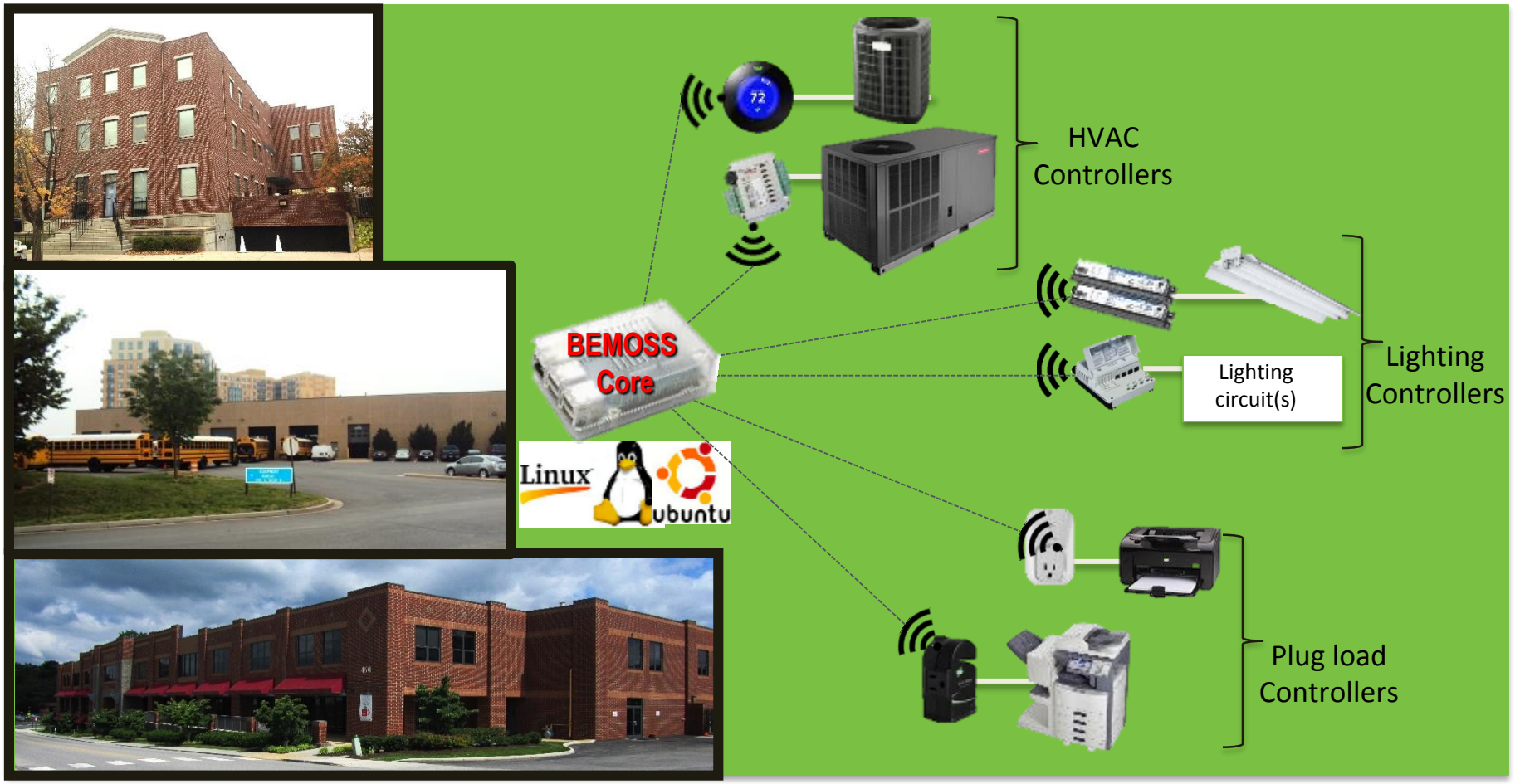
Building Energy Management Open-Source Software (BEMOSS)

