Disclaimer

Fault Detection and Diagnosis in Higher Education

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Jared Parker, Michigan State University
Jessica Granderson, Lawrence Berkeley National Laboratory

BBA EMIS Project Team Meeting, April 15, 2016

Supported by DOE Building Technologies Office, A. Mitchell

Agenda

- Participant Introductions - Name, Organization
- EMIS Team Overview
- Presentation by Doug Litwiller, University of Iowa and Jared Parker, Michigan State University
- EMIS Team Next Steps

EMIS Project Team Overview

- Activity: adopt or expand use of EMIS in your organization
  - **Smart Energy Analytics Campaign – launches May 9th at Summit. Sign up as a Participant: www.smart-energy-analytics.org**
  - Peer learning, guest presentations
    - GSA EMIS demo
    - EMIS meets Lighting & Electrical
    - EMIS in the Healthcare/Hospital Sector
    - **FDD in the Higher Education Sector**
    - BBA member implementation best practices and lessons learned
- BBA-EMIS Team Site for meeting materials and existing resources
  - Synthesis of existing EMIS resources, "Cliff's Notes"
  - Hyperlinked regional guide to EMIS utility incentives
  - Vendor overviews and guest login access
  - EMIS procurement support materials – master spec and RFP, selection guidance
  - EMIS Primer

Energy Management and Information Systems (EMIS)

EMIS are a broad family of tools to monitor, analyze, and control building energy use and system performance

Whole Building Level EMIS

- Benchmarking and Monthly Utility Bill Analysis
- Energy Information System
- Advanced EIS

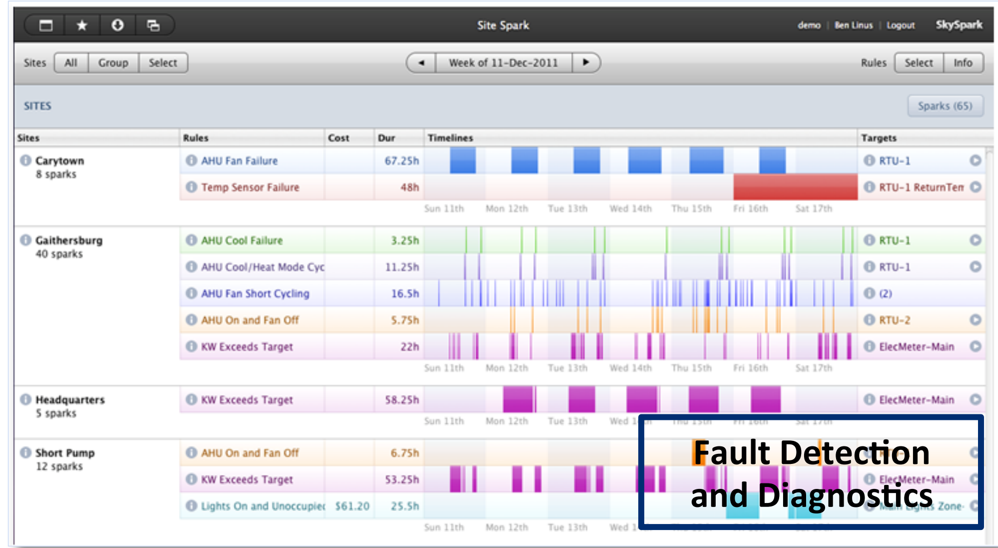
System Level EMIS

- Building Automation System
- Fault Detection and Diagnostics
- Automated System Optimization

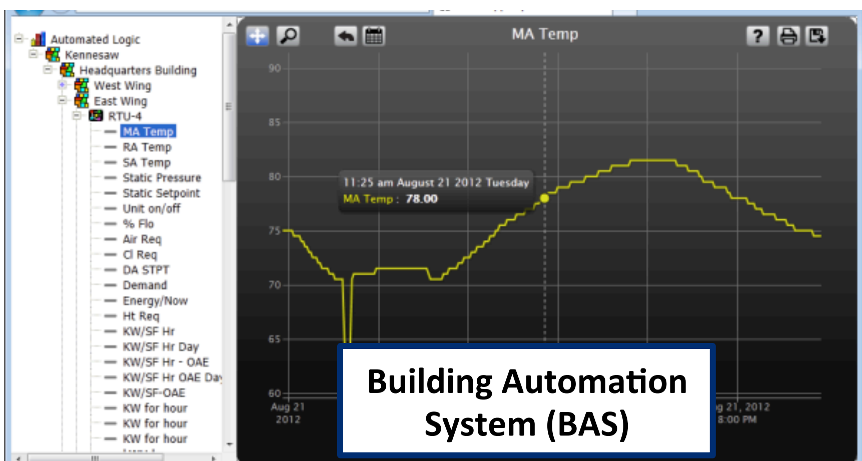
* The boundaries can be fuzzy; some tools cross categories, e.g., energy information systems with FDD and benchmarking capabilities

EMIS Examples

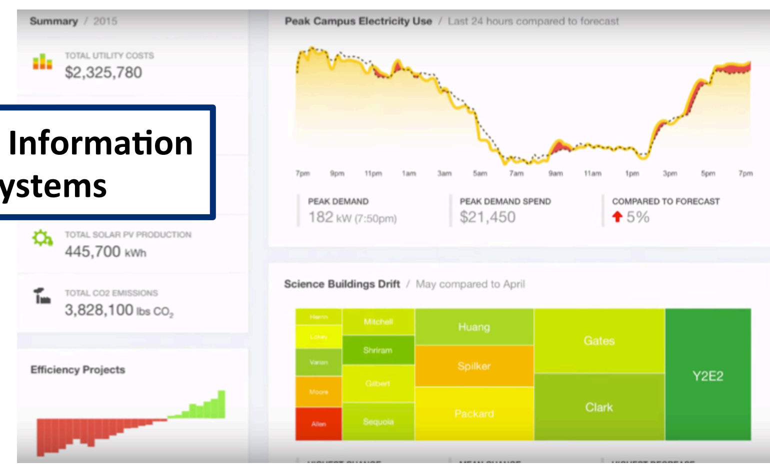
Benchmarking and Monthly Utility Bill Analysis



