sMAP: Integrating and Managing Physical Data

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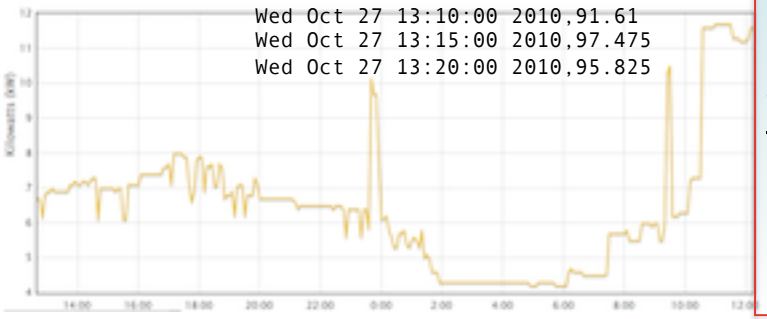
Physical data is everywhere

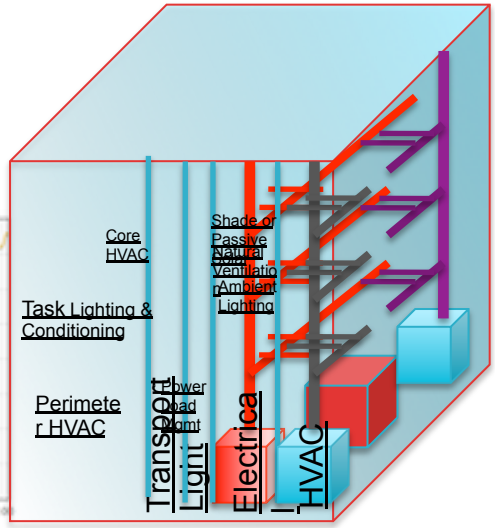
Information from the world

Timeseries

```
Wed Oct 27 12:35:00 2010,92.8
Wed Oct 27 12:40:00 2010,91.6
Wed Oct 27 12:45:00 2010,92.76
Wed Oct 27 12:50:00 2010,89.445
Wed Oct 27 12:55:00 2010,95.0
Wed Oct 27 13:00:00 2010,94.005
Wed Oct 27 13:05:00 2010,96.3
Wed Oct 27 13:10:00 2010,91.61
Wed Oct 27 13:15:00 2010,97.475
Wed Oct 27 13:20:00 2010,95.825
```



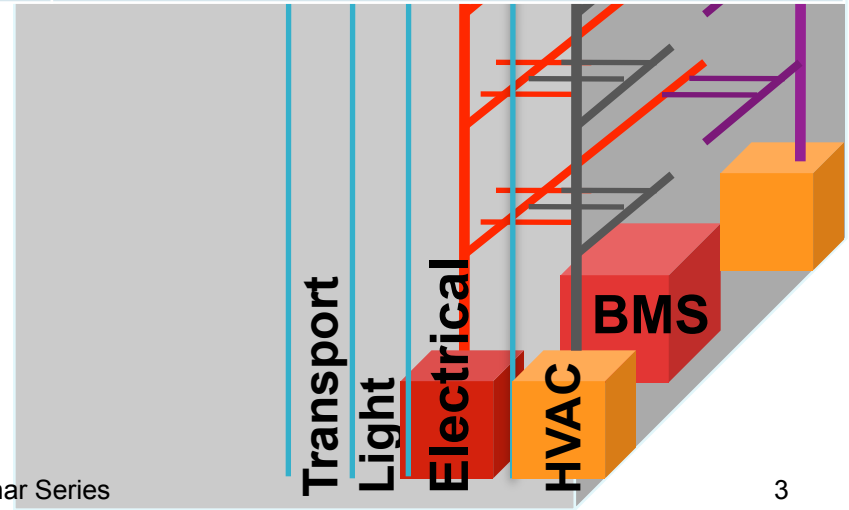
Buildings



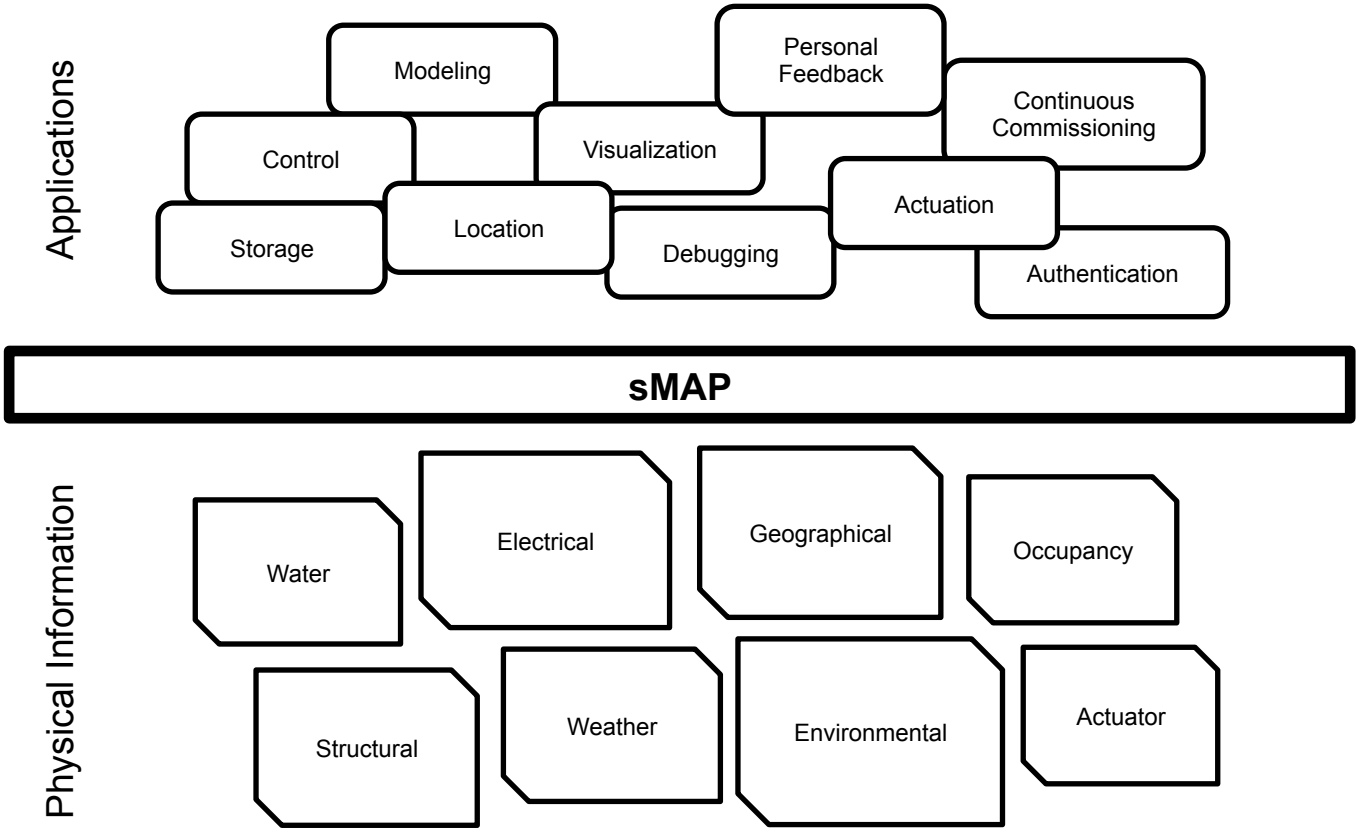
"Smart Buildings" Existing Protocols

Protocol	Year	Network	Example Applications
Modbus	1979	RS-485, TCP/IP	Panel monitoring, alarms
Fieldbus/ HART	1988	various	Industrial Control
BACnet	1995	ARCNET, Ethernet, IP, RS-232, *etc.*	HVAC, Lighting, Fire…
WirelessHART	2007	802.15.4e	Industrial control, wire replacement
Zigbee SEP 2.0	2011	802.15.4	Plug-load monitoring

- HUGE installed/legacy base
- Multiple generations of hardware and software in the same building
- Typical integration: proprietary vertical Building Management System (BMS)
  - Data in at the bottom
  - Data products out at the top