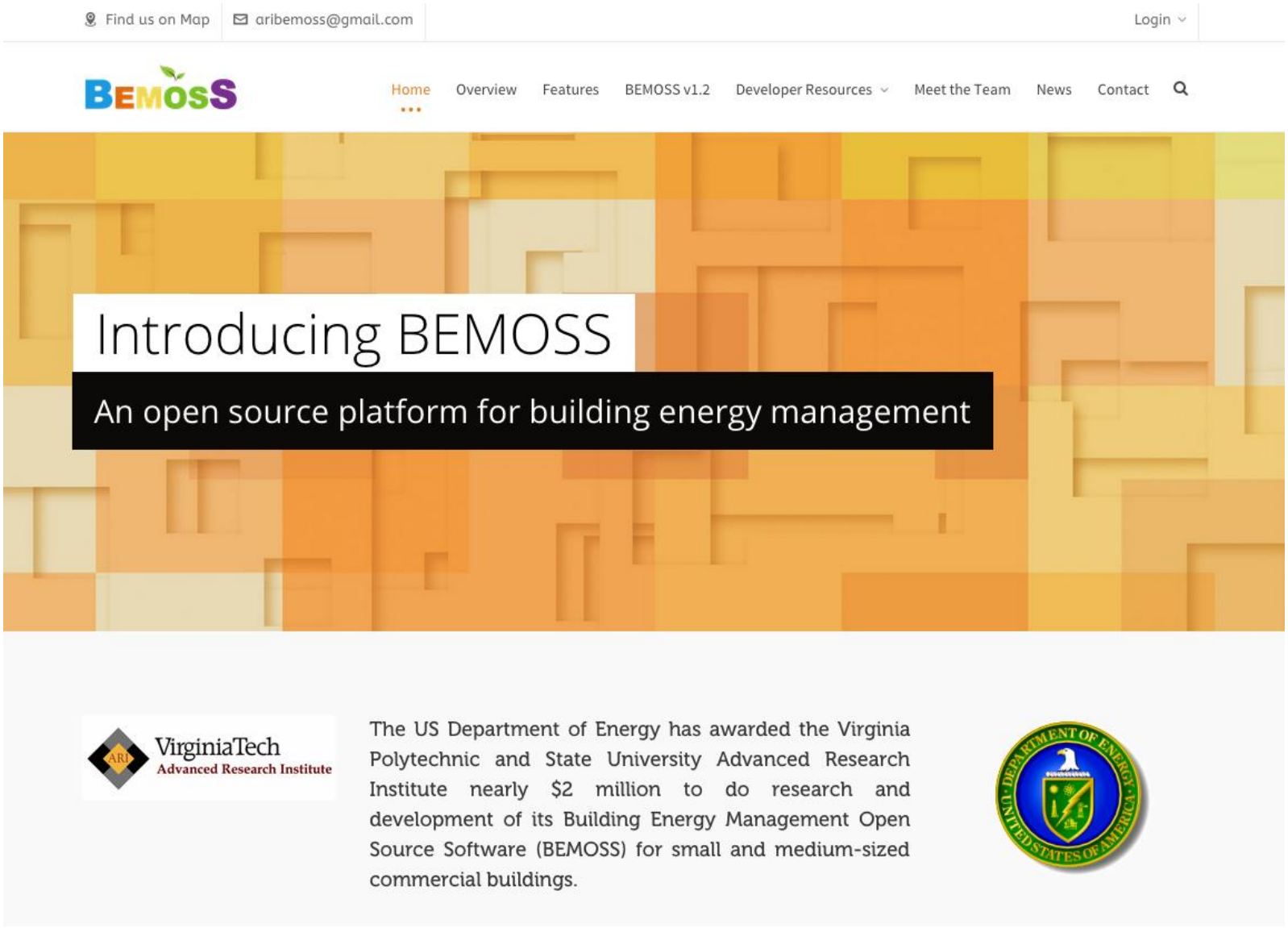
2016 Building Technologies Office Peer Review



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Saifur Rahman (srahman@vt.edu)
Virginia Tech

BEMOSS.org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Introducing BEMOSS
An open source platform for building energy management
VirginiaTech
Advanced Research Institute
The US Department of Energy has awarded the Virginia Polytechnic and State University Advanced Research Institute nearly $2 million to do research and development of its Building Energy Management Open Source Software (BEMOSS) for small and medium-sized commercial buildings.

