FLEXLAB (Facility for Low Energy eXperiments in Buildings)

2014 Building Technologies Office Peer Review

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Project Summary – FLEXLAB Operational Launch & Support

Timeline:

Start date: October 1, 2013

Planned end date: September 30, 2014 - Ongoing

Key Milestones

1. Workshop on business model, logic models and success metrics – Oct 2013
2. Logic models and success metrics, Go/No Go – Jan 2014
3. Industry partner commitments and letters of intent – 3/31/14

Budget:

Total DOE $ to date: $1,150k (FY14) (includes Operations, and Calibration & Model Validation projects)

Total future DOE $: $TBD

Target Market/Audience:

FLEXLAB's initial target markets are Utilities, Manufacturers, and the AECO community.

Key Partners:

Webcor & Genentech	Consortium for Energy Efficiency
Daikin	Southern California Edison
Philips	National Association of State Energy Officials
CA Utility	Bonneville Power Administration
Prospect Silicon Valley	Navayuga Engineering Co.

Project Goals (5Yr):

To develop and accelerate demonstration and deployment of integrated technologies and systems that achieve deep energy savings, e.g. on the order of 50% at $0.05/kWh CCE, or that optimize controls to facilitate grid integration by:

- *Developing or demonstrating 25 technologies, systems or controls strategies*
- *FLEXLAB technologies or systems being demonstrated in at least 15 sites, or transferred to 5 deployment partners with intent to review in their demonstration, incentive or DSM programs*

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FLEXLAB Background & Concept

- LBNL received ARRA funds to construct FLEXLAB, a unique facility dedicated to:

  - Developing and applying new test methods and solutions including **highly-efficient, integrated building systems** under realistic operating conditions

  - Focuses on:
    - Comprehensive whole building **systems integration**
    - **Specific end use integration and component interactions** (e.g., HVAC, lighting, windows, envelope, plug loads control systems)
    - **Controls hardware and sensors**
    - **Simulation and tools** for design through operations

- Input from 35 industry partners helped define FLEXLAB capabilities

- FLEXLAB configurations can match the full range of commercial retrofit and new construction options

FLEXLAB and the Integrated Systems Research Agenda

Current Design and Research Paradigm – Silo Approach

Single component or isolated system EEM	→	**5-20% Energy Savings for the isolated component or system**
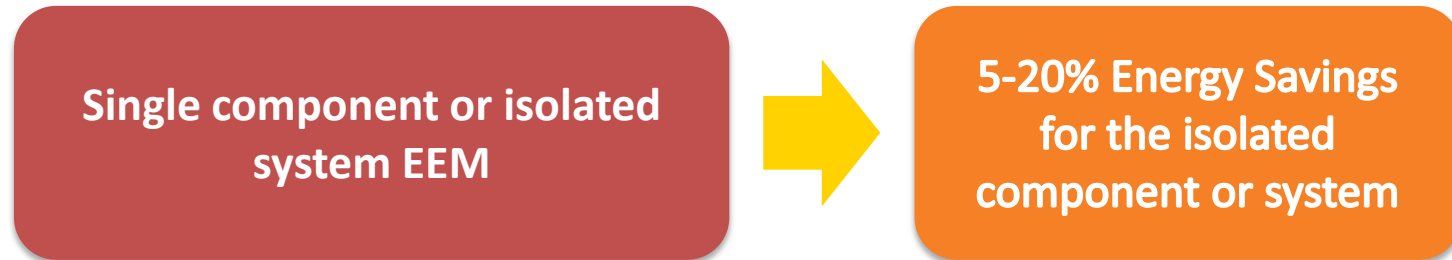
Integrated Building Systems Approach

Multi-system integrated EEMs	→	**30-50%+ Whole Building Energy Savings**

In order to achieve the aggressive energy savings needed to reach federal, state and local goals, integrated approaches must be taken

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FLEXLAB Core Components

- **Four Exterior Building Testbeds**
  - Integrated Systems and Components
  - **Completion April 2014**

- **Lighting & Plug Load Testbed**
  - Controls, Visual Comfort & Behavior
  - **Now in Operation**

- **Virtual Design/Visualization Testbed**
  - Virtual Integrated Design & Visualization of Experiments
  - **Now in Operation**

- **Staffed by National Lab Scientists & Technicians**

"To transform commercial building industry practice from a component-based focus to integrated systems in design and operations, achieving cost-effective, aggressive net-zero energy goals in new and existing buildings."

