Low-Cost Open Platform For Monitoring and Control of Buildings (VOLTTRON)

PNNL, ORNL
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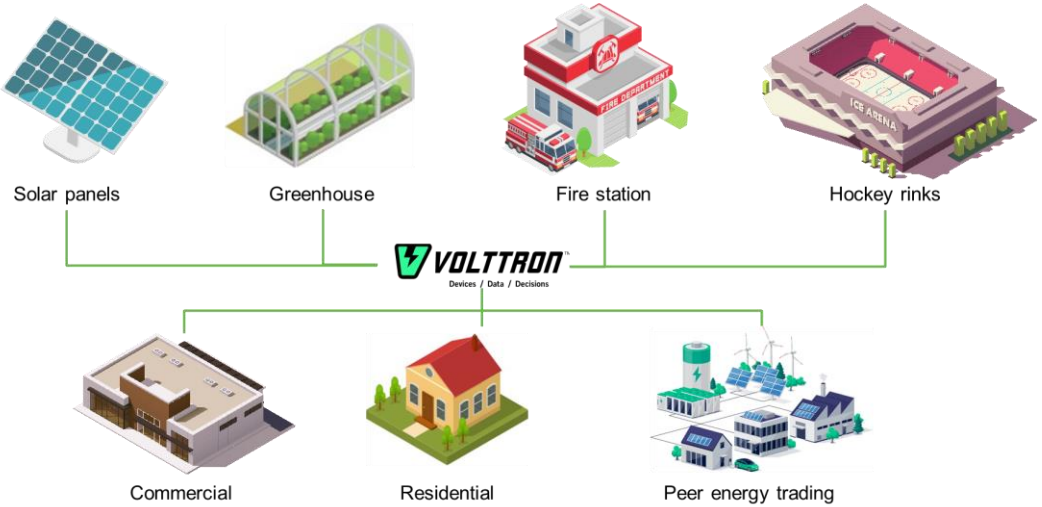
Building a Community-led Decarbonization Solutions Platform

Objective and Outcome

Promote and support a collaborative community creating energy efficiency and carbon reduction solutions through an open-source software platform which provides a common base functionality for monitoring and control of buildings and devices.



Team and Partners

PNNL – Platform Development

ORNL (FY23 – FY25) – Use Case Development

Guidehouse – Community Survey

Stats

Performance Period: 10/1/2021 – 9/30/2022

DOE budget: $1,238k

Milestone 1: First Quarterly User Meeting

Milestone 2: Eclipse VOLTTRON 2021 Release Candidate

Milestone 3: New Threat Profile for a representative organization

Background and Moving Forward

VOLTTRON™ from prototype to platform

Community Organization and Support, Outreach, Onboarding

- Future Power Grid Initiative
- Prototype Demonstration
- Patented Codebase

- Open-Source
- Multi-Lab RTU HVAC Project
- User Forum Kickoff
- Community building
- Device Connection
- Transactive Campus

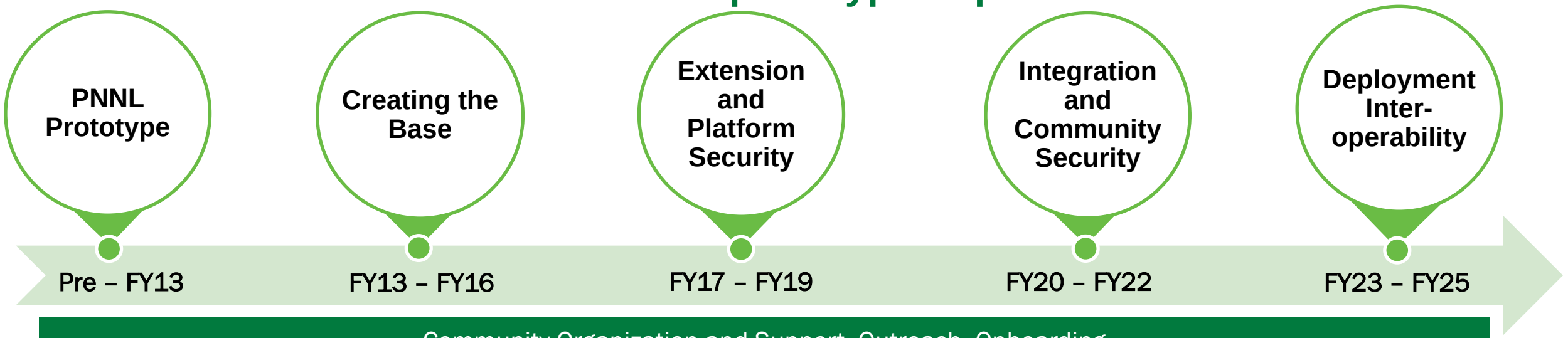
- Multi-platform communication
- Data Storage Framework
- Deployment management
- Simulation integration