Project Summary

Timeline:

Start date: November 1, 2013

Planned end date: March 31, 2017

Key Milestones

1. Target release BEMOSS v2.0 on Github – 03/31/2016
2. Target release BEMOSS v3.0 on Github – 03/31/2017

Key Partners:

Arlington County, VA
Danfoss Corporation
Virginia Tech Foundation

Budget:

Total Project $ to Date:

- DOE: $1,206,348
- Cost Share: $69,861

Total Project $:

- DOE: $1,985,795
- Cost Share: $69,884

Project Outcome:

The **Building Energy Management Open Source Software (BEMOSS)** platform, along with the user interface for three plug-and-play compatible controllers –HVAC, lighting and plug loads, that can help small- and medium-sized commercial buildings to improve energy efficiency and facilitate their demand response implementation.

Purpose and Objectives

Problem Statement: Lack of inexpensive open-source building energy management (BEM) software solutions that allow seamless integration with device controllers (HVAC, lighting and plug loads) from various manufacturers.

Target Market and Audience: Small- and medium-sized commercial buildings

Impact of Project:

1. Project endpoint: Make available an open-source and cost-effective solution for building energy management.
2. Project outcomes:
   a. Near-term outcomes (1yr): A few pilot sites demonstrating how BEMOSS can provide energy savings and peak demand reductions in buildings; and participation from software developers to build more App.
   b. Intermediate outcomes: (1-3yr): Growing number of BEMOSS deployment in buildings; and founding of start-up company(ies) which commercializes BEMOSS and provides maintenance services.
   c. Long-term outcomes(3yr+): Widespread use of BEMOSS in small- and medium-sized commercial buildings.

Approach

Approach:

Phase 1: BEMOSS software development (2014)

Phase 2: Lab testing and software enhancement (2015)

Phase 3: Demonstration in buildings (2016)

Key Issues: BEMOSS addresses plug & play and interoperability issues of selected HVAC, lighting and plug load controllers for energy savings and peak demand reduction in small- and medium-sized commercial buildings.

Distinctive Characteristics: Open source software that can provide low-cost deployment of building energy management, allowing energy savings and facilitating demand response implementation.

BEMOSS is Built upon Open-Source Software

VOLTTRON™ was used as a platform to host our BEMOSS solution. It is open-source and not hardware specific.

Linux

ubuntu

Other software used:

python

C++

jQuery
write less, do more.

JavaScript

PostgreSQL

django

Bootstrap

ZeroMQ

Cassandra

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BEMOSS Interoperability

Communication Technologies

- ❑ Ethernet (IEEE 802.3)
- ❑ Serial Interface (RS-485)
- ❑ ZigBee (IEEE 802.15.4)
- ❑ WiFi (IEEE 802.11)

Data Exchange Protocols

- ❑ BACnet (IP and MS/TP)
- ❑ Modbus (RTU and TCP)
- ❑ Web (e.g., XML, JSON, RSS/Atom)
- ❑ ZigBee API
- ❑ Smart Energy (SE)
- ❑ OpenADR (Open Automated Demand Response)

BEMOSS Plug & Play

With BEMOSS discovery agent, we know:

- The device is present in the building.
- Device model number, e.g., 3M-50.
- What the device can do, e.g., monitor temperature and adjust set point.

BEMOSS automatically discovers new load controllers deployed in a building

BEMOSS on Various Embedded Devices

Cubieboard

CPU: Arm Cortex A15x4 @2GHz, A7x4 @1.3GHz
RAM: 2 GB
Price: $138
Size: 5.8”x5.6”