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FLEXLAB Capabilities – Exterior Testbeds

- **Side-by-side comparative testing**

- **Controlled environment**
  - Capabilities to simulate wide range of climates
  - Precisely controlled internal loads

- **Well instrumented and metered facility**
  - High granularity of power measurement
  - High accuracy sensors – temperature, pressure, air and water flow, heat flux, etc.

- **Highly flexible testbeds – interior and exterior**
  - HVAC, lighting, glazing, skylights, shading, etc.

- **Mockup new construction and retrofit conditions**
  - First fit outs represent 1980s, current code and net zero

- **Provides access to multiple flexible systems**
  - Many manufacturers don't have testing facilities to integrate controls with other systems

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Purpose and Objectives of FLEXLAB

Problem Statement: Key challenges for 3 target users:

FLEXLAB Delivers

	Challenges
Utilities	**Component** level ET reaching cost-effective max. **System** level ET opportunities need comparison studies to determine savings. **Field demo variable conditions** unsuited for systems assessment.
	Design assistance programs need **validated strategies**
	Modeling tools need to include ET, and predict with confidence
Manufacturers	**Manufacturers lack facilities** and expertise to develop & test integrated solutions across building systems
	Products and solutions need **validated performance** against baselines for integration into codes and standards
	Design tools need to accurately represent new ET for adoption
AECO Architects, Engineers, Contractors (Owners)	**Technology** performance data needed to design with **confidence**
	Performance based mockups optimize and quantify performance to allow **design** to be predicted with **confidence**. Opportunities for better construction, Cx **lowering change orders and total costs**.
	Buildings tend to use more energy than design predictions. **Simulation tool algorithms need validation**.

High accuracy comparative tests

Develop/test integrated system solutions

Validated tools close gap- predicted to actual performance

Project Goals – Near Term

1. **Manufacturers and R&D Broadly -** Develop or demonstrate 3-5 technologies or systems, including 1-2 integrated building systems and controls technologies, enabling 50% energy savings.

2. **Utilities (ET Demonstration) -** Provide high accuracy performance data for two technologies for utilities incentive and DSM programs, that when coupled with calibrated simulation models enables broader impacts analysis.

3. **AECO** - Provide test data and recommendations for 1-2 building system designs stemming from performance-based design mockups.

4. **Operations** - Develop high availability, efficient and safe operational practices along with a set of research projects that grows the FLEXLAB business model into self-sufficiency in a 5 year timeframe.

Integrated Systems ❖ *Targeted Demonstrations* ❖ *Design Performance*

Purpose and Objectives

Target Market and Audience: Commercial buildings sector, retrofit and new construction, 6.5 quad Btus. Target audience - Utilities (particularly Emerging Technologies (ET) programs), Manufacturers and AECO.

Planned Contribution to Energy Efficiency:
1. FLEXLAB's research projects:
    - Technology and controls development, optimization and validation, particularly for integrated systems:
        - Lighting/daylighting controls with automated shading
        - HVAC controls with automated shades
    - Develop and validate design and ops tools – e.g. Energy Plus algorithms, Cx, M&V and auditing tools
2. Measuring Achievements – Metrics tracked for operations and research.
    - Research projects energy savings
    - Deployment partners tech transfer
    - Other ops metrics, e.g.: usage of testbeds, accuracy maintenance, progress to self-sufficient business model, industry outreach

Industry Partner & Research Project Pipeline (FY14)

- Philips (daylighting with automated shading)
- Daikin (VRF algorithm development and testing)
- Webcor/Genentech
- CA Utility (2 projects – integrated envelops/lighting; HVAC advanced controls for load shape reduction)
- Hyundai (model predictive control & testbed experiment design)
- DOE (5 projects – testbed calibration and simulation tool validation; transactive controls demonstration; ARPA-E backpack energy model development testing; smart windows controls validation; hybrid wireless lighting testing)
- Work for Others (non-DOE) totals 1.15M in FY14

Deployment Partners
- National Electrical Contractors Association
- Prospect Silicon Valley (cleantech to market demonstration center)

Industry Partner & Research Project Pipeline (FY15 - On)

Active discussions occurring with a range of industry partners including:

- Philips
- Daikin
- Large internet / technology leader
- CA Utilities
- Johnson Controls
- BPA
- Hyundai
- Nissan
- Tesla
- CEE, NASEO, and others….

Deployment Partners
- National Electrical Contractors Association/IBEW
- Prospect Silicon Valley
- Architecture 2030

Approach

Approach:

- Deliver and support a fully operational, and calibrated facility. Develop calibration and accuracy determination test plan and execute.