- Simulation Framework
- Community Security Analysis
- Microservice prototype
- Utility Signals
- Deployment Tooling
- Open Source Foundation Transition

- Microservice Implementation
- Semantic Interoperability
- Field Deployment Demonstrations
- Communication improvements

Background and Moving Forward

VOLTTRON™ from prototype to platform



Community Organization and Support, Outreach, Onboarding

Pacific Northwest National Laboratory
OAK RIDGE National Laboratory
BERKELEY LAB
transformative wave
Intellimation
SES CONSULTING
NREL National Renewable Energy Laboratory
QualityLogic
intwine connect
KIER KOREA INSTITUTE OF ENERGY RESEARCH
ACE IoT SOLUTIONS
ecolong
THE UNIVERSITY OF TOLEDO 1872
PennState
SkyCentrics
ENPHASE.
Alto Tech
WhyGrene Energy Exchange
SINC ENERGY
Verdicity The Marketplace for Smart Buildings
AVISTA
slipstream
Rede BUILDING ENERGY EFFICIENCY
i4 energy
75F

Challenges

- **Achieving BTO's vision for a net-zero U.S. building sector by 2050 will require**
  - Addressing **small and medium commercial buildings (SMCBs)** without "built-up" multi-component HVAC and Building Automation Systems (BAS). These are 82% of commercial buildings, 55% by floor area.
  - Promoting energy equity by enabling energy savings and improved performance in SMCBs in underserved communities (including schools)
  - Increasing building demand flexibility and improve building participation in decarbonization, energy efficiency, and grid response strategies

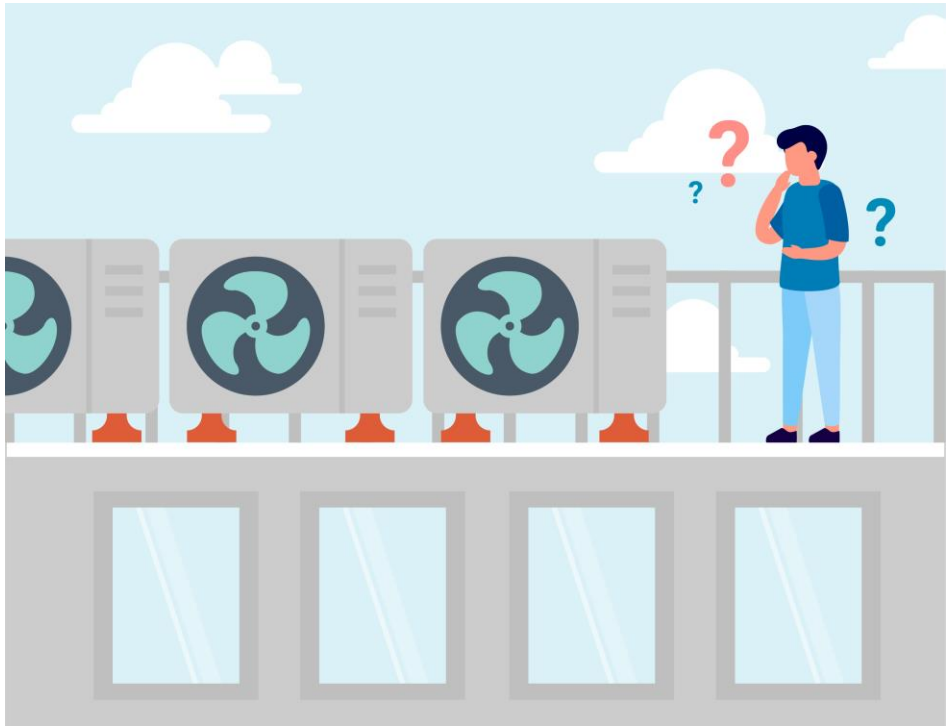
- **Monitoring and control can be part of the solution, but addressing this market will require**
  - Reducing cost of developing and deploying new monitoring and control products
  - Reducing barriers to entry associated with proprietary platforms: vendor lock-in, data ownership questions, and high costs (a significant barrier for SMCBs in general and especially for SMCBs in underserved communities)