ODROID Hardkernel

XU4

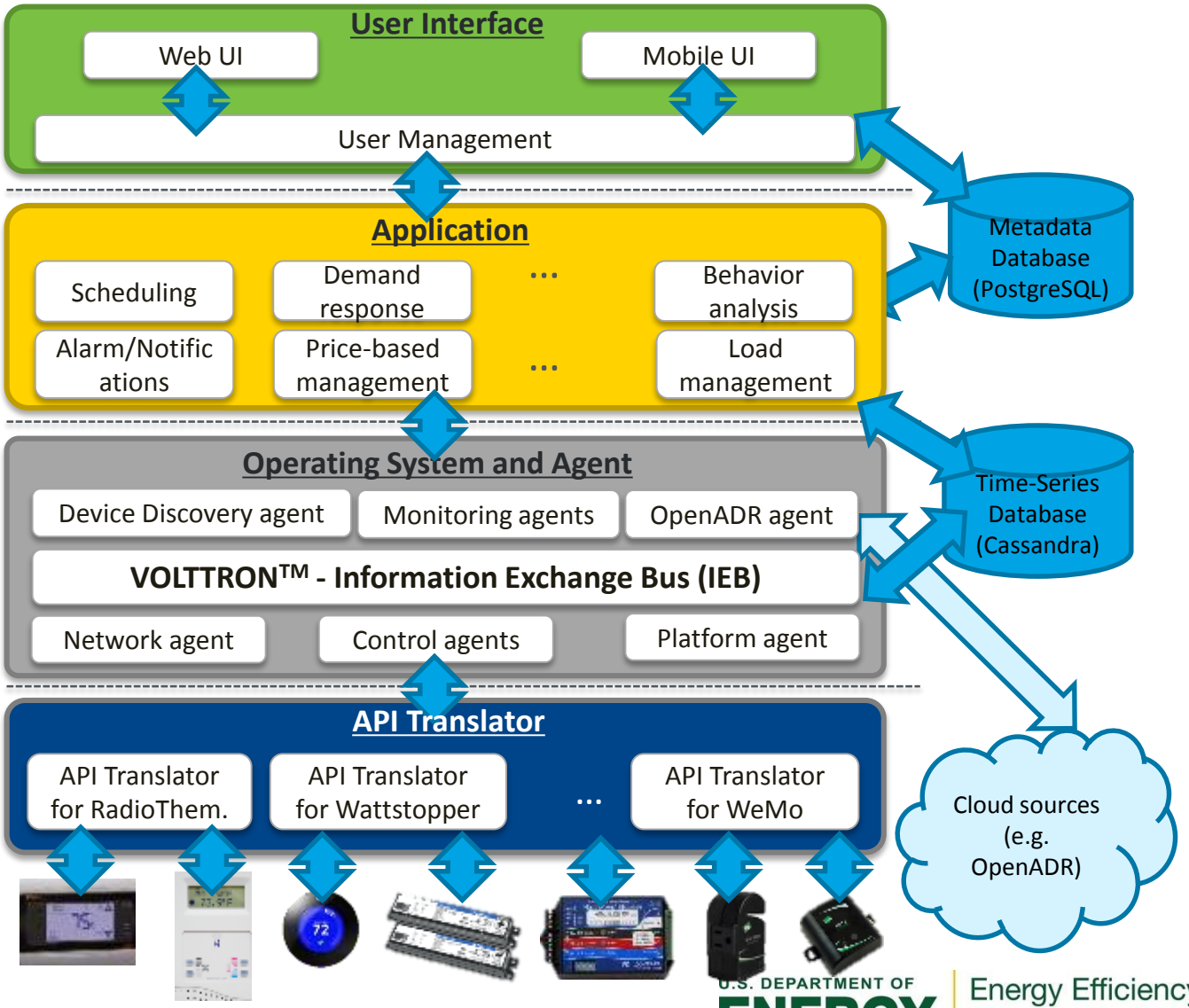
CPU: Arm Cortex A15x4 @2GHz, A7x4 @1.4GHz
RAM: 2 GB
Price: $74
Size: 3.3”x2.3”

WANDBOARD.ORG

CPU: Arm Cortex A9 Quad core @ 1 GHz
RAM: 1 GB
Price: $129
Size: 3.4”x2.4”

This enables low-cost deployment, and expandability.

