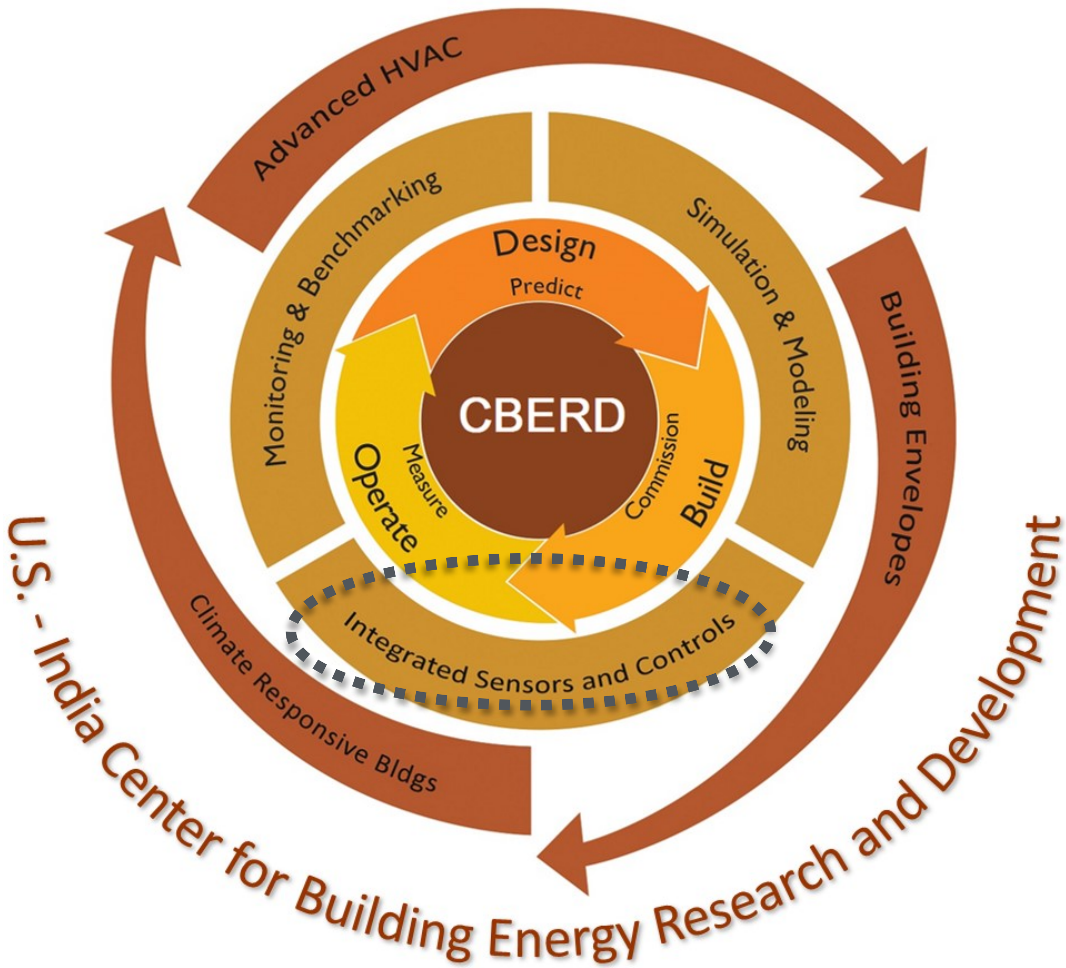
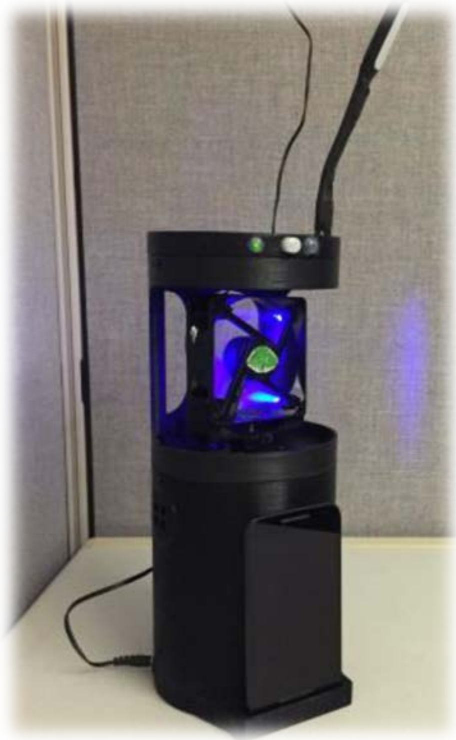
CBERD Integrated Sensors and Controls