Project Goals

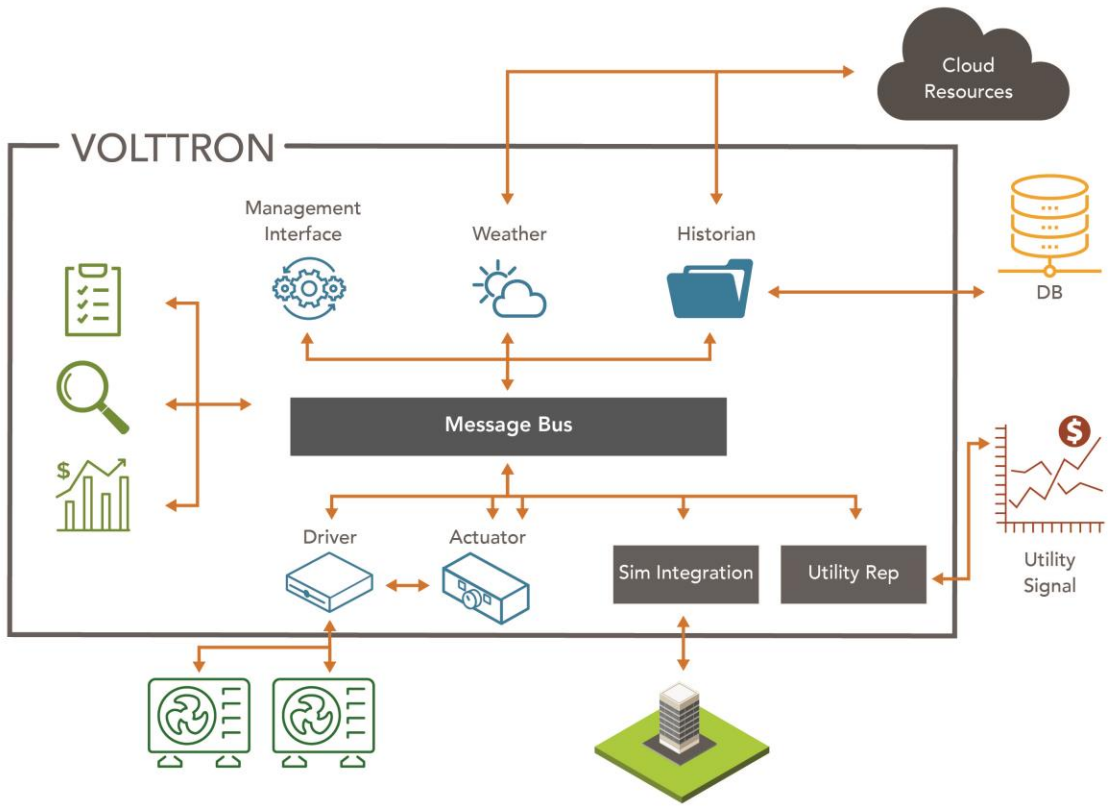
- **Enable control in SMCBs to accelerate deployment of energy efficiency and grid service application to support decarbonization**
- **Provide a secure, functional platform that can act as a starting point for solutions**
  - Reduce solution development time and effort
  - Jumpstart developers who can focus on turning their algorithms into deployable applications
  - Applications built against a reference platform can be evaluated without requiring a license or specialized hardware/software
- **Lower barrier of entry for non-software focused companies**
  - Streamline and simplify the platform's remote configuration and monitoring capabilities, requiring less time on site for setup and fewer on-site visits for maintenance
- **Build up a collaborative community of users who inform and contribute to the development of the platform and its use cases**

A Secure Platform for Monitoring and Control -- Requirements

- **I have a building with various components and systems that I want to monitor and control. I don't have a BAS and can't afford one. What do I need?**
  - A computer and operating-system on which to run local monitoring and control algorithms securely
  - A way to communicate with local components using multiple protocols (BACnet, ModBus, OpenADR, etc.)
  - A way to store data
  - A way to aggregate multiple local instances in a building or campus for large scale applications
  - A way to securely communicate with the outside world (e.g., the cloud) for long-term storage, compute-intensive services, and even larger-scale aggregation