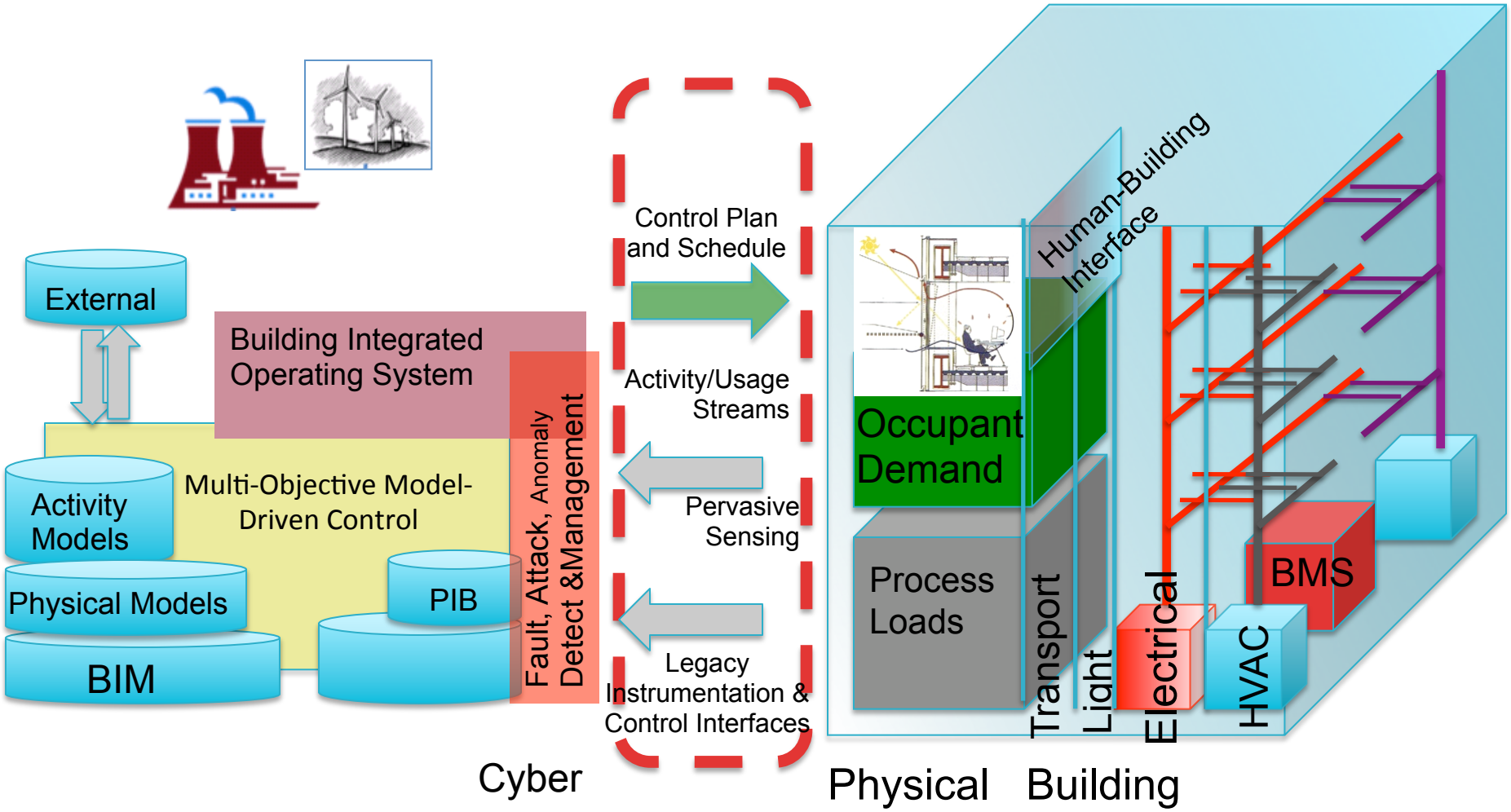
Original Design Point



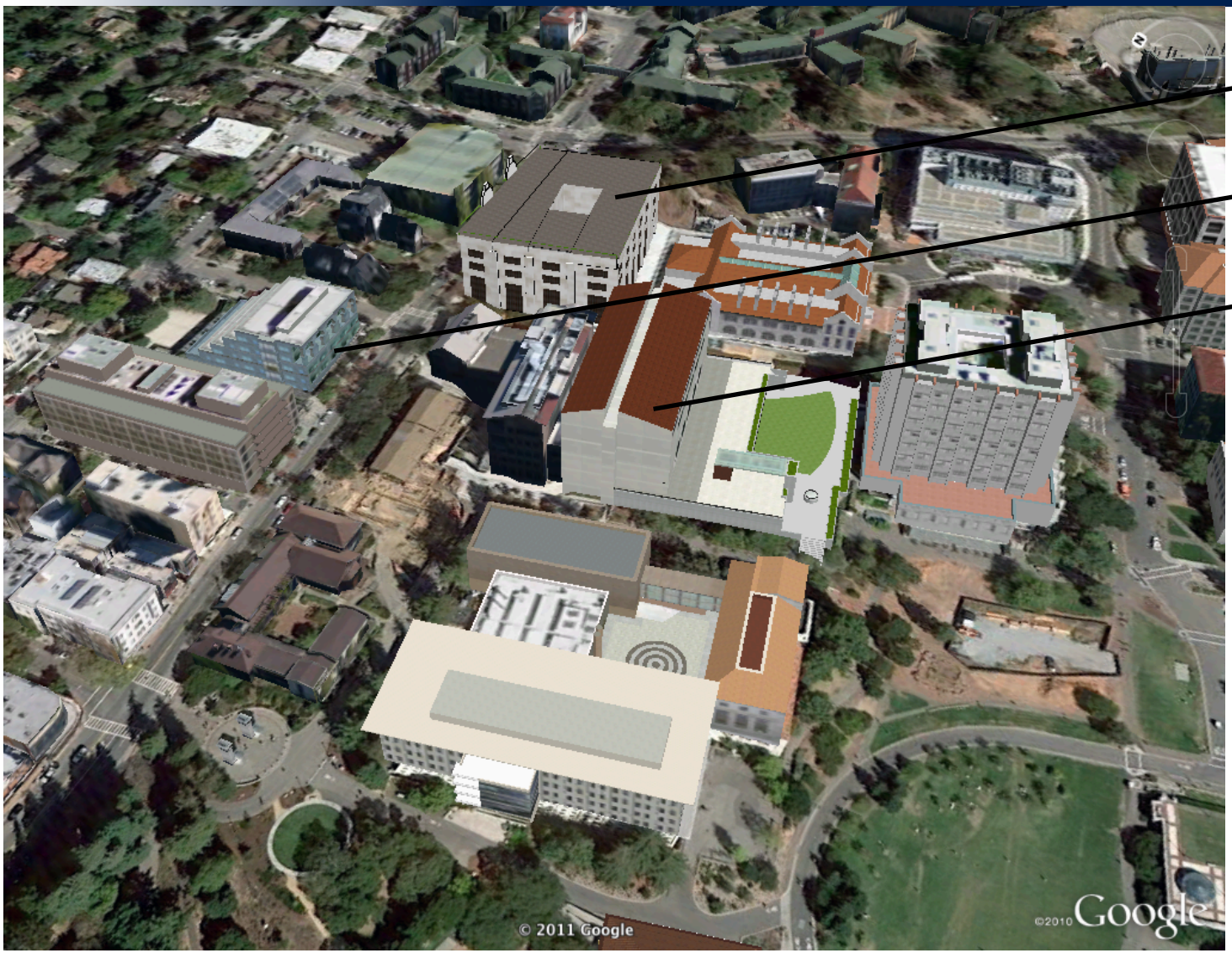
- Make available diverse information sources
- Support publishing to the Internet

WHERE IS SMAP USED

Cyber / Physical Building



Building Testbeds

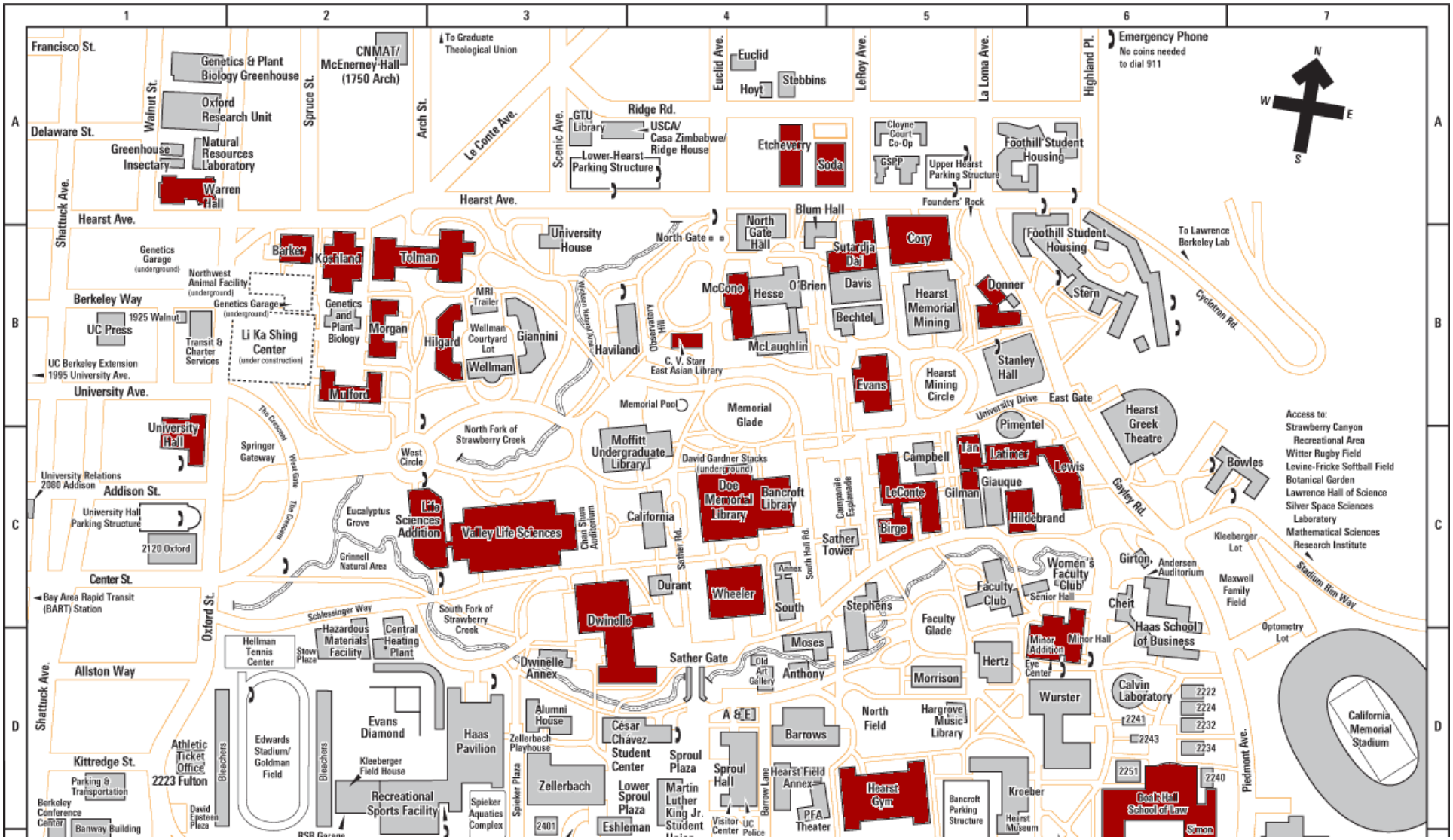


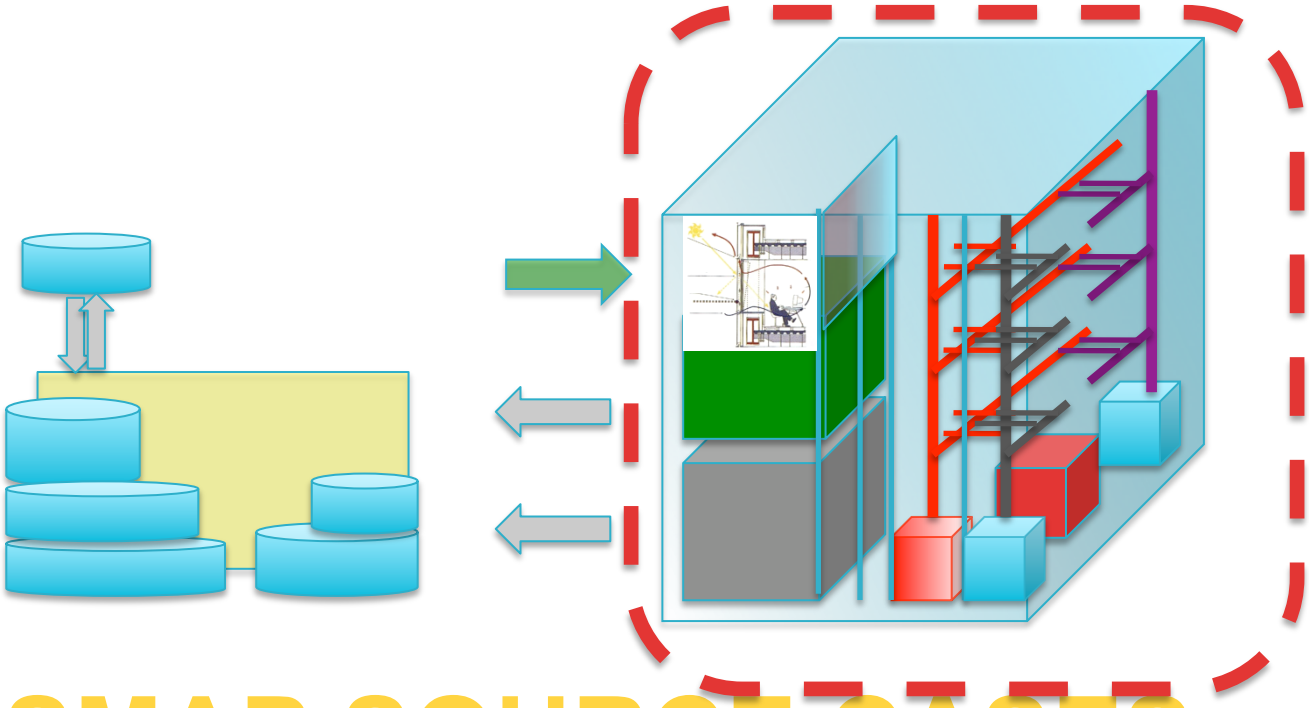
Cory Hall

Soda Hall

S-D Hall

LoCal Virtual Campus





SMAP SOURCE CASES

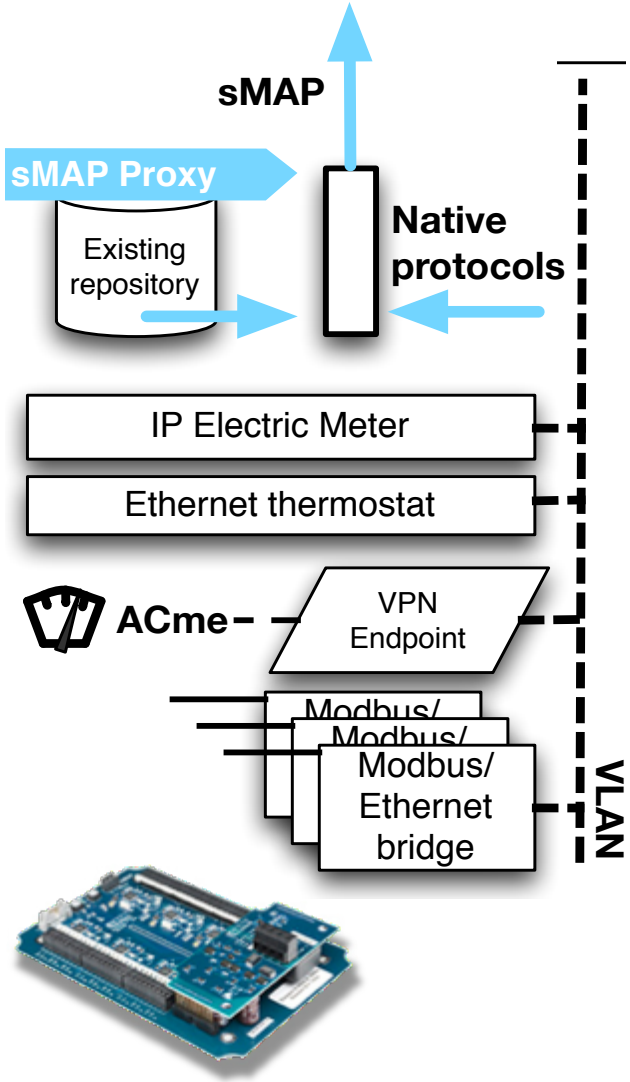
sMAP Redesign

- Design iteration based on 2 years' experience
- Case studies
  - Building management system integration
  - Retrofit system
  - Repository integration
  - Transient instrumentation

