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

DOE/BTO Summary Wrap-Up

Technical Meeting on the Software Framework for Transactive Energy: VOLTTRON

Hosted by the Virginia Tech Advanced Research Institute 900 Glebe Rd., Arlington, VA

July 23-24, 2015

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Meeting Objectives/Background

- DOE/BTO held the meetings to:
  - Discuss current and future applications that utilize the VOLTTRON platform to demonstrate transactive energy principles in buildings
  - Outline use cases of the technology
  - Showcase several building/grid applications, such as building energy efficiency, EV charging, and integration of renewables
- And seek answers to three key questions:
  - Being Inclusive: Who else should be involved with DOE? Who else should be here? Who else is attacking this opportunity?
  - Being Responsive: What else is out there like VOLTTRON or is a companion to it that we should discuss? Who is using VOLTTRON now, in whole or in part, or applications upon which it is built?
  - Being Capable: What capabilities would you like to see VOLTTRON have to increase its value to you? What's missing and why is it important?

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Meeting Agenda – July 23 (Day 1)

- EERE And Grid Integration: Role Of Transaction-based Controls
  - Purpose, Context & Motivation for Transaction-Based Reference Platform (DOE, PNNL)
- Transaction-based Controls: VOLTTRON Open Source Solution
  - Overview of Development from 1.0 to 3.0 (PNNL)
  - Technical Overview and Features (PNNL)
  - Scalability Testing (ORNL)
  - Platform Security and Hardening (PNNL)
- Real-world Deployment Of Applications And Lessons Learned
  - BEMOSS Open Source Controls for Small Buildings (VA Tech)
  - EE and Grid Services for Small & Medium-Sized Commercial Buildings (Transformative Wave)
  - VOLTTRON™ Transactional Node (QualityLogic)
  - Unified HVAC and Refrigeration Control for Small Supermarkets (ORNL)
  - Automatic Fault Detection and Diagnostics for Air-Handling Units (Drexel)

Meeting Agenda – July 24 (Day 2)

- Follow-up from 2014 Meeting (We Heard You)
  - Changes Made in Response to 2014 Meeting at Case Western and suggestions/ideas for community development & future development (PNNL)
- Using VOLTTRON 3.0
  - Primer: How to use the new features in Version 3.0 (PNNL)
- The Low-Hanging Fruit: Opportunities for Applications
  - Enabling Vehicle-to-Building Integration (PNNL)
  - Transaction-Based Operation of Resource Constrained Systems (LBNL)
  - Energy Efficiency and Grid Services for C-Stores and Supermarkets (Emerson Climate Technologies)
  - Massachusetts Innovation Challenge using VOLTTRON (MA Clean Energy Center)
- Tours Both Days of VA Tech BEMOSS lab
  - Load controllers -- monitor, control, user interface, and security

Meeting Participants

Industry

- Alstom
- Bosch
- Carrier-UTC
- EA Dynamics
- Emerson
- Intellimation
- Johnson Controls
- PacStar
- QualityLogic
- Transformative Wave Technologies
- UTRC
- Upper Bay

Trade Associations

- AHRI
- EPRI
- National Association of Realtors
- NEMA
- NRECA

Labs & Universities

- Case Western Reserve Univ.
- Consortium for Building Energy Innovation
- Drexel Univ.
- Iowa State
- LBNL
- Navigant
- NREL
- ORNL
- PNNL
- Virginia Tech

NGOs and Gov't

- ACEEE
- BPA
- CEE
- DOE
  - ARPA-E
  - Office of Electricity
  - Solar
- Massachusetts Clean Energy Center
- NRDC

Webinar Participants

Industry

- Amzur Technologies
- EA Dynamics
- Emerson
- ICM Controls
- Power Hub Systems
- Watt Stopper

Labs & Universities

- BNL
- Case Western
- Drexel
- NREL
- PNNL
- Purdue
- Washington State University

NGOs and Gov't

- DOE Office of Electricity

Key Meeting Takeaways – Programmatic (1 of 2)

- Develop white paper on other related systems
  - Are they complementary?
  - Are we coordinated?
  - Provide information to help make the case for VOLTTRON for EVs
- Facilitate and Increase Coordination and Collaboration
  - Separate Technical Development Meeting from Policy/Application Meeting
  - Share information on feature development to enhance collaboration
  - Increase utility involvement
  - Closely coordinate with Duke Energy OpenFMB
  - Increase industry engagement with end-user
    - E.g., International Center for Shopping Centers
  - Create a virtual testbed for VOLTTRON
    - Need simulated devices from community

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Key Meeting Takeaways – Programmatic (2 of 2)

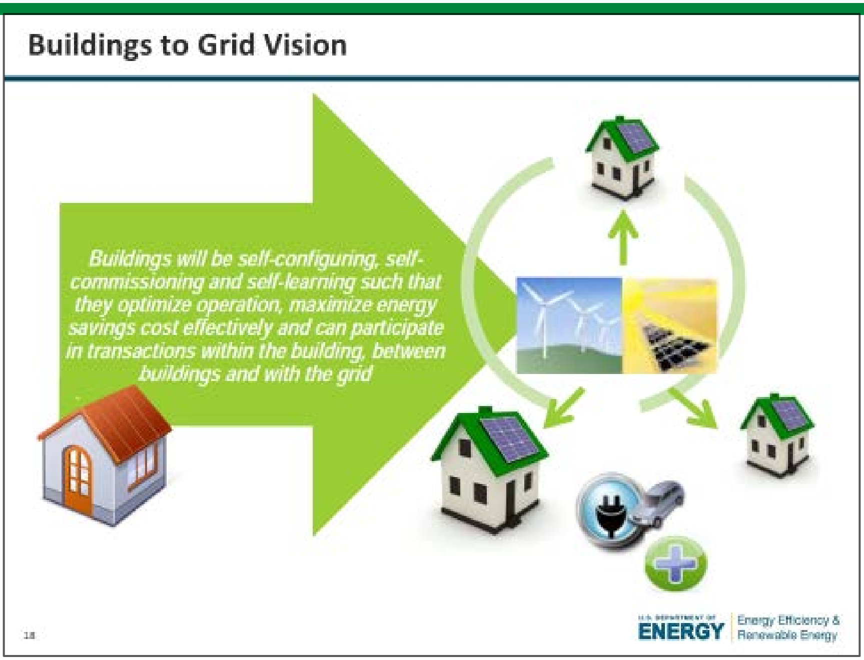
- Manage and support Certification, Customization, and Future Releases
  - Develop a test method or tool for self certification
  - Have third party certify that an implementation meets the standards
  - Support customization of User Interfaces for VOLLTRON
  - Single official organization or entity should release VOLTTRON
- Provide guidance on how to deploy VOLTTRON under different scenarios
  - Buildings, Campuses, and Individual Systems
- Develop a meta-analysis of lessons learned from state and other organizations policies and programs to
  - Reduce peak, increase DR, increase efficiency and DR
- Adjust FY16 Based on priorities from workshop

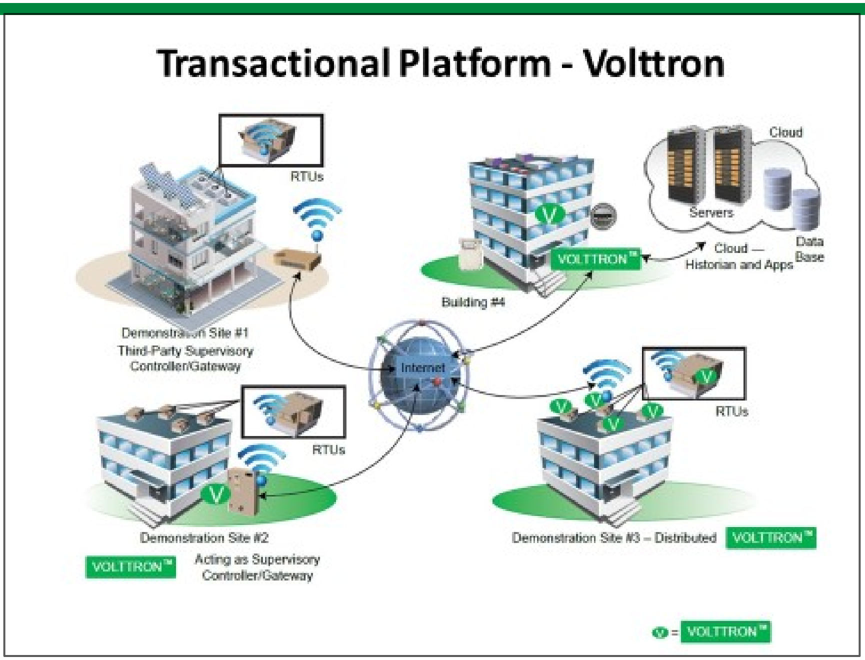
Key Meeting Takeaways – Technical

- Add more debugging tools
  - Easy traceability of agent activities
  - Correlating logs and back tracing
- Don't Introduce complexity
  - Keep it simple and easy to learn
  - Easy to become familiar with and implement quickly
- Develop "VOLTTRON Light" for IoT devices
  - Stand-alone device that can participate in the platform
- Create a standard process for auto mapping and consistent naming of devices
- Hold a VOLTTRON Hackathon (Short-term development)
- Increase "White Hat" testing of VOLTTRON security
- Add an agent developer mode to reduce time for development cycle