2017 Building Technologies Office Peer Review





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Project Summary

Timeline:

Start date: October 2012

Planned end date: September 2017

Key Milestones

1. Initial lab-based proof-of-concept of integrated control of lighting, plug loads, and thermal zone-level comfort conditioning. verifying that switching building to backup power leads to >10% decrease in zone+workstation power use [LBNL & IIIT]. Summer 2017

Budget:

Total Project $ to Date:

- DOE: $750K Cost Share: $385K

Total Project $:

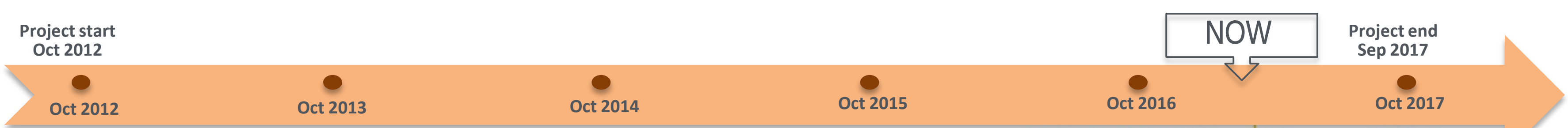
- DOE: $950K Cost Share: $75K

Key Partners:

International Institute of Information Technology, Hyderabad	Lighting Research Center - Rensselaer Polytechnic Institute
Indian Institute of Management Ahmedabad	Honeywell US
Philips Research US/India	

Project Outcome:

Developed an integrated workstation control system (lighting, plug loads and HVAC), demonstrated in Indian and US test-beds, based on open source transaction based controls.



Purpose and Objectives

Problem Statement:

- Conditioning a **whole building** misses Energy Efficiency opportunities
- *"Need for increased building system **interoperability** through connected devices" (BOE BTO MYPP)*
- Loads in buildings do not adjust to **constrained** energy resources. *"Only 10% of customers participate demand response programs*" (*DOE BTO MYPP*)

Solving this problem requires:

- **Personal** comfort delivery and control.
- New control paradigms for buildings using software-driven tools and services like the **Transactive Energy** frameworks.

Target Market and Audience:

- Commercial building owners and system innovators.
- Projected energy savings: 42 TBtu/year (U.S.); 6.7 TBtu/year (India)

Impact of Project: This project will:

- Demonstrate an integrated workstation control system (lighting, plug loads and HVAC) in a US and Indian test-bed. Release source code enabling transaction based control.

Definitions

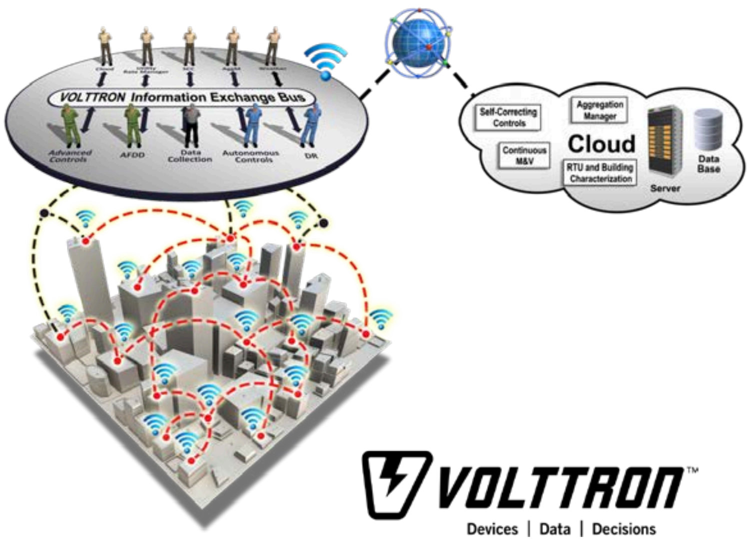
Transactive Energy

Techniques for **managing** the generation, consumption or flow of **electric power** within an electric power system through the use of **economic** or market based constructs while considering grid reliability constraints.