Fault Detection and Diagnostics



Building Automation System (BAS)



Energy Information Systems

Benchmarking: Performance Systems Development
BAS: Automated Logic

FDD: SkyFoundry
EIS: Lucid

EMIS in Higher Education Sector

- Diversity of building types – dormitory, classroom, laboratory, office, healthcare facility, garage
- Variable occupancy throughout day and year
- Mix of central plant, package units
- Campus-wide metering, not building metering
- Utility billing – multiple billing customers in same building, need for Recharges to tenants
- Availability of specially trained students in energy management, use of students in "living lab"

Implementing Fault Detection and Diagnostics in Higher Education

The University of Iowa FDD Journey

Doug Litwiller   Katie Rossmann   Tom Moore   Scott Sellner   Lou Galante   Bob Tandy

University of Iowa

April 15, 2016

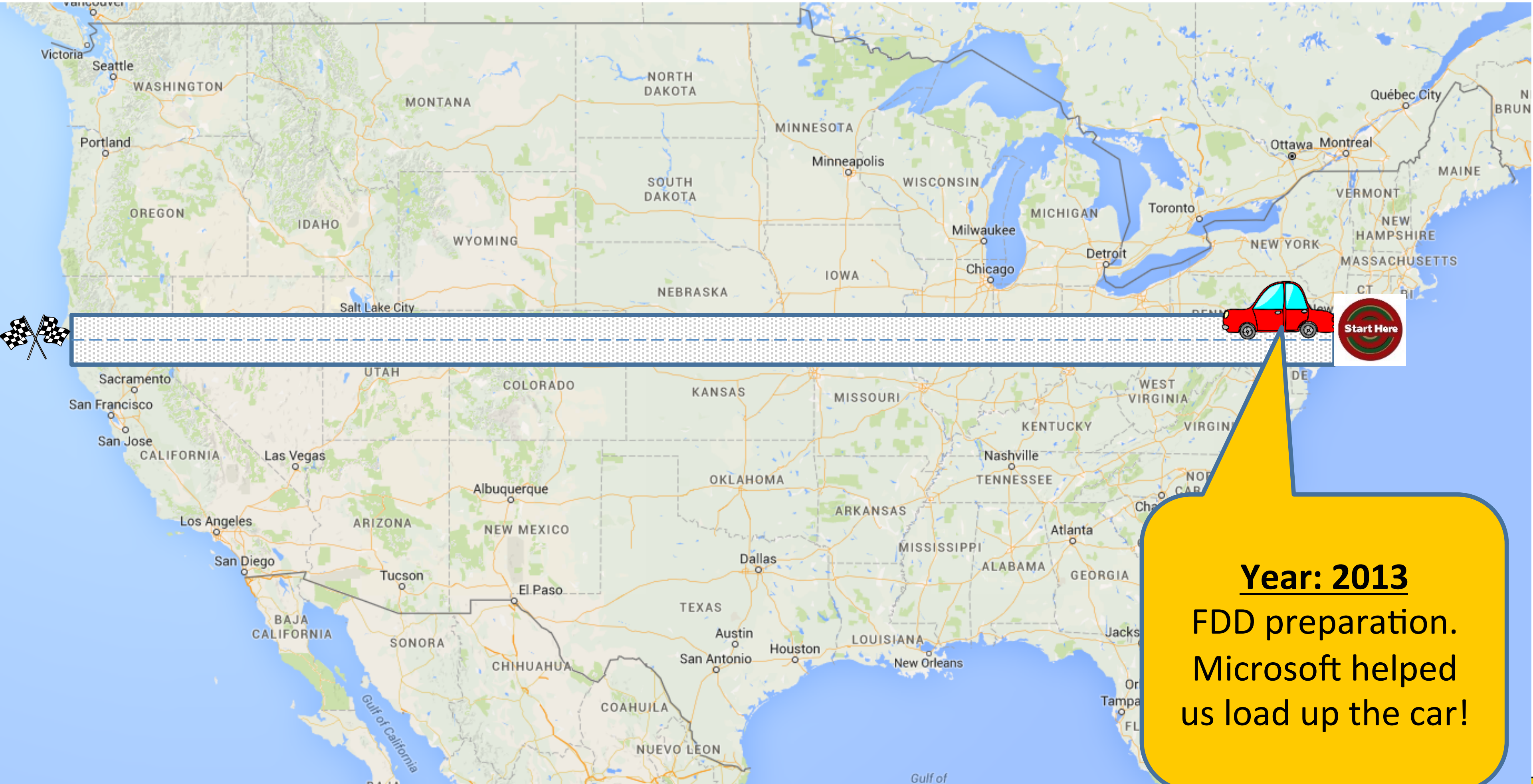
Facilities Management
The University of Iowa