- Marketing and outreach plan, targeted to audience. Refine value propositions, and pitches, aligned with FLEXLAB goals.

- Develop business model, refine annually reviewing pipeline and ops costs.

- Develop and execute safe, efficient operational processes and system to track success metrics.

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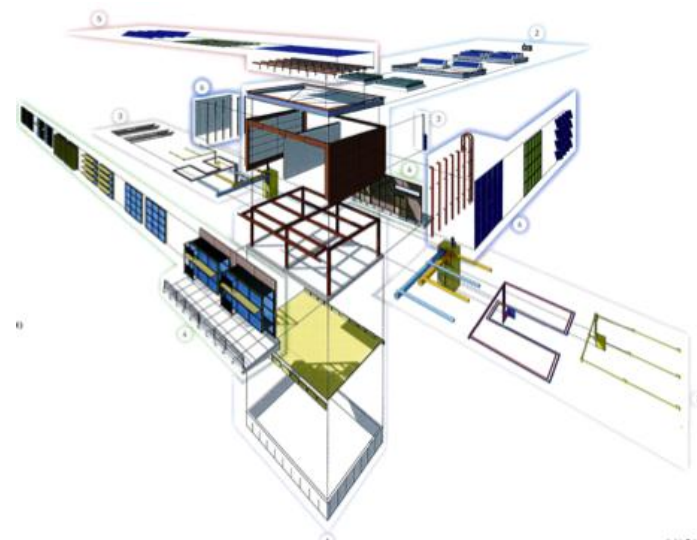
Approach

Key Issues:

- Industry is currently siloed by technology areas – e.g. lighting, HVAC, envelope. Developing integrated collaborations requires a heavier lift and new engagement models.

  –Addressing by identifying key centralized industry organization partners.

- DOE operational funding support has been instrumental for facility startup, initial outreach and business development. Known operational support in outyears is fundamental to further develop a industry cost share model that move towards a self-sufficiency.

Distinctive Characteristics: FLEXLAB emphasizes not only a fully customizable research platform for integrated systems studies, but it also consists of a network of industry partners to both inform R&D needs and aid in deployment.
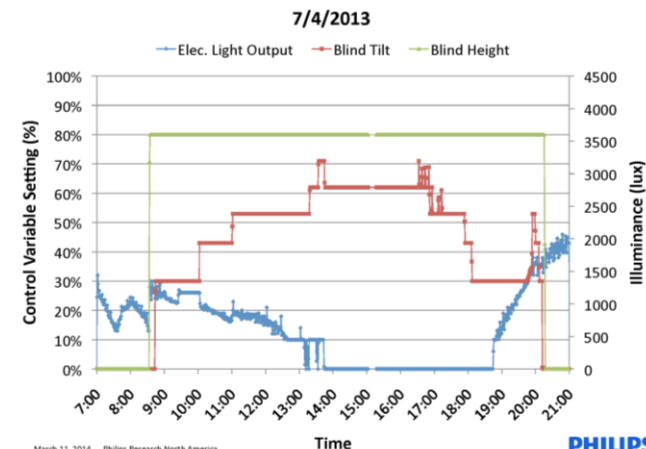
Progress and Accomplishments

Discoveries: Utilities ET programs are primed to work collaboratively on ET and research projects, sharing similar needs and concerns in ET and codes development.

Accomplishments:
- Testing of DAQ/controls architecture, developed basic models
- Completion of first experiment in Lighting and Plug Loads Testbed – Philips Lighting with Somfy automated shading, glare and dimming control
- Calibration test plan
- Logic models for all Ops areas with success metrics – *Operations Management, Business Development* and *Service Offering*
- Business and safety processes
- First exterior TB project – Webcor/Genentech, mockup of 250k sf building design to optimize integrated design elements for energy use, pre-Cx, O&M, occupant feedback increase acceptance of design, reduce risk for execution
- MSA discussions (e.g. CEE, CA utilities, NASEO)
- Over 65 tours, and 400+ visitors since Oct 2013.

Time Series Sample – System Behavior
7/4/2013

— Elec. Light Output   — Blind Tilt   — Blind Height

6   March 11, 2014   Philips Research North America

PHILIPS

Progress and Accomplishments

Project Contribution to Energy Efficiency : Construction of the exterior testbeds has not yet completed, so research results from these testbeds are not yet available.

- Lighting and Plug Loads testbed - Philips Lighting, testing and demonstrating dimmable lighting controls couple with automated shading and occupant controls for visual and thermal comfort, 35% energy savings
- Industry Partnership Program in development, creates key stakeholder relationships. MOU executed with Prospect Silicon Valley – a cleantech to market demonstration and deployment center.