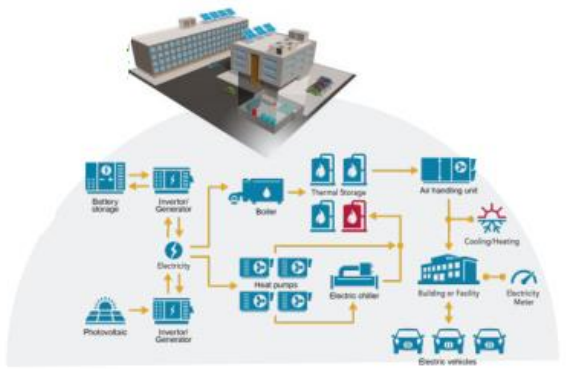


A Secure Platform for Monitoring and Control -- VOLTTRON



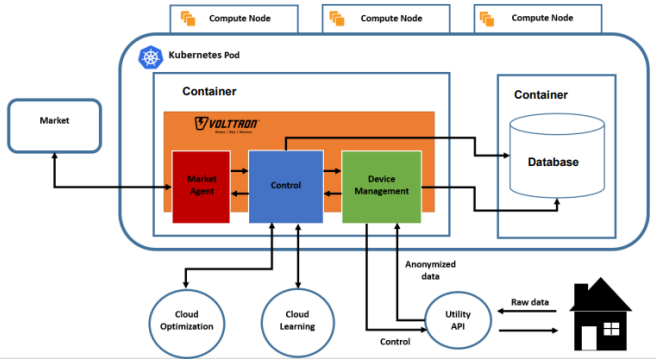
- VOLTTRON: a secure "operating system" for monitoring and control applications
  - Not a specific monitoring or control application itself
  - Lightweight, can run on off-the-shelf low cost computers, e.g., Raspberry Pi
  - Publish-subscribe (pub-sub) message bus architecture
    - Supports aggregation of multiple instances
  - Library of protocol drivers, e.g., BACnet, Modbus
  - Extensible data storage, e.g., locally, database, cloud
  - Library of "utility" agents, e.g., weather, historian
  - Integration with simulation for pre-deployment testing
  - Secure
- **Also: open-source**
  - Applications contributed by labs, academia, industry
  - No vendor or software lock-in, no black boxes
  - Community of users ready to collaborate

VOLTTRON In Research And Real-World Deployments



Utility Collaboration

PNNL-Edo-Avista Collaborative Research –
Eco district field demonstration of technologies that advance commercial building energy efficiency and transactive control (TC) of distributed energy resources (DERs)



ORNL Oak Leaf Architecture (Altus Neighborhood)

National Lab Research

ORNL's Smart Neighborhood – Optimize each home's HVAC, water heating (WH) system to minimize cost while maintaining occupancy comfort. VOLTTRON is used as underlying platform for data collection and control of home's HVAC and WH systems

Ref: https://aceiotsolutions.com/

Industry Adoption

AceIoT leverages VOLTTRON on their commercial building gateway to -
"provide customers with low cost approaches to acquire, access and manage data from distributed control systems and sensors"

Approach

Flexible Deployment Solution

- Enable easy and flexible VOLTTRON platform deployment options for RTU, non-BAS, BACnet, and many other use cases

Simulation Integration

- Integration with simulation tools (BOPTest) for easy testing before field deployment

Data Collection and Storage

- Framework for adding new protocols for communication with a range of devices
- Integration with utility signals allowing the applications to participate in utility strategies

Security

- Community engagement to educate on security best practices
- Develop Threat Profiles for community deployment use cases

Semantic Interoperability Support

- Enable development of vendor neutral solutions with standardized data models

Outreach

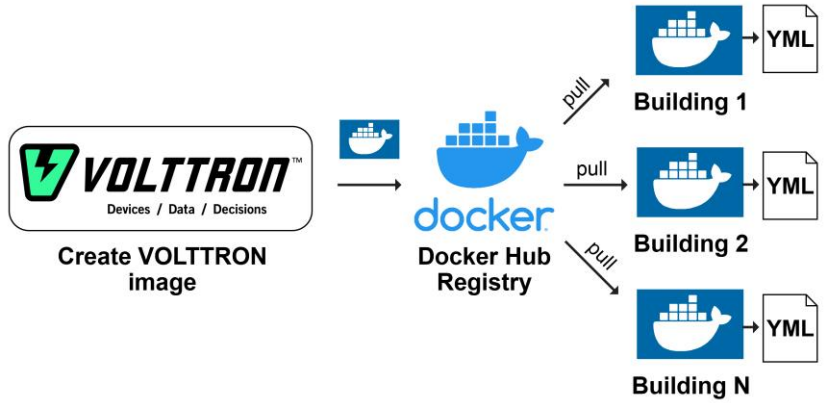
- Build a community of users which can inform development directions, contribute back features, assist with testing, and collaborate

