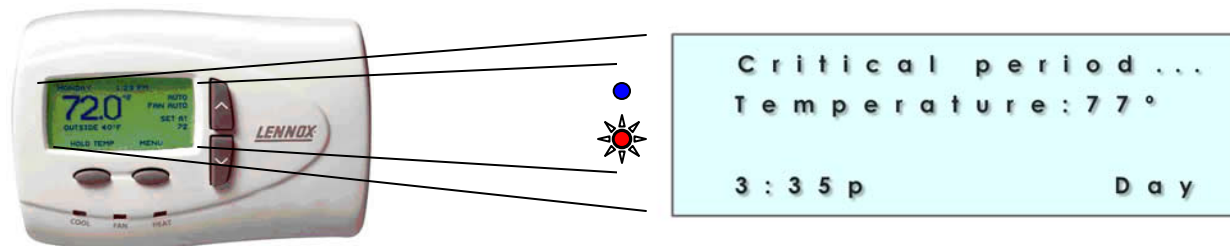
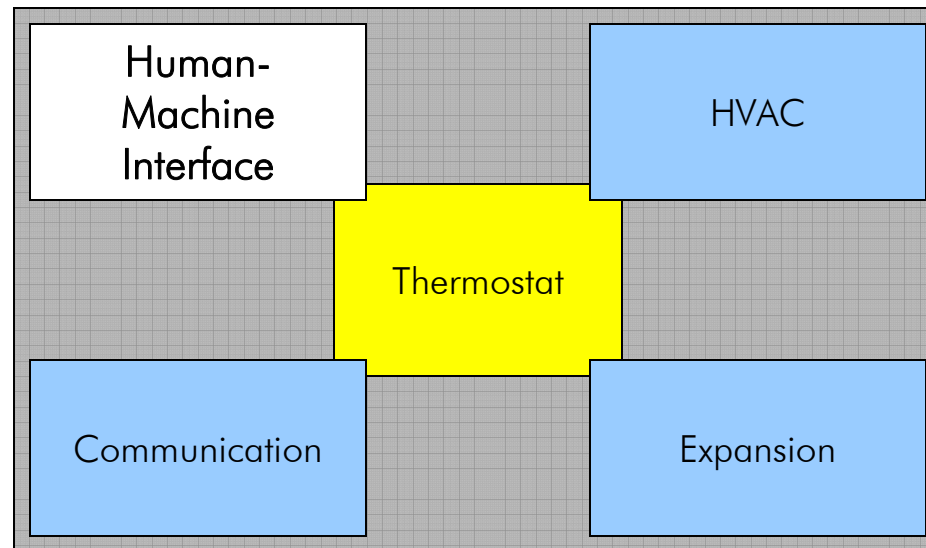
Standard 1-way receiver built-in for DR signals





PCT System Interfaces

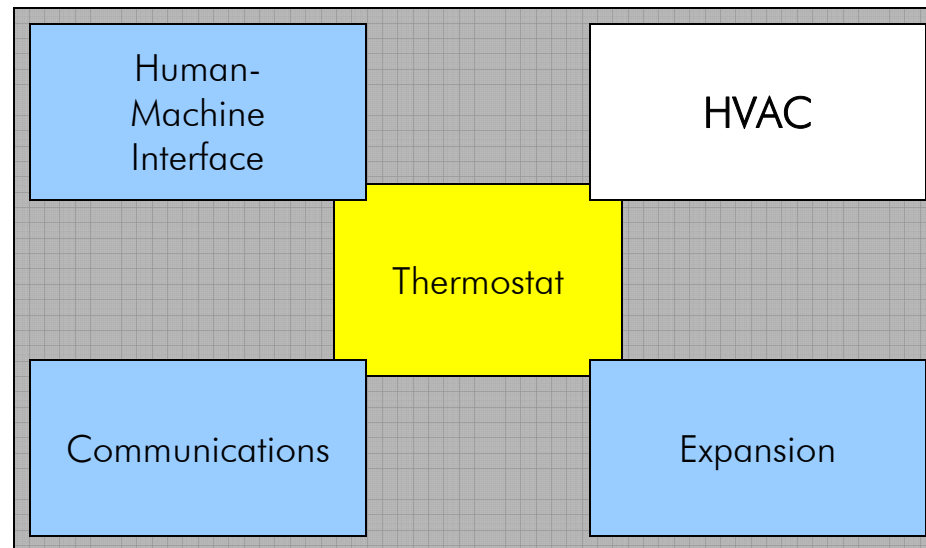
Requirements for information presented to the resident and necessary inputs (i.e. override a curtailment)





PCT System Interfaces

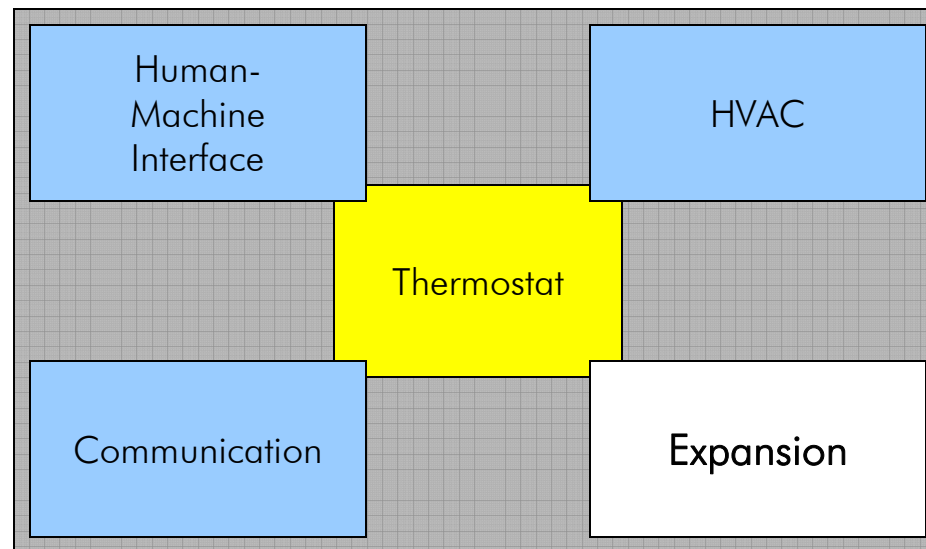
Standard statewide interface to legacy (existing) analog HVAC appliances and future digitally-controlled systems





PCT System Interfaces

Standard port to support add-on devices:
 2-way communication (AMI), removable memory (audit)





Four Key Research Questions for UCB Team to Answer

1. **CEC's PCT Vision** - Technically feasible? Price less than \$100? Developed within T24 timeline?
2. **Technical Issues** - What technical issues need to be considered for policy, technology, and system design?
3. **Statewide One-Way Communication System** - What technology is most appropriate? Is it reliable enough? What R&D tasks are necessary to implement it?
4. **Systemic Control** - What impact will PCT's actually have on system demand? Are there unforeseen and unintended consequences? What control strategies should be considered?