Awards/Recognition: Engineering News Record cover story, Sept 2013, circulation 280k.

Project Integration and Collaboration

Project Integration:

Partners, Subcontractors, and Collaborators:
- First projects - Philips Lighting, CA Utility and Webcor/Genentech. Future projects in discussions (SCE, BPA, CEE, NASEO, NEEP etc.)
- Deployment partners in development, including MOU executed with Prospect Silicon Valley, NECA/IBEW and Architecture 2030.

Communications:
- Hosted multiple workshops, events and tours in 2013/14 (e.g. USGBC and ASHRAE High Performance Building conference)
- FLEXLAB Operations Team meets weekly, coordinates with construction project, facilities, EH&S (safety) and other LBNL divisions regularly
- Targeted discussions with industry stakeholders ongoing

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Next Steps and Future Plans

Next Steps and Future Plans:

1. Launch of FLEXLAB Operations - execution of business processes, metrics tracking, safety process, onboarding of projects.
2. Testbed calibration, assess accuracies.
3. Execution of FY14 FLEXLAB projects.
4. Business development – complete 'Voice of the Customer' interviews. Refine value propositions and materials. Continued outreach to key strategic industry partners, define projects.
5. Execution of Master Service Agreements (e.g. NASEO)

For continued success – BTO provided operational support in FY14. To minimize need for this support in future years FLEXLAB uses an operations and business model plans that is based on attracting adequate partners/projects (including DOE) to stabilize and grow to a self-sufficient model.

Building on this work – BTO and others can support strategic collaboration and deployment opportunities. FLEXLAB is a limited resource, moving forward will need to focus on projects with greatest potential for impact and deployment.

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REFERENCE SLIDES

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Project Budget

Project Budget: 1,150k (FY14). Includes Operational Launch support, and Calibration and Model Validation projects. Other DOE funded research projects not included.

Variances: No variances from the FY14 budget have occurred or are planned.

Cost to Date: 225.7k (to end of Feb 2014). Spend rate expected to increase as facility is turned over to operations.

Additional Funding: FLEXLAB RDD&D projects are funded by project sponsors which vary from federal to state, utility and private sources. FY14 projected $1,150k non-DOE funding.

Budget History					
FY2013 (past)		FY2014 (current)		FY2015 – Ongoing (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
		1,150k	~350k	TBD	Varies by Project – up to 100%