Enabling Simplified and Flexible Deployment

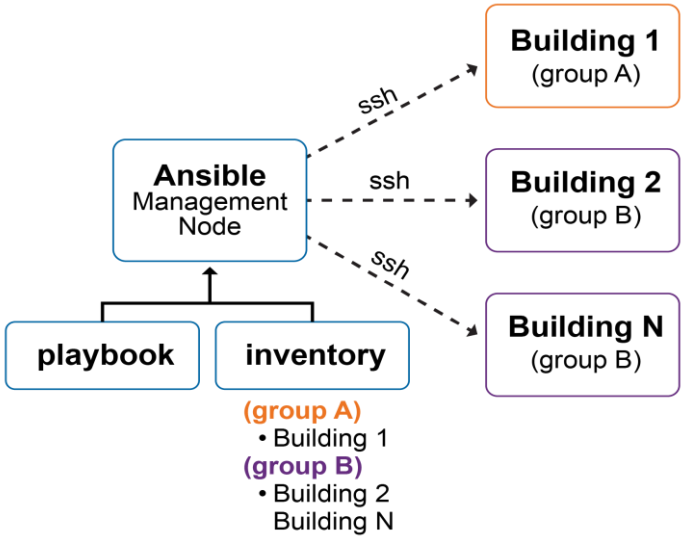
- Reduce complexity of deploying the platform and applications for community use cases
- Breaking up codebase into a “microservice” architecture allows for more targeted deployments by including minimum needed
- Separate code repositories for applications to simplify contribution and clarify ownership
- Utilize standard install service used by software developers (PyPi for Python install)
- Only required applications can be installed, thereby reducing installation steps for the end user

Deployment Services

- Need standardized mechanism to install, manage and monitor scaled deployments
- VOLTTRON docker images provide reproducible way to install VOLTTRON and applications
  - Isolated runtime environment, easily portable
  - Extensible for multi-platform deployments
- Ansible-based VOLTTRON deployment provisions better infrastructure management
  - Automated host configuration
  - Automated setup of VOLTTRON on each host
  - Driver and application configuration
  - Starting platform and associated agents on each host
- Ansible-VOLTTRON deployment services used to manage PNNL campus deployment



Docker based deployment



Ansible based deployment

Empowering Platform Users

- **Utility Signal Integration**
  - Integration of OpenADR, DNP3 signals to support grid service applications
- **Support semantic Interoperability**
  - Worked with LBNL on automatic device configuration using standard building data models
- **Cybersecurity Engagement**
  - PNNL engaged VOLTTRON community for Threat Profiles of deployment use cases
  - EOS Utilized profile to engage with potential clients
  - Community engaging PNNL to subcontract for this service
- **Transition to Open-Source Foundation**
  - Eclipse Foundation provides framework for governing open source projects
  - Pre-release microservice codebase maintained through Eclipse Foundation repository
  - Community members can become committers to lead the project

Community Outreach, Feature Engagement and Working Groups

- Organizations focus on varied combinations of features depending on their use case
  - Hold bi-weekly office hours for technical support
  - Quarterly User Meetings to showcase new features and encourage feature adoption
- Working Groups help set technical direction, contribute early feedback, ensure multiple perspectives
  - Message Bus and Authentication
  - Device communication protocols and configuration
  - Utility signal integration (OpenADR)

DATA COLLECTION – ALL
- BACnet – EOS, ACEIoT Solutions
- Modbus – WhyGrene, Enphase
- Utility Signals – EcoLong, ACEIoT, WhyGreene
- Other – EPRI, UCSD, ORNL

UTILITY SIGNALS
- OpenADR – Slipstream, EcoLong, ACEIoT Solutions
- DNP3, IEEE 2030.5 – EcoLong, Slipstream

DEPLOYMENT SERVICES – ALL
- Deployment hooks and tools – ACEIoT, ORNL (Georgia Southern), PNNL