Gridwise Architectural Council

VOLTTRON

A open source distributed **control** and sensing **software** platform supporting Transactive Energy, developed by Pacific Northwest National Laboratory (PNNL).



VOLTTRON™
Devices | Data | Decisions

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Approach

Approach:

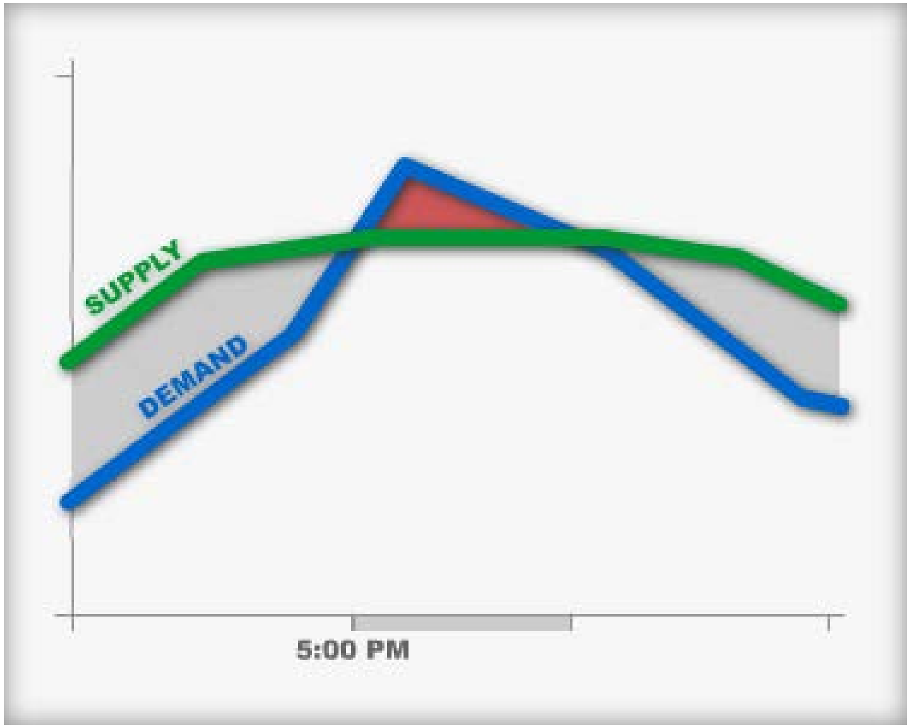
- *DOE BTO MYPP Sensors and Controls Goals:*
  - *"Enabling **integration** of buildings with the rest of the electrical grid" ,*
  - *"Provide continuous, real-time **information** on building components and systems"*
- Utilize open-architecture control platform for buildings with transaction-based controls
- Field-test VOLTTRON with a far less reliable grid (India) and with generators
- Address lighting, HVAC and plug loads

Key Issues:

- Shift from simulation based transactive controls to real devices
- How do we keep occupants happy?