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Project Plan and Schedule

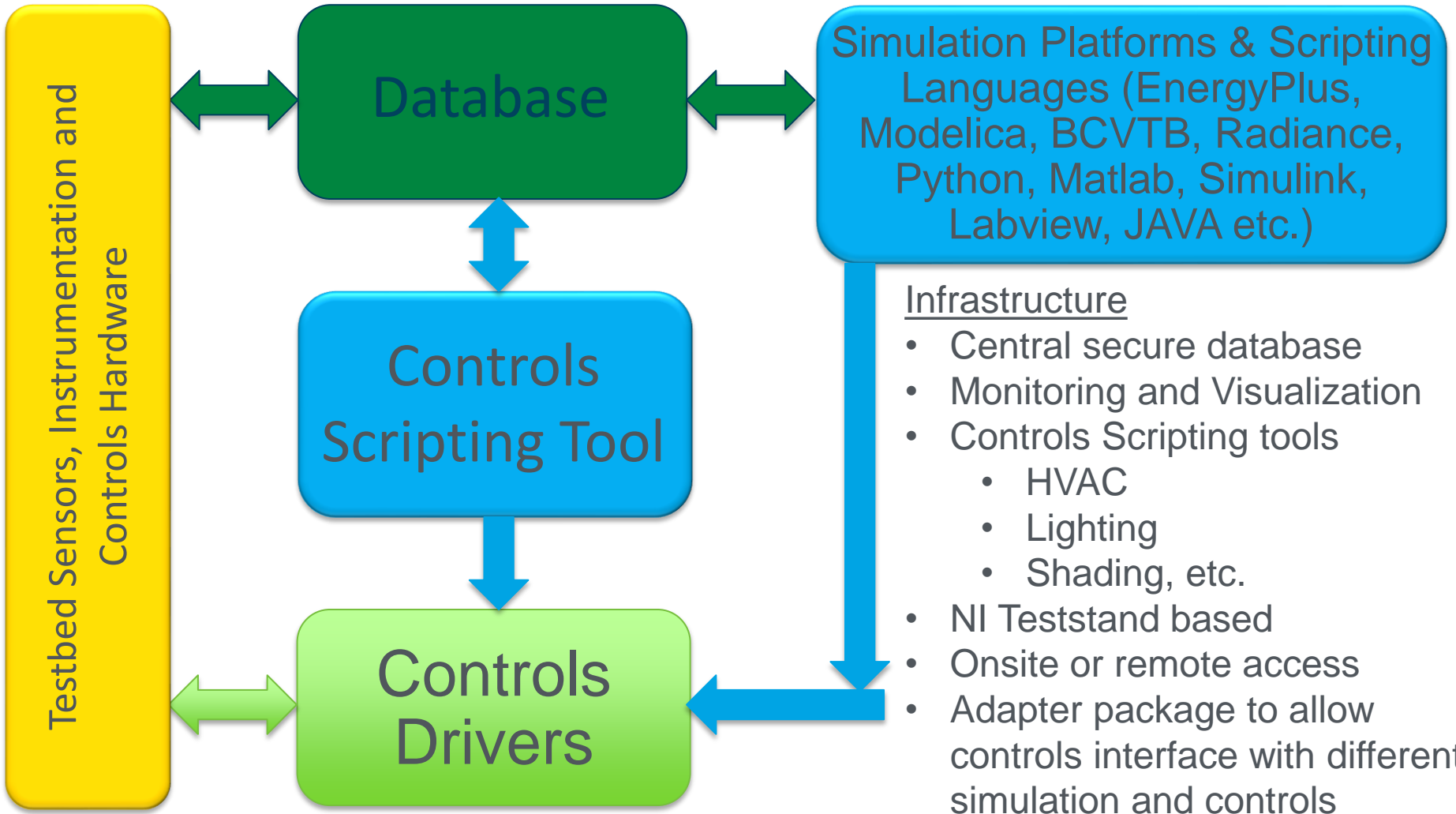| Project Schedule													
Project Start: Oct. 1, 2013			Completed Work										
Projected End: Sept. 30, 2014 - ongoing			Active Task (in progress work)										
		◆	Milestone/Deliverable (Originally Planned)										
		◆	Milestone/Deliverable (Actual)										
	FY2013				FY2014				FY2015				
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	
Past Work													
Q1 Milestone: Workshop on Business model, logic models					◆								
Q1 Milestone: Logic models developed with metrics for success for Operations, Business Development and Service Offering.						◆◆							
Q1 Milestone: Go/No Go Decision.						◆◆							
Q2 Milestone: Metrics tracking, industry partners commited, and further partners stating interest.						◆							
Current/Future Work													
Q3 Milestone: Maintenance and calibration processes developed and commenced.							◆				◆		
Q4 Milestone: FY15 project pipeline developed, with deployment partners.								◆				◆	

- Go/No Go Decision meeting was rescheduled to mid-January to coincide with a visit by Roland Risser, BTO.
- Calibration and model validation activities delayed due to delay in construction project turn over to operations of 4 months.

Features - Exterior Testbeds

- **Flexible interior space**, including variable ceiling heights, raised floor at varying heights, and interior partitions may be relocated for zonal studies
  - Two cells, with removable adiabatic wall in between

- **Interchangeable façade elements**, shading, glazing, skylights - permits study of high performance integrated dynamic & façade systems

- **Interchangeable HVAC systems** - permits study of both air-based systems, (VAV, UFAD, DOAS etc) and water-based systems (fan coils, radiant heating and cooling, VAV)

- **Interchangeable lighting** – direct/indirect light fixture studies, and lighting designs that emphasize daylighting controls, and task lighting applications