Agenda

1. Introduction to the University of Iowa
2. The UI FDDA "Journey"
3. Next Steps
4. Questions

University of Iowa

330	Buildings
19M ft²	Building Square Footage
3.8M ft²	Hospital Square Footage
31,000	Students
23,000	Faculty and Staff
$30+M	Total Energy Spend
$431M	Research Funding
$1B	New Construction by 2016



Year: 2013

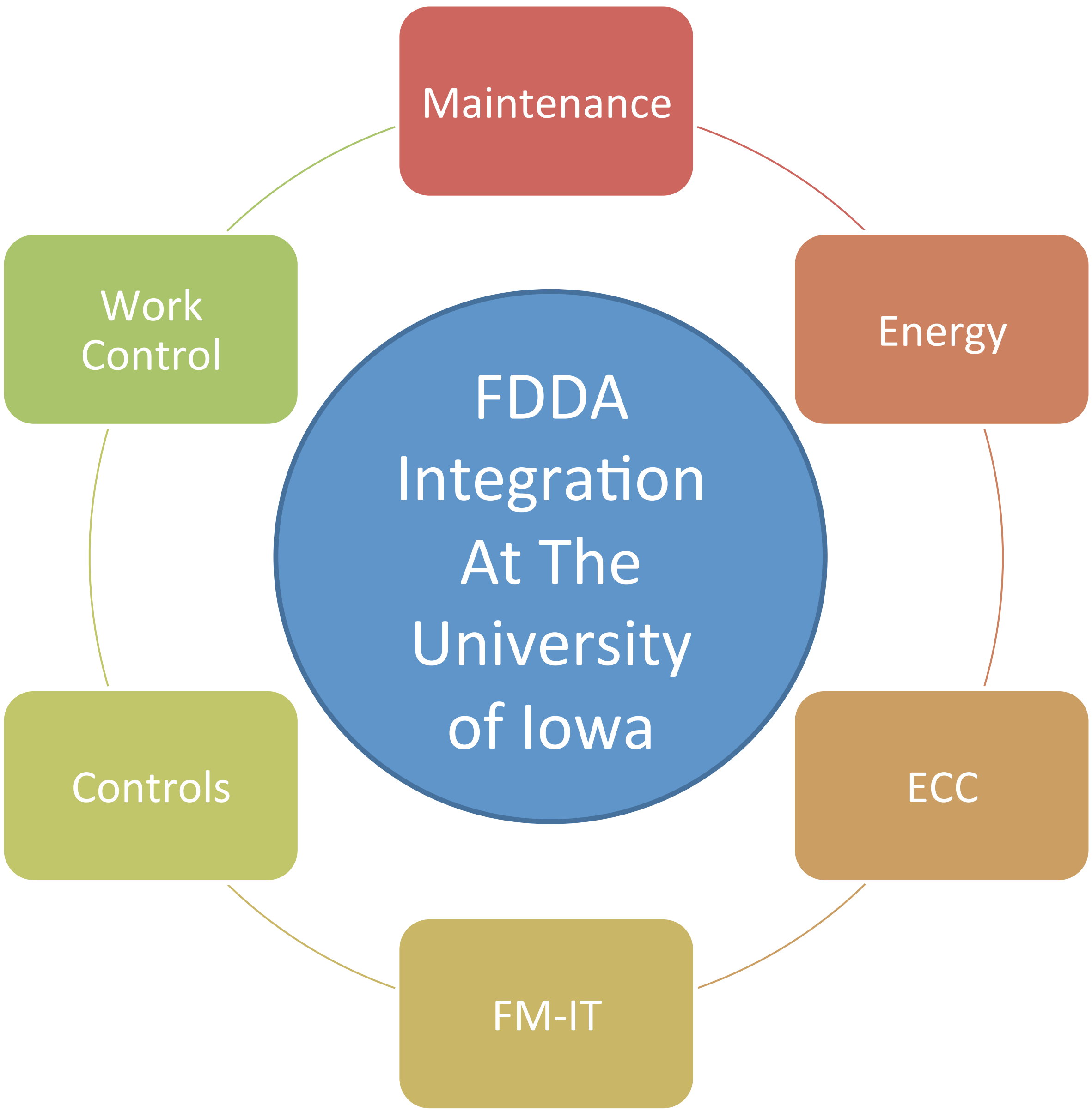
FDD preparation.

