# Volttron Implementation:
# Automated Fault Detection and Diagnosis for AHU-VAV Systems

Volttron Workshop

23 July 2015
Arlington, VA

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# Overview/Agenda

1. **Introduction**
   - Faults in AHU-VAV Systems
2. **Diagnostics**
   - Methods & Requirements
3. **Volttron Integration**
   - Platform overview
   - Drivers
   - Database
   - Agents
4. **Why Volttron?**
   - Benefits for research & for ir
5. **Going Forward**


# AHU-VAV Systems

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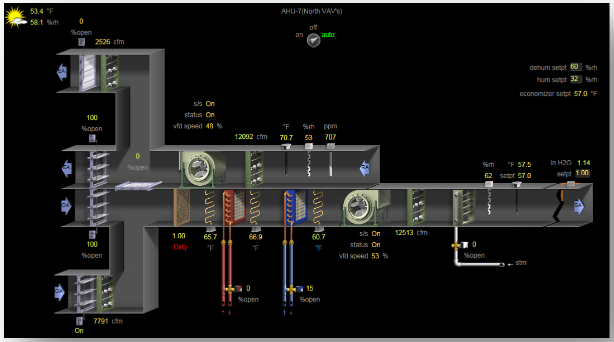
**AHUs are utilized in over 30% of all commercial building floor space**

- Air handling units (AHUs) manage heat/energy exchange and ventilation
- As a result, faulty operation has significant energy and health/safety impacts




**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

# Diagnostics

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***Market-driven challenges for Automated Fault Detection and Diagnosis (AFDD)***

- Lack of willingness to invest in AFDD
  - Difficult to demonstrate the value
- Physical system upgrades
- Engineering time/expense for method refinement increases costs
- Low tolerance for false alarms
- Require a non-intrusive strategy that will not impact:
  - Control strategies
  - Comfort

# Faults

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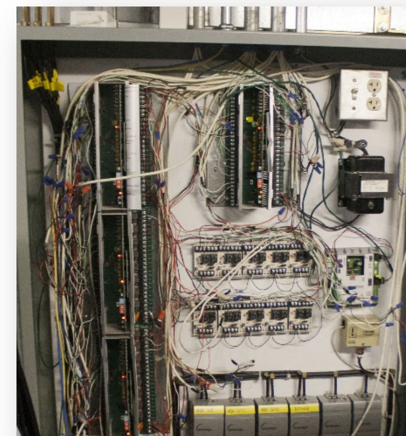
## Mechanical Failure/Degradation

- Dampers
- Valves
- Fans
- Sensors

## Control Issues

- Improper Sequencing
- Instability
- Cycling



## Maintenance Items

- Filters
- Belts
- Coils

## Operator/Maintenance Error

- Forgotten overrides
- Disabled features
- Improper installation/repair

# Value

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## Benefits

- Improved comfort (productivity)
- Energy Savings
- Improvement in air quality
- Increased equipment lifetime
- Improved service scheduling

**Difficult to accurately quantify!**

## Costs

- Engineering labor
  - Getting data out of the building
  - Mapping points
  - Customization and tuning
- Additional hardware

**Opportunity to reduce costs through increased automation**

# Approach – AHU Diagnostics

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**Plug-and-play implementation**

- Minimal upfront engineering costs (no modeling/ customization requirements)
- No specialized training data
- Automatically "learns" system characteristics
- Adapts to any sensor set or configuration

**De-couples detection and diagnostic algorithms**

- Reduced computational requirements
- Cross-validation of results

**Demonstrated to be effective for all types of faults**

- Dampers, valves, fans, sensors, controls, etc.