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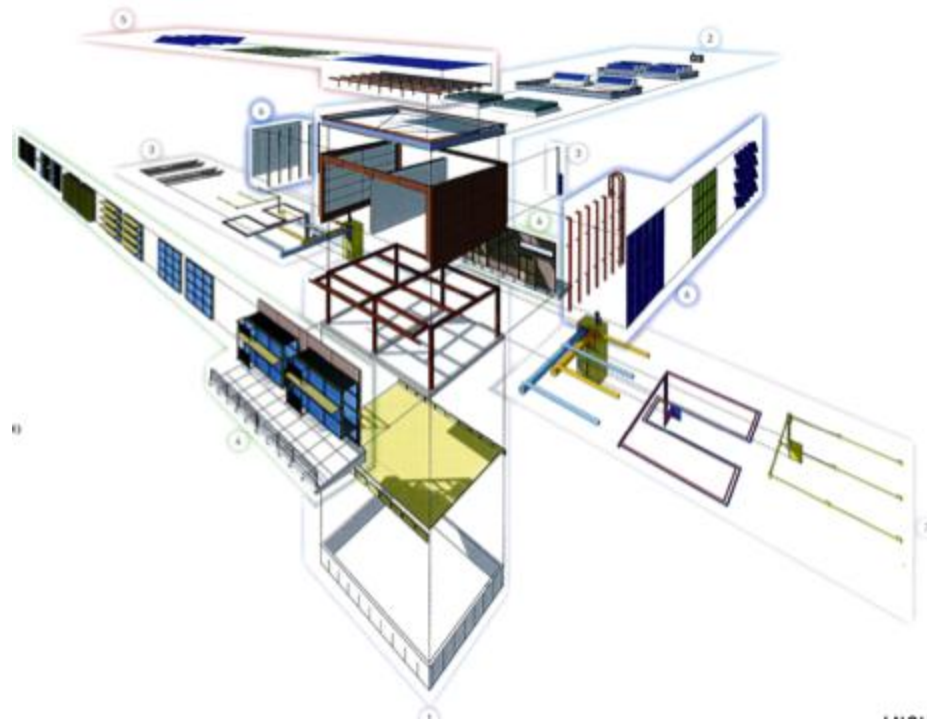
Data Acquisition and Controls

Testbed Sensors, Instrumentation and Controls Hardware

Database

Controls Scripting Tool

Controls Drivers

Simulation Platforms & Scripting Languages (EnergyPlus, Modelica, BCVTB, Radiance, Python, Matlab, Simulink, Labview, JAVA etc.)

Infrastructure
- Central secure database
- Monitoring and Visualization
- Controls Scripting tools
  - HVAC
  - Lighting
  - Shading, etc.
- NI Teststand based
- Onsite or remote access
- Adapter package to allow controls interface with different simulation and controls platforms; I/O mapping via TCP/IP layer

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Features – Lighting and Plug Loads Testbed

- 3000sf occupied workspace
- Occupancy sensors at lighting zone level and workstation/occupant level
- Capable of multiple zones for comparative testing
- Photosensors at individual workstations
- Reprogrammable lighting and plug loads controls
- Individual occupant controls – workstation digital switches reprogrammable to control lights or plugs
- Power measurement at individual outlet level and each light fixture
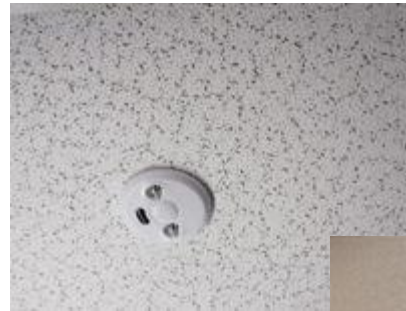
Initial Target Markets

- **Investor Owned Utilities (IOUs)**

- **Design/Build/Operate Community (aka AECO)**

- **Manufacturers of Building Industry Products**

FLEXLAB's key offerings:

- **Real, built environment, testing conditions:** FLEXLAB is unique in the US in its ability to provide side-by-side testing of fully integrated building systems (envelope, lighting, HVAC) in a fully reconfigurable space

- **Unparalleled data collection, interpretation and analysis capability:** The only highly customizable 'built-up' research environment for technology development & validation through real-time, objective, high quality, high accuracy data.

- **Risk reduction in early testing and demonstration:** Unique ability to test strategies or systems, set up and evaluate controlled or user interactions.

- **Unique** early in the product development or design/construction cycle, thus speeding "time to market" and **Insightful Testing Opportunities** reducing risk.

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FLEXLAB Value Propositions to Industry

- Utilities (Emerging Technologies Programs)
  - To provide high accuracy, emerging technology testing capabilities that, when coupled with calibrated simulation models, will allow utilities to prime their pipeline of emerging technology, <u>and reduce demonstration costs</u> by narrowing physical testing scope, <u>increasing test accuracies</u>, and thereby enabling more effective sector impacts analysis.

- Manufacturers and R&D Broadly
  - To provide efficient, <u>flexible integrated building systems and controls</u> testing capabilities enabling aggressive energy saving research and development opportunities.

PHILIPS

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FLEXLAB Value Propositions to Industry

- Architects, Engineers, Contractors and Owners
  - To position and make FLEXLAB available to the design/construction/owner community as a <u>design and prototyping resource that measures and demonstrates performance of innovative building systems</u>. Unlike typical construction mockups, FLEXLAB not only lowers risk in constructability of systems, but also accurately demonstrates and quantifies building performance and provides early opportunities for construction, simulation and controls efficiency improvements, lowering change order generation and increased costs and time for commissioning.