Presentations at the Meeting

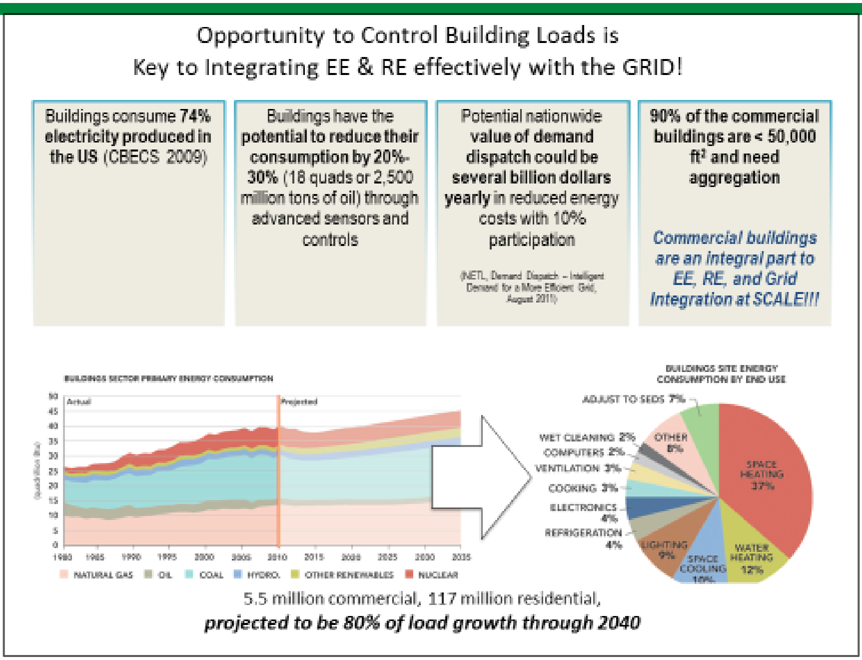
Vision for Buildings to Grid Interoperability (Risser, BTO)

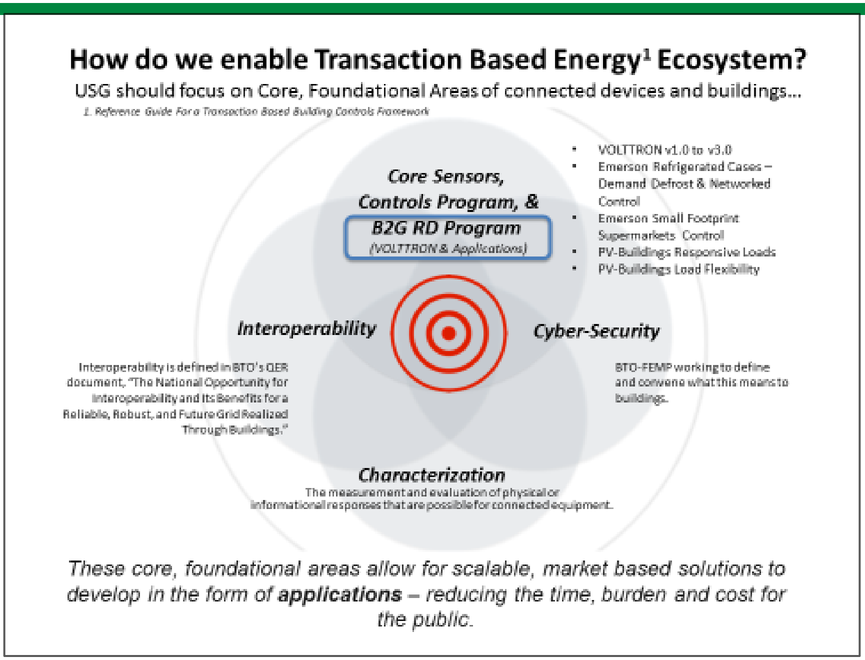




- Vision
  - Buildings operating at optimum energy efficiency over lifetime, interoperating effectively with the grid.
  - Buildings that are self-configuring, self-commissioning, self-learning, self-diagnosing, self-healing, and self-transacting to enable continuous optimal performance.
  - Lower overall building operating costs and higher asset valuation.
- Interoperability
  - Interoperability is supported by a Transactional Network Platform
  - DOE's "connected controls" investments use an open source solution
  - VOLTTRON is an innovative distributed control and sensing software platform

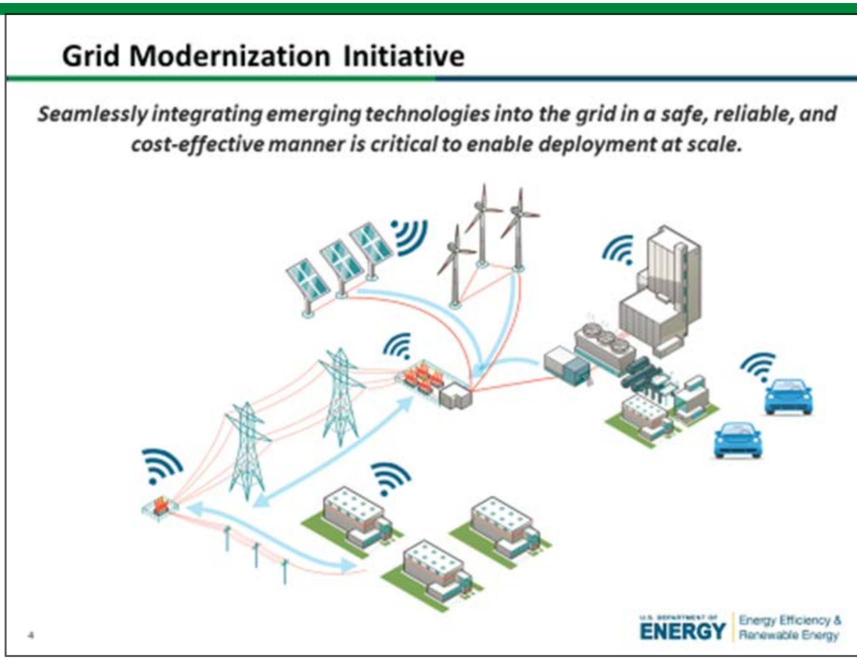
EERE & Buildings to Grid Integration (Hagerman, BTO)

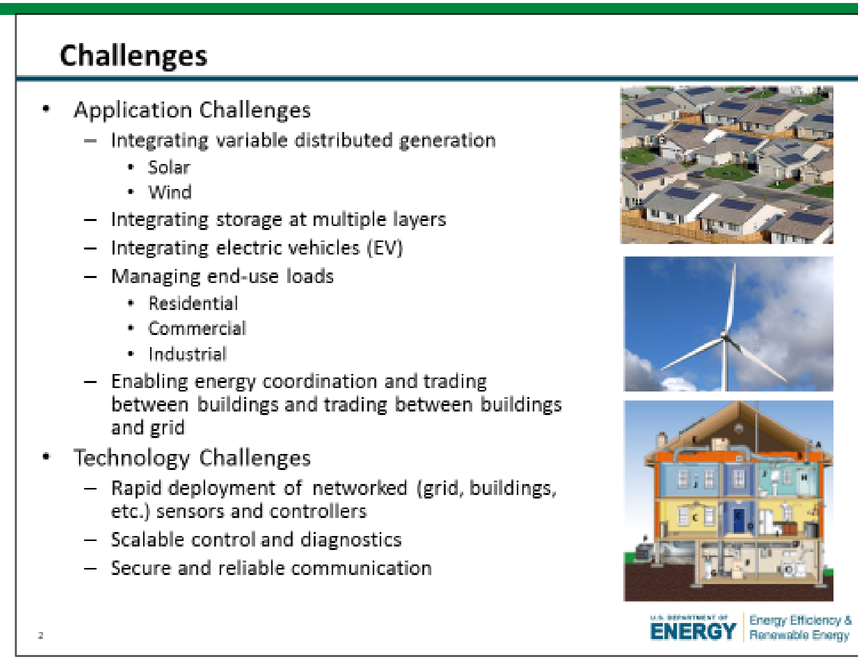




- Potential nationwide value of demand dispatch could be several billion dollars yearly in reduced energy costs with 10% participation
- Buildings have a large role in helping to enhance grid reliability and enabling the rapid integration of Renewable Energy and Storage.
- BUT, Buildings today are limited by existing controls systems that can't easily transact at the speed or scale that is required by the grid
  - High cost to "get it right" with existing technology and economics
  - Currently only implemented in large buildings
  - Components are emerging with greater capabilities of control
- Building solutions must "think across the meter"

Motivation for the Transaction-Based Reference Platform (Hernandez, PNNL)





- Buildings need to be smarter to participate in transactions within the building, with other buildings, and with grid entities.
- Sensors and controls at the whole building level and at the component level are fundamental to optimize DER and the grid.
- The transactional network enables energy saving retrofit solutions and the networked systems to transact with all grid connected devices (e.g. EV, storage) and with the grid to help mitigate DER related disturbances.