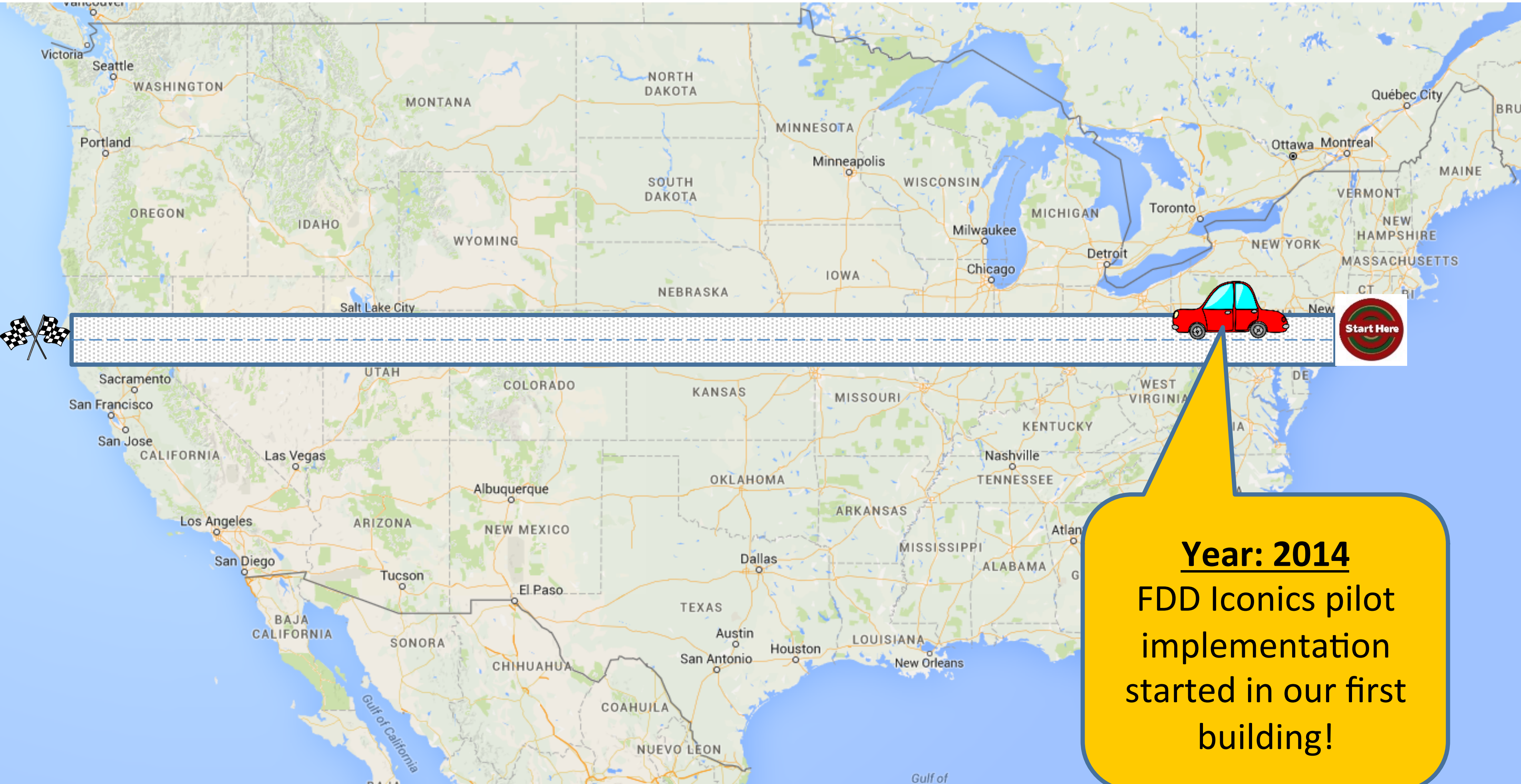
Microsoft helped us load up the car!

FDDA At The University of Iowa

Primary Drivers

1. Maintain occupant comfort
2. Identify equipment and system issues BEFORE the occupants do – be proactive!
3. Maintain peak building system performance – eliminate the "five year RCx" cycle
4. Reduce building maintenance costs
5. Reduce energy consumption
6. Prioritization and scheduling of work


Maintenance
Work
Control
Energy
FDDA
Integration
At The
University
of Iowa
Controls
ECC
FM-IT