Case 1: Building Testbed

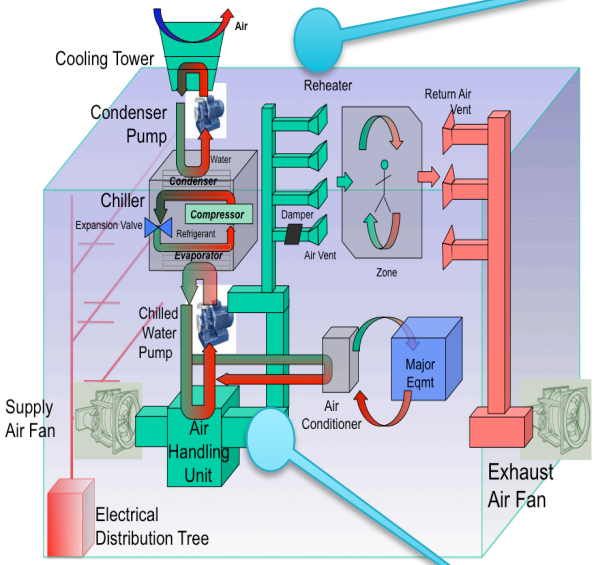
- CEC-funded “building-to-grid” testbed
- System retrofit into Cory Hall
- Integrate existing meters, historical data repositories seamlessly

Meter	Communication	N
3-Phase Electric	Modbus	65
Whole bldg electric	Proprietary XML	1
Steam	Modbus	1
Condensate	Modbus	1
ACme	6lowpan/IPv6	20
Weather	SDI-12	1
Thermostat	Ethernet	1



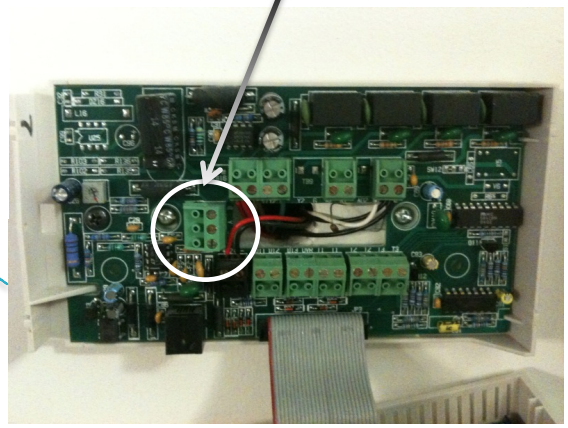
Monitoring in Progress

Rooftop climate



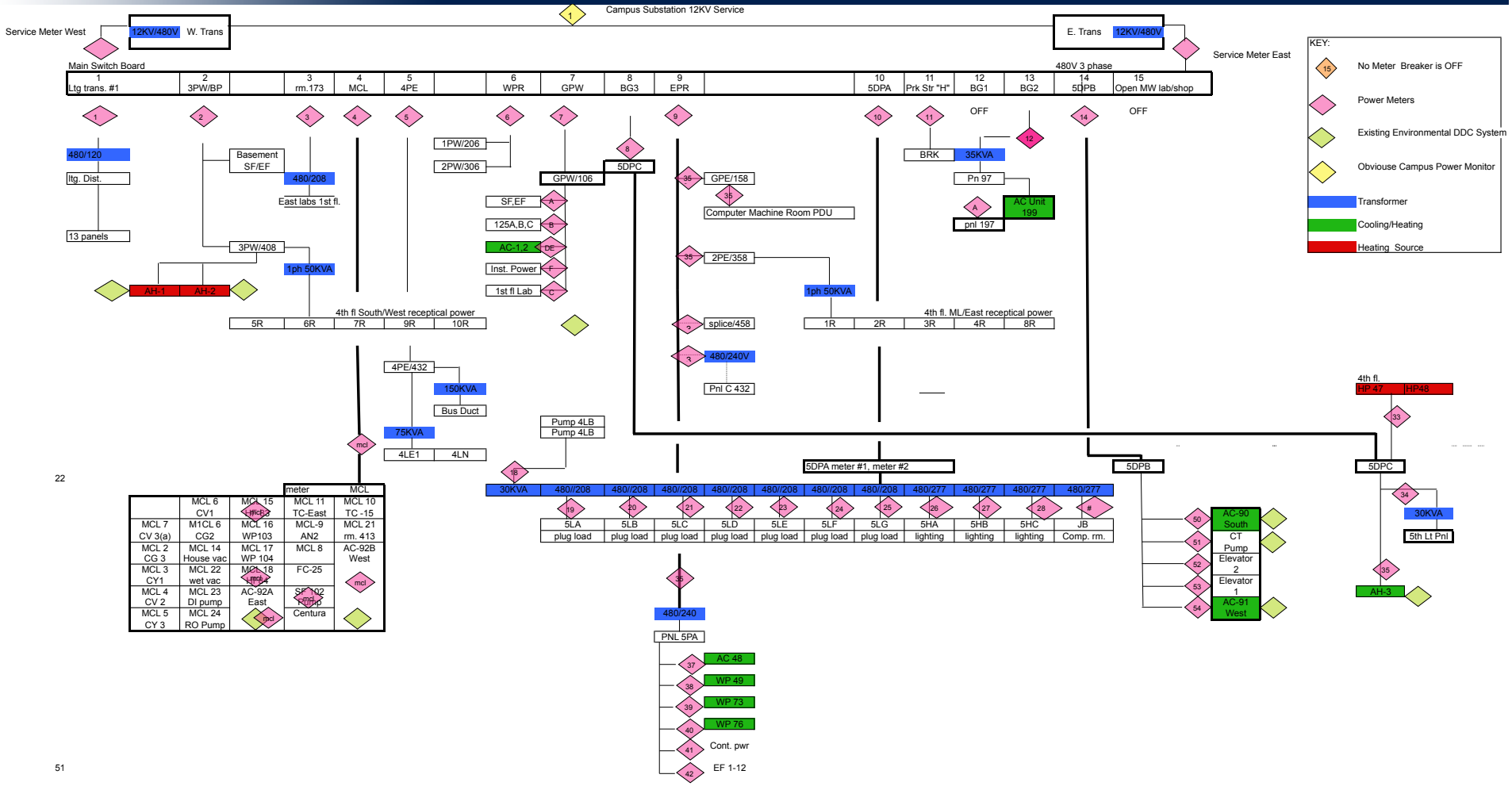
Building Environmental Manufacturing Infrastructure

RS-485



Actuation: thermostat control

Cory Hall Power Flow

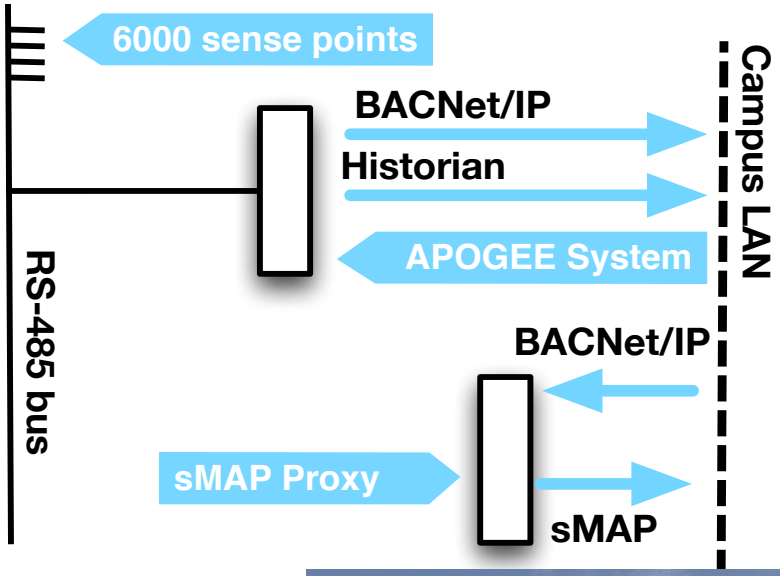


Cory Hall Retrofit Takeaways

- Represent ***complex relationships between meter elements***
  - Relate instrumentation, system, and physical views of plant
- Highly diverse sources of data

Case 2: Building Management System

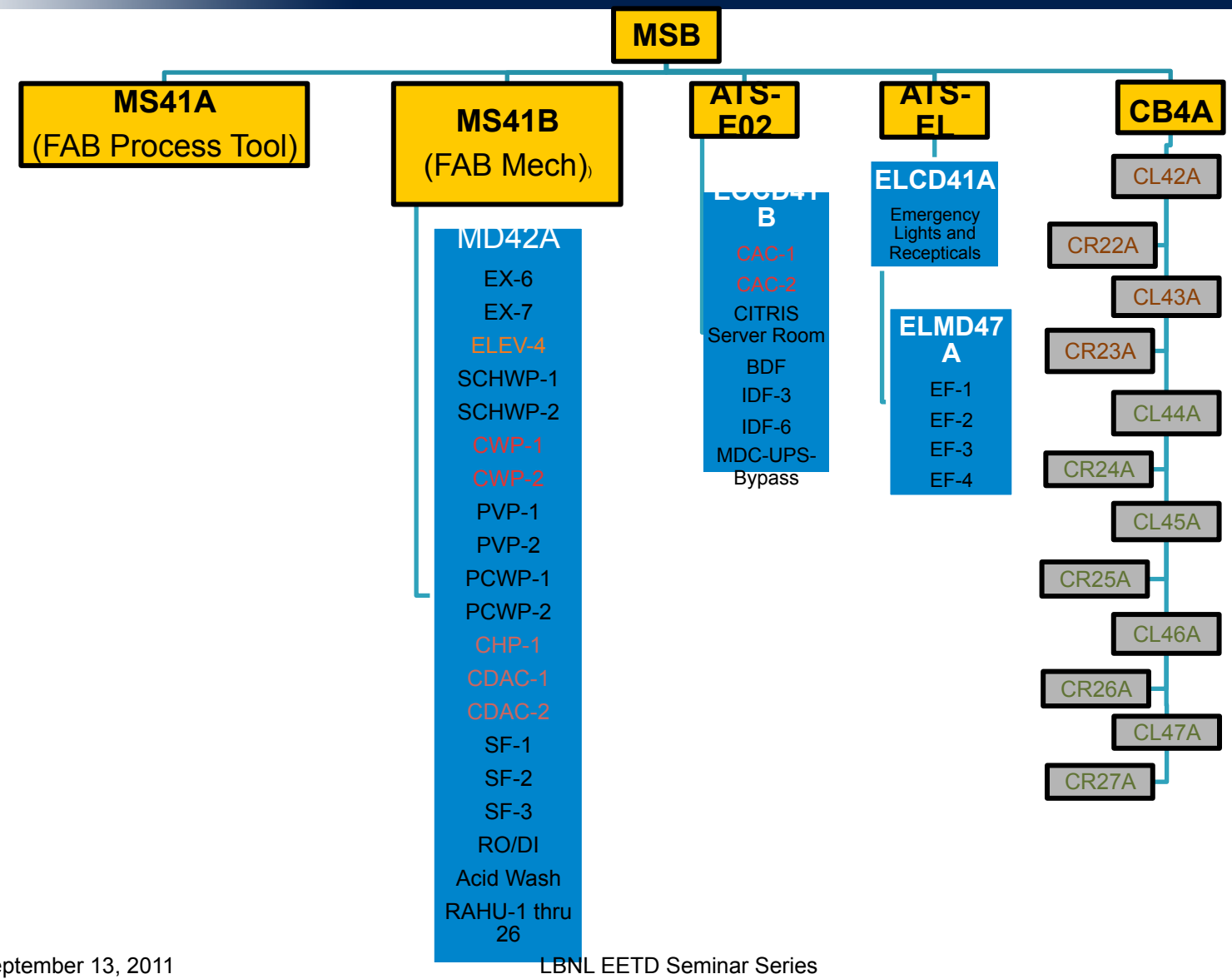
- Sutardja-Dai (SDH) Hall
  - Managed with Siemens Apogee System
- Shared serial bus, polled by master
- ***Large number of points, high data volume***
- ***Similarly complex data relationships***