VOLTTRON 1.0 to 3.0 History (Haack, PNNL)

VOLTTRON Attributes

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- Provides a single point of contact between applications, devices, and external resources
  - Isolates applications from the details of devices being controlled
  - Additional resources can easily be added and utilized through the message bus without requiring changes to existing resources/agents
  - Applications can specify data of interest
  - Applications can publish their own events/data for use by other agents or for storage
- Device communication
  - Drivers for communicating with Modbus and BACnet enabled devices
  - Custom communication schemes can be supported
- Platform Features
  - Scheduler – Handles locking control of devices (reading does not require a lock)
    - Application reserves a timeslot
  - Ease of application development
  - Collection of utilities and base applications to simplify development
  - Goal is to allow researchers to focus on implementing their algorithm, not dealing with the specifics of the platform
  - Data archiver – devices readings and application results stored to a historian

Proposed VOLTTRON 4.0

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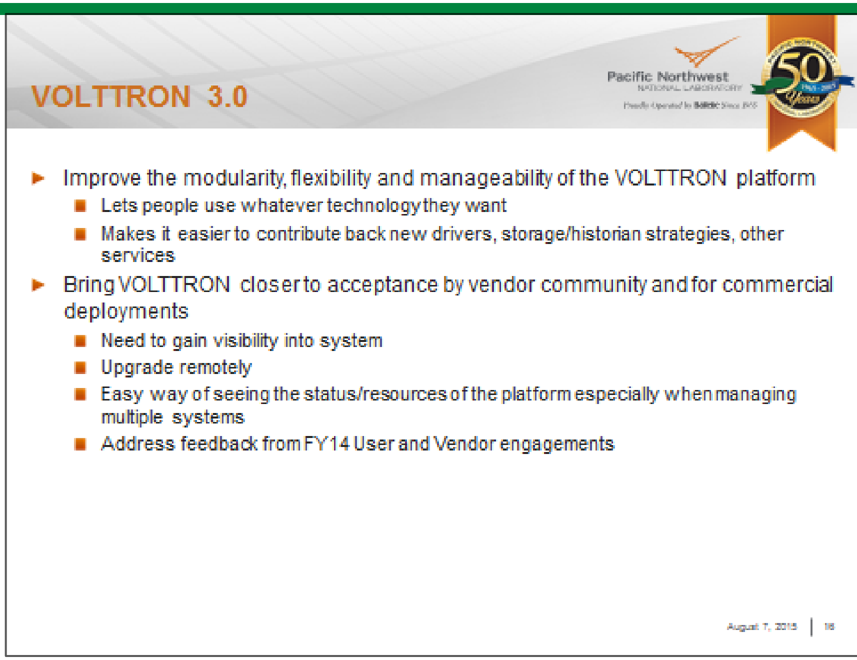
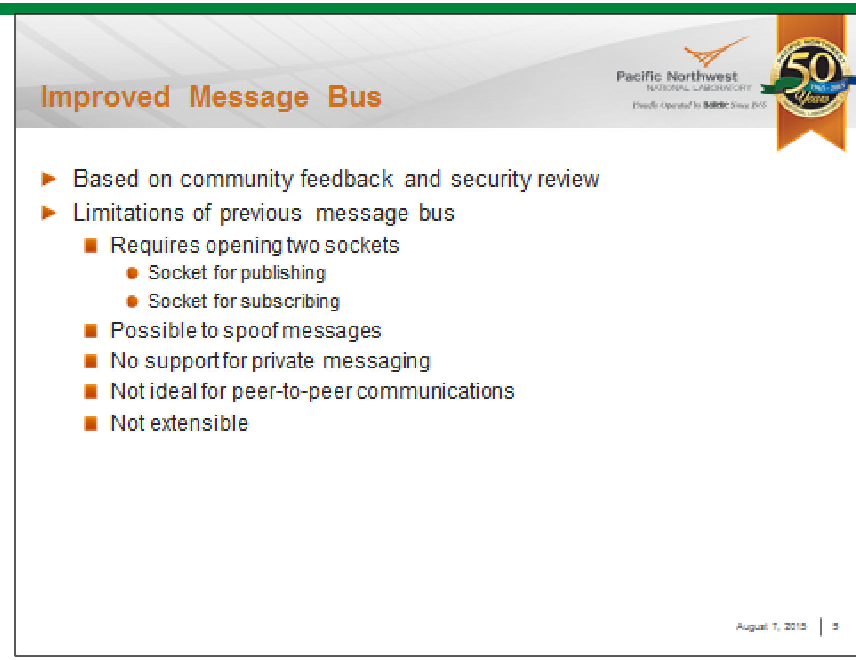
- Exploiting existing capabilities for more complex demonstrations
  - Distributed Multi-Agent Energy Efficiency application
- VOLTTRON Management Central enhancement
  - Closer integration with VOLTTRON Central Analytics
  - Real-time analytics
- Continue to enhance VOLTTRON security
- Utilize VOLTTRON as a way to increase security of underlying platform
  - Cybersecurity agent application
- Community priorities
  - Common capability needs expressed by community
- VOLTTRON Hackathon
  - Activity to spur outside use of VOLTTRON for new applications

- VOLTTRON History Overview
  - PNNL internally developed initial version to address secure and reliable platform for deploying intelligent applications at the edge
  - Open source reimplementation for BTO Transactional Network project integrating applications, devices and remote resources
  - Continued development to meet needs of community
- Priorities
  - Maintain “easy to get started” quality while increasing security and manageability

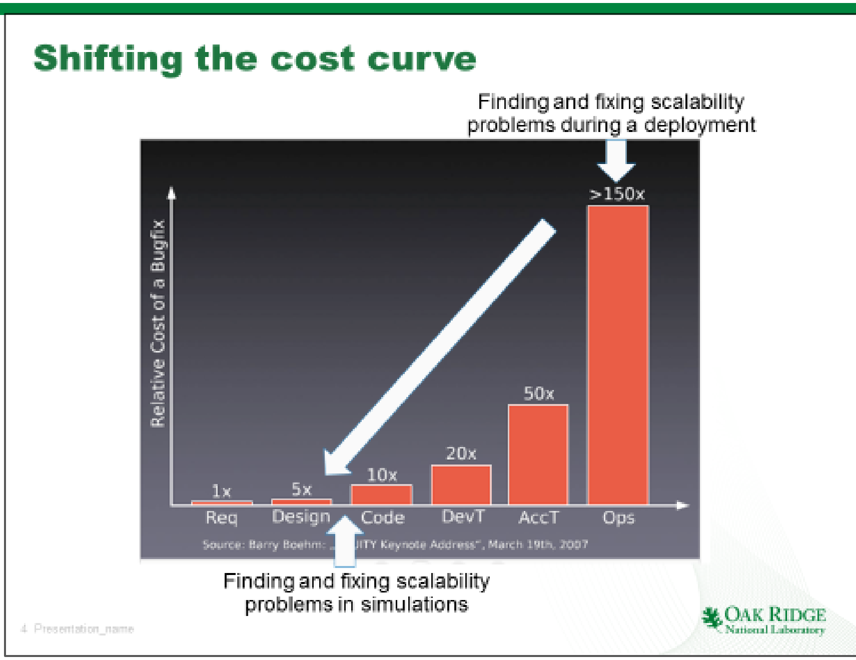
VOLTTRON™ 3.0 Technical Overview and Features (Carpenter, PNNL)