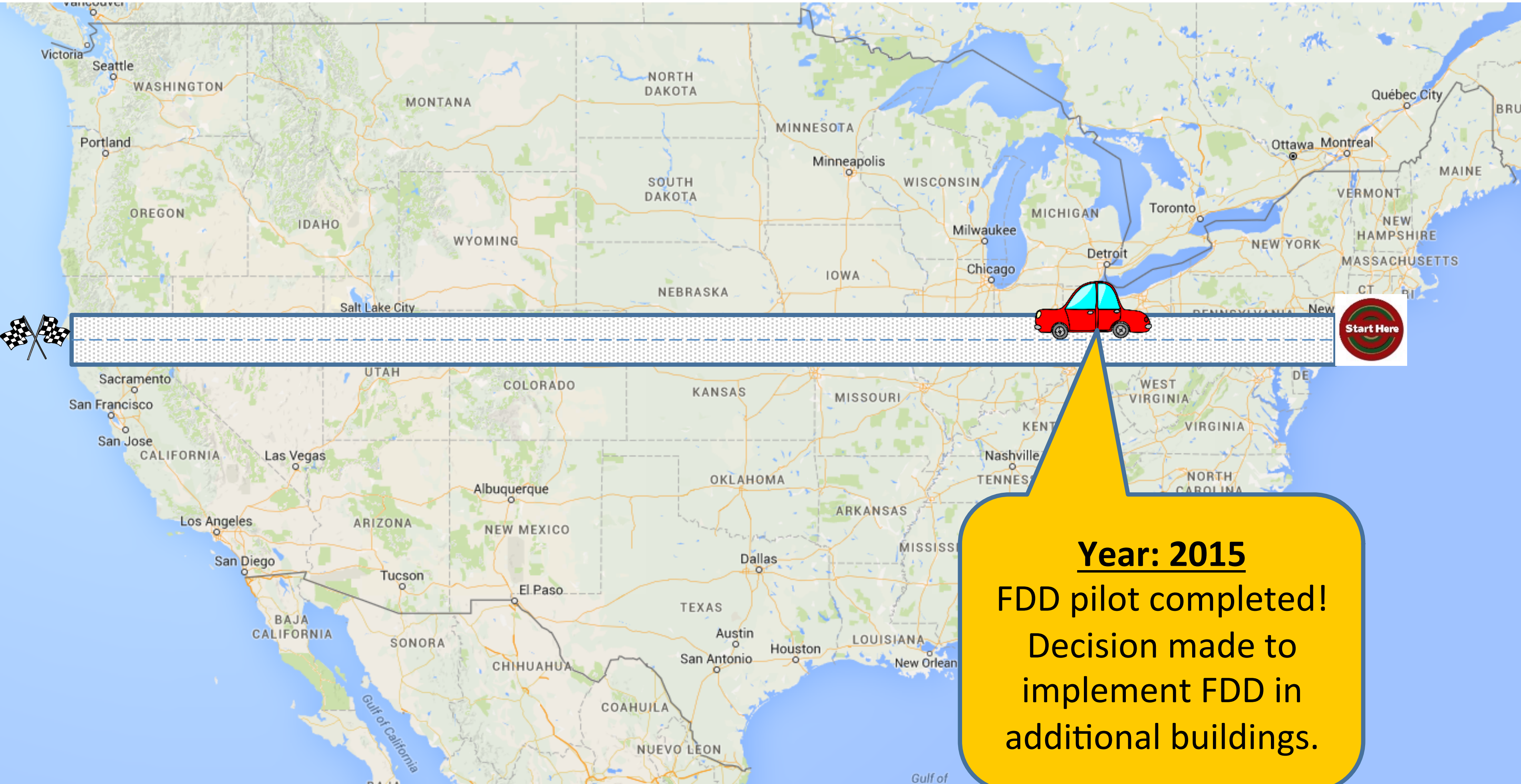
Year: 2014

FDD Iconics pilot implementation started in our first building!

Pappajohn Biomedical Discovery Building

Building Function
Lab building with cutting edge research in diabetes, deafness and brain science as well as complex diseases affecting the heart and lungs

Building Facts:
- Completion: 2014
- Square Feet: 256,000
- Project Cost: ~$130,000,000
- LEED Gold building
- Aircuity, Phoenix lab controls
- JCI BAS
- Submetering



<u>Year: 2015</u>

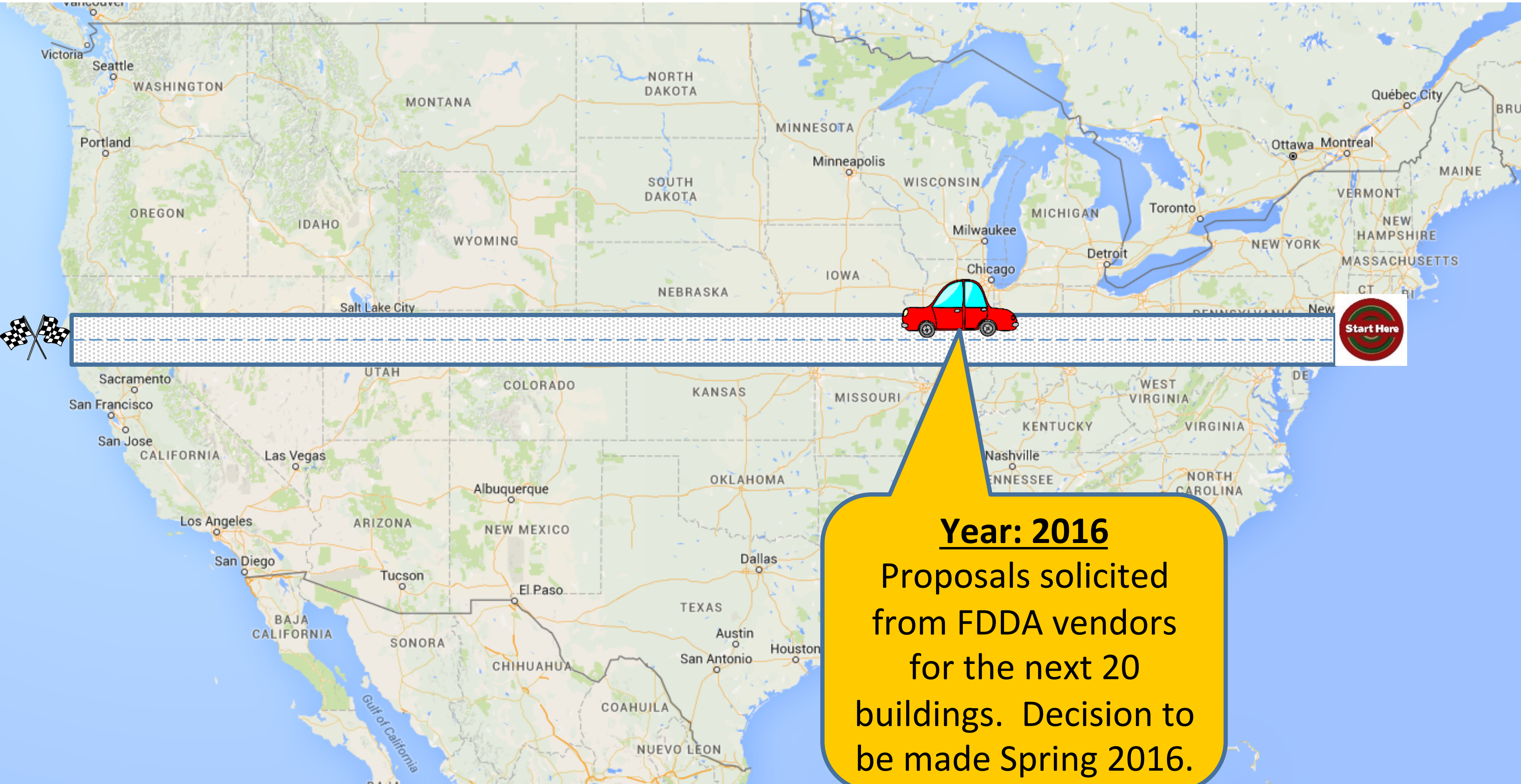
FDD pilot completed! Decision made to implement FDD in additional buildings.