BEMOSS Software Architecture



Living Laboratory – Building 1

1021 Prince St.,
Alexandria, VA 22314

Area: 25,000 SF
Energy: 14-25 MWh/mo.
Peak load: 61 kW

Living Laboratory Setup

- Thermostats (WiFi)
- Plug load controllers (WiFi)
- Motion sensor (WiFi)
- Environment sensor (WiFi)
- Power meter (Modbus)





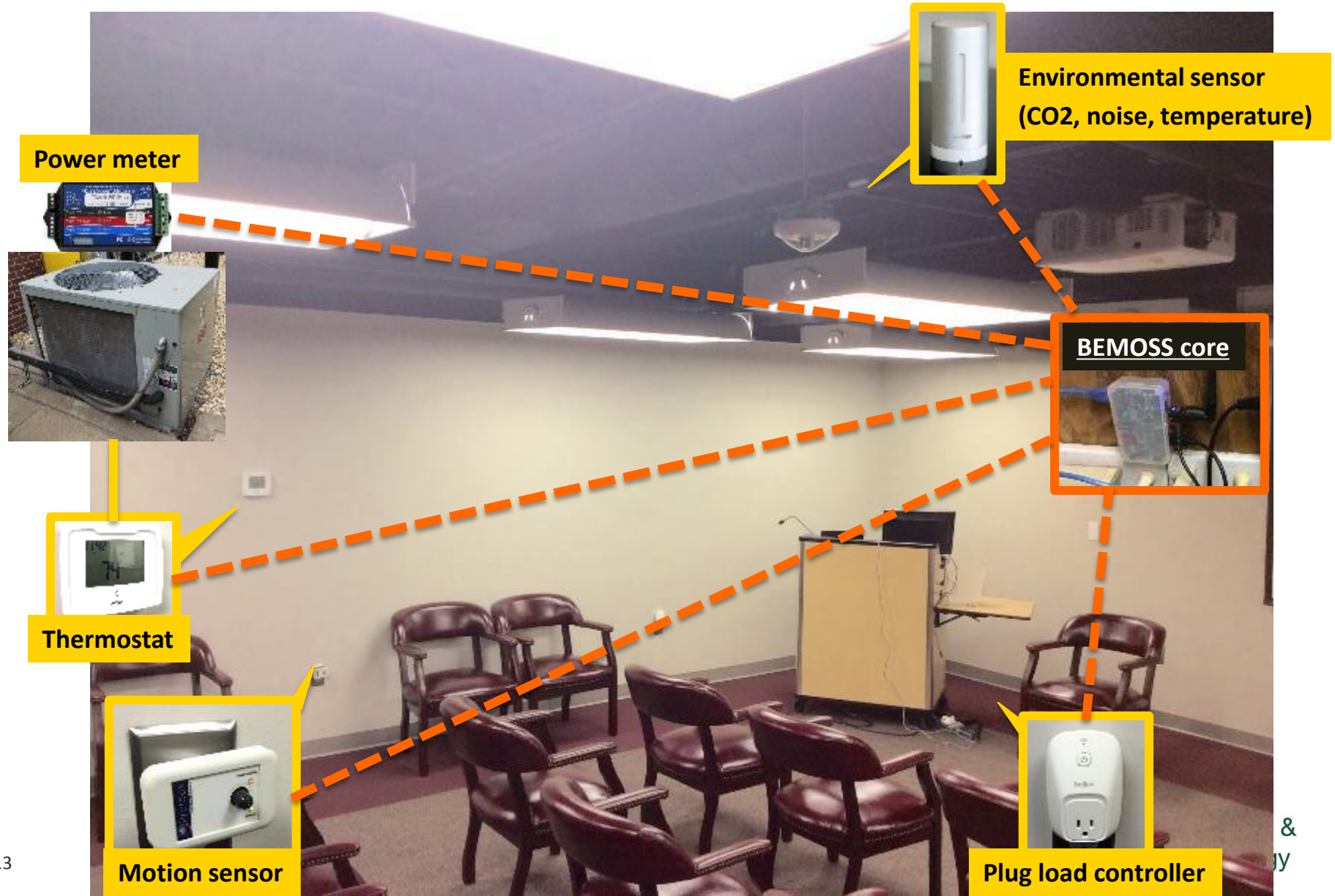
Floor 3 – Classroom

- 1 thermostat
- 3 plug load controllers
- 1 motion sensor
- 1 environment sensor (CO_2, temp, humidity)
- 1 power meter
- BEMOSS core
- BEMOSS node