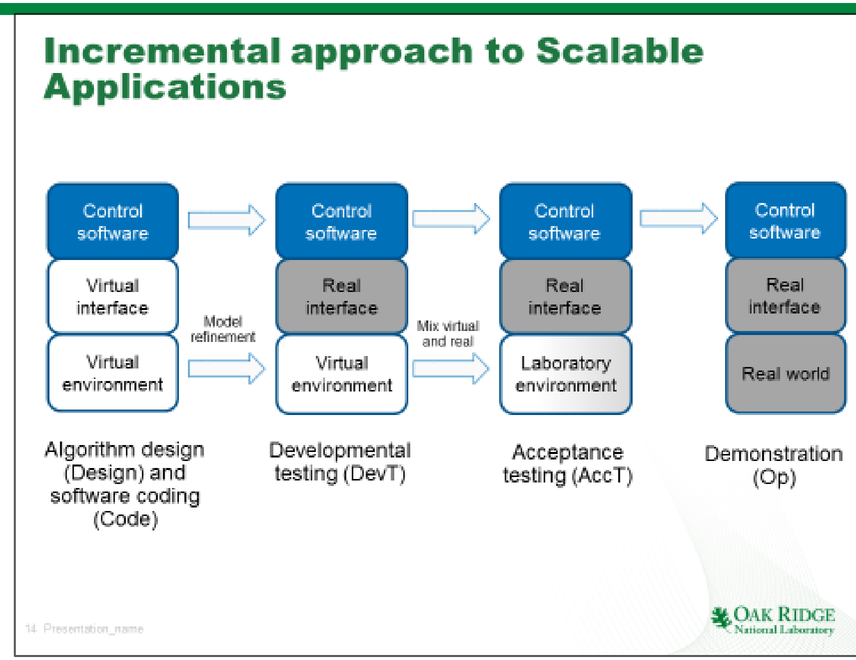




- Address community feedback
  - Improve security of message bus
  - Peer-to-peer option for large transfers
  - Improved manageability and visibility of system
  - Increase flexibility of device drivers and data storage
- Needs
  - Improved debugging capability
  - Simulation and self-certification framework

Scalability Analysis of VOLTTRON Platform (Kuruganti, ORNL)





- **Motivation**: Field trials at a large scale are prohibitively expensive
  - No way to test for scalability prior to a large scale deployment
  - This drives up costs by finding and fixing problems after, rather than before, a large deployment
- **Objective**: Develop a simulation-based deployment environment for testing VOLTTRON applications at scales that cannot be cost-effectively realized in a field or laboratory setting
- **Outcome**: A virtual deployment laboratory for testing and refining scalability of VOLTTRON-based applications

VOLTTRON™: Security Features and Discussion (Carpenter & Akyol, PNNL)

VOLTTRON Security Goals (including 3.0 release)

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- Protecting the integrity of agent programming through cryptographic means
- Protecting agents from using excessive system resources to ensure platform stability
- Protecting agent configuration (and work orders) from manipulation
- Securing communications between VOLTTRON platforms and external data sources
- Securing communications between platform instances, including the transfer of agents
- Securing communications between agents running on the same VOLTTRON platform

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Platform Hardening must be comprehensive to be successful

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- Hardening includes:
  - Physical security. Limit who has access to the device. Locked room, locked cabinet with no physical access is preferred. Enable chassis intrusion detection and reporting if possible.
  - Low-level device security. Password protect the BIOS. Ensure periodic updates to keep the BIOS secure. Disable devices that are not needed via the BIOS.
  - Boot security. Restrict boot devices. Disable auto-booting of external devices. Secure the boot loader. Require a password to boot anything other than default kernel.
  - For critical applications, use of a FIPS certified cryptographic module is highly recommended to secure private key material.

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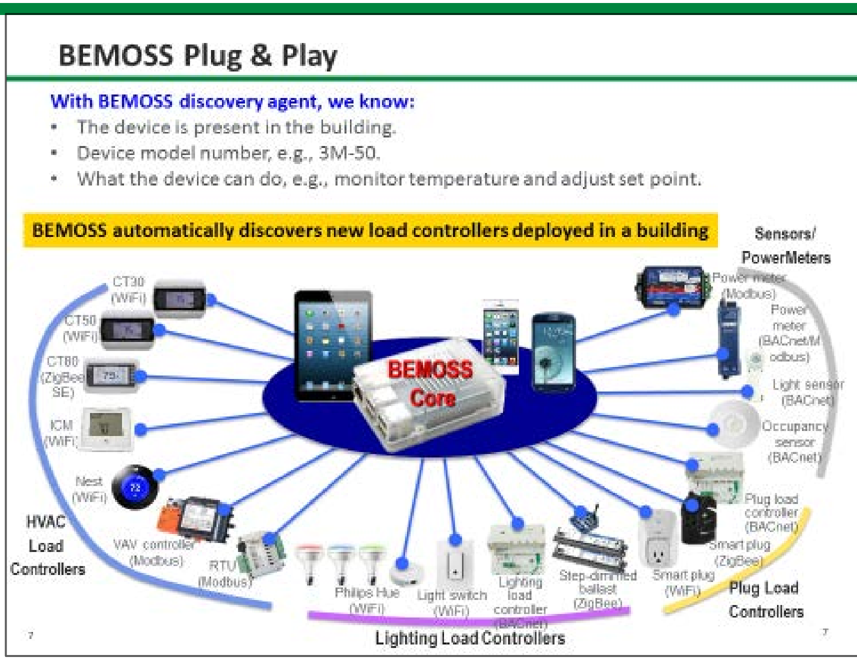
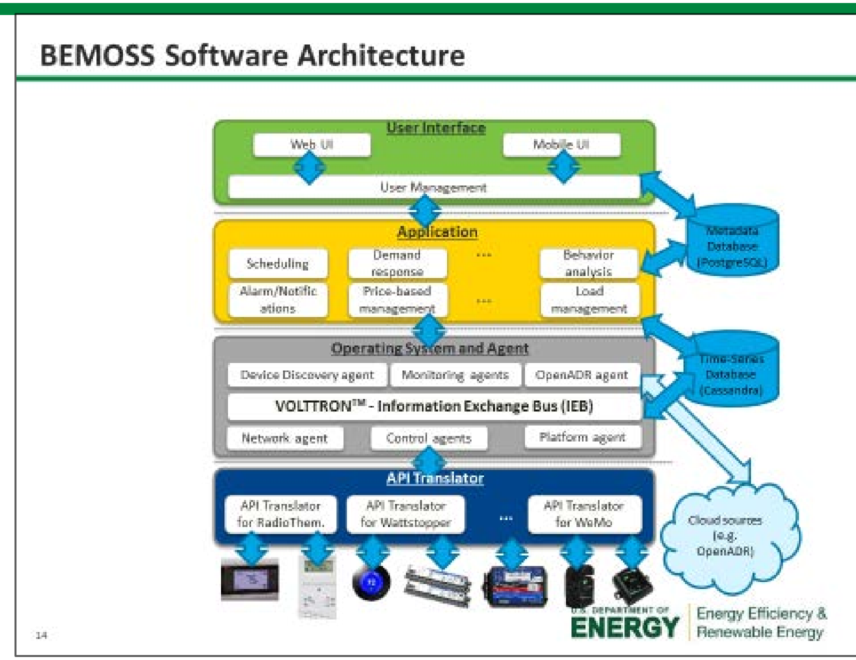
- Securing the Platform
  - Discussion of security white paper which details threats and mitigations to the platform and underlying resources
  - Security focus in 2.0 and previous was protecting the platform from the outside world
  - Security focus in 3.0 on protecting the interior of the platform.
- Securing the deployment environment
  - Recommendations for securing the underlying hardware and networking resources

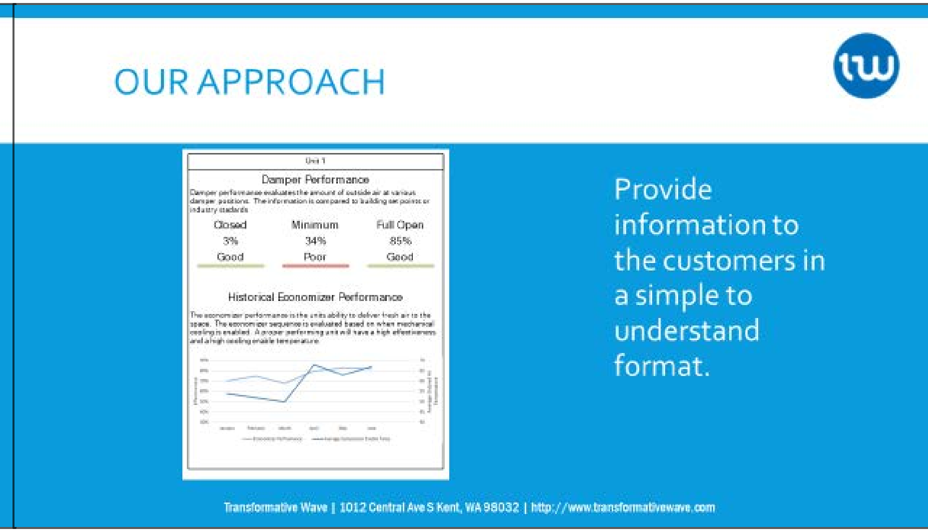
Building Energy Management Open-Source Software (BEMOSS) (Rahman, Virginia Tech)