SDH Apogee System

- 1358 control settings
  - Set points, Relays (lights, pumps, etc), Schedules
- 2291 meters/sensors
  - Power (building, floor, lights, chiller, pumps, etc)
    - Current, voltage, apparent, real, reactive, peak
  - Temp (rooms, chilled water, hot water)
  - Air volume
  - Alarms, Errors
- 2165 control outputs
  - Dampers, valves, min/max flow, fan speed, PID parameters
- 72 other

SDH Power Flow

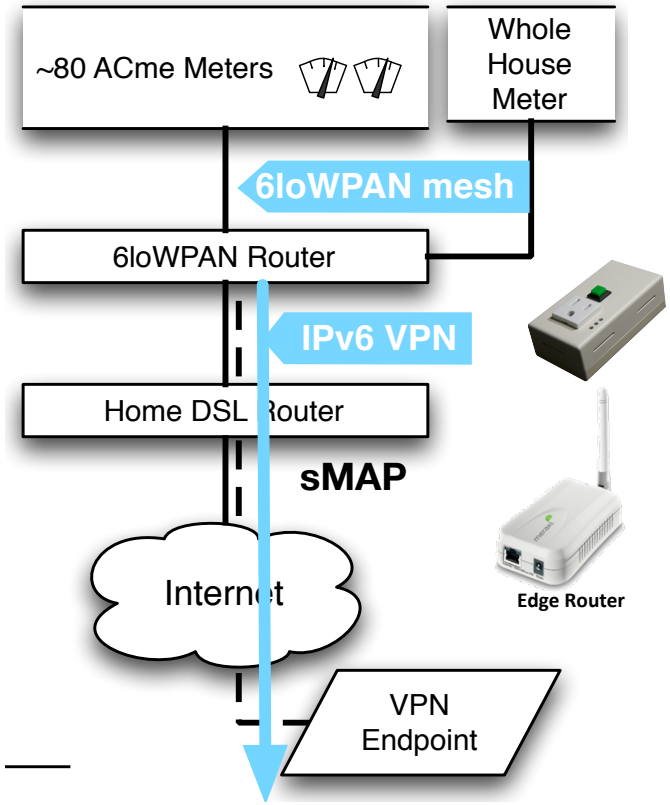


Case 3: Residential Plug-Loads

Dense plug-load metering using wireless mesh networks

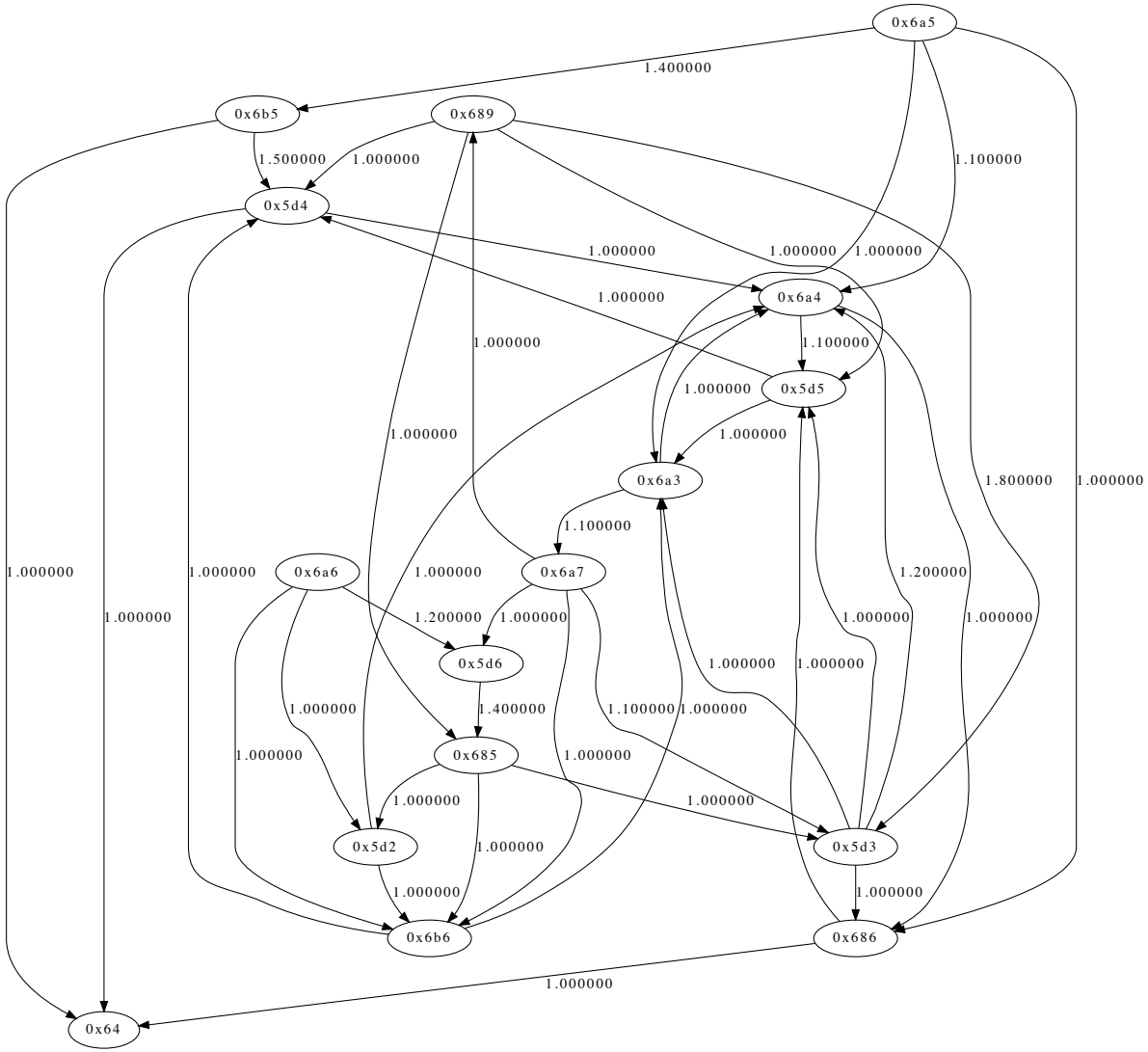
Goal: understand the use patterns of appliances

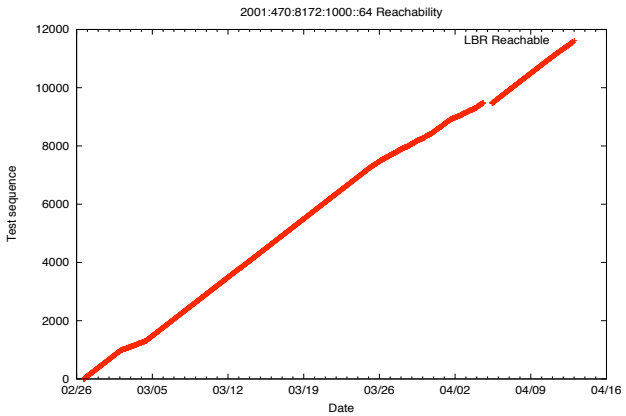
- Deployment methodology for inventory and stratified sampling of loads
- ***Takeaways: unreliability of home internet, NATed operation***

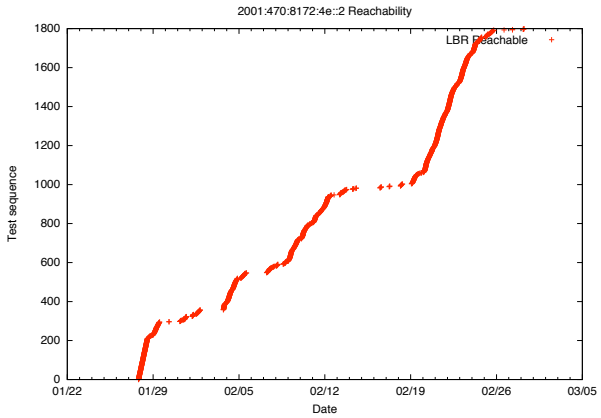


(With LBNL MELS group)