Floor 2

- 5 thermostats
- 5 power meters

Classroom being Monitored by BEMOSS Core



Building 2 – Equipment Bureau in Arlington, VA

2701 S Taylor St,
Arlington, VA 22206

Office building size: 5,000 sqft
Electricity consumption: N/A

Building 3 – Retails and Offices in Blacksburg, VA

460 Turner St
Blacksburg, VA 24060

Office building size: 41,301 sqft
Electricity consumption: 49,800-65,200kWh/month

Progress and Accomplishments

Accomplishments:
Target date for BEMOSS v2.0 release in Github: 3/31/2016

Market Impact:
Energy savings and peak demand reduction from adjusting thermostat set points, light intensity and status of plug loads.

Lessons Learned:
API of devices can change overtime. A possible mitigation approach is to sign a contract with device manufacturers to make the developer aware of any API changes before their release.

Project Integration and Collaboration

Project Integration:

- The BEMOSS advisory committee with representatives from 22 organizations from government and Industry has been established. The advisory committee members meet face-to-face on a quarterly basis with additional email exchanges based on work at hand.

Project Integration and Collaboration (Cont'd)

Partners, Subcontractors, and Collaborators:

Partner	Role
Arlington County	Offers access to Long Branch Nature Center for energy consumption data
Danfoss Corp.	Supports in modeling the performance of HVAC units under different operating conditions
VT Foundation	Offers access to buildings in Alexandria and Blacksburg, VA for BEMOSS demonstration

Communications:

- ❑ "BEMOSS: An agent platform to facilitate grid-interactive building operation with IoT devices" presented at ISGT Asia 2015, Nov 2015, Bangkok, Thailand.
- ❑ Invited talk at Arlington Public Library, Arlington, VA, sponsored by the joint Northern Virginia/Washington PES Chapter, in collaboration with the Industrial Applications and Control System Society Chapters in Northern Virginia and Washington, 24 June 2015, Arlington, VA.
- ❑ Invited Talk at Syracuse University, Co-organized by Dept. of EECS, Syracuse University & AP/MTT/EMC Chapter of the IEEE Syracuse Section Syracuse, NY, 19 June 2015, Syracuse, NY.
- ❑ "BEMOSS: An Agent Platform to Enable Grid-Interactive Building Operation with IoT Devices", presentation at the Workshop on Big Data Analytics in CPS: Enabling the Move from IoT to Real-Time Control, 6 April 2015, Seattle, WA.

Next Steps and Future Plans

Next Steps and Future Plans:

- ❑ BEMOSS deployment in three small and medium-sized buildings
- ❑ Functionality test and operational availability evaluation
- ❑ Estimation of electricity savings potential
- ❑ Transition of BEMOSS to v3.0
- ❑ Delivery of BEMOSS software tool v3.0 in Github