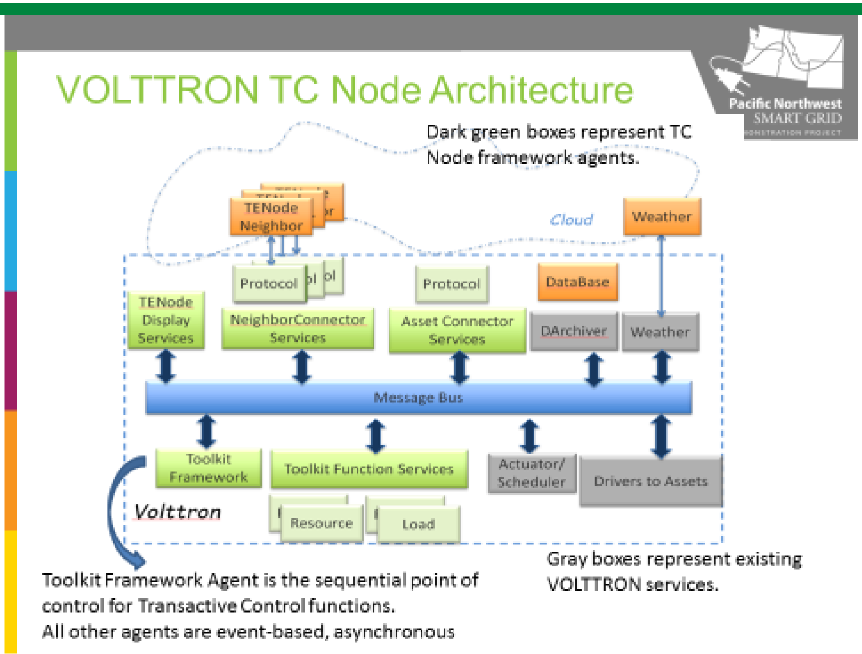
- BEMOSS is a solution engineered to improve sensing and control of equipment in small- and medium-sized commercial buildings.
- BEMOSS monitors and controls 3 major loads in buildings: HVAC, Lighting, Plug loads
- BEMOSS improves energy efficiency and facilitates DR implementation in buildings.

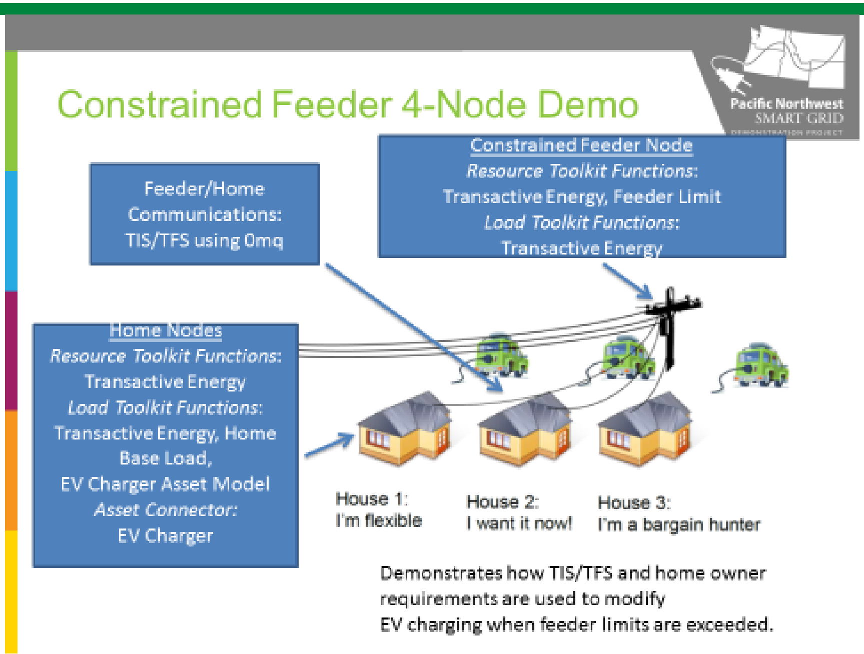
Energy Efficiency, Demand Response, and Volttron (Sipe, Transformative Wave)



- Wants and Needs
  - Utilities need more capacity to handle grid growth & balance load on grid for stability
  - Businesses want to lower operating expenses and want remote control over their facilities
- VOLTTRON Helps
  - Can operate on low cost platforms, in Cloud
  - Moves intelligence from site level controller to zone level controller
  - Open Source, Flexible, Versatile
- Can operate both EE and DR on the same platform

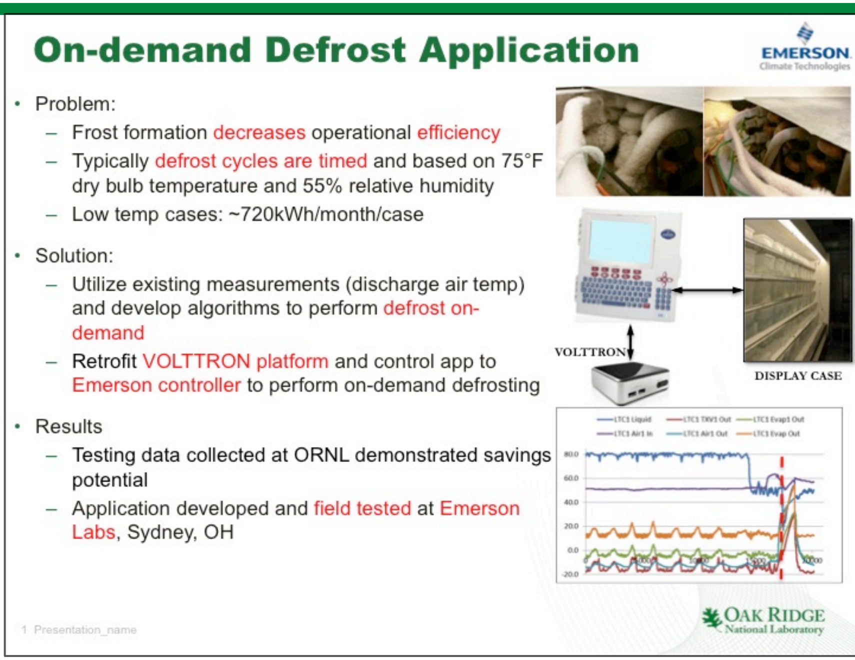
VOLTTRON Transactive Control Node: Case Study (Rankin, QualityLogic)

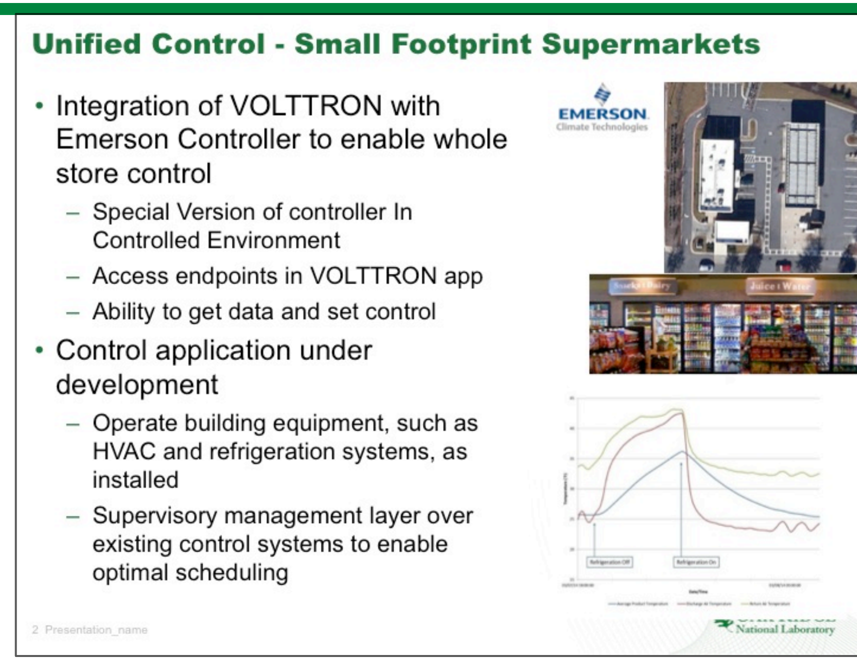




- TC Node: An implementation of Transactive Energy that uses exchange of incentive/feedback schedules, along with local information to make decisions about controlling local assets.
- VOLTTRON: Integration platform for devices (RTUs, HVACs), with external resources, services and applications.
- Pacific NW Smart Grid Demo Project: A unique distributed control and communication system with localized power generation/load decisions that addresses
  - Integrating renewable energy
  - Improving reliability
  - Cost reduction
  - Empowering consumers