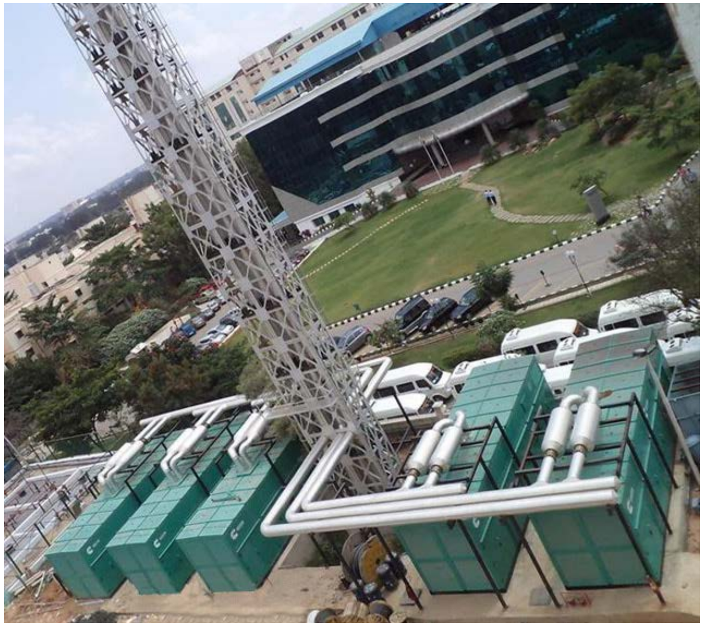
Distinctive Characteristics: Shifting from whole building management to individual workspace control to develop Grid Responsive Buildings

Problem: Constrained energy resources



US: Demand Response programs to address limited supply

(source: NexEnergy)



India: 5x1.5MW backup generators at office complex for grid outages

(source: Powerica)

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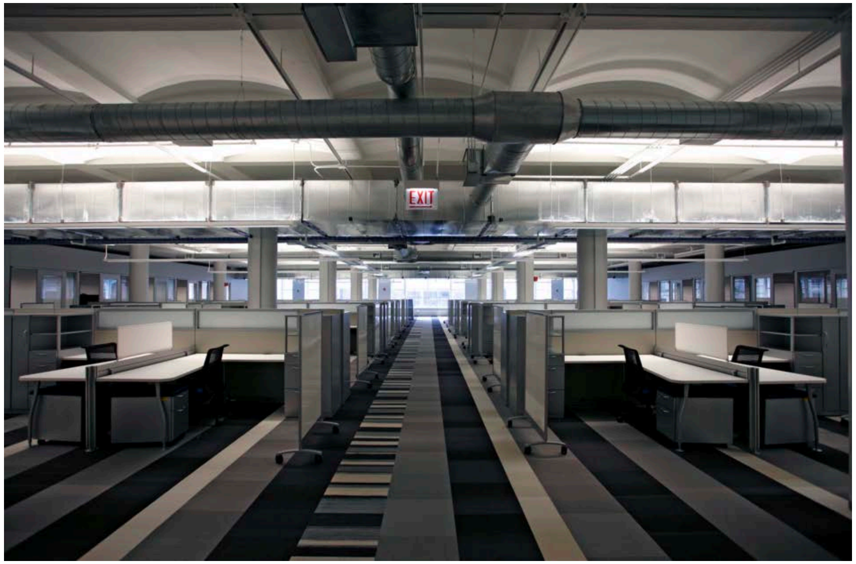
Solution

- Managing energy consumption on an individual workspace level instead of whole building level (bottom-up). But aggregating from workstation to zone to building.

From this → To this



Conditioning of a whole building

i-SPACE

Smart Plug Strip

VOLTTRON™
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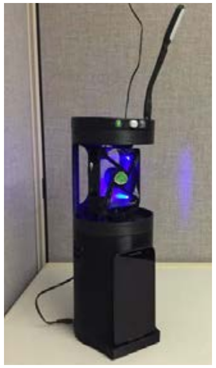
Transactive Software