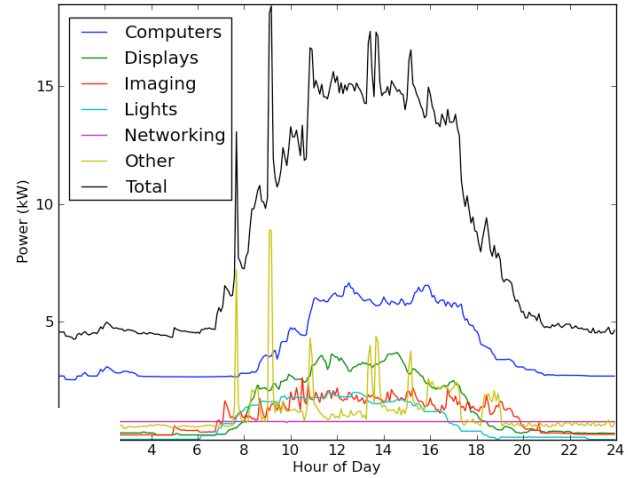
Network Complexity & Reachability

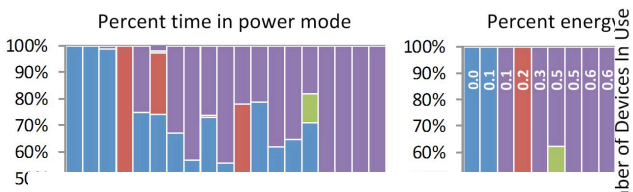


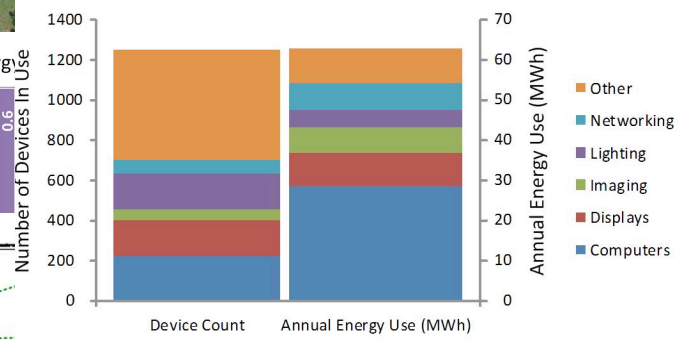


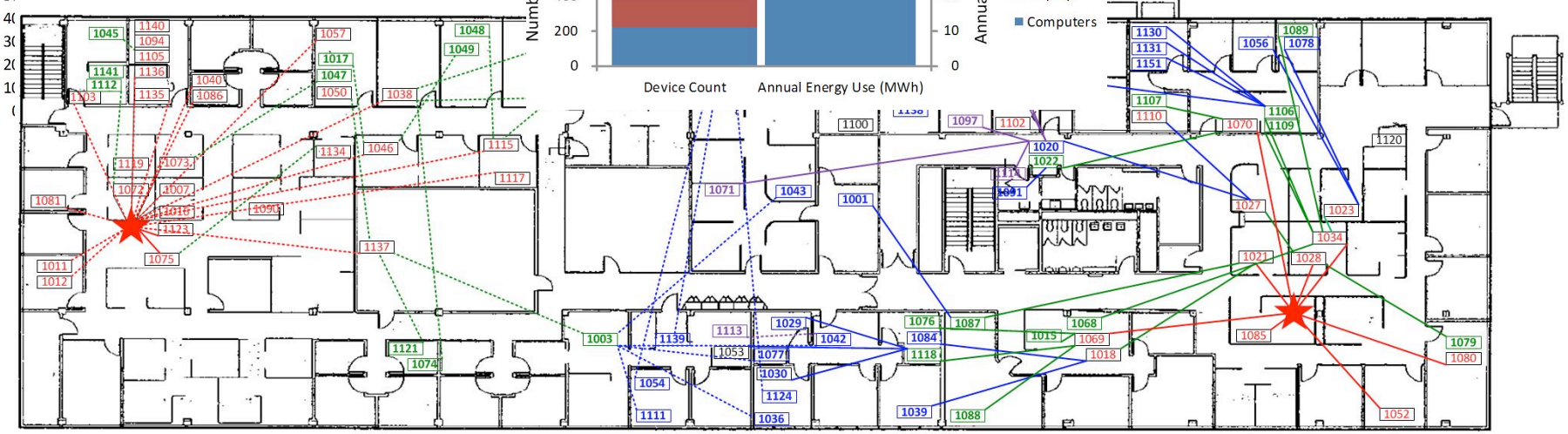


DOE MELS => Appliance Energy









(Re)design Takeaways

- Integrating heterogeneous communication substrates is [still] a must
  - Was a goal of sMAP 1
  - Better support is possible
- Intermittent connectivity is unavoidable
  - Don't lose data when not necessary
  - Design for reliability
- Existing repositories are unavoidable
  - Efficient import/export of data (same as a trickle load)
  - Well known requirement of existing BI/decision support products
- Accept metadata from existing systems when available

sMAP 1 Overview

```
/                          # list resource under URI root [GET]
  /data                    # list sense points under resource data [GET]
    / [sense_point]        # select a sense point [GET]
      /meter               # meters provide this service [GET]
        / [channel]        # a particular channel [GET]
          /reading         # meter reading [GET]
          /format          # calibration and units [GET/POST]
          /parameter       # sampling parameter [GET/POST]
          /profile         # history of readings [GET]
```

- ➔ Represent units, sampling parameters of the underlying device, for each channel
- ➔ Expose over HTTP

Change 1: Represent Timeseries

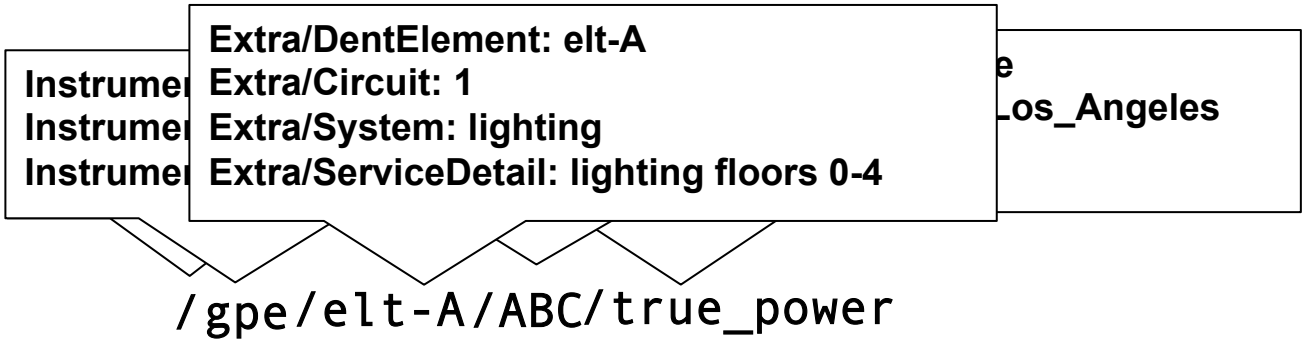
- Objects are *Timeseries* and *Collections*
- *Timeseries* are durably identified
  - A collection of structured key-value pairs, data
  - Data is (time, value[, seqno]) vectors
- *Collections* group timeseries with shared metadata

```
{
 "/" : {
    "Contents" : ["sensor0"],
    “Metadata” : { “SourceName” : “Example sMAP Source” },
   },
 "/sensor0" : { "Contents” :["channel1"] },
 "/sensor0/channel0" : {
   "uuid" : "a7f63910-ddc6-11e0-8ab9-13c4da852bbc",
   "Readings" : [ [1315890624000, 12.5 ] ]
  }
}
```

collections

timeseires

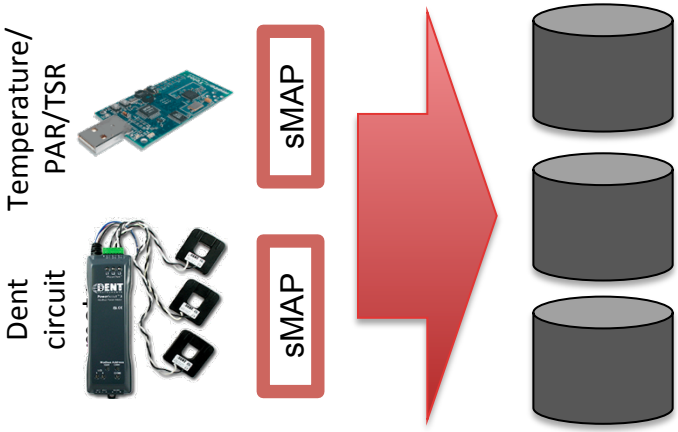
Change 2: Simple Metadata



- Each stream can be “tagged” with key-value pairs
- Easy to tag related collections of points
- Natural way to represent “subset of” relation

OSS sMAP Source Implementation

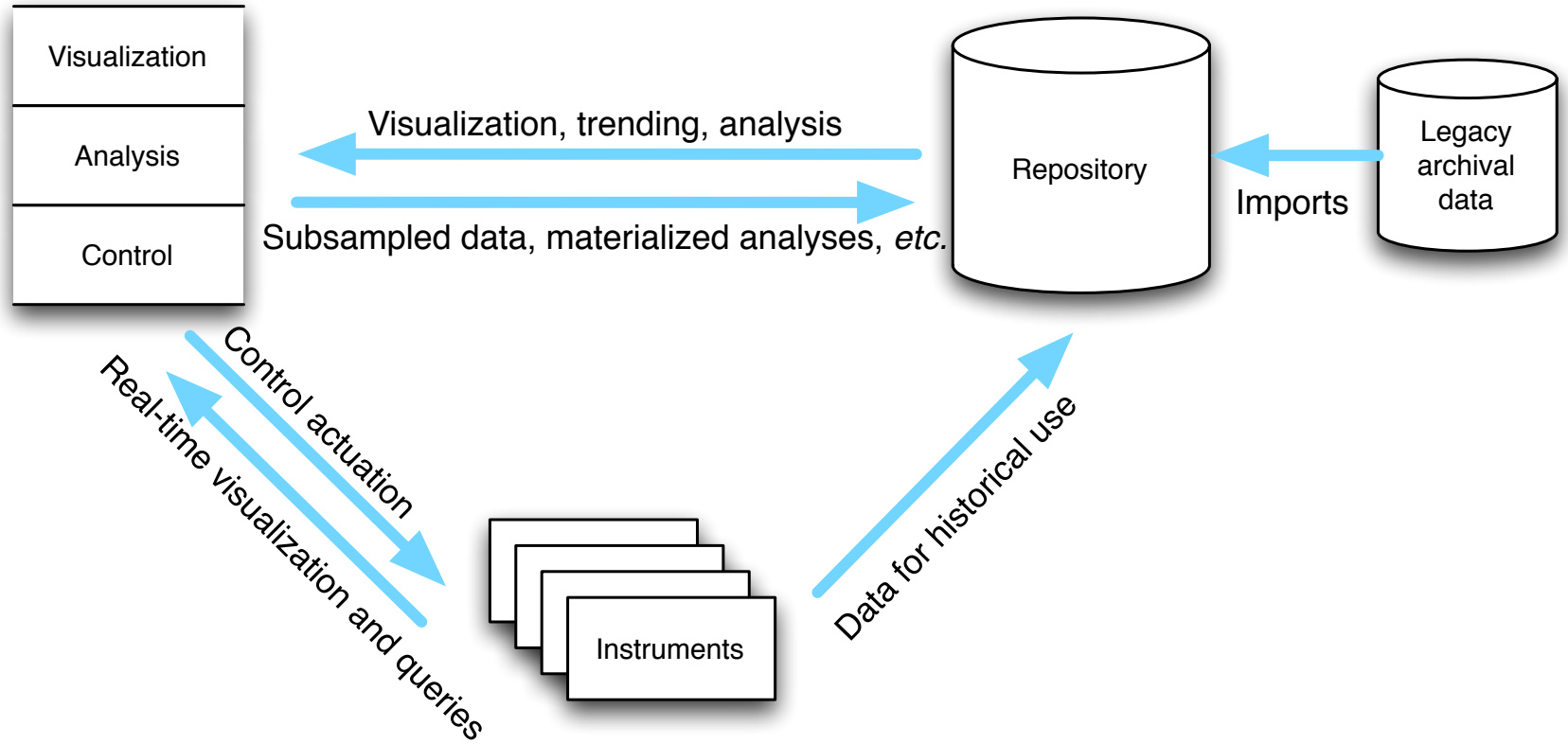
- Implementation of new design
  - Focus on ease of writing new source
- **Reliable delivery** with local buffering
- Multiple configuration options for **adding metadata**, setting up drivers
- Growing driver library
- Documentation, tutorials, *etc*.
- Focus on minimum effort to add new source