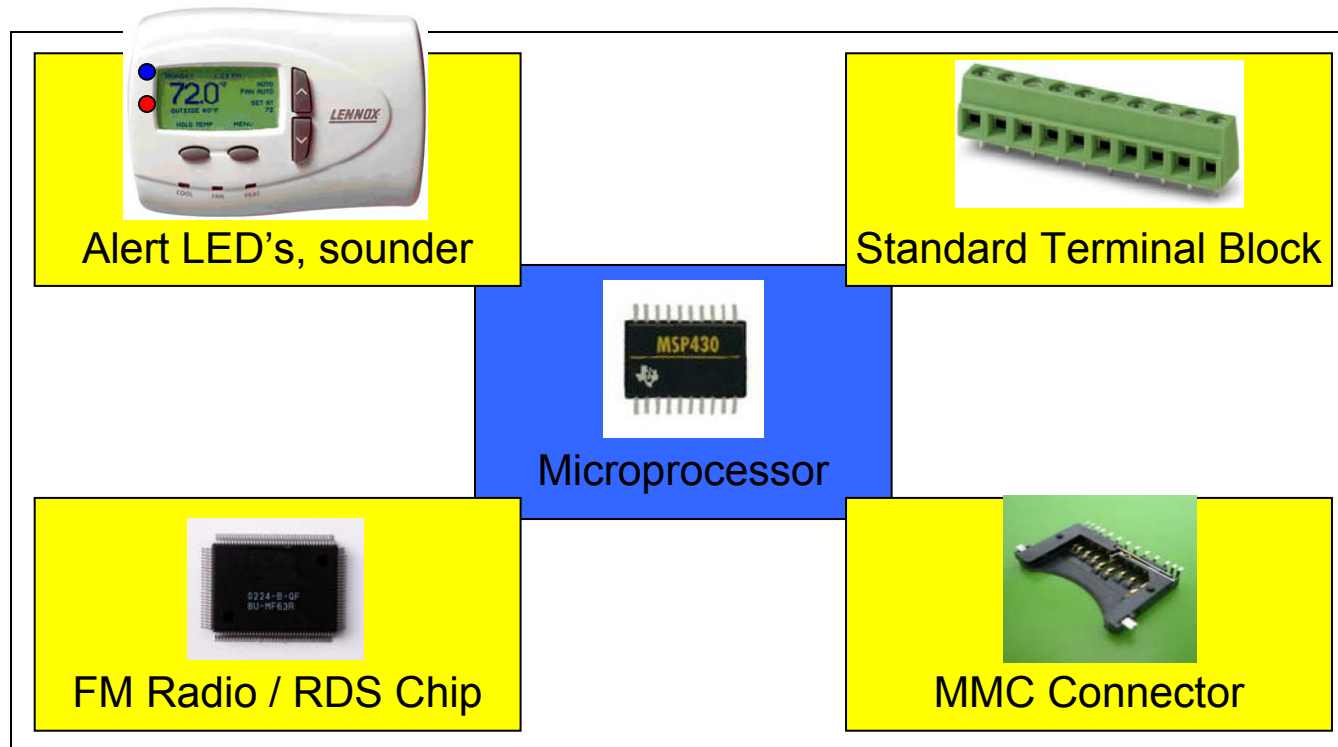
CEC Vision

- Technically feasible?
- Price less than \$100?
- Developed within T24 timeline?



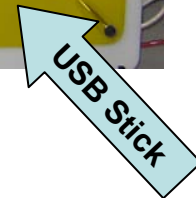
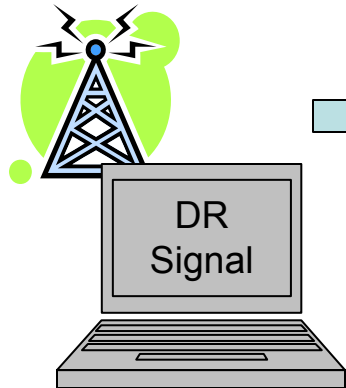
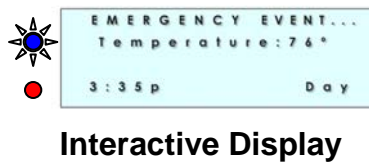
Minimum-Functionality PCT