Facilities Management
The University of Iowa

Pappajohn Biomedical Discovery Building FDDA Pilot

Lessons Learned & Best Practices

1. Training, Training, Training
2. Identify all major stakeholders and get buy-in
3. It’s not just an energy management tool
4. Minimize duplication of graphics
5. IT involvement is critical (security, data maintenance, installation hurdles, etc.)
6. Leverage the expertise and the resources of a “systems integrator”
7. Fine-tune the operational processes
8. Upper management champion



<u>Year: 2016</u>

Proposals solicited from FDDA vendors for the next 20 buildings. Decision to be made Spring 2016.

Facilities Management

The University of Iowa

Building Common Name	Type Code Description	Gross Area	Total Energy Cost	YearBuilt
Pappajohn Biomedical Discovery Building	Laboratory Intensive	257,511	$ 1,111,000	2014
College of Public Health Building	Administration/Office/Classroom	156,698	$ 334,000	2011
Carver Biomedical Research Building	Laboratory Intensive	136,442	$ 2,025,000	2005
Medical Education Research Facility	Laboratory Intensive	231,144	$ 2,225,000	2002
Chemistry Building	Laboratory Intensive	258,789	$ 1,841,000	1922
Dental Science Building	Mixed Laboratory	259,232	$ 1,502,000	1973
Medical Laboratories	Laboratory Intensive	228,171	$ 2,052,000	1927
Biology Building	Laboratory Intensive	115,206	$ 929,000	1905
Lindquist Center	Administration/Office/Classroom	174,101	$ 930,000	1972
Eckstein Medical Research Building	Laboratory Intensive	139,000	$ 942,000	1988
Medical Education Building	Administration/Office/Classroom	105,099	$ 525,000	1919
Campus Recreation and Wellness Center	Recreation center/Natatorium	258,199	$ 1,214,000	2010
Spence Labs	Mixed Laboratory	52,287	$ 378,000	1968
Biology Building East	Laboratory Intensive	62,347	$ 484,000	2000
Trowbridge Hall	Mixed Laboratory	60,471	$ 229,000	1916
Van Allen Hall	Mixed Laboratory	196,452	$ 472,000	1964
MacLean Hall	Administration/Office/Classroom	73,521	$ 227,000	1912
Blank Honors Center	Administration/Office/Classroom	61,793	$ 142,000	2003
Voxman Music building	Performance Hall/Practice Space/Classroom	189,289	$ 473,000	In Construction
Hancher Auditorium Replacement Facility	Auditorium	191,977	$ 473,000	In Construction