**P*assive* method** (no intrusive testing)

**Demonstrated using data from four commercial buildings**

- Naturally occurring faults and artificial fault experiments

# Approach – AHU Diagnostics

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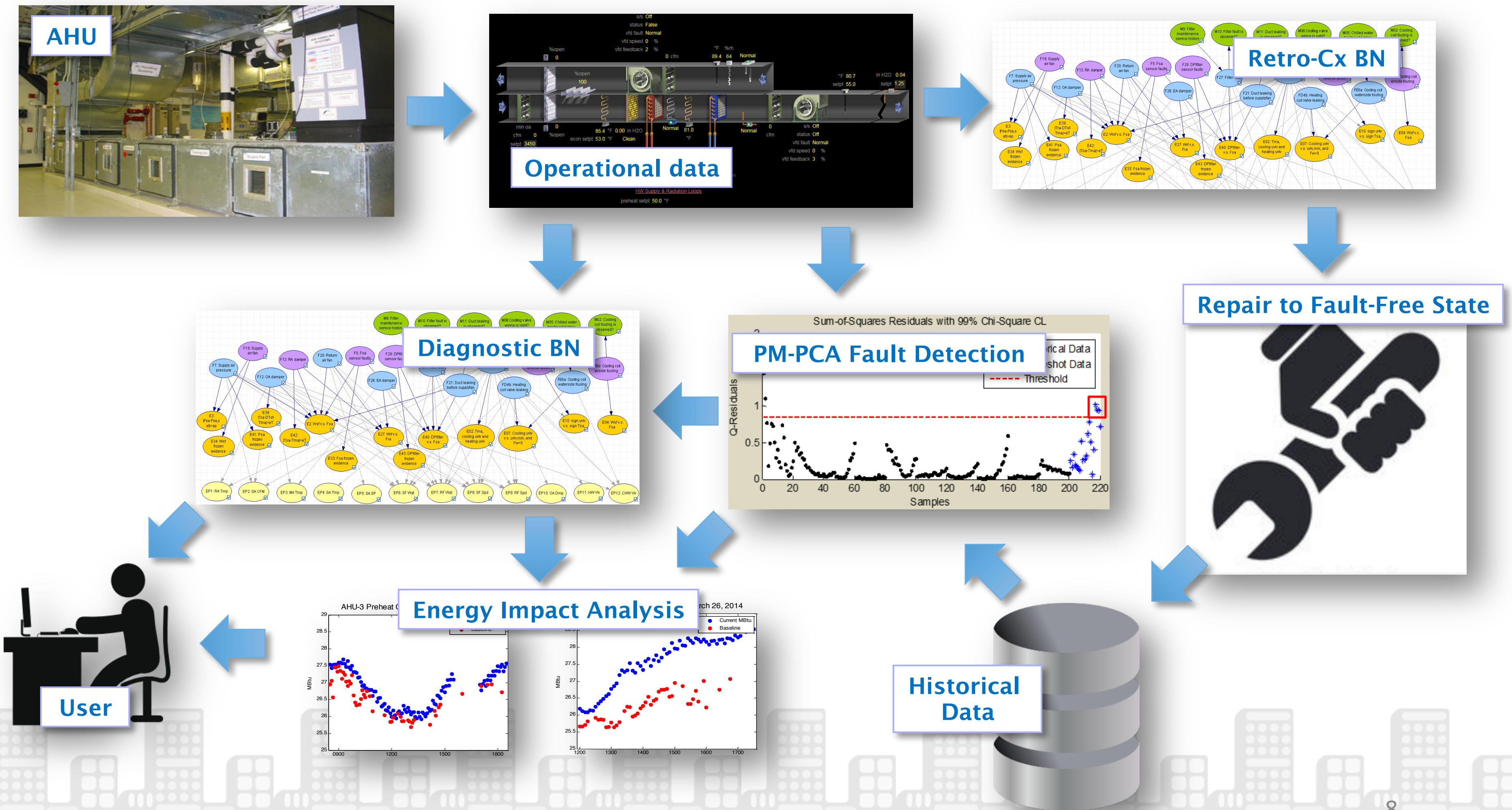