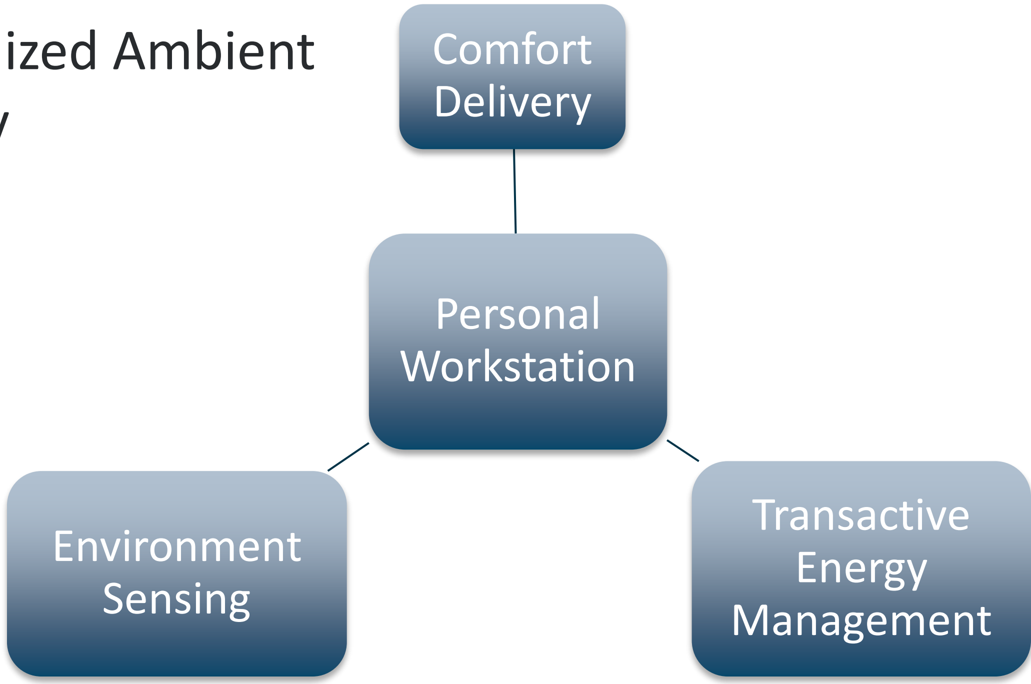


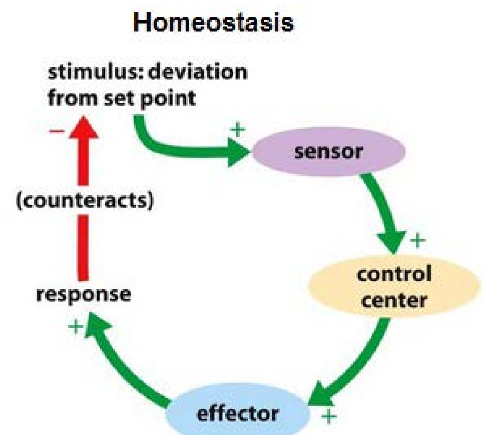
Smart Hub with fans, light and sensing

Hyperlocal workstation comfort conditioning and plugloads control

i-SPACE

- Intelligent System for Personalized Ambient Comfort, and Energy Efficiency
- Personal workstation with
  - Local heating/cooling
  - Task light
  - Plug load control
  - Environment sensing
- Responsive to
  - Occupancy
  - Demand Response
  - Grid outages
  - Real time electricity pricing
- Operates similar to human homeostasis
- Provisional Patent filed, joint US-India IP





Smart Plug Strip

- A plug strip that can identify its loads by looking at the power characteristics. The plug strip can also control outlets.
- Detection of a high-wattage space heater can alert to discomfort and inefficient conditioning.
- Combined with occupancy sensor can switch off loads