- Bill of materials for a minimum-functionality PCT that costs less than \$20





Proof of Concept Demonstration

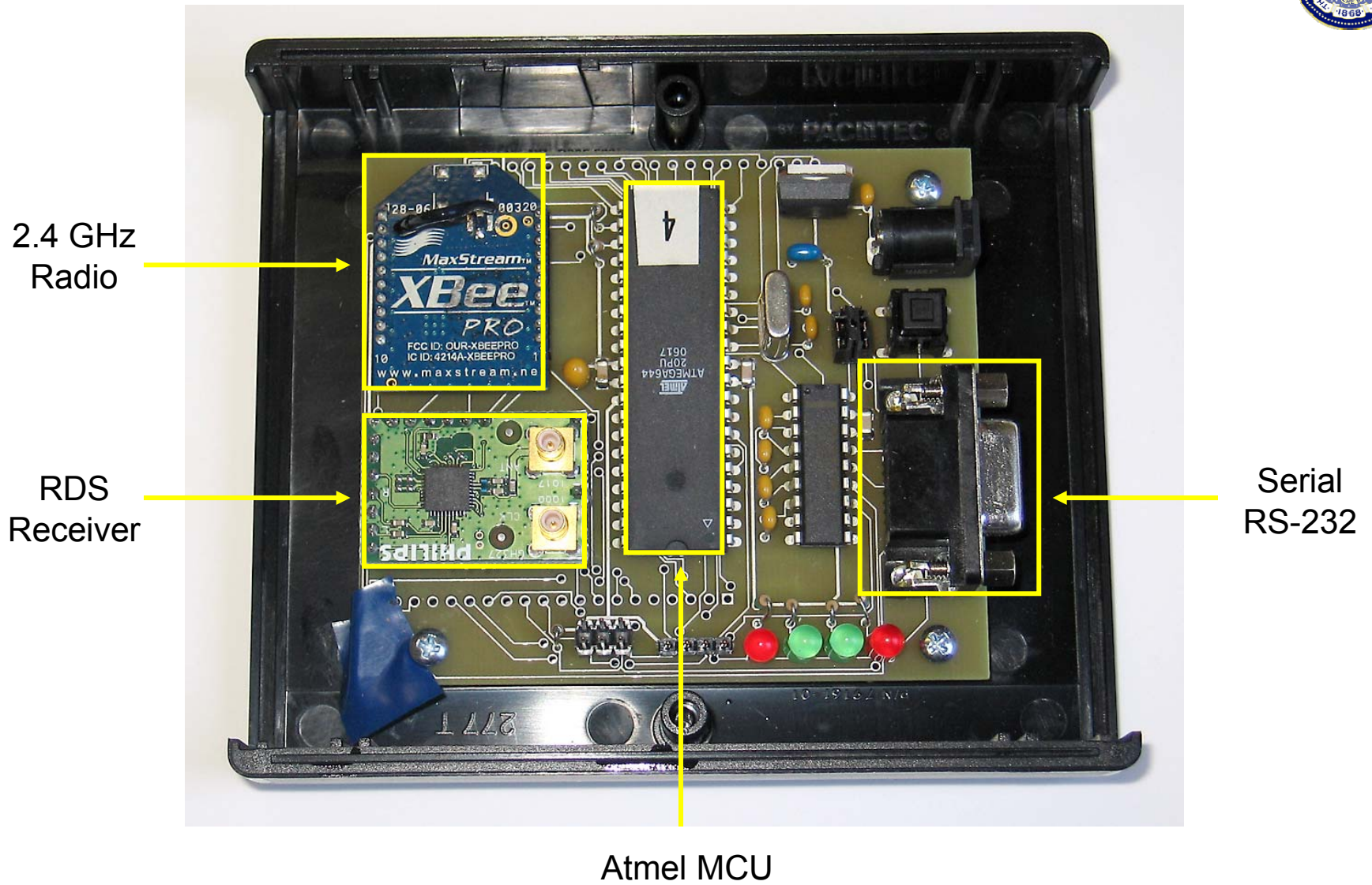


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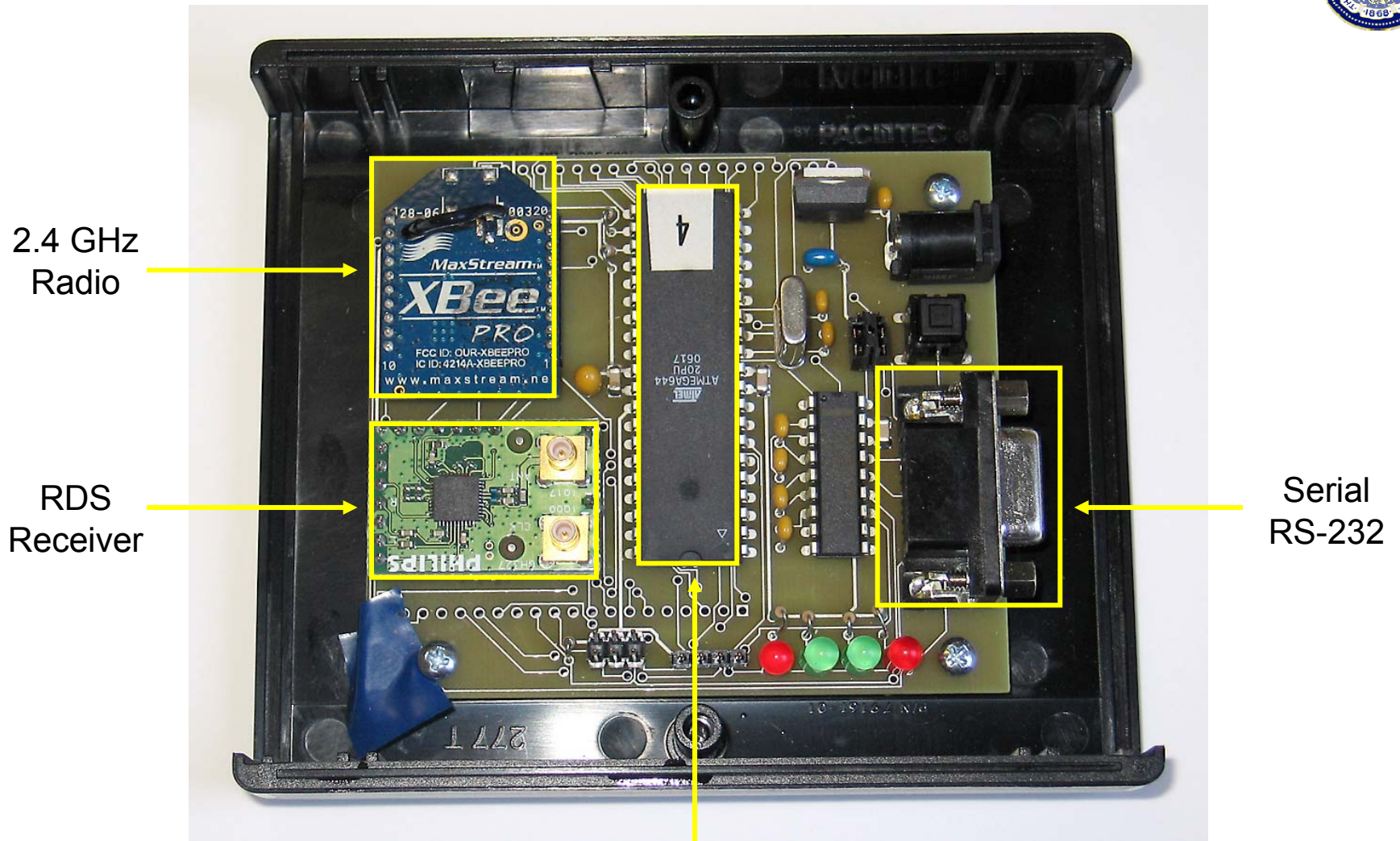
Technical Issues

not going to cover them today ...