# Volttron Tasks

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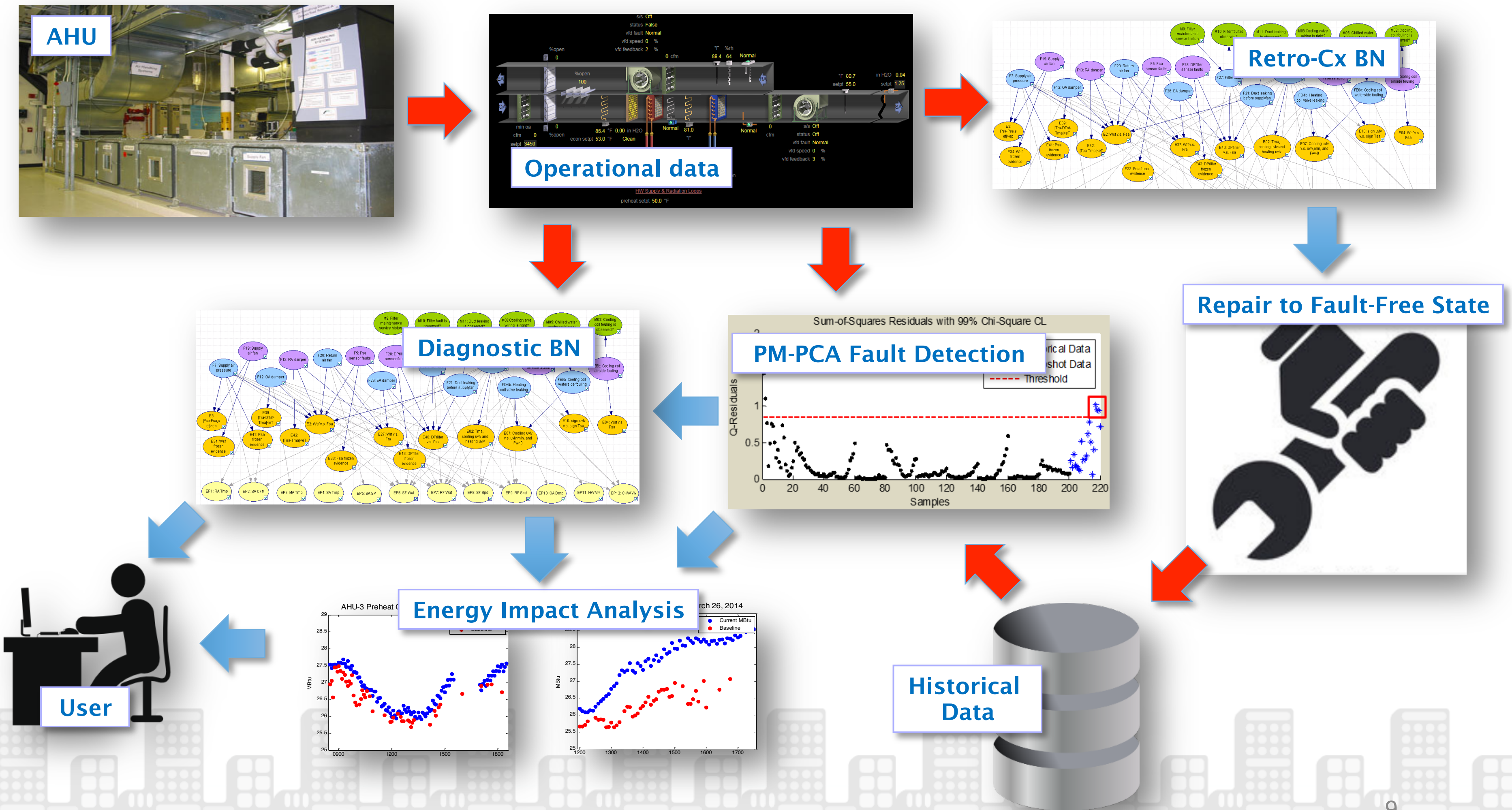

# Volttron Demonstration

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[Stratton Hall (Philadelphia, PA)]

- Three stories, 74,000 ft$^2$
- Mix of offices and classrooms
- Psychology department building
- 2 AHUs, 54 VAV-boxes
- District chiller cooling
- District steam heating

# Volttron Overview

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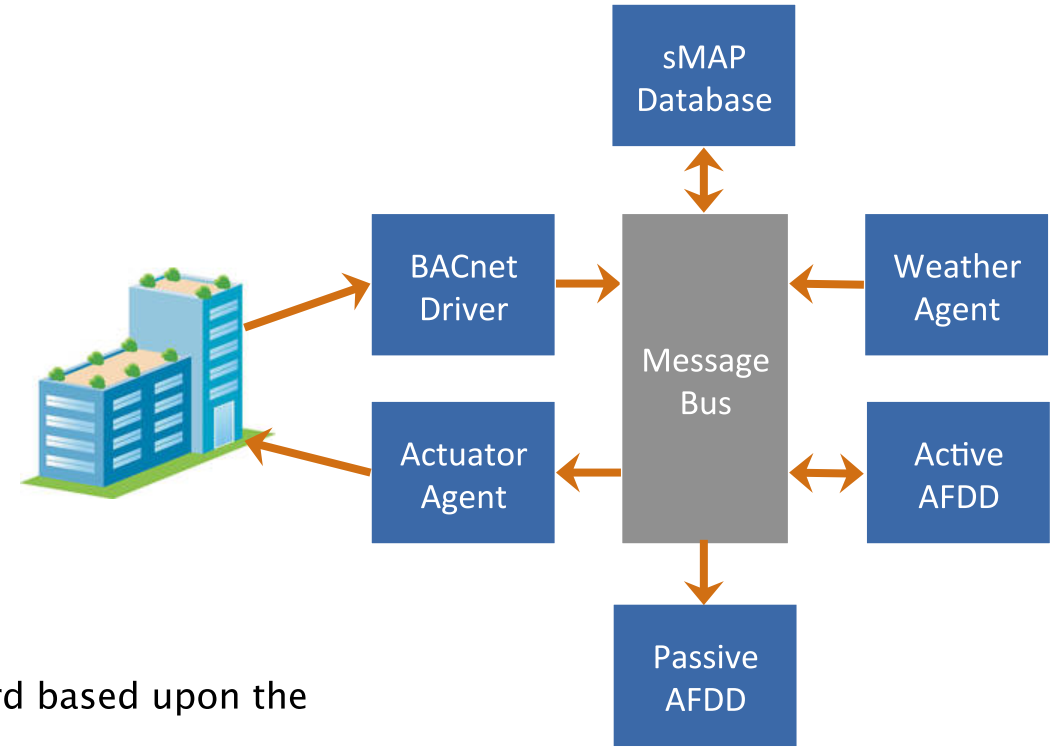
## Volttron Setup