APPLICATIONS
- Intellimation, EcoLong, ACEIoT, Verdicity, ORNL, UCSD

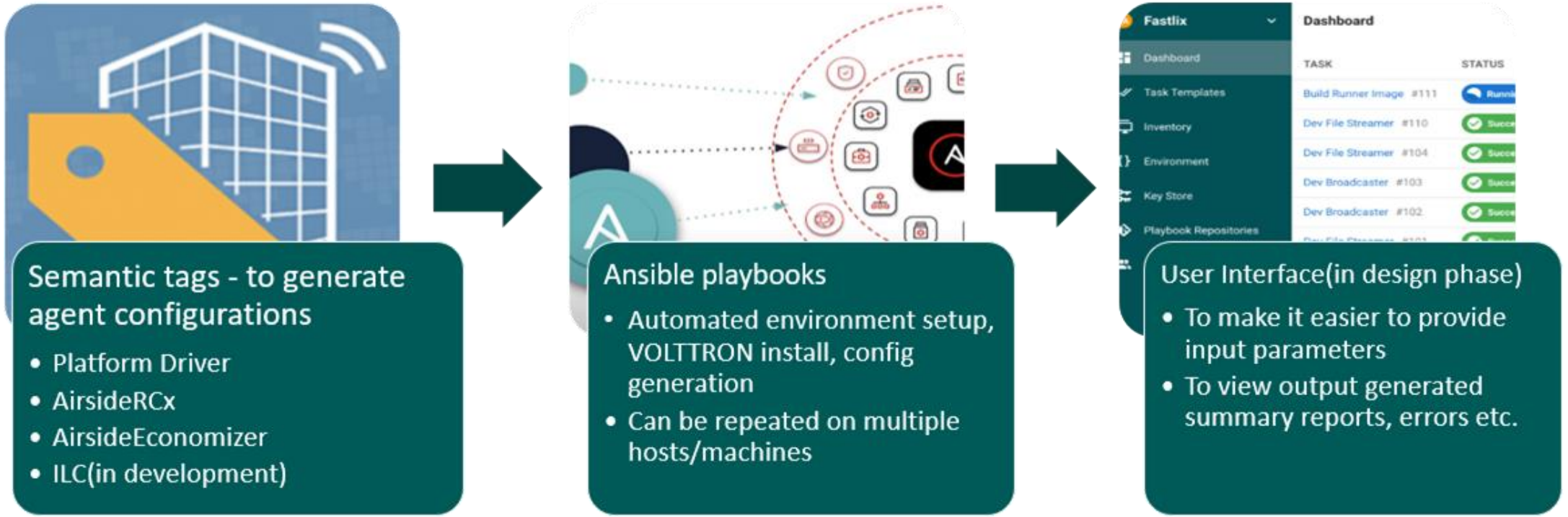
INTEROPERABILITY AND TAGGING
- Intellimation, EPRI, LBNL

SIMULATION INTEGRATION
- EcoLong, LLNL

SECURITY
- EOS, ACEIoT Solutions, WhyGrene, I4 Utility Grid

Technology Commercialization Projects

- **Intellimation TCF -** Reduce configuration steps for applications such as ILC and enabling easy deployment into Intellimation's systems.