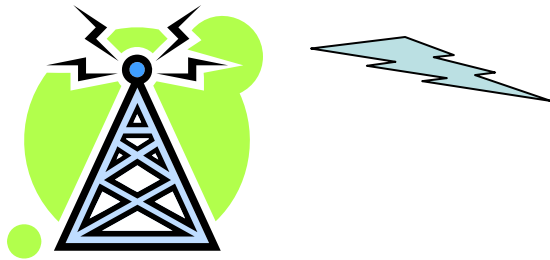
One-way Communication

- What technology is most appropriate?
- Is it reliable enough?
- What R&D tasks are necessary to implement it?





RDS Measurement in Homes

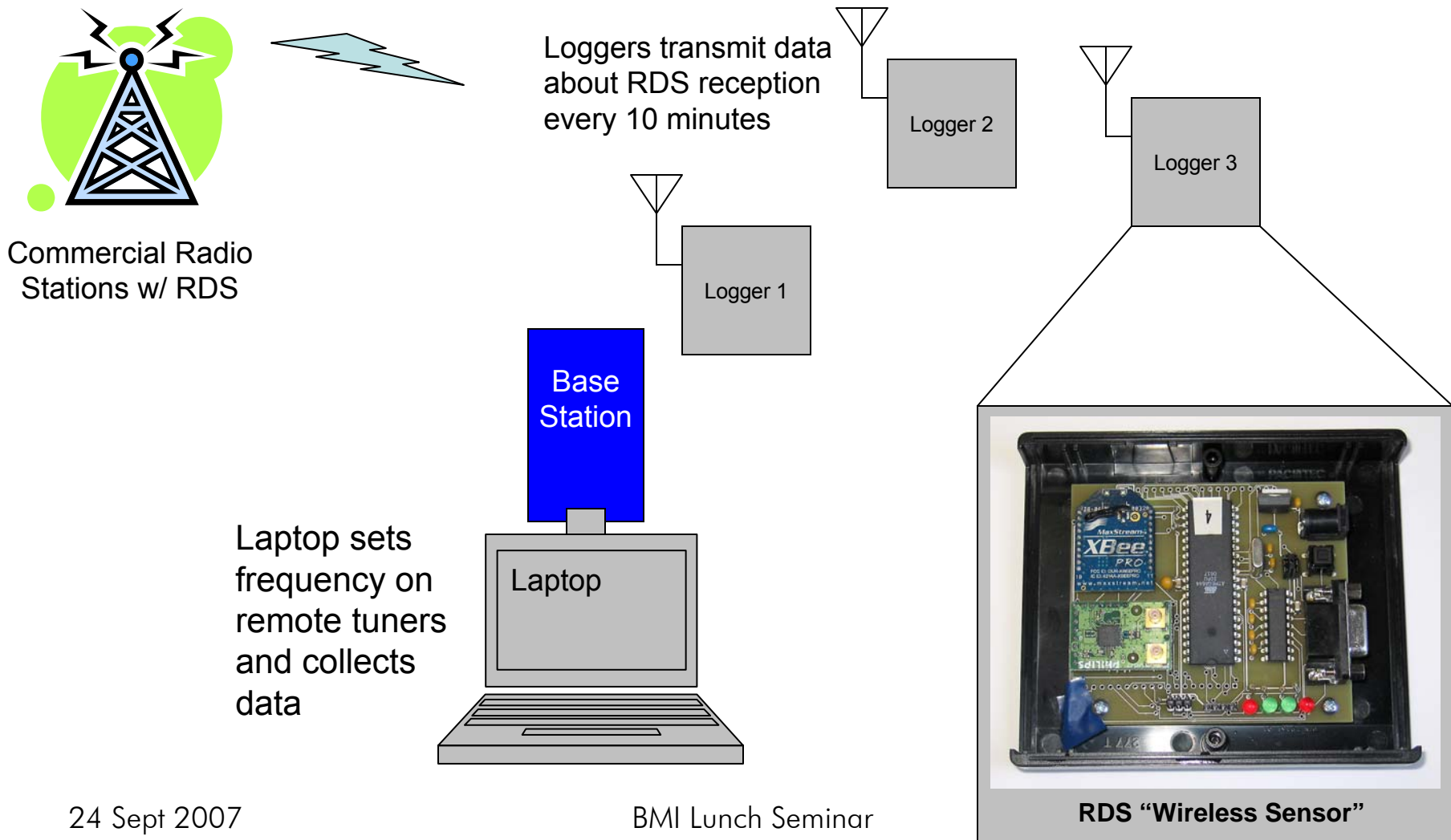


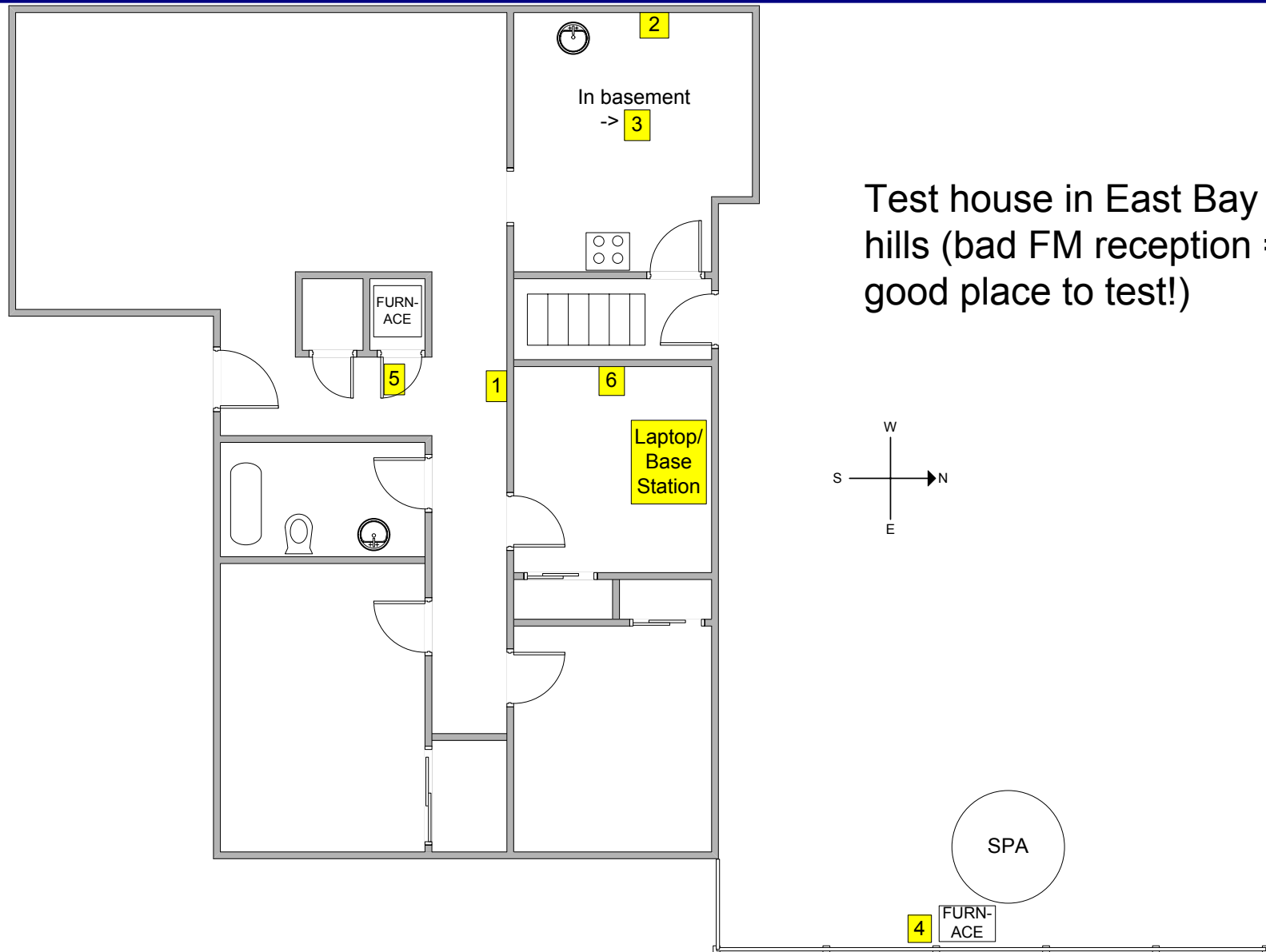
Commercial Radio Stations w/ RDS





RDS Measurement In Homes





Test house in East Bay hills (bad FM reception = good place to test!)



94.9 MHz

Node Location (appliance/room)	With Dipole Antenna	With Monopole Antenna
Thermostat/Hallway	25.79	N/A
Microwave/Kitchen	100	92.30
Washer/Basement	99.59	100
Spa Furnace/Outside	99.98	67.81
Furnace/Closet	29.80	100
Computer/Office	99.99	100

% of Data Received



94.9 MHz

Node Location (appliance/room)	With Dipole Antenna	With Monopole Antenna
Thermostat/Hallway	25.79	N/A
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Washer/Basement	99.59	100
Spa Furnace/Outside	99.98	67.81
Furnace/Closet	29.80	100
Computer/Office	99.99	100

Antenna location & orientation makes a big difference