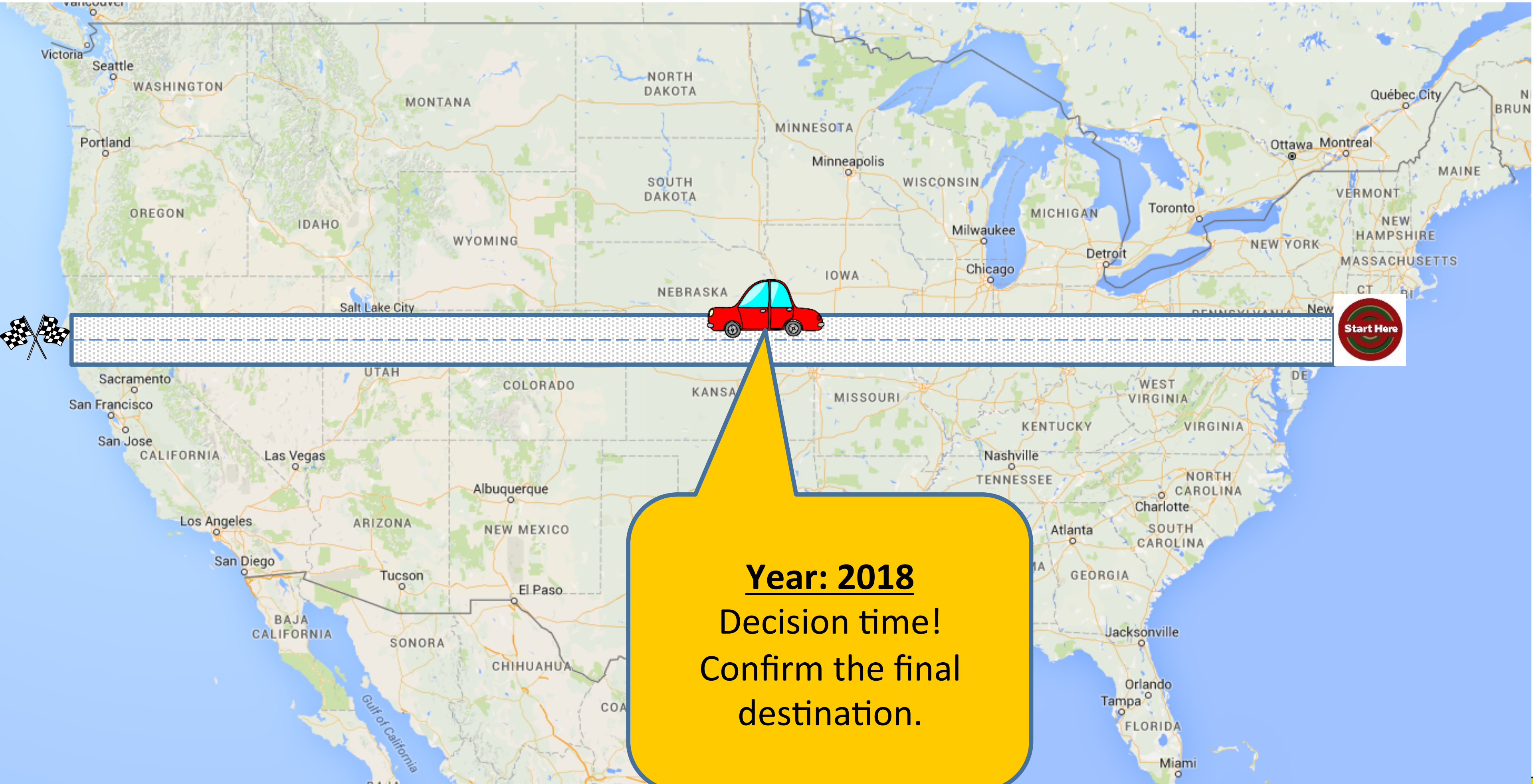
FDDA Request For Proposals

Primary Criteria

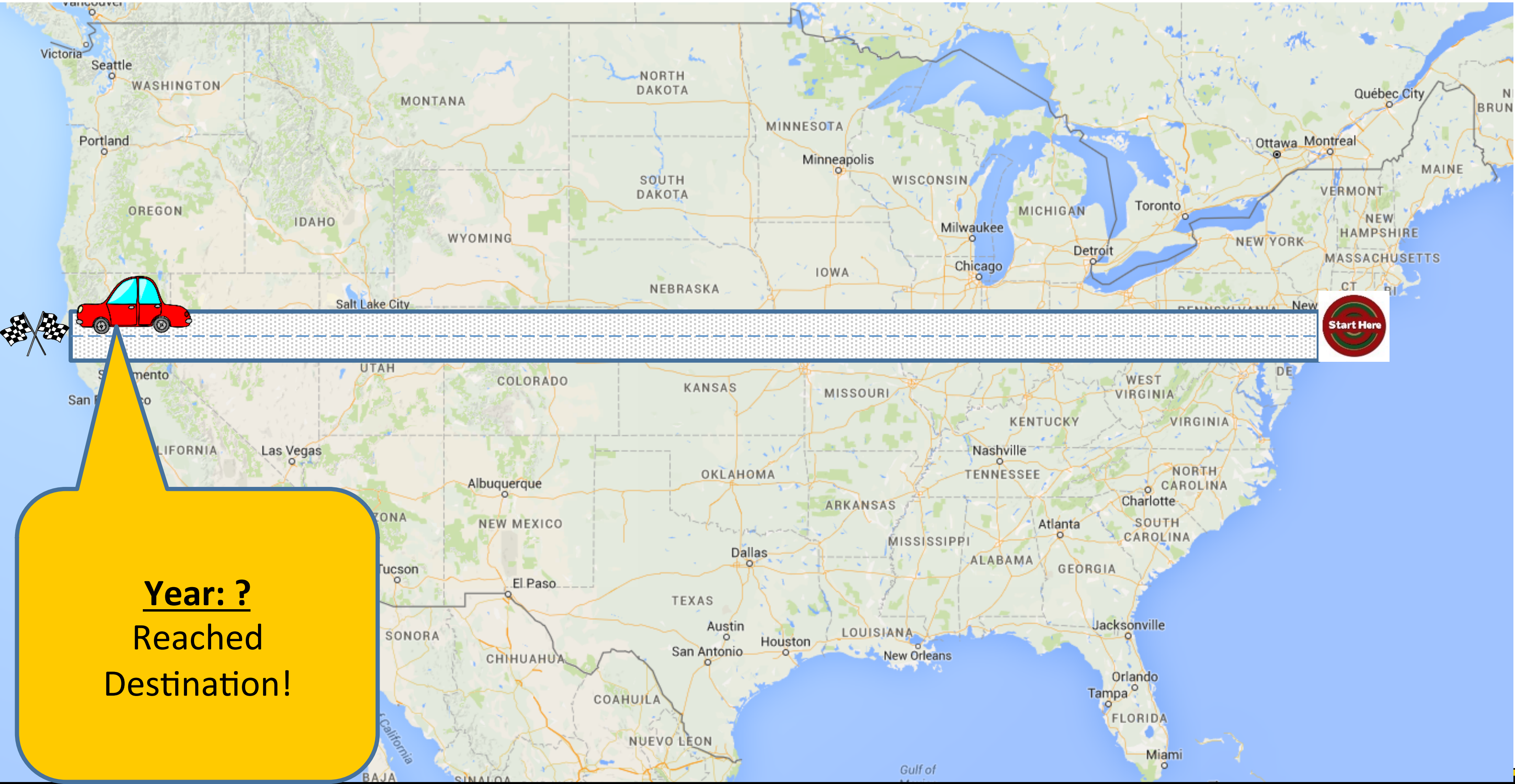
1. Experience
2. Customizable by the UI team
3. Integration with other UI systems (e.g. CMMS)
4. Not limited to HVAC systems
5. Ease of use – “Developers” and “Users”
6. Cost
7. Training
8. Analysis in-house

Year: 2017

Onboarding complete for the first 20 buildings.