- Runs on Linux
- Straightforward installation and configuration

## Architecture

- Data from the building is passed into the message bus
- From the message bus, different agents can act on the data and send control signals to the building using the actuator agent.



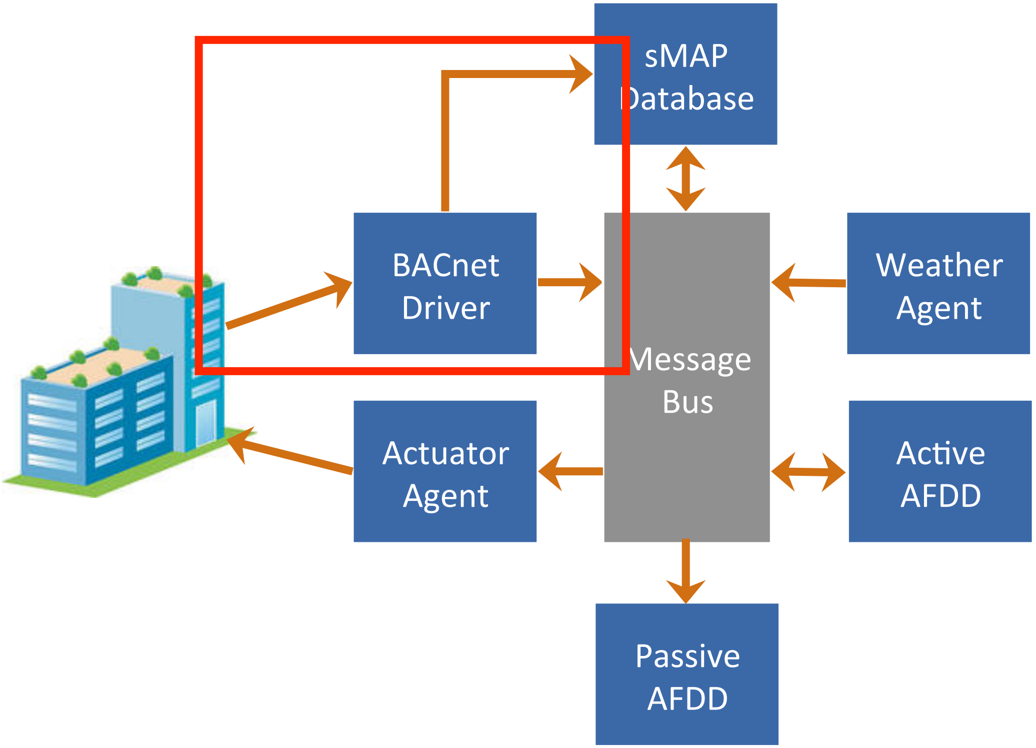

## Agent Development

- Agent development is straightforward based upon the sample agents developed by PNNL
- All of the different components interact using a simple publish/subscribe method

# Getting Data

## BACnet Driver

- Configuration tool automatically detects BACnet traffic on network
- Provides a list of available BACnet point names
- BACnet driver gathers data from the building in real time and publishes to the message bus