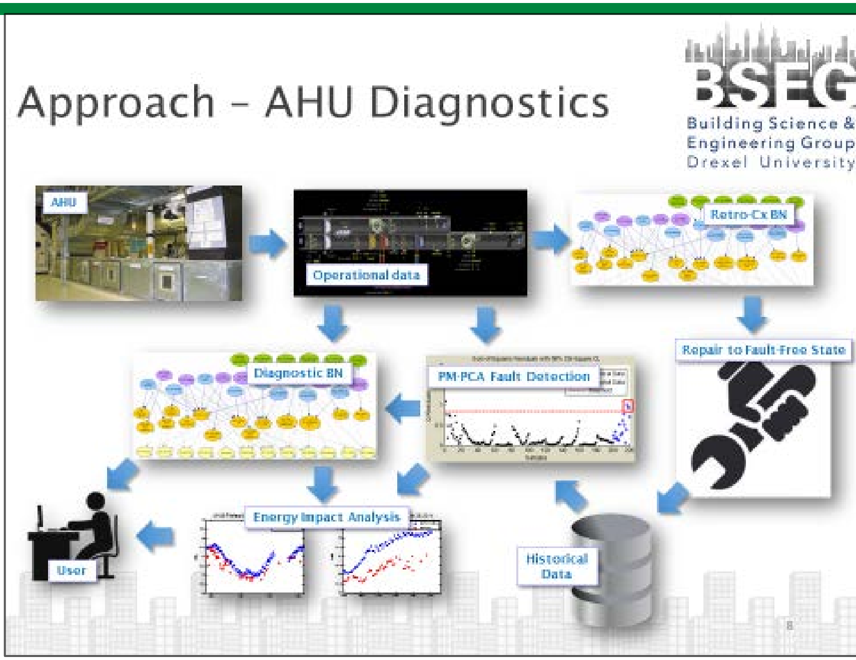
Unified HVAC and Refrigeration Control Systems for Small Footprint Supermarkets (Kuruganti, ORNL)

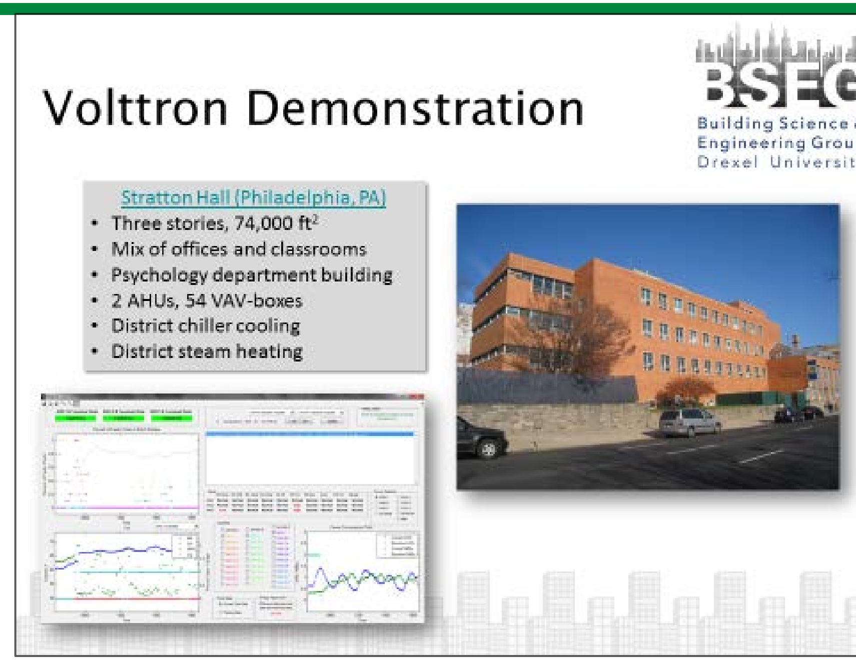




- Developed and demonstrated on-demand defrost application
- Working with Emerson as development and deployment partner
- Developing whole-store unified supervisory control of HVAC and refrigeration system to improve energy efficiency, reduce peak demand, and enable transactive services

Volttron Implementation: Automated Fault Detection and Diagnosis for AHU-VAV Systems (Regnier & Wen, Drexel)





- AHUs are utilized in over 30% of all commercial building floor space
- Difficulties for AHU-VAV systems
  - "Built-up" (custom) one-of-a-kind systems, Low sensor density and quality, Multiple operational modes, Continuously transient operation, Non-linear system
- Implementation Process
  - Install sMAP server
  - Add static building data to sMAP for testing
  - Install & test VOLTTRON
  - Develop VOLTTRON agent & test data passing
  - Connect to Drexel buildings

Key Meeting Takeaways from 2014 Meeting at Case Western and Changes Made to VOLTTRON in Response (Katipamula, PNNL)

Programmatic Priorities

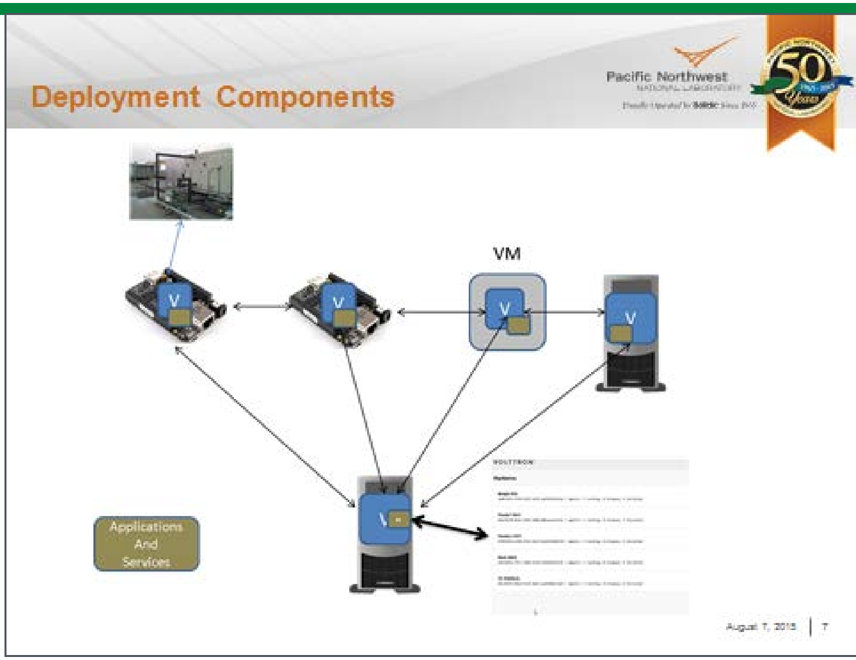
1. Increase VOLTTRON outreach efforts
   - IEEE and ACM (Virginia Tech Professor S. Rahman(offered to host VOLTTRON session at February IEEE meeting in DC if desired by DOE
     - A VOLTTRON workshop host by Consortium for Building Energy Innovation
     - A VOLTTRON session was organized at the February IEEE meeting
   - Sponsor Annual User Development meeting piggybacking on existing meetings/conferences
     - A VOLTTRON session at Energy Exchange 2015 in August (which provide training to energy managers at Fed sites)
     - Will hold a 3rd VOLTTRON users' meeting next year
2. Draft detailed roadmap for VOLTTRON development, with public input
   - A reference document has been prepared; we will seek public input and we plan to revise and update it
   - Transaction-Based Building Controls Framework, Volume 2: Platform Descriptive Model and Requirements. PNNL-24395
     - Please provide feedback at volttron@pnnl.gov
   - http://transactionalnetwork.pnnl.gov/publications.stm
3. Present a strawman for VOLTTRON community structure, and then get public input on it
   - We have a draft document, which needs stakeholder input and refinement

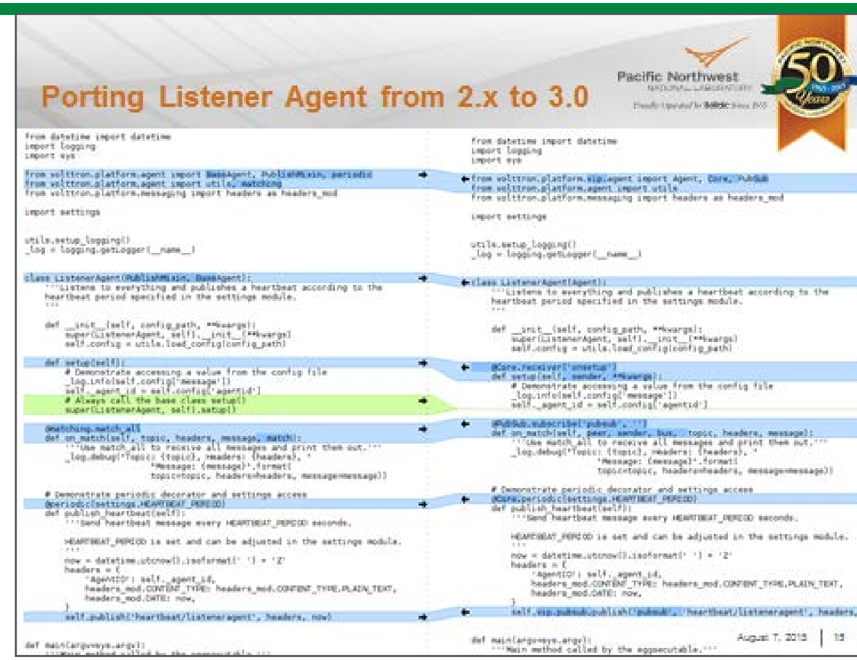
Technical Priorities

1. VOLTTRON has been developed to be very general purpose, but standards would help application developers. Some of these standards may fall out of other ongoing research. Including apps to platform services, app to app, and common data/representation models
   - LBNL created a strawman
   - Encourage others to comment at: https://github.com/VOLTTRON/volttron/wiki/Data-Model-Standards
2. Set of simple, clear, specific agents (including a non - Python agent) which demonstrate how to work with platform services. These agents could also serve as templates for building more complex agents.
   - Example implementations of new drivers and historians, RPC calls
   - Will continue to expand example sets
   - LauncherAgent is a generic way to launch non-Python agents
3. The contributed applications need more documentation to understand what they are doing. These complex applications provide more realistic examples of operation than the simple example agents
   - All PNNL developed agents/applications have detailed documentation
     - http://transactionalnetwork.pnnl.gov/publications.stm
     - Links to other labs and Virginia Tech sites are also included on this page