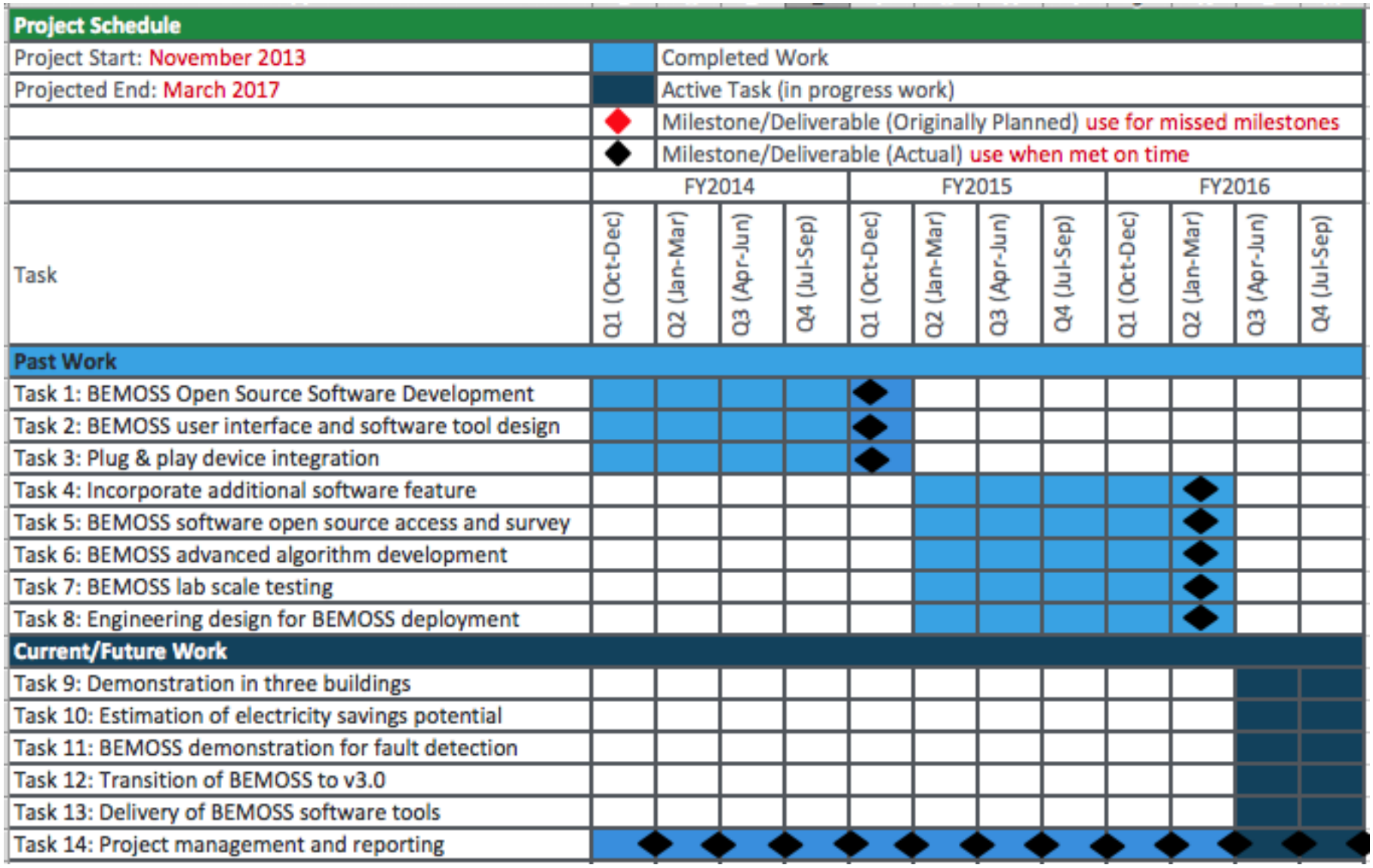
REFERENCE SLIDES

Project Budget

Project Budget: DOE: $1,985,795 VT: $69,884
Variances: N/A
Cost to Date: DOE: $1,206,348 VT: $69,861
Additional Funding: N/A