# Getting Data

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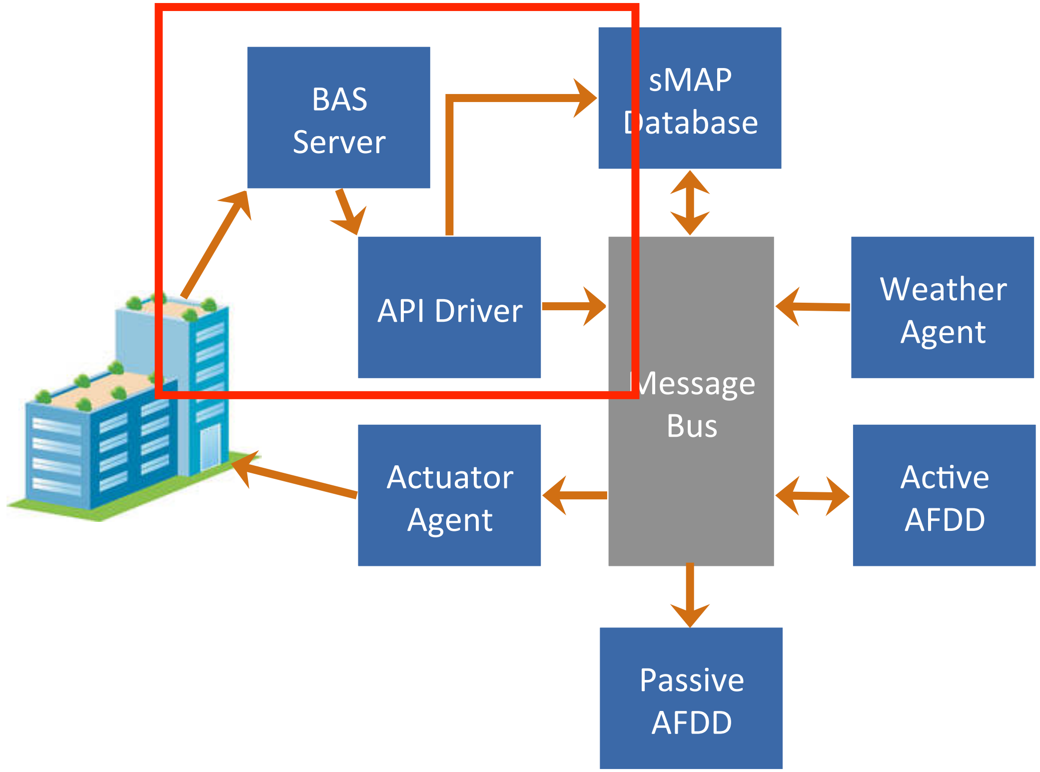
## Alternate Configuration

- As soon as we configured our Volttron instance using the BACnet driver, our ability to access the data was removed due to security upgrades
- At our demonstration site, the network configuration was modified so access to the BACnet data required physical relocation of our Volttron computer
- Since we are doing development, physical access to the Volttron machine is required
- Wrote a driver to pull data from the BAS server instead (via https API)




**Testing and development of this approach are ongoing**

# Getting Data

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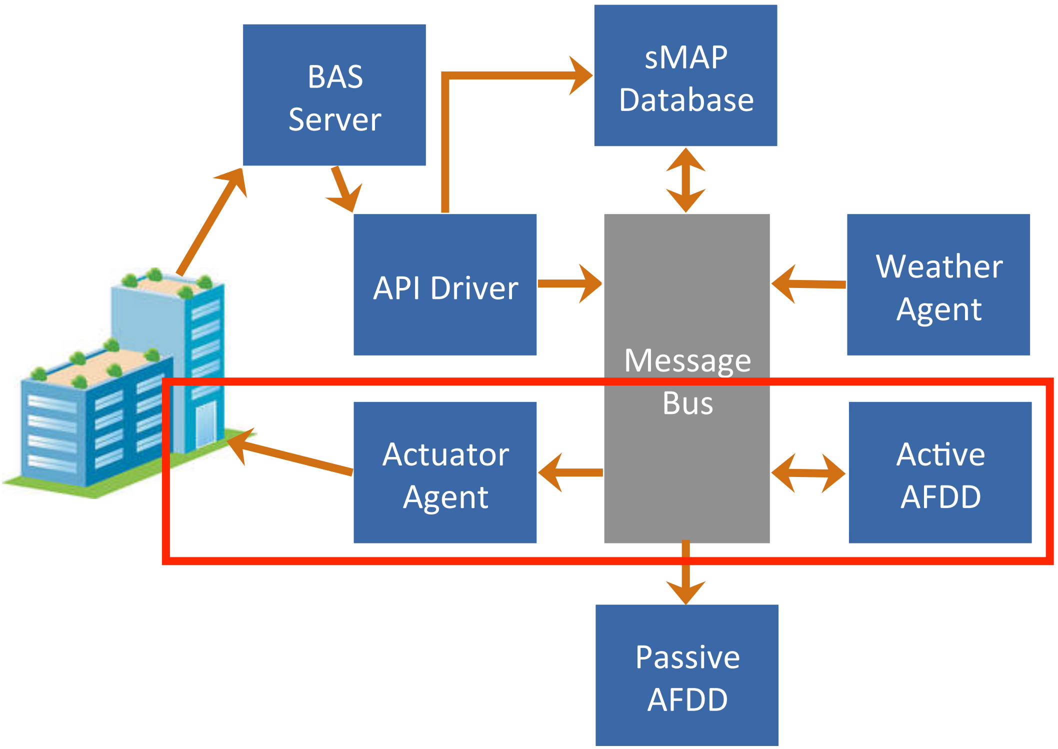
### "Active" AFDD

- Active AFDD refers to manipulating the building controls through a set of actions designed to identify faulty behavior
- There are instances where it is difficult to differentiate between faults with high confidence using passive methods
- We were interested in testing PNNL's active AFDD agent, and possibly incorporating it into our work.
- However, we will have to write our own actuator agent due to the same issues presented with the BACnet driver.