- Feedback from previous workshops, meetings, office hours, etc. fed directly into FY15 priorities
  - Secure message bus and have peer-to-peer option
  - Allow for any storage solution for historian and make writing drivers easier
  - Improve visibility and manageability of platform
- Encourage continued communication with team to help set FY16 priorities

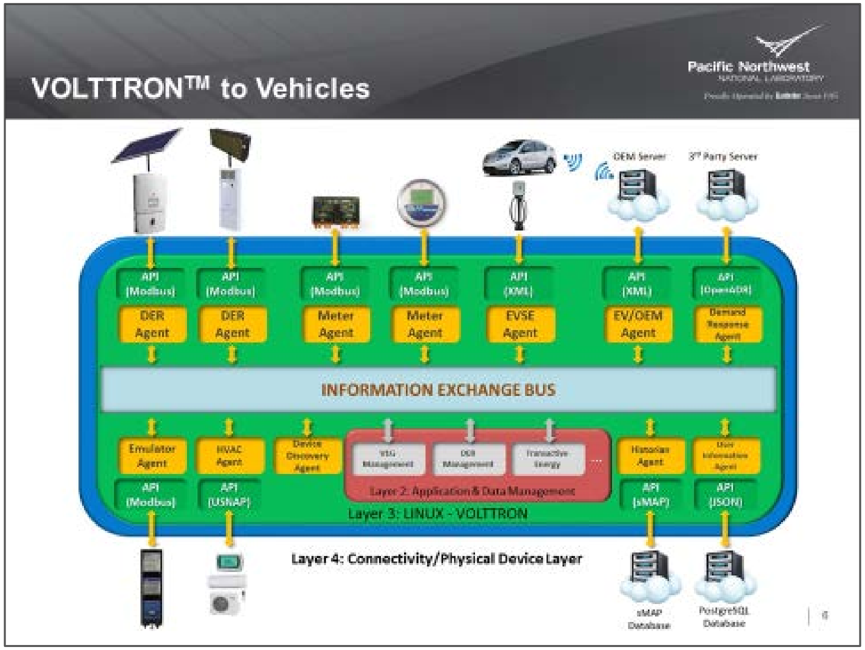
VOLTTRON Primer (Haack & Carpenter, PNNL)





- Detailed presentation of new features
  - Transition from v2 to v3 agents
  - Replacing sMAP in drivers and historian with alternative storage solutions
  - Clarification of terms and example deployments
- Next steps
  - Office hours will be used for in-depth discussion of features
  - Encourage community to use features of GitHub to make suggestions, track progress, use as interaction space

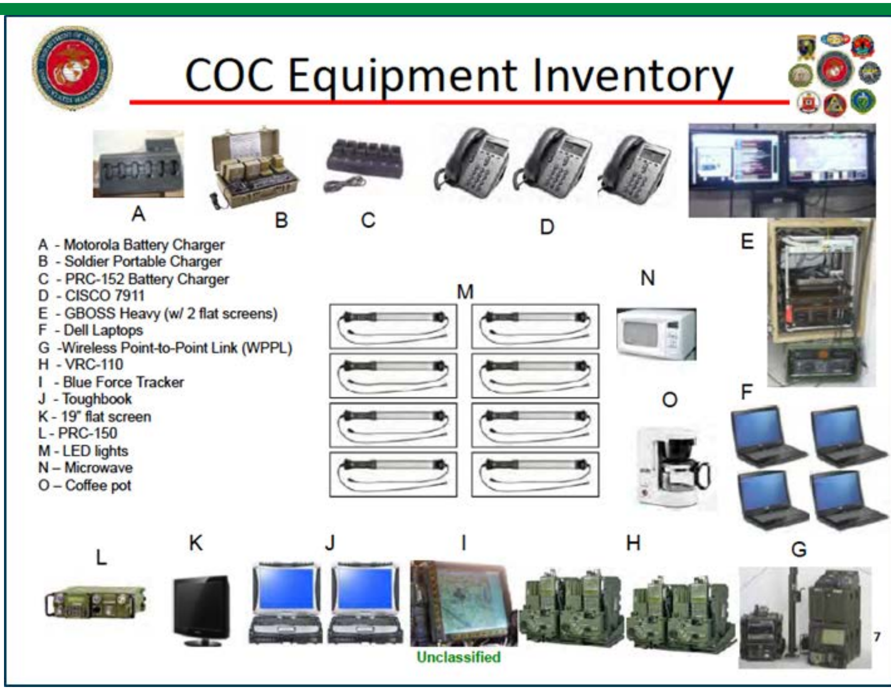
VOLTTRON Enabling Vehicle-to-Building Integration (Pratt, PNNL)

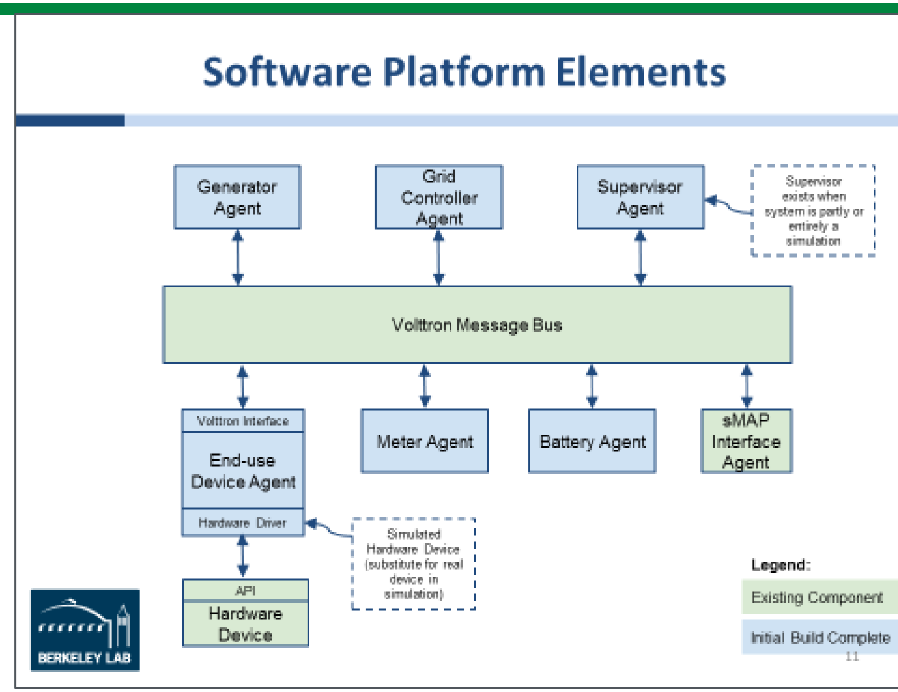


- Managed charging is needed
  - EV adoption growth expected
    - Distribution feeder loads limiting with growing electric vehicle population
    - EV charging can mitigate the local feeder effects of solar or wind renewables generation
- VOLTTRON can enable unique EV charging characteristics:
  - Flexible – charging can typically be delayed without impact
  - Variable charging rates
  - Dynamic charging rate change capability
  - Peak loading / demand charge reductions
  - EV charging is geographically distributed
  - Longer range PEVs will use higher charging power

Transaction-Based Operation of Resource Constrained Systems (Brown, LBNL)