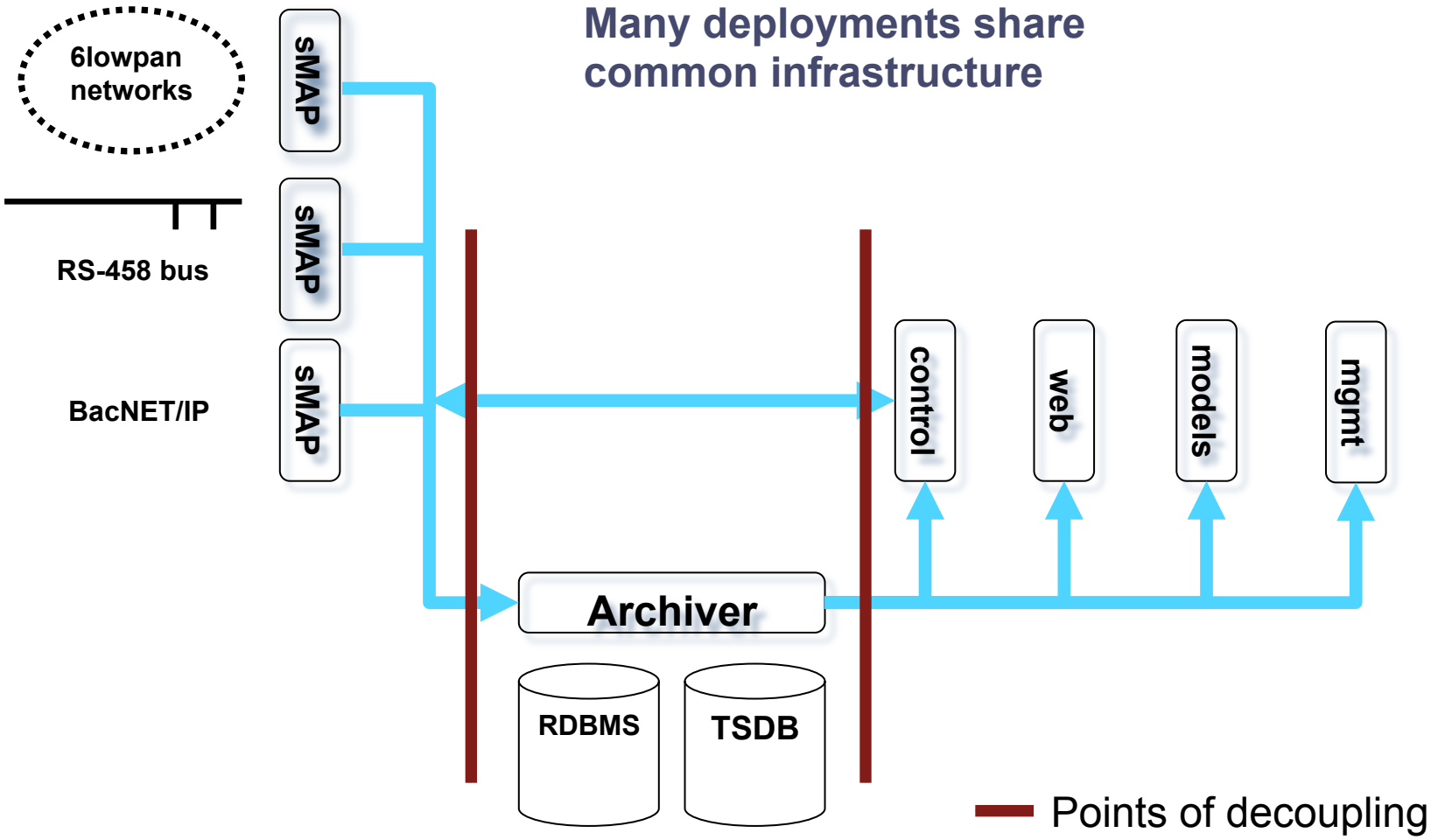
http://cs.berkeley.edu/~stevedh/smap2/

INFRASTRUCTURE

sMAP Architectural Evolution

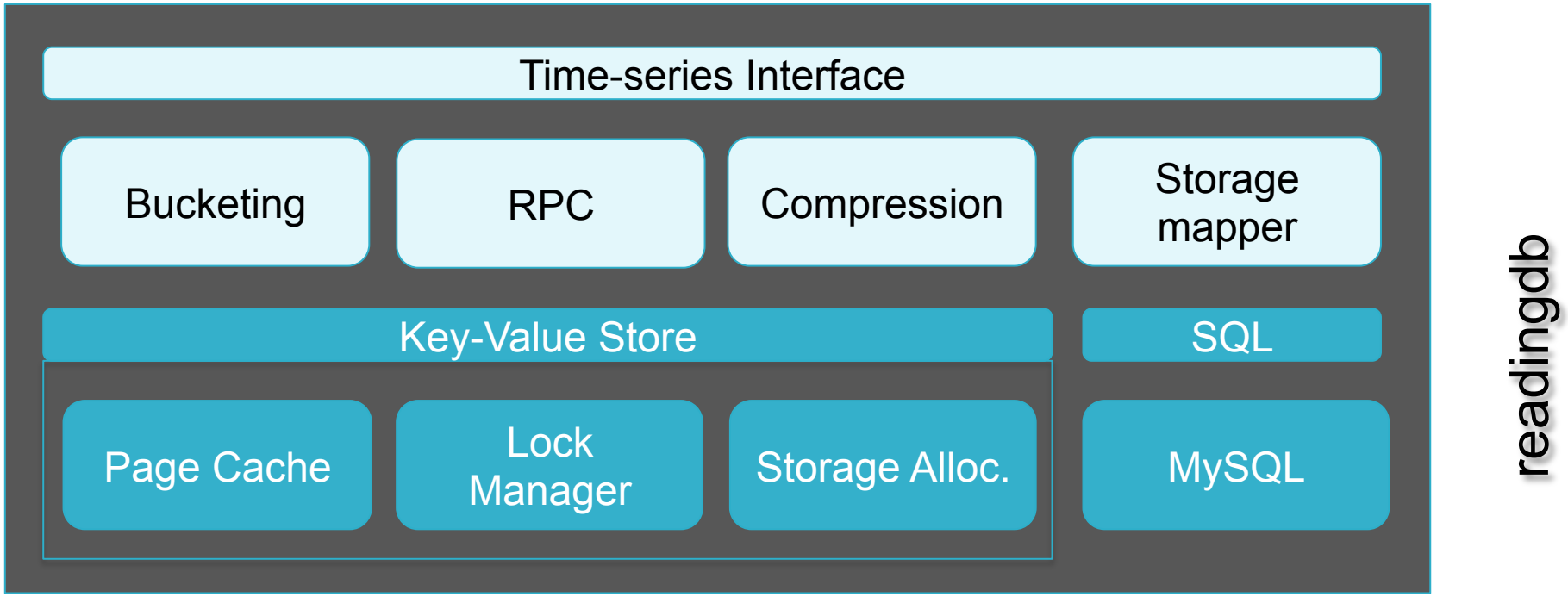


Shared Services Using sMAP

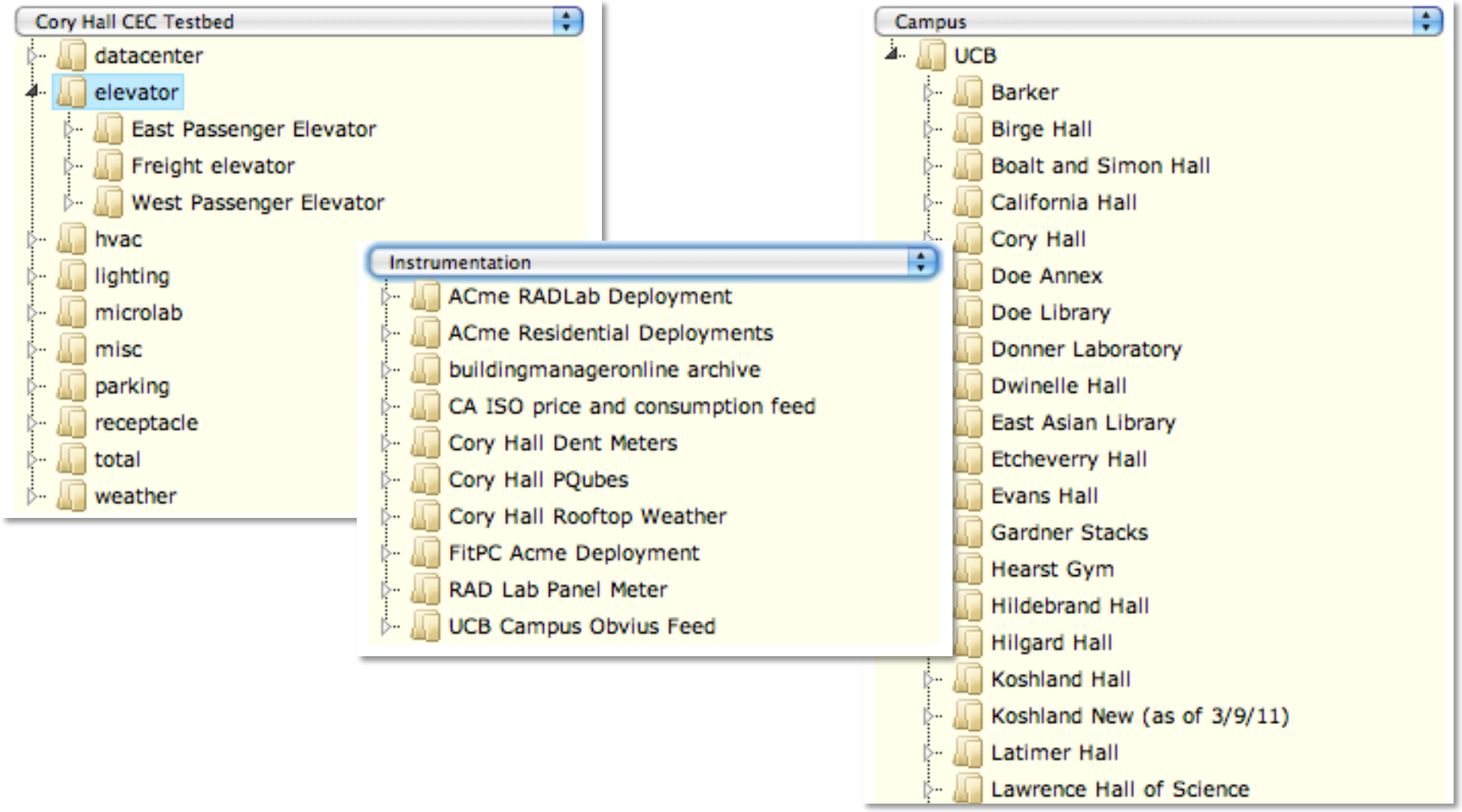


High-performance Storage Service

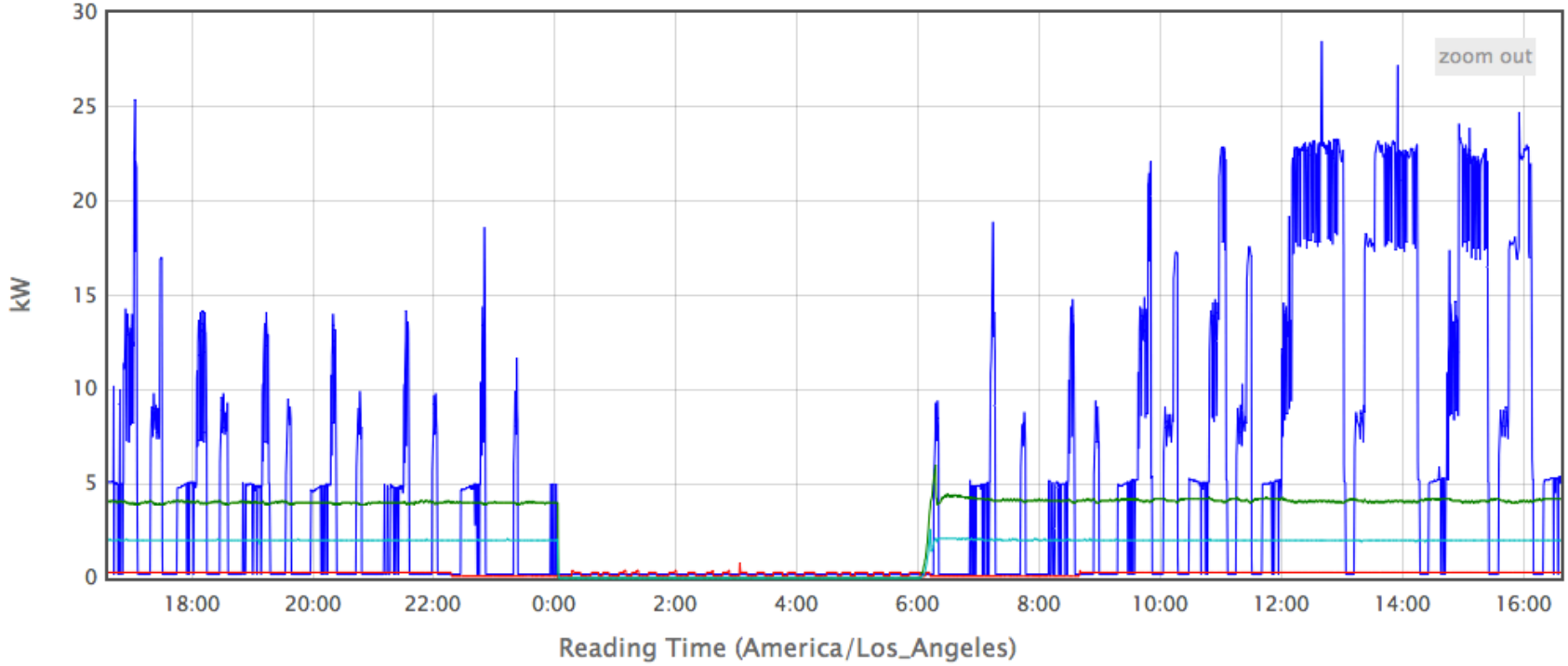
- Low-latency, high speed access to archived readings
- 3.4 billion readings, 3.5 bytes/reading on disk