# Getting Data

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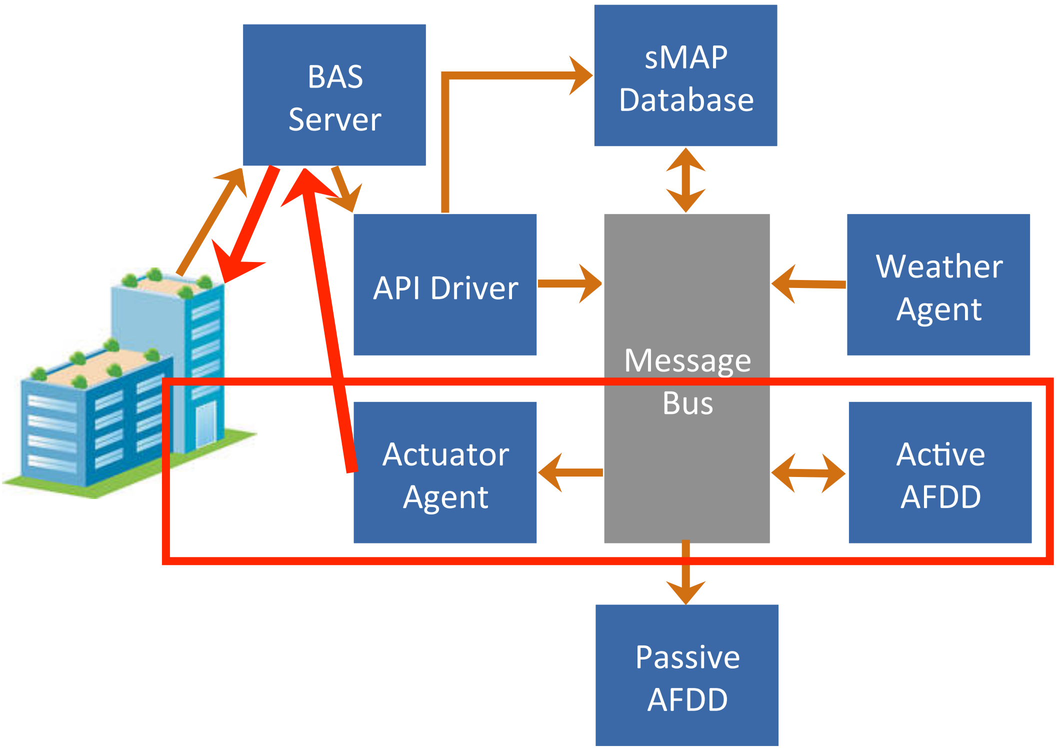