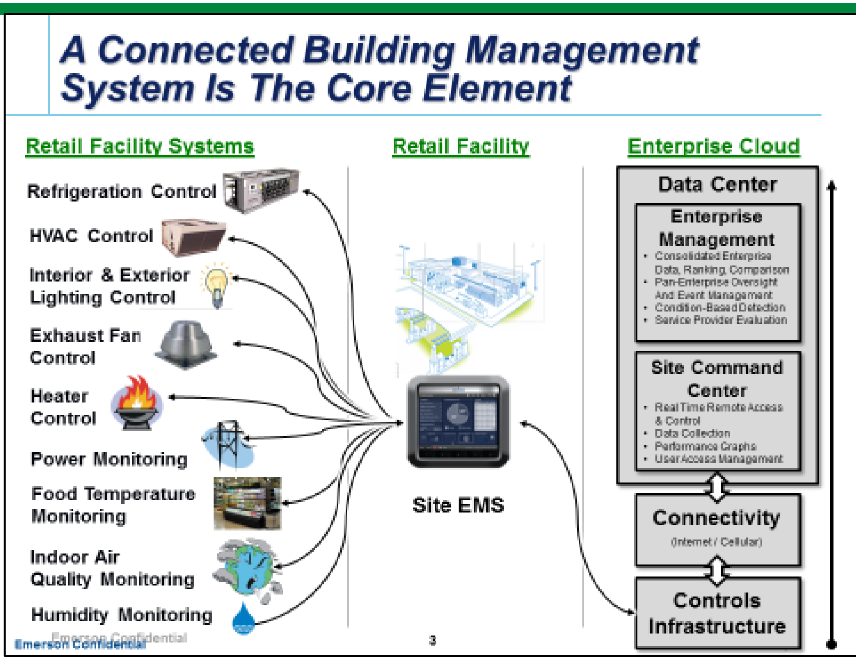
Placeholder

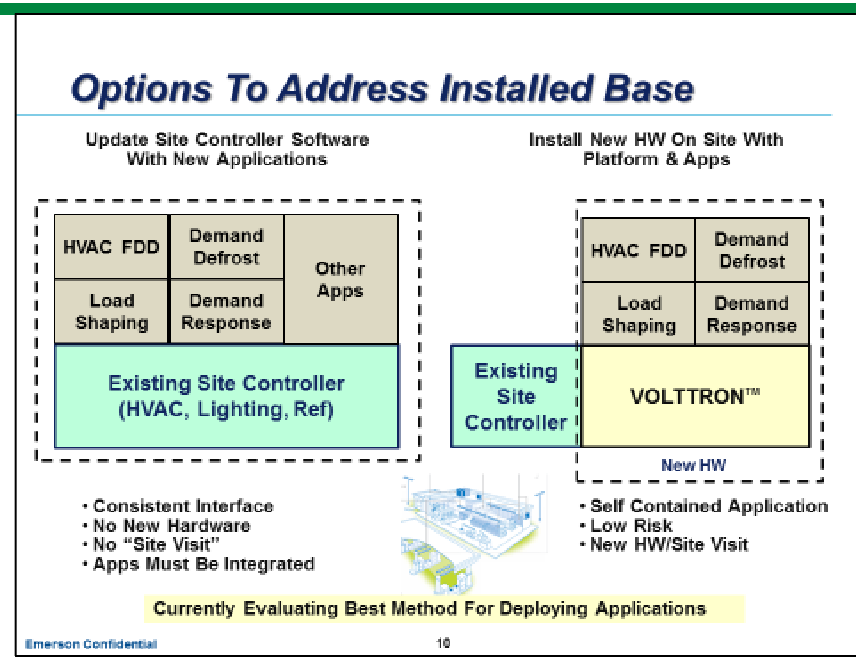




- Objective
  - Integrate representative contingency-base load and generation assets into transactional network
  - Demonstrate operation of microgrid using transactional network
  - Demonstration should use hardware components where feasible
- Use representative civilian equipment for proof-of-concept test
- Software agents initially tested in framework that simulates hardware
- Device power consumption estimated from measuring actual device
- Benefits of simulation:
  - Test many different configurations, algorithms, and elasticity curves
  - Run (much) faster than real-time; quick analysis of many options
  - May be useful for testing other VOLTTRON agents in future

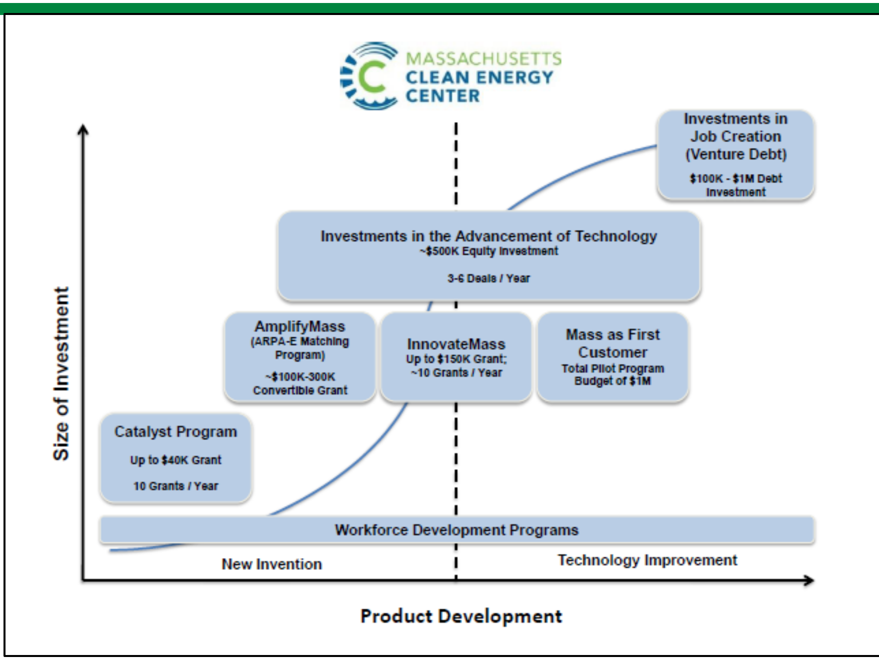
Energy Efficiency and Grid Services For C Stores & Supermarkets (Wallace, Emerson)

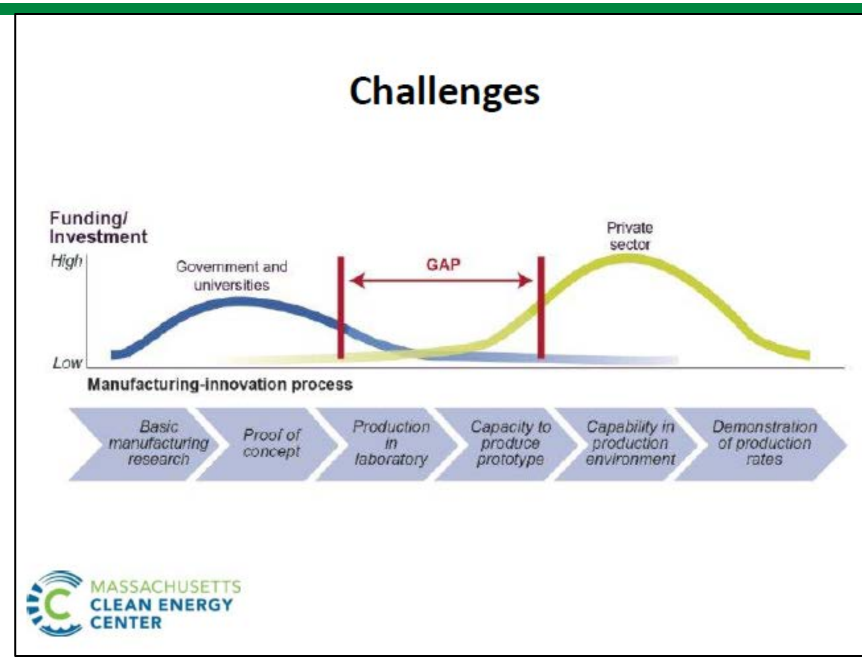




- Energy Management Is A Key Part Of Retail Operations With Major Impact On The "Bottom Line"
- Demand Defrost Application Demonstrated
  - Problem: Frost Formation On The Evaporator Coils Decreases System Operational Efficiency
  - Solution: Retrofit Volttron Platform And Control App To Emerson E2 Controller To Perform On-demand Defrosting
  - Results: Test Data Collected At ORNL Demonstrated Savings Potential, Application Developed And Field Testing At Emerson Labs, Sydney, OH– Testing Data Showed Up To 75% Reduction In Defrost Energy (39,650 – 57,900 Kwh/Store/Year)
- Emerson Interested In Adopting The Application

Massachusetts Clean Energy Center Transactive Energy Challenge (Nelson, Massachusetts Clean Energy Center)





- Transactive Energy Challenge Goals
  - Complement existing transactive energy pilot efforts
  - Address energy challenges unique to our region
  - Create opportunities for Massachusetts based companies
  - Leverage existing or planned clean energy incentive funding administered by state energy offices
  - Target funding: $500,000 plus match requirement
- Transactive Energy Challenge: Possible Focal Points
  - Thermal storage - integrate thermal storage into residential scale pilot
  - Existing Buildings/Plug and Play – focus on affordable, scalable tech deployment targeting dispatchable load
  - V2G – leverage utility interest/investment in EV infrastructure
  - Behind meter – focus strictly on load management within building