94.9 MHz

Node Location (appliance/room)	With Dipole Antenna	With Monopole Antenna
Thermostat/Hallway	25.79	N/A
Microwave/Kitchen	100	92.30
Washer/Basement	99.59	100
Spa Furnace/Outside	99.98	67.81
Furnace/Closet	29.80	100
Computer/Office	99.99	100

101.3 MHz

Node Location (appliance/room)	With Dipole Antenna	With Monopole Antenna
Thermostat/Hallway	99.94	N/A
Microwave/Kitchen	99.49	66.38
Washer/Basement	99.59	99.99
Spa Furnace/Outside	67.21	28.17
Furnace/Closet	99.94	95.53
Computer/Office	96.56	62.82

A second station provides nearly complete coverage in this case



PCT Systemic Control

- What impact will PCT's actually have on system demand?
- Are there unforeseen and unintended consequences?
- What control strategies should be considered?



Load Group Simulation

Load Group

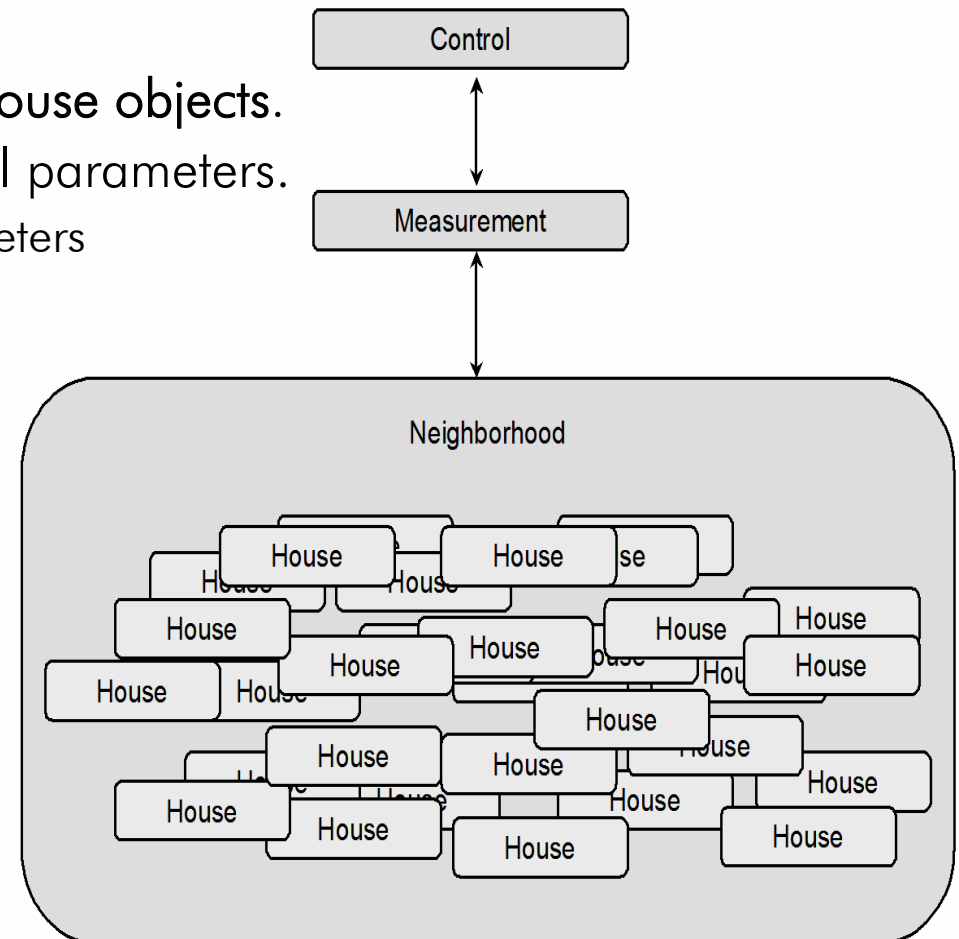
- Made up of an array of house objects.
- Each house has individual parameters.
 - Random thermal parameters
 - Random setpoints
 - Random efficiencies
- Each house has a PCT