Utilities

Utilities managing EE, ET and DR programs

Will be able to validate <u>emerging technologies</u> by testing and empirically assessing the impact of their proposed new technologies, systems and operational and integrated design strategies. Including:

- Performance of a broad range of commercial building ET assessments without the need to enlist suitable customer host site(s)
- Validation of proposed deemed measures and customized system retrofits
- Empirical confirmation of new construction modeling and simulations in support of design assistance and rebate determinations for programs such as Saving By Design.
- Accelerated testing of select emerging technologies, in cases where discrete performance at lower sun angles is of interest, which can be simulated in the rotational testbed

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Utilities

Utilities managing EE, ET and DR programs

Will be able to validate <u>other program enhancements</u> by testing and empirically assessing the impact of their proposed new technologies, systems and operational and integrated design strategies. Including:

- Confirmation of singular or interactive system enhancements for <u>codes & standards</u> programs
- <u>Performance data for improving Title 24 compliance systems</u>
- System level performance metrics (lighting, HVAC, etc.)
- <u>Auditing, M&V and Cx process</u> and metrics to support outcome-based codes
  - Simplified Acceptance Tests
- Communications and control capabilities and local, micro-grid or grid-enabled load controls strategies
- Offers more <u>building specific and customized training</u> that utilities support through training centers across the country such as the Iowa Energy Center or the Pacific Energy Center.

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First FLEXLAB Ext. Testbed Project – Webcor/Genentech

- Performance based mockup of of 250k sf new construction design
- Optimization of shading, lighting, controls systems, interiors design
- Pre-vetting of O&M needs of systems
- Pre-Cx system review
- Calibrated simulation models to provide higher accuracy performance of built systems
- Provides the results and resources to guarantee performance of design
- Constructability assessment

Testing period May – July 2014

Upcoming FLEXLAB Projects – CA Utility

- High Performance Envelope with Optimized Lighting, Daylighting, and Office Equipment Loads
    - Test and demonstrate systems that provide 20-40% energy savings over T24
    - Focus on 50-65% WWR glazing assemblies, and deep daylighting strategies

- High Performance Building HVAC and Controls
    - Summer, winter and swing season testing of a suite of low energy HVAC strategies
    - Comparison study of systems
    - Focus on load shape reductions, peak reduction, overall energy savings

Testing period starts summer 2014

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External Demand – Project Pipeline