Tag Browser

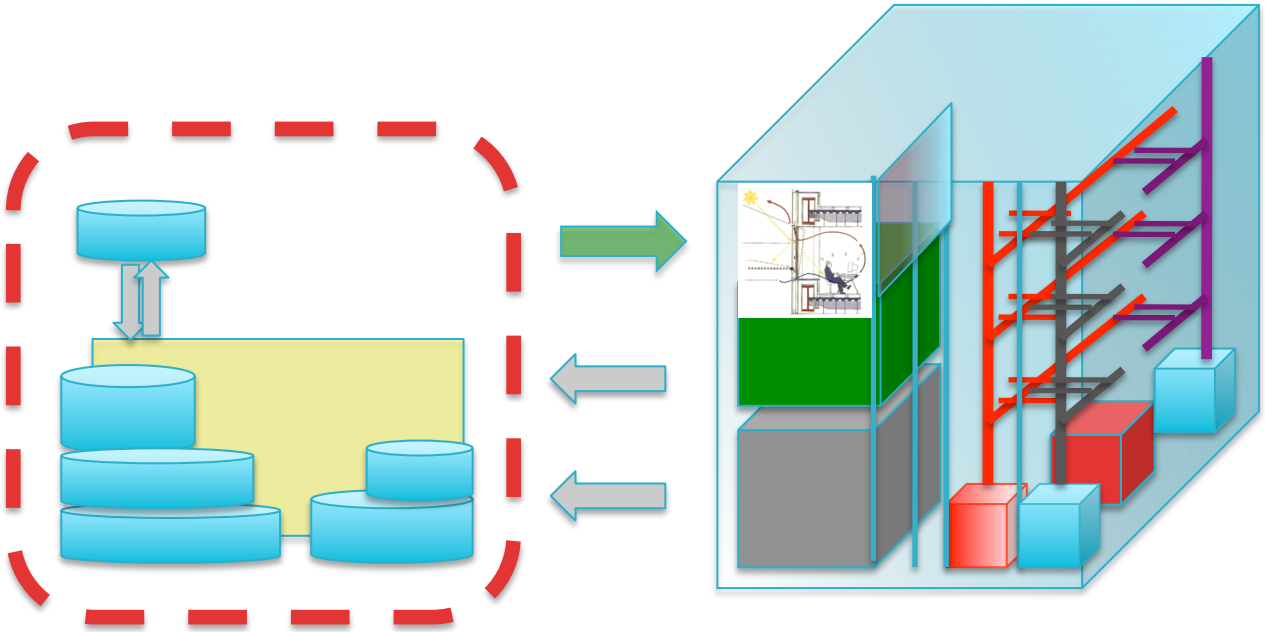

Cory Hall CEC Testbed
datacenter
elevator
East Passenger Elevator
Freight elevator
West Passenger Elevator
hvac
lighting
microlab
misc
parking
receptacle
total
weather
Instrumentation
ACme RADLab Deployment
ACme Residential Deployments
buildingmanageronline archive
CA ISO price and consumption feed
Cory Hall Dent Meters
Cory Hall PQubes
Cory Hall Rooftop Weather
FitPC Acme Deployment
RAD Lab Panel Meter
UCB Campus Obvius Feed
Campus
UCB
Barker
Birge Hall
Boalt and Simon Hall
California Hall
Cory Hall
Doe Annex
Doe Library
Donner Laboratory
Dwinelle Hall
East Asian Library
Etcheverry Hall
Evans Hall
Gardner Stacks
Hearst Gym
Hildebrand Hall
Hilgard Hall
Koshland Hall
Koshland New (as of 3/9/11)
Latimer Hall
Lawrence Hall of Science

Plotting and Exploration



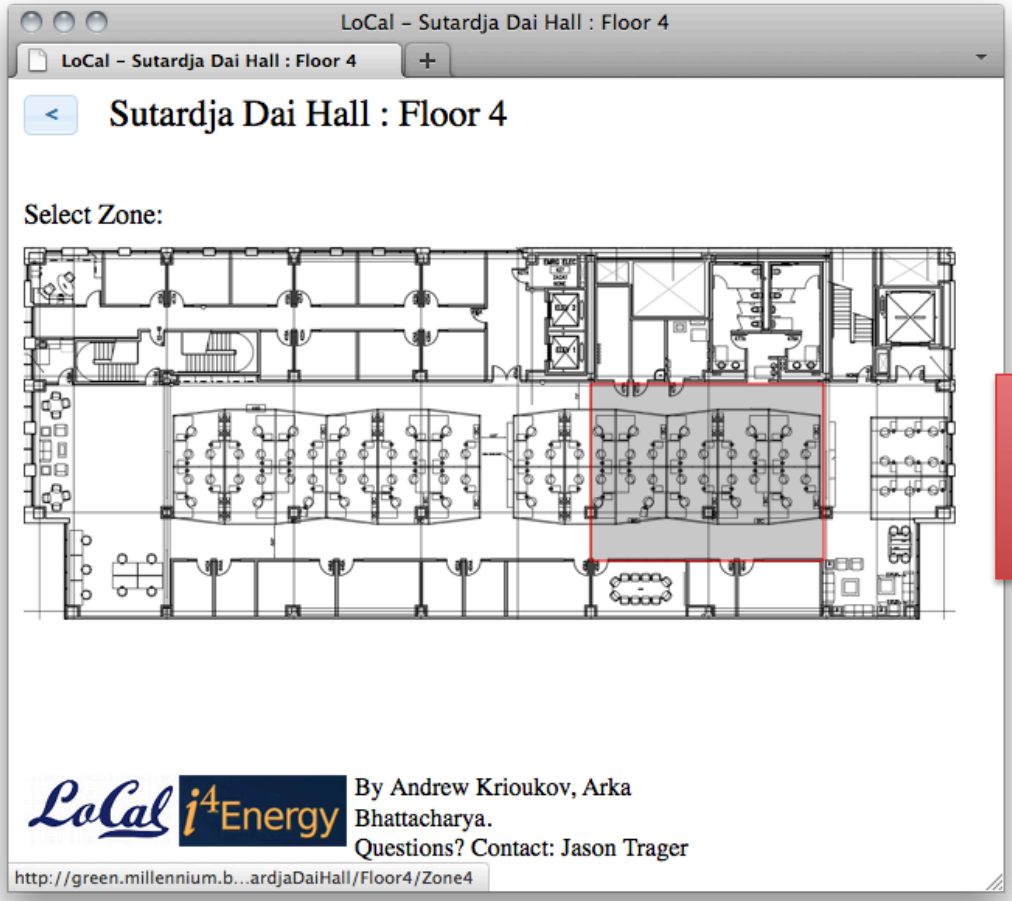
Sunday September 11, 2011 16 | Monday September 12, 2011 16 | now | reset | Select Streams | Plot | Clear | Stack | Autoupdate | permalink

- More | Hide Series | DOP :: AH-3, DOP HVAC
- More | Hide Series | DOP :: SF-3, Supply Fan, DOP
- More | Hide Series | DOP :: Two Exhaust fans two speed
- More | Hide Series | DOP :: Return Fan-3, DOP