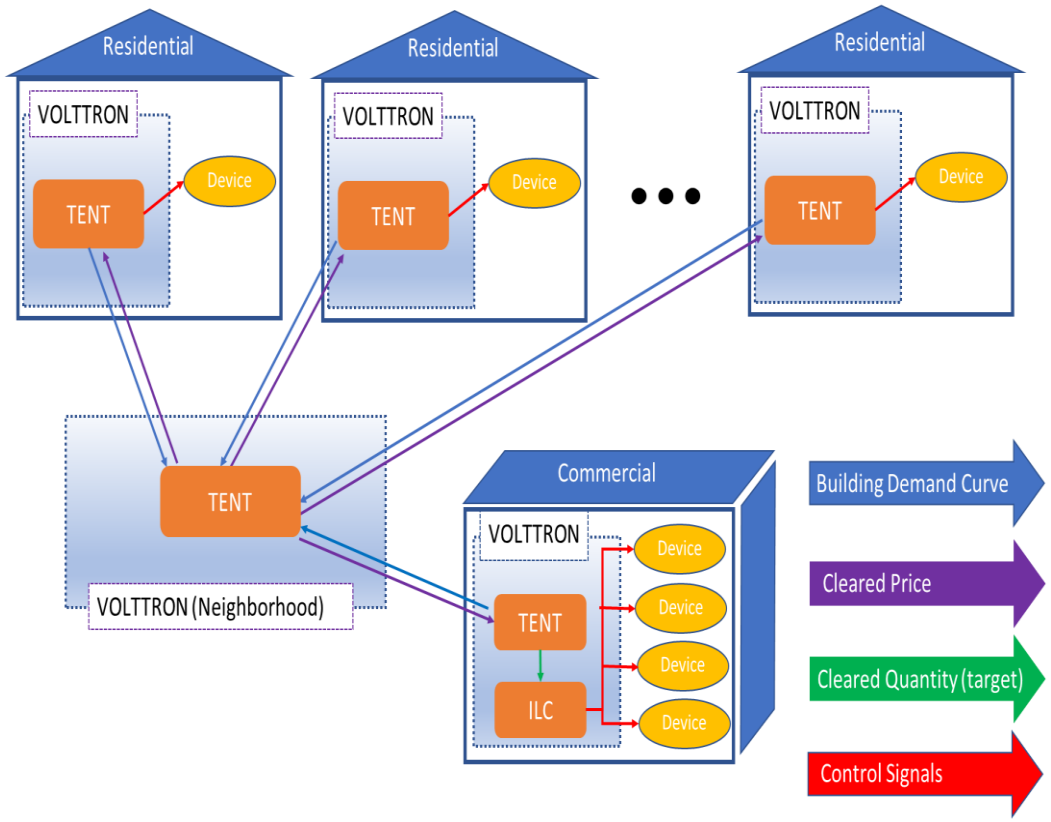


Technology Commercialization Projects

- **ecoLong TCF –**

Develop Secure Energy Management System for
- DERs to participate in wholesale markets and provide services to the grid
- Intelligently control the energy in residential buildings to the desired level while maintaining occupancy comfort

Customize VOLTTRON hosted Transactive Network Template (TENT) to enable transactive market-based control of DERs in households



Risks/Mitigations

- **Risks**
  - Continuity of platform support in the face of changing federal budgets
  - Meeting the support needs of VOLTTRON users with a wide spectrum of technical capabilities and use cases
  - Current user forum format does not grow the community sufficiently
- **Mitigations**
  - Build up community under open source foundation, provide users a sense of shared ownership
  - Focus on deployment tooling to reduce expertise needed for setup and management
  - Identify conference and other opportunities to reach a wider audience

Follow-on Work

- Focus on enabling non-BAS buildings with legacy devices to participate in energy applications
- Identify community members for field demonstrations and early adopters
- Determine long term support strategy with community

Continued support for energy efficiency applications in decarbonization efforts

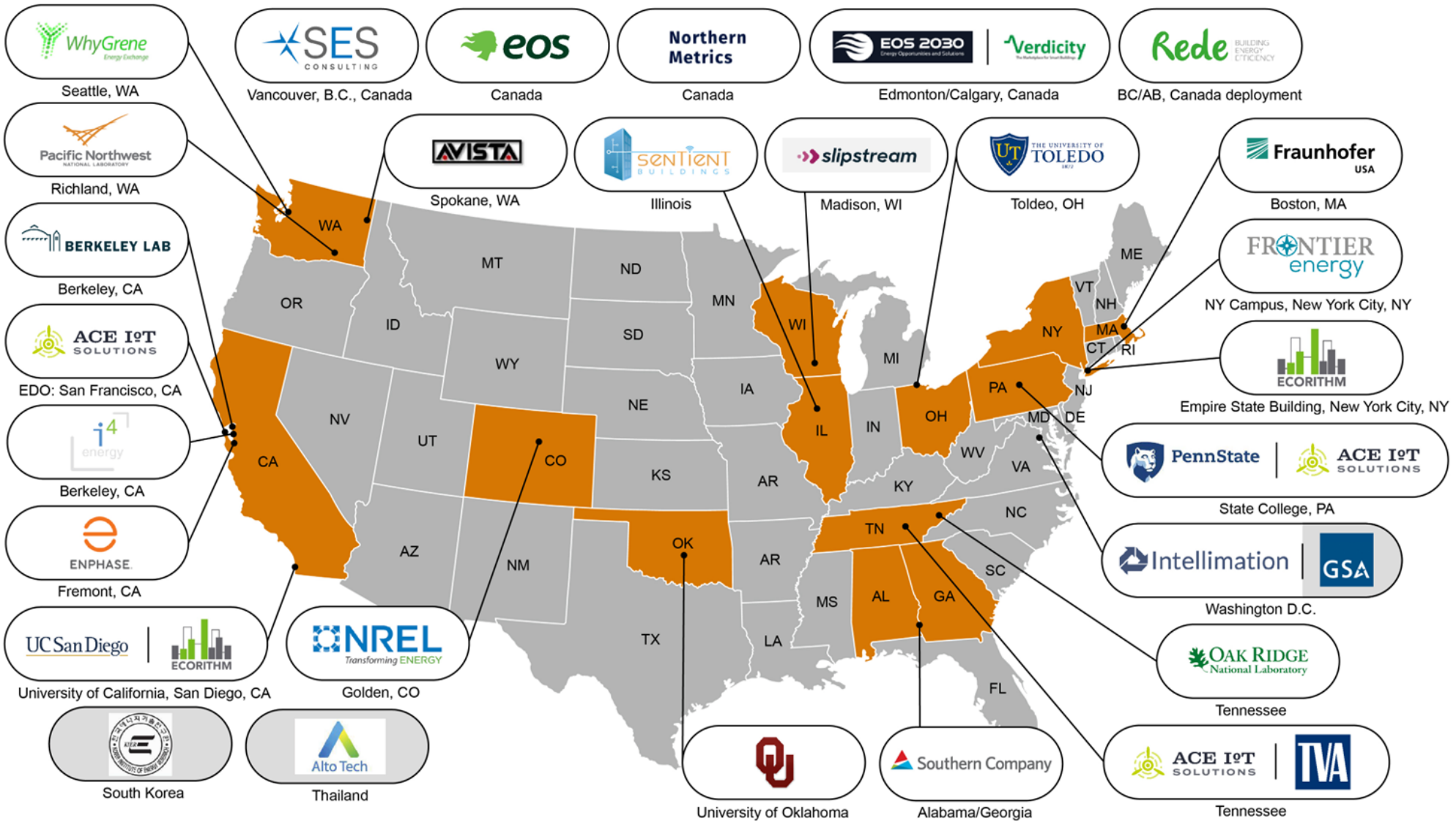
Improve deployment capabilities for users implementing VOLTTRON based solutions