Measurement

- Aggregates power (HVAC power only)

Control

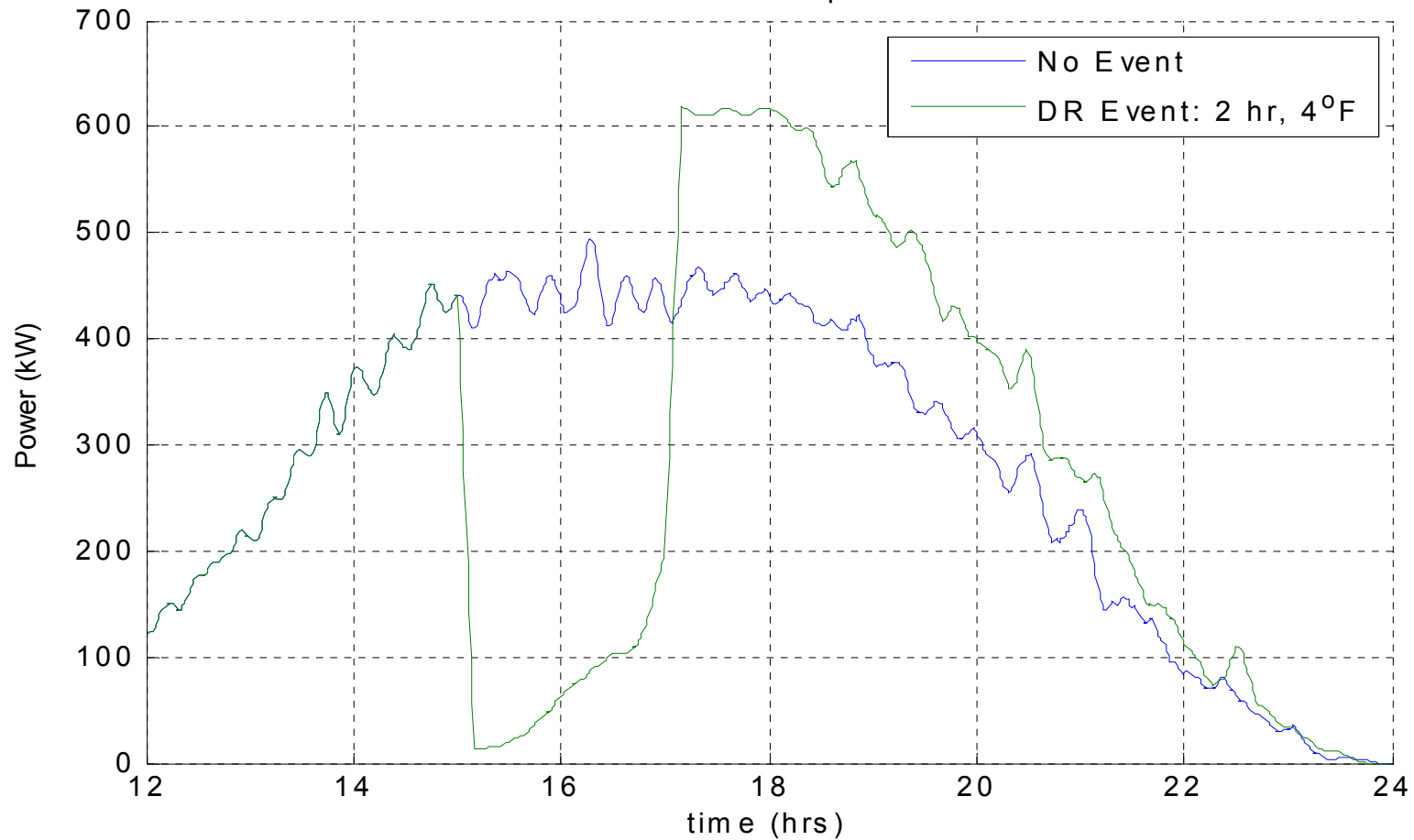
- Send DR messages
- *The interesting part!*