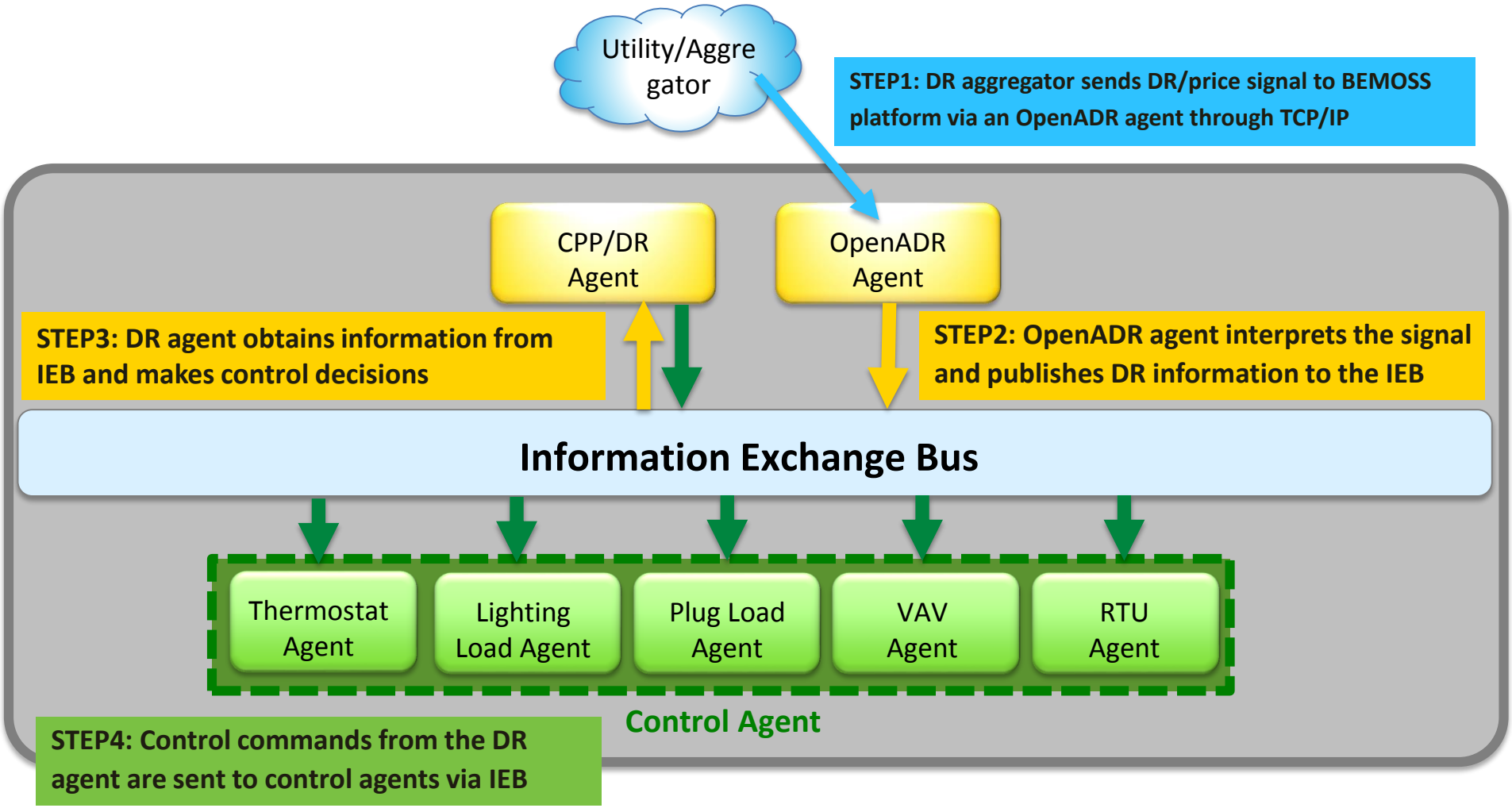
Budget History					
Budget Year 2 January 2015 – January 2016 (past)		Budget Year 3 March 2016 – March 2017 (current)		Future (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$706,403	$0	$779,448	$23	$0	$0

Project Plan and Schedule



BEMOSS accepts OpenADR signals (CPP or DR)

- BEMOSS can accept simulated OpenADR signals and take actions.



BEMOSS Security

BEMOSS utilizes built-in security features provided by VOLTTRON™, and provides enhanced security features.

Device Security	Platform Security	UI Security
◆ Rely on existing device security, e.g., SSL, TLS (if available) ◆ Add additional protection: ➢ Tampering checking ➢ Abnormal control behavior checking ➢ Device approval process	◆ Rely on VOLTTRON security: ➢ Agent validation ➢ Agent packaging ➢ Resource management ◆ Add additional protection: ➢ BEMOSS core authorization ➢ BEMOSS node authorization	◆ Role-based access control ◆ Password protected with SHA256 encryption ◆ User input validation ◆ Error handling