**Presently investigating this option…**

# Data Historian

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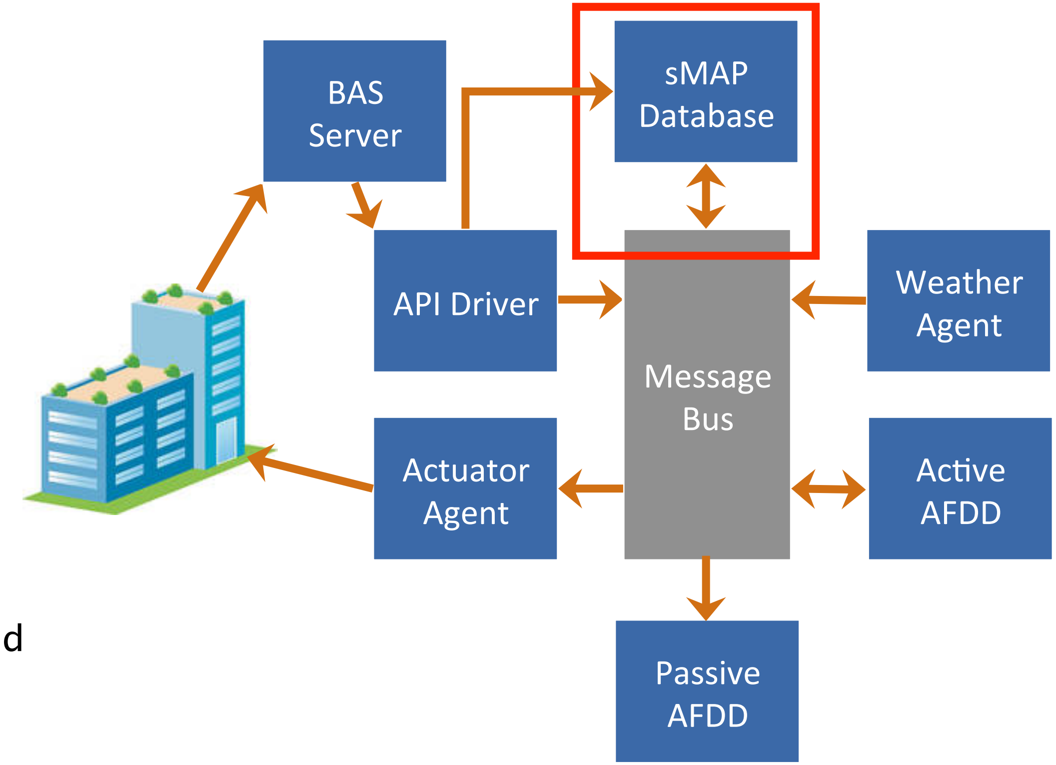
### sMAP Database

- Presently the only archiving option for Volttron
- Quick for time-series data
- Running on Ubuntu server
- Does not accept string data
- Easy configuration using publish
- Agents can access historical data through the message bus
- Stores results from AFDD agent
- Starting testing as part of a back-end for a web-based AFDD interface this summer

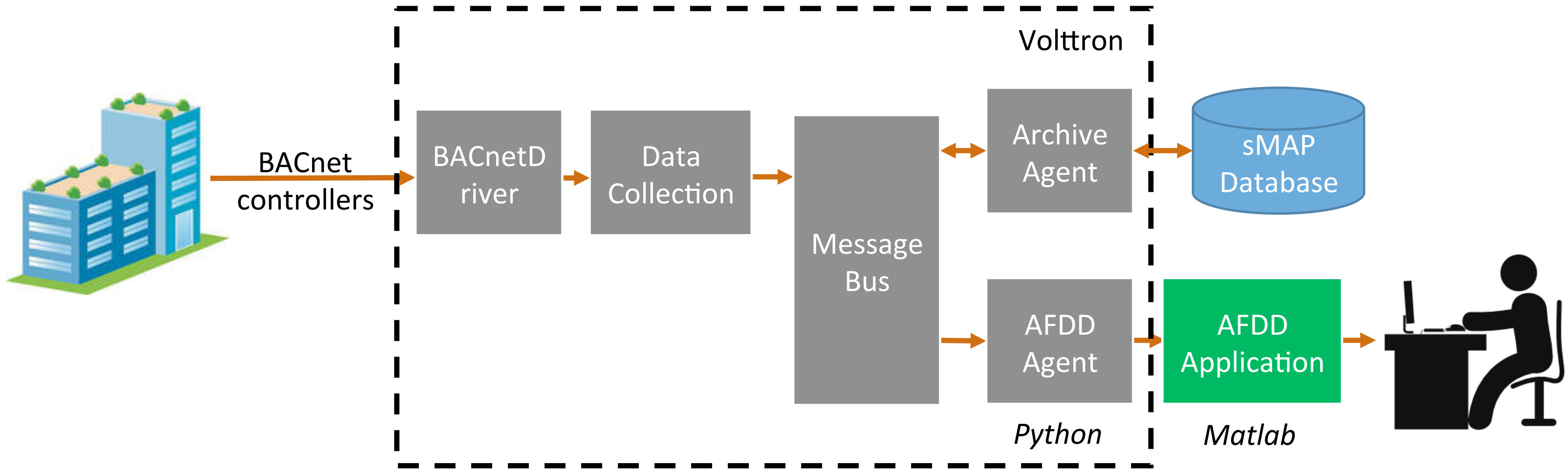



**Prior to Volttron being implemented, we had been storing building data on MySQL and "flat databases" optimized for our AFDD algorithm.**