Smart Plug Strip, all UL listed components

Use of space heaters can indicate problems

Innovation Corps

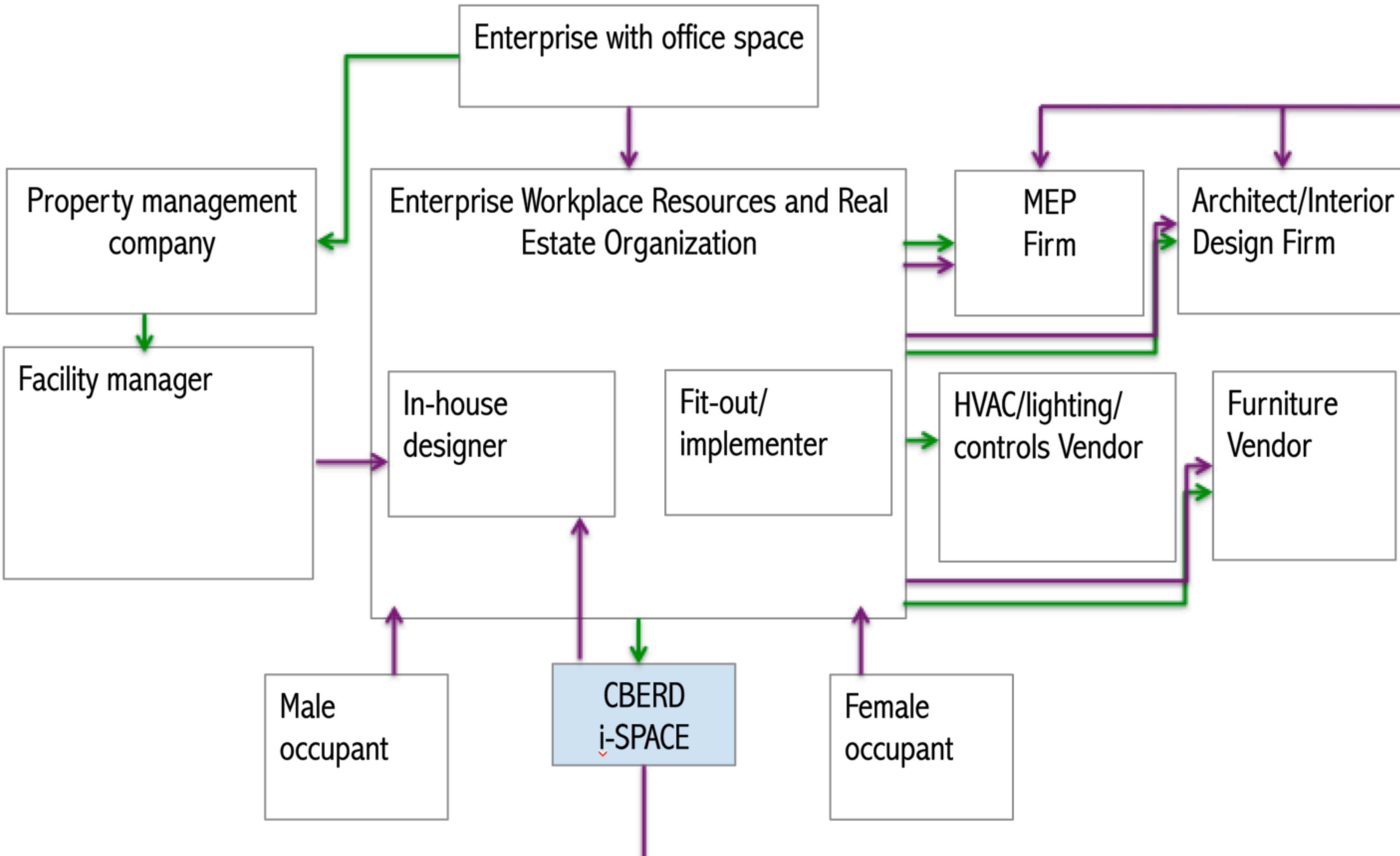
- 8 day intensive iCorps program with UC Berkeley Haas Business School on i-SPACE technology. Seed funding cost-share from EERE.
  - Understanding customer segments, value propositions
  - 15 interviews conducted with various partners
  - Define ecosystem and key stakeholders

Business Model Canvas

Key Partners	Key Activities	Value Proposition	Customer Relations	Customer Segments
- Control companies - HVAC suppliers - Comfort delivery - Furniture vendors - ESCOs - Utilities (incentives) - Contract manufacturer	- Productivity/comfort - Develop prototype H/W - Test integrated system - Prioritize customer features/functionality - Develop relationships w/ key partners - Propose utility rate	- New revenue stream from an automated integrated platform for buildings - Energy opex savings and reduced time spent on hot/cold calls - Employee health and productivity; **asset as a revenue stream** ~~-Increased comfort, sense of control~~ –Increased clientele , perceived as innovative consultancy	- Initial acquisition - Scale from individual to building wide deployment	- Control companies/ Furniture vendors - Facility managers - Building owners/ **Workplace Resources and Real Estate** ~~-Individual office occupants, Possibly cultural/gender biased~~ - A&E consultant firm
	Key Resources - BT expertise +IP - DR/TN software - Test Labs - IIIT-H , India expertise - Contract manufacturer		**Channels** - Consumer retail - Furniture fit outs - Utility incentives - Delivery: HVAC/ lighting/ fans/ air filtration providers	