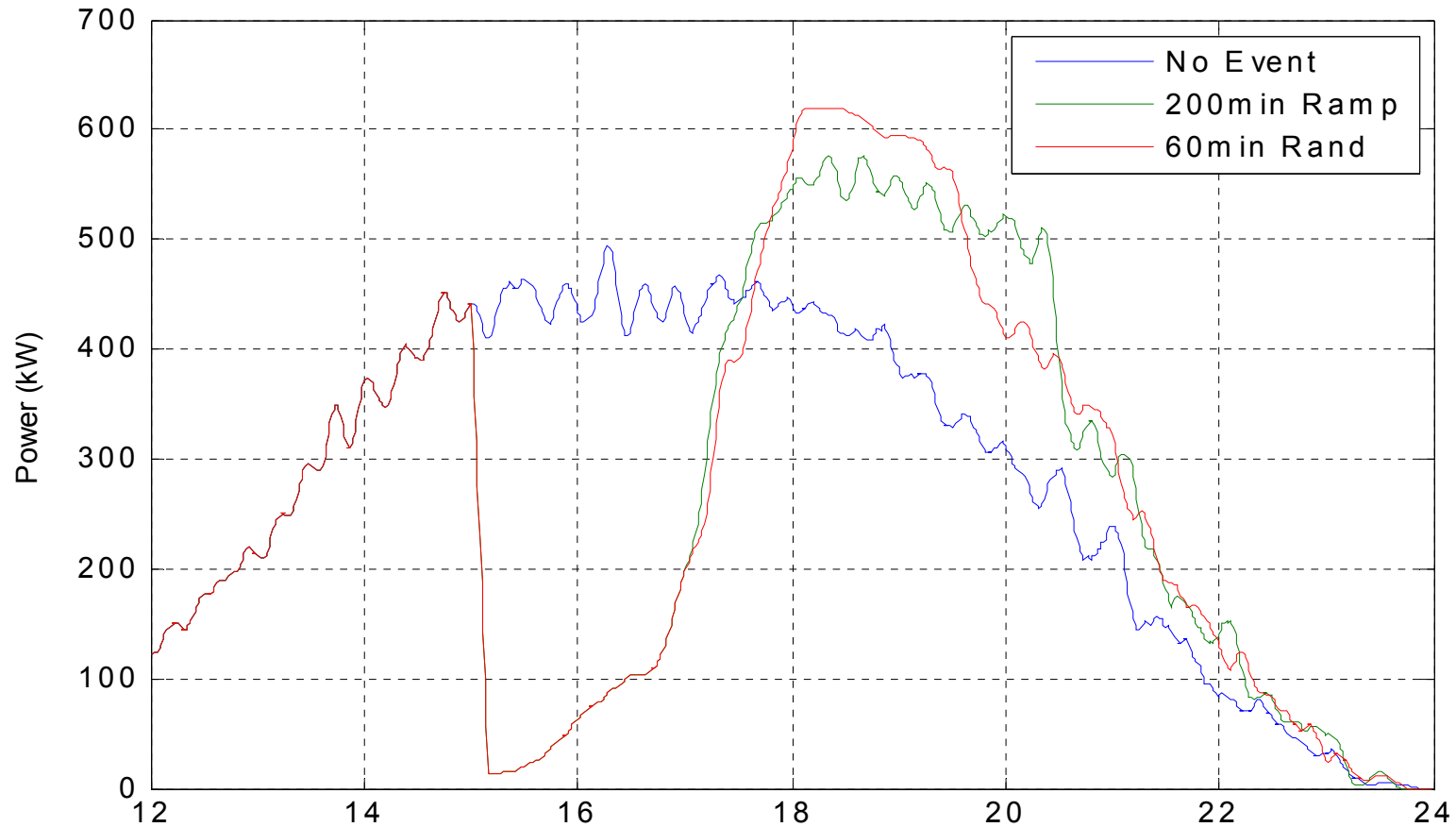
Simple DR Event Results

DR Event Comparison





Exit Strategy, Ramp vs. Random



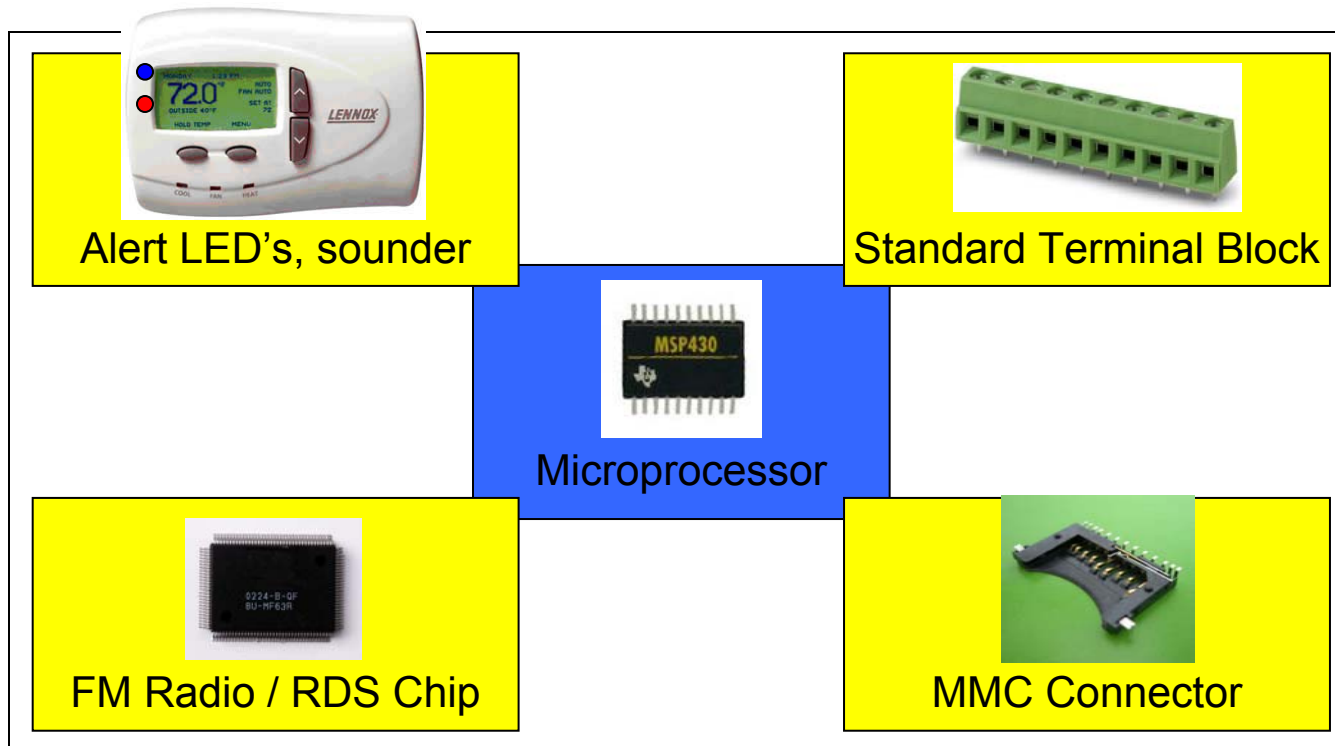


closing thoughts

(the future of residential DR)