# AFDD Configuration

## Implementation Alternatives (Passive vs. Active)

Initial implementation using a *cloud agent* design connected to a building




**Using Matlab for algorithm development speeds agent development and rapid prototyping/testing of algorithms.**

# AFDD Configuration

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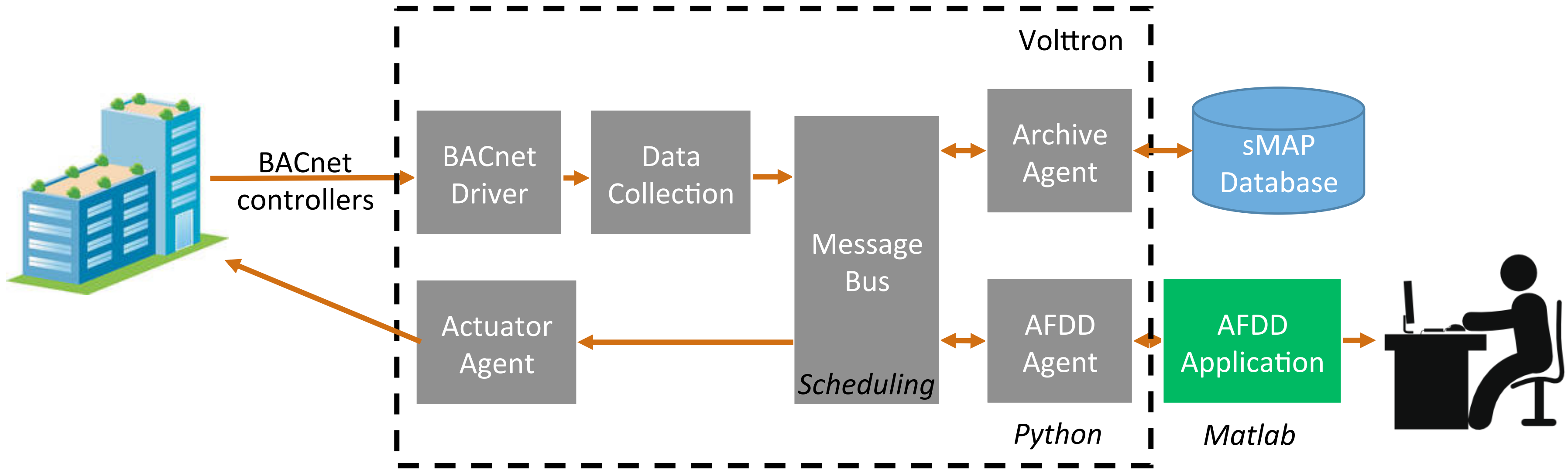
## Implementation Alternatives (Passive vs. Active)

Implementation using an *active agent* design connected to a building




**Using Matlab for algorithm development speeds agent development and rapid prototyping/testing of algorithms.**

# Why Volttron?

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## Decision to Develop a Volttron Agent

- Open-source
- Many platform services already developed and available
  - Database, archiving, drivers for data retrieval
- Integration with other “agents” via a single point of contact for device interface
- Security
- Implementation flexibility
  - Cloud-based application (API)
  - Local application (Volttron control agent for “active” diagnostics)

Allows us to generate a comprehensive solution in less time, and at a lower cost

# Implementation Process

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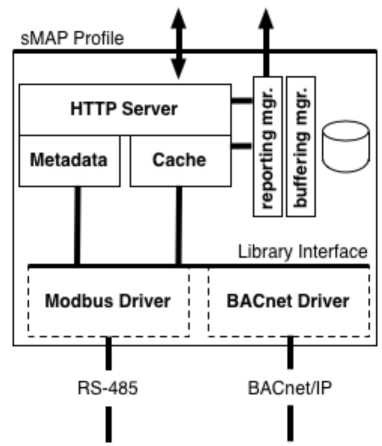
## Our Process

- Install sMAP server
- Add static building data to sMAP for testing
- Install & test Volttron
- Develop Volttron agent & test data passing
- Connect to Drexel buildings
  - BACnet driver
  - Custom driver

## Future Steps

- Continue AFDD demonstration
- Develop web-based AFDD interface
- Integrate active diagnostics
- Add more buildings to our demonstration



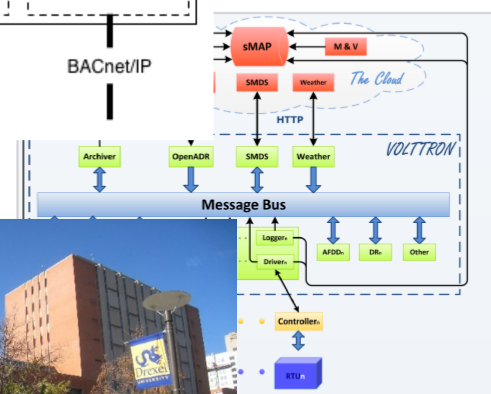




*Image sources: sMAP User Guide, Volttron User Guide, Drexel website*