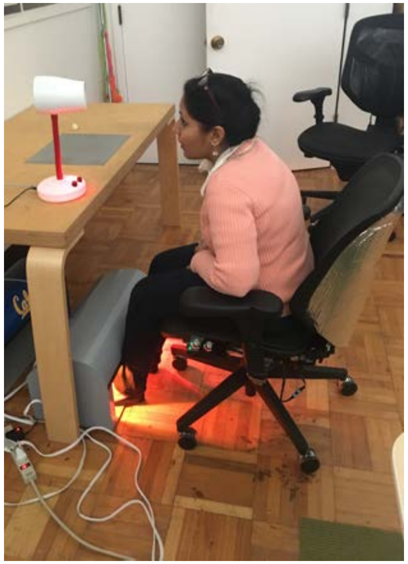
Cost Structure	Revenue Streams
- Low Capex, contract manufacturing - R&D cost - Testing cost - Awareness and marketing	- Product - Service-based?

Ecosystem: Flows of $ and information



Energy Efficiency and Demand Response

- Normally buildings conditioned to 72-74F and 500 lux everywhere
- Provide local workstation comfort and control allows 69-76F zone temperatures, by providing local heating and cooling. Saving HVAC energy.
  - Foot warmer, heated / cooled chair, fans
  - Condition only when occupant present
- Task lights allow lower overall light levels
- This project focuses on how to control these devices, not how they deliver comfort



Heated chair, foot warmer and fan

- (Hoyt et al., 2015) shows that the energy use of efficient personal comfort systems can be reduced to under 25 W/occupant over time, which is **20–50 times less** than the per- occupant energy use of central heating and cooling systems.
- Demand Response: Temporarily reduce services, use local storage.

Software implementation

- Based on PNNL Volttron and LBNL/DoD Local Power Distribution Manager (LPDM)
- Overall design and whole building and zone level code developed by LBNL.
- Code for Smart Plug Strip and Smart Hub developed by Indian partners, assisted by LBNL staff.
- LBNL working with Philips Lighting on integration between lighting and distributed energy resources like storage and PV.

Progress and Accomplishments

Accomplishments:

- Smart plug-strip with load detection and load switching
- Smart Hub with integrated sensors, task light and fan
- Transactional software implemented for various components
- Field test planned for April 2017 in FLEXLAB at LBNL.

Market Impact: Interviewed building owners interested in personal workstation control to reduce **hot and cold calls** and get distributed **sensor data**. IoT devices are becoming more common and allow easy **integration** into i-SPACE. Indian team (IIIT-H) is starting to use VOLTTRON for their integrated control. Potential for new **contributions to VOLTTRON** open source software.

Lessons Learned: Building occupants don't 'want' Demand Response capabilities. They want a comfortable workspace that they can control. Building owners want both productive/happy employees and grid connected capabilities like Demand Response enabled buildings.

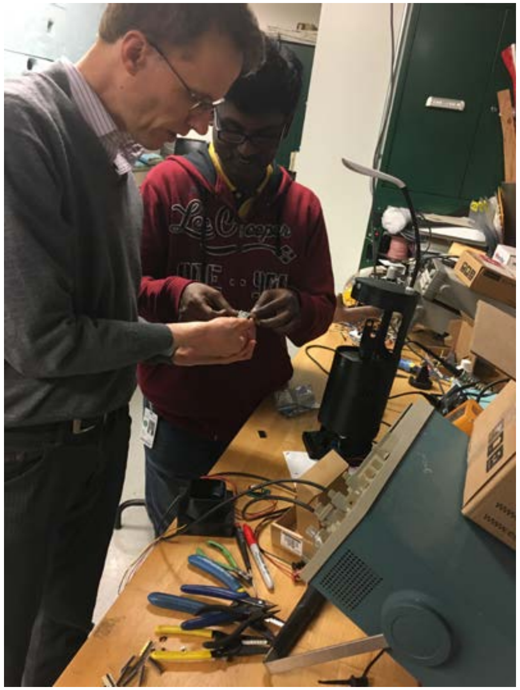
Project Integration and Collaboration

Project Integration:

- Weekly calls with Indian and US research partners
- Visiting student and professor from India in Summer 2016 and Winter 2017
- Testing of algorithms and technology in India and US

Partners, Subcontractors, and Collaborators:

- Lighting Research Center at Rensselaer Polytechnic Institute
- International Institute of Information Technology, Hyderabad, India
- Indian Institute of Management Ahmedabad
- Philips Research



LBNL and IIT-H researchers assembling a Smart Hub

Communications:

- Volttron Users Meeting presentations
- UC Berkeley iCorps
- CBERD Industry Partners Forum
- 2 Papers on smart powerstrip

Next Steps and Future Plans

FLEXLAB Facility at LBNL

Next Steps and Future Plans:

- In April 2017 we will start an occupied testbed study at LBNL's FLEXLAB facility. This experiment will incorporate all the technologies mentioned in this presentation. We will measure the energy consumption and load reduction, while evaluating the occupants response and satisfaction
- Based on lessons learned from the iCorps project about the customer segments and value propositions we plan to target certain business segments for commercialization.

REFERENCE SLIDES

Project Budget

Project Budget:

~FY 13-14: $125K for overall coordination and activity on transactional controls, $50K on activity on lighting

~FY 15-17: $150K for overall coordination and activity on transactional controls, $50K on activity on lighting

Variances:

Budget above includes additional 25K provided for FY 15-17 for overall coordination after three original sub-tasks combined in FY15

-Cost to Date: Total funds till date: 750K, cost to date: $690K

Additional Funding: NA

Budget History					
Oct 2012– FY 2016 (past)		FY 2017 (current)		FY 2018 – Sept 2018	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
750 K * Total expected funding	385 K	200K (expected)	75K		

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Project Plan and Schedule

Project Schedule

Project Start: 10/1/12

Projected End: 9/30/17

- Completed Work
- Active Task (in progress work)
- Milestone/Deliverable (Originally Planned)
- Milestone/Deliverable (Actual)

	FY2013				FY2014				FY2015				FY2016				FY2017			
Task 3: Integrated Sensors and Controls	Q1 (Oc	Q2 (Ja	Q3 (Ap	Q4 (Ju	Q1 (Oc	Q2 (Ja	Q3 (Ap	Q4 (Ju	Q1 (Oc	Q2 (Ja	Q3 (Ap	Q4 (Ju	Q1 (Oc	Q2 (Ja	Q3 (Ap	Q4 (Ju	Q1 (Oc	Q2 (Ja	Q3 (Ap	Q4 (Jul-
FY2016 Q3 Milestone, Subtask 3.2: Optimal load-shedding algorithms for task-ambient lighting systems developed [RPI]																				
FY2016 Q4 Milestone, Subtask 3.1: VOLTTRON Transactional Network controller developed for workstation energy management; coordinated control of HVAC, lighting, and plug load components demonstrated through full range of operating modes[LBNL]																				
FY2016 Q4 Milestone, Subtask 3.1: Sensors and controls embedded in office furniture systems [IIT]																				
FY2016 Q4 Milestone, Subtask 3.3: GRB model including CBERD technology data tested [IIMA]																				
FY2016 Q4 Milestone, Subtask 3.1: On screen GUI for occupant controls developed [IIIT]																				
FY2017 Q1 Milestone, Subtask 3.2: Methods to trade-off light-source color properties and input power developed [RPI]																				
FY2017 Q2 Milestone, Subtask 3.1: Initial lab-based proof-of-concept of integrated control of lighting, plug loads, and thermal zone-level comfort conditioning. verifying that switching building to backup power leads to >10% decrease in zone+workstation power use [LBNL																				
FY2017 Q2 Milestone: 3.1 Initial lab-based proof-of-concept of integrated control of lighting, plug loads, and thermal zone-level thermal comfort conditioning [LBNL & IIIT],																				
FY2017 Q2 Milestone: 3.3 Finalization of GRB model [IIMA]																				
FY2017 Q2 Milestone: 3.2 Develop methods to trade-off light-source color properties and input power [RPI]																				