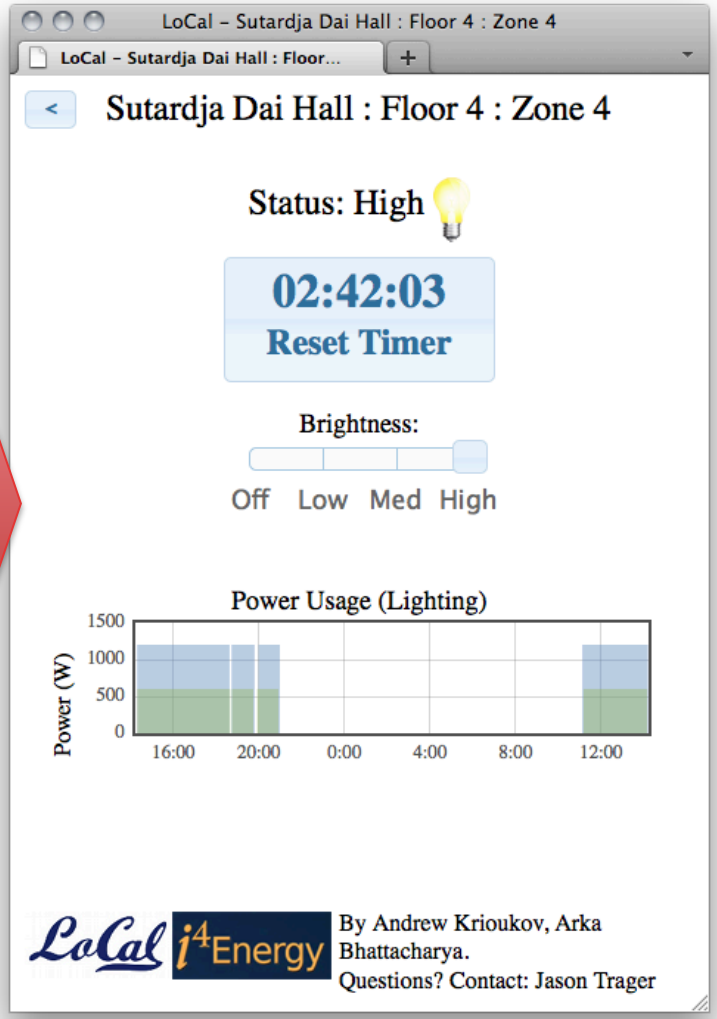


APPLICATIONS

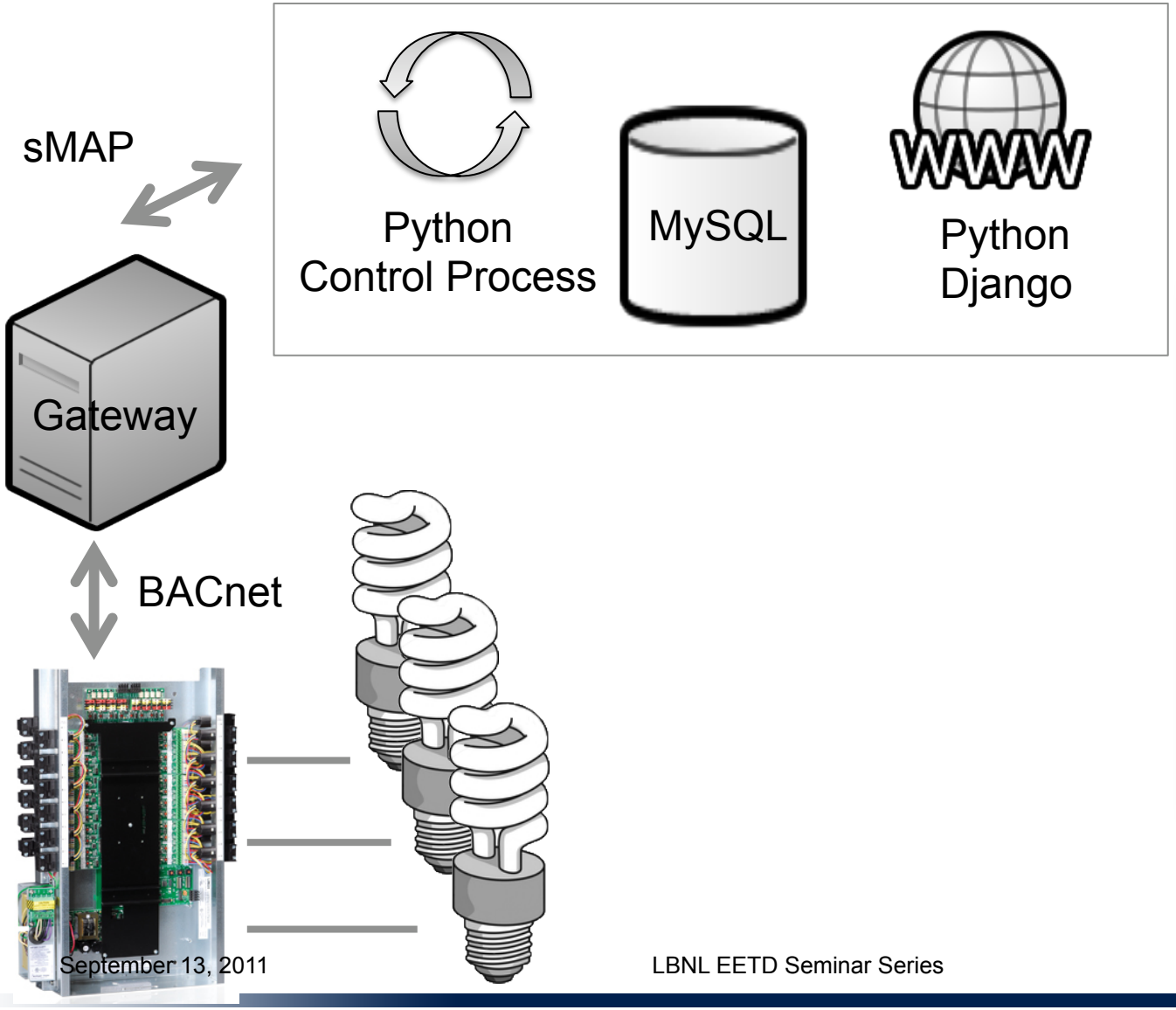
Personalized Lighting Control

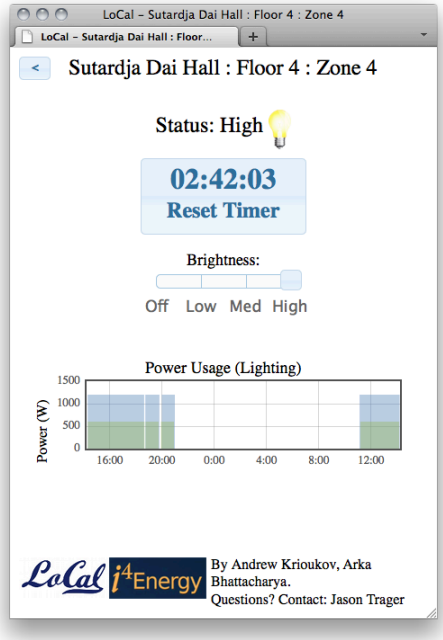


(Andrew Krioukov)

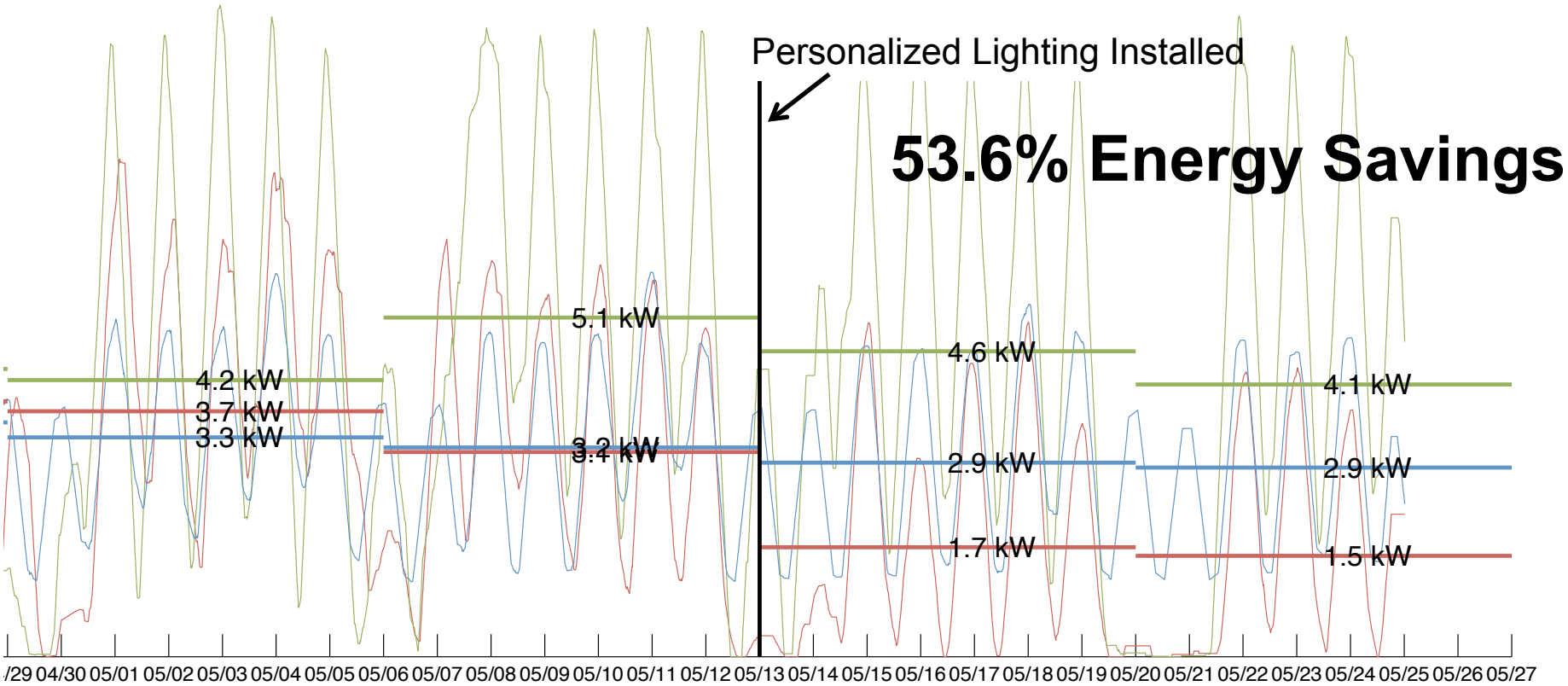


Design


sMAP
Python
Control Process
MySQL
Python
Django
HTTP
Gateway
BACnet


LoCal – Sutardja Dai Hall : Floor 4 : Zone 4
Sutardja Dai Hall : Floor 4 : Zone 4
Status: High
02:42:03
Reset Timer
Brightness:
Off Low Med High
Power Usage (Lighting)
Power (W)
1500
1000
500
0
16:00
20:00
0:00
4:00
8:00
12:00
By Andrew Krioukov, Arka Bhattacharya.
Questions? Contact: Jason Trager

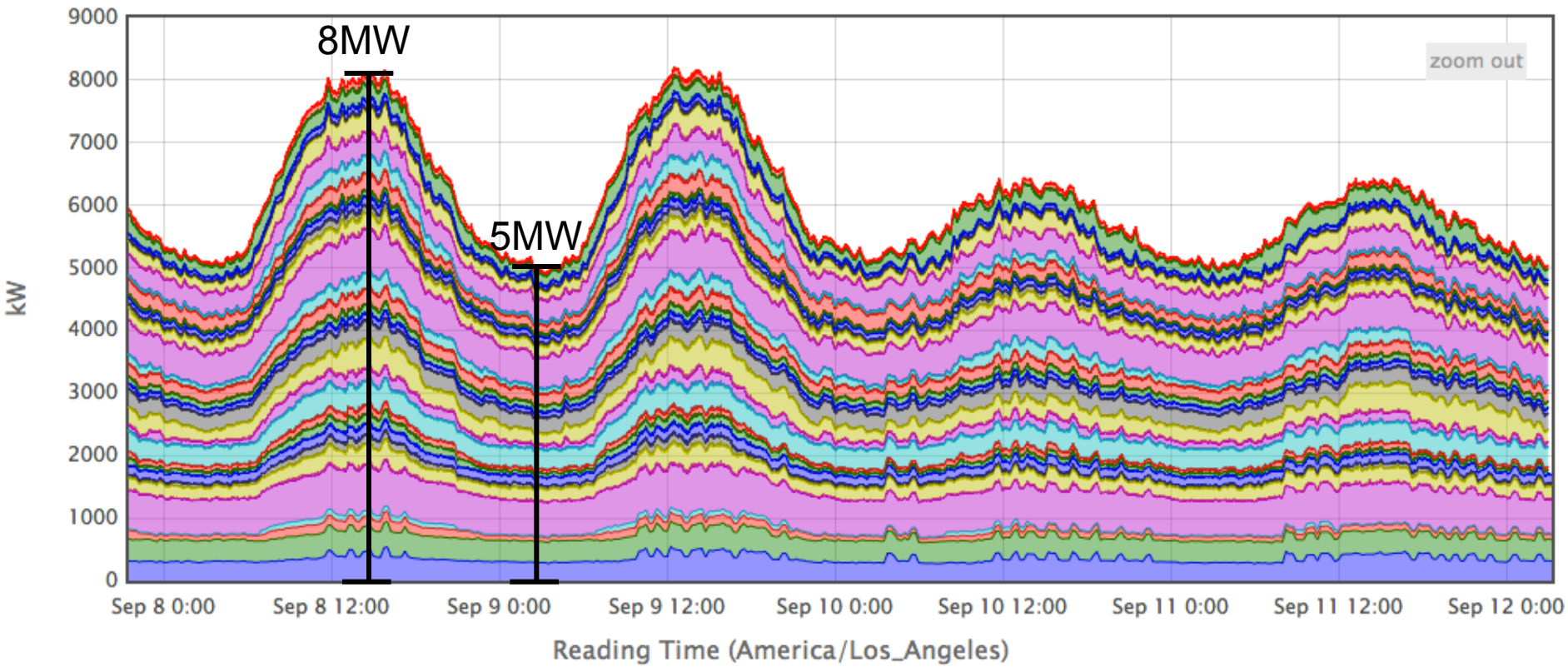
Energy Savings



		Before 5/13	After 5/13
Control	6th Floor	3.38 kW	2.91 kW (86.3%)
Control	5th Floor	4.52 kW	4.42 kW (97.8%)
Experiment	4th Floor	3.47 kW	1.61 kW (46.4%)

1.86 kW saved

Live Virtual Campus Breakdown



→Built with data from three systems

Other Projects in Progress

- Demand response
  - Shed 30% of load on demand in SDH
- Learning-Based Model Predictive Control of HVAC Systems
  - Save 30-70% using improved
- Numerous reductions in Cory Hall: to stuck dampers, devices knocked off schedule, corroded pipes, *etc.*
  - Manual detection of anomalies
  - Challenge is to automate sifting through the data

Conclusions

- sMAP as interchange format introduces architectural flexibility
  - Same story as in CAD/BIM, many other places
  - Especially important in a research context to enable fast moving “hypothesis testing”
- In this case, the protocol should be designed with the Internet in mind
  - We didn’t talk about this much

http://new.openbms.org

http://cs.berkeley.edu/~stevedh/smap2/

http://code.google.com/p/smap-data/

QUESTIONS

Outline

- LoCal project overview
  - Networked electric grid
  - Extensive load participation in decision
- Project approach
  - Commercial buildings, residences, datacenters: virtual campus
  - Commonality: time series data collection, analysis, feedback
- What is sMAP
  - A family of protocols & conventions
  - An open-source reference implementation
- Why does sMAP exist?
- Where is sMAP used
  - Transfer of time-series data
- What have we done with sMAP?
- What is the future of sMAP?