PCT Interfaces





Resident Interaction



HVAC Actuation



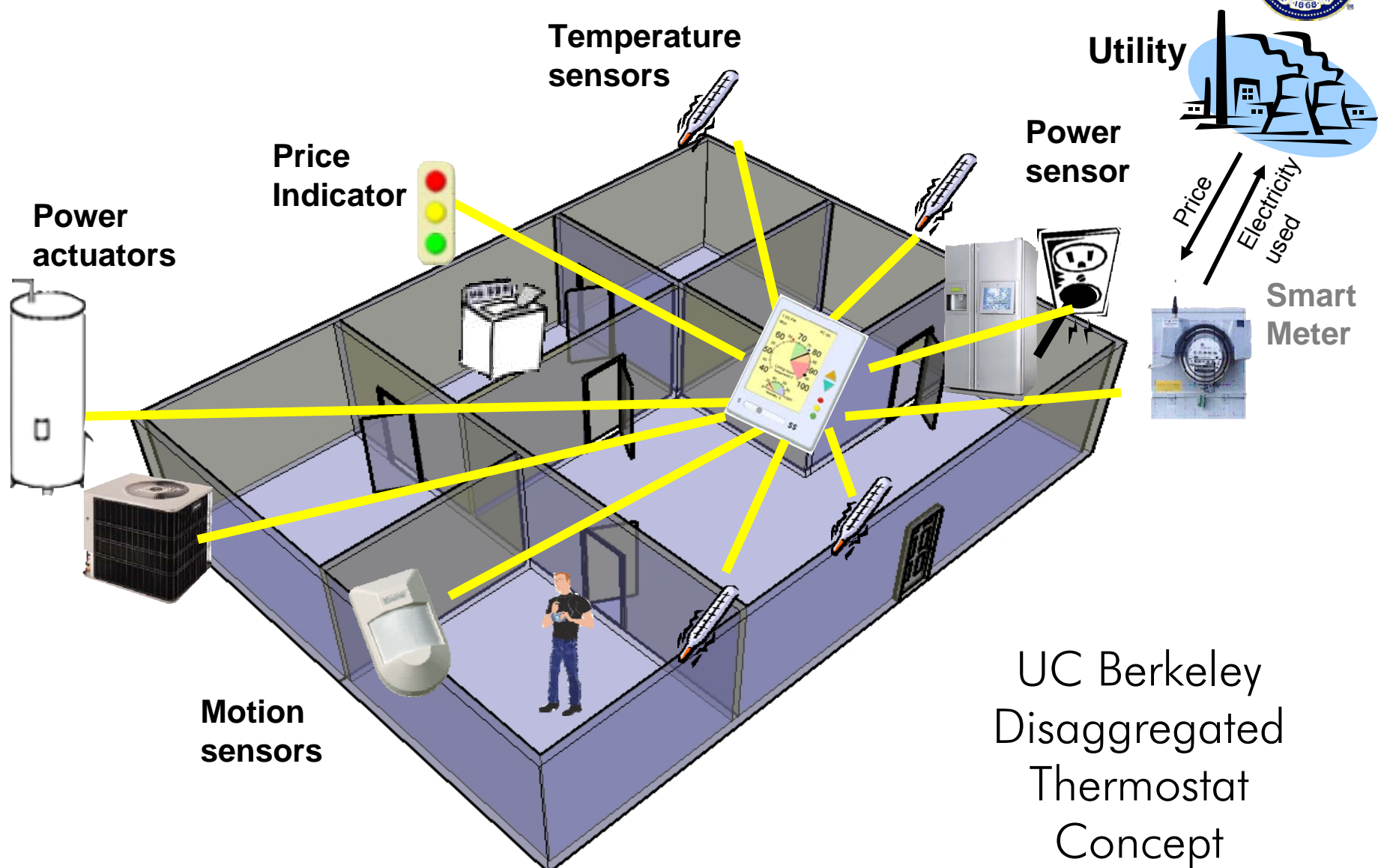
Energy Control



Utility Communication Gateway

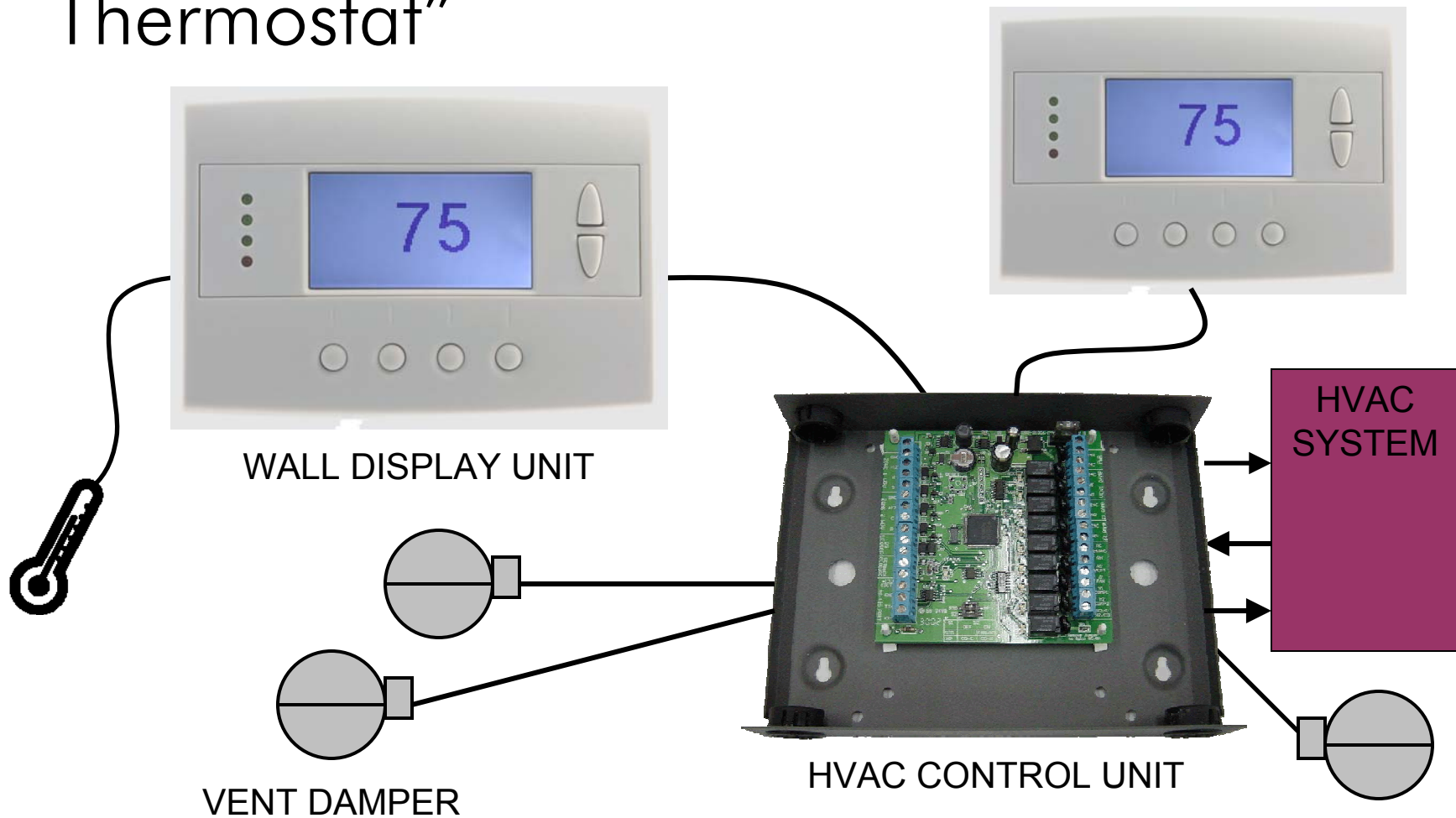


Expansion Functionality





RCS Multizone "Disaggregated Thermostat"





thank you



Questions?

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- Special thanks to:
 - Ron Hofmann, PIER
 - Gaymond Yee, CIEE