- Industry Partner Sponsored Projects
  - AECO Community
    - 1 project currently in place (Webcor)
    - 2 more in the pipeline
  - Utilities
    - 2 projects with 1 major sponsor (CA Utility)
    - 2 collaborations in discussion, one with CEE (Consortium for Energy Efficiency)
  - Manufacturers
    - 1 project currently in place (Daikin)
    - In discussion with several other manufacturers
  - Federal/State/Local Interests
    - 2 projects currently committed
    - EPIC solicitation – broad strategy to use facility across research interests at CEC
- EAB excited to communicate a broad deployment agenda
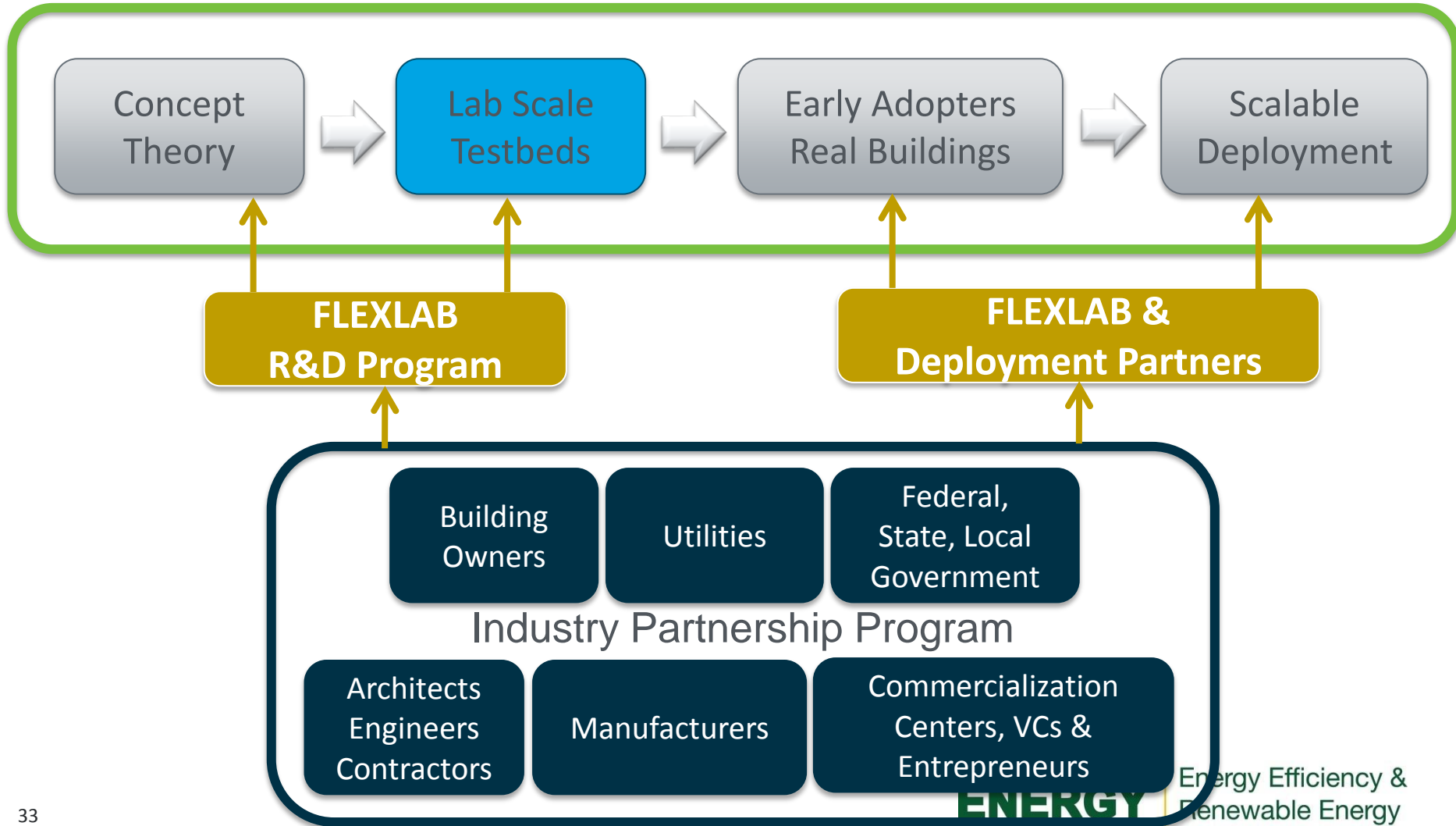- Assessing best deployment strategy

FY14 BTO FLEXLAB Projects

- Commercial Building Integration
  - Lutron wireless/hybrid testing (Occ. Lighting & Plug Loads TB)
  - Core Sensors and Controls (Occ. Lighting & Plug Loads TB)

- Emerging Technology
  - Core Windows (Exterior Testbeds)
  - Building Energy Modeling: Validation, Calibration and Uncertainty – Simulation Model Validation using FLEXLAB (Exterior Testbeds)
  - Transactive Lighting Controls, Volttron application (Occ. Lighting & Plug Loads TB)

- Future BTO work:
  - Small Commercial Controls FOA testing (if moves into next phase)

FLEXLAB RDD&D Deployment Chain

- FLEXLAB provides proof of concept, reduces risk for early adopters
- With partners lined up and technologies demonstrated, FLEXLAB accelerates the deployment curve

Concept Theory → Lab Scale Testbeds → Early Adopters Real Buildings → Scalable Deployment

FLEXLAB R&D Program

FLEXLAB & Deployment Partners

Industry Partnership Program

Building Owners

Utilities

Federal, State, Local Government

Architects Engineers Contractors

Manufacturers

Commercialization Centers, VCs & Entrepreneurs

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Purpose and Objectives

Problem Statement: FLEXLAB addresses key challenges for its target users:

- **Utilities** – Emerging technologies have started to reach their maximum cost-effective potential for specific products. Utilities are looking towards systems level EE as the next opportunity for deep energy savings, but need *high accuracy testing with true comparison studies* to understand baseline system level performance and technology savings potential. Field demonstration programs are costly, with variable thermal and operational performance, making systems level assessments extremely difficult to achieve with confidence.

- **Manufacturers** – Building technologies and controls are being asked to perform in increasingly integrated ways for industry to achieve energy savings, e.g. integrated systems, demand response. Manufacturers lack facilities and expertise to *develop and test integrated solutions across building systems*.

- **AECO** – Per NBI's 2008 study, EUIs of low energy buildings tend to use much more energy than their design predicts. Industry needs *validated tools and technologies to close the gap of predicted to actual performance.*

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