Integration of utility signals to support grid interactive applications

Connection to residential hubs (such as HomeAssistant) to expand non-BAS device integration

Continue to support building a collaborative community of users

International Impact: VOLTTRON



Thank You

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REFERENCE SLIDES

Team

PNNL



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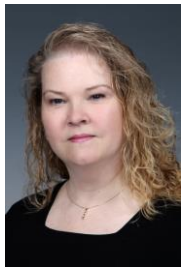
PM: Jereme Haack
Tech Lead: Craig Allwardt



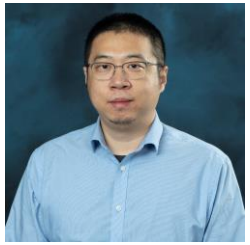


Campus Deployment
Nathan Tenney, Robert Lutes, Wendy Cowley



Development Team
Chandrika Sivaramakrishan, Keifi Mo, David Raker

ORNL

Helia Zandi
Sen Huang

Guidehouse


Jim Young, Ed Barbour

Project Execution

	FY2022				FY2023			
Planned budget	$ 1,360,940				$ 886,165			
Spent budget	$ 1,238,528							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work								
Task 1.2a: First Quarterly User Meeting	◆							
Task 5: Update Rooftop Unit Comparison Calculator (RTUCC)	◆	◆						
Go/No-Go: Community buy-in of VOLTTRON Deployment Strategy		◆						
Task 3.1a: Eclipse VOLTTRON 2021 Release Candidate	◆							
Task 2.1a: VOLTTRON Deployment Strategy white paper		◆						
Task 5: Update Rooftop Unit Comparison Calculator (RTUCC)		◆						
Task 4.1a: Abuse case analysis for selected VOLTTRON				◆				
Task 4.2b: New Threat Profile for a representative organization				◆				
Current/Future Work								
Task 1.3: Release candidate of platform					◆			
Task 5: RTUCC support and wrap-up						◆		
Task 1.2a: First Quarterly User meeting								
Task 1.1: Summary Report of Community Feedback								
Task 1.2b: Second Quarterly User meeting								
Task 1.2c: Third Quarterly User meeting								
Task 1.4: Integration of BOPTest framework								
Task 1.2d: Fourth Quarterly User meeting								
Task 1.3: Eclipse VOLTTRON 2023 Release Candidate								

- Go/No-Go: Community Buy-In of VOLTTRON Deployment Strategy
  - Community validation of white paper presented at user meeting