Year: 2018
Decision time!
Confirm the final destination.
Start Here
Seattle
WASHINGTON
Victoria
Portland
OREGON
IDAHO
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
MINNESOTA
Minneapolis
WISCONSIN
IOWA
MICHIGAN
Milwaukee
Chicago
Detroit
Toronto
Ottawa
Montreal
Québec City
MAINE
VERMONT
NEW HAMPSHIRE
NEW YORK
MASSACHUSETTS
CT
Salt Lake City
UTAH
COLORADO
KANSA
MISSOURI
WEST VIRGINIA
VIRGINIA
KENTUCKY
Nashville
TENNESSEE
NORTH CAROLINA
Charlotte
SOUTH CAROLINA
Atlanta
GEORGIA
Jacksonville
Orlando
Tampa
FLORIDA
Miami
Sacramento
San Francisco
San Jose
CALIFORNIA
Las Vegas
Los Angeles
San Diego
ARIZONA
Tucson
Albuquerque
NEW MEXICO
El Paso
BAJA CALIFORNIA
SONORA
CHIHUAHUA
Gulf of California



Year: ?

Reached Destination!

Potential Next Steps

1. Complete onboarding of next twenty buildings
2. Include FDDA in the scope of new capital construction – leverage it as a commissioning tool.
3. Onboarding of all major General Education Fund (GEF) campus buildings
4. Onboarding of non-General Education Fund (GEF) campus buildings

Questions

Thank You!

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Michigan State University – Fault Detection Program

Pilot Structure, Status, Lessons Learned and Future Plans

April 15th, 2016

Jared Parker – Ongoing Commissioning Specialist,

Building Performance Services

Michigan State University AFDD Pilot – Structure and Reasoning (What did we want?)

From the Energy Analytics point of view:

- **Flexibility of calculations and the ability to automatically provide metrics important to various stakeholders on campus**
  - **Such as Pounds of steam, BTUs, kWh, Pounds of Co2, etc.**
  - **Changes in the consumption and demand on utilities relative to FDD,ECM,LC/NC and M&R items completion**
  - **Weather Normalization and other normalization tools to provide various levels of information to different audiences based on their roles/interests**

Michigan State University AFDD Pilot – Structure and Reasoning (What did we want?)

From the Building Management Software point of view:

- Avoid significant increases in traffic related to the Data collected (what we ended up referring to as "near real time"

- Provide Insight into the current sequences and identify problems that fall into 3 basic groups

  1. Bad Operation/Bad Sequences – IE poor outside air control; poor performing heating or cooling loops; Overridden equipment/setpoints/control loops, etc.

  2. Unexpected "normal" Operation – setpoints overridden that create operational issues or efficiency losses; schedules that do not fit the requirements of the equipment; un-needed warm up/cool down sequences; etc.

  3. Broken Things – Valves, dampers, sensor, sequences and etc.

Michigan State University AFDD Pilot – Structure and Reasoning (What did we want?)

From the Commissioning/Building Performance Point of view:

- Dynamic reporting of Faults including cost avoidance, return on investment and general “dashboard” flexibility.
- Visualization of energy data and a fault’s potential impact on building utilities – as well as visualization of:
  - Energy Conservation Measures (ECM)
  - Low Cost/No Cost Measures (LC/NC)
  - Maintenance and Repair items identified through commissioning
- Historical Data comparisons of various timeframes to identify if/when to revisit a building via commissioning, and to what extent

Michigan State University AFDD Pilot – Structure and Reasoning (Requirements vs Preferences)

Fault Detection Diagnostics Pilot – RFP Structure:

Requirements:

- Rules must be customizable by customer – unusual sequences require unusual parameters to tell the difference between "this is wrong" and "this is just how that system operates"
- Integration with our existing utility system – we did not want to connect directly to existing meters, but rather pull the data from the existing historian
  - Which lead to a high priority preference of Local data storage and user managed data storage
- Data Throttling – Real time/Near Real Time/Support for importing Trends

High Priority Preferences:

- Direct Integration to our GIS system
- Self Integration and Development (as much as possible)
- Mobile/Web client with favorable licensing structure
- Ability to provide "near real time" data acquisition rather than a "big data" approach.

Michigan State University AFDD Pilot – RFP Considerations/ Lessons Learned

One of the most important lessons we have taken away from the pilot is that we should have spent more time thinking about what problems we did and did not want to solve.

- **Clearly define the problem you want to solve – and as much as you are able how you want to solve it.**
  - **Who is going to manage it**
  - **Who is performing the development work**
    - **Graphics**
    - **Dashboards**
    - **Data Management**
  - **Who is responsible for IT and HVAC support**

Michigan State University AFDD Pilot – RFP Considerations/ Lessons Learned

- **Clearly define the problems you are NOT trying to solve – Identify what you have that works good and you want to/plan to keep – Sales presentations present a multitude of possibilities (workflow management, other types of analytical offerings, Building/System information Models, etc.…)**

- **When you have a good hammer, there are a lot of things that start to look like nails that you may already have perfectly serviceable tools to use for.**

An example for us would be GIS – while our solution software offers GIS integration, it is not a superior tool to the current GIS system we are using , rather, it is an excellent supplement to it – another venue to reach and interact with it, not a replacement.

Another would be direct workflow management – we use FAMIS as our workflow management, but it also does a lot of other things that we could not readily replace with the FDD solution's workflow management software – but integration with the system would be advantageous

Michigan State University AFDD Pilot – Execution

We Selected 5 buildings for the pilot of different eras, air handler and control types and different uses – to hopefully get a broad spectrum of the challenges particular buildings may present to us.

Building Name:	Type:	Size:	Description:
Erickson Hall	Office	219,248	Owner's initial EB Cx building, primarily office. Built in 1957 Primarily mixed air office AHU systems (Siemens)
Food Safety and Toxicology	Research Lab/Classroom Lab	115,132	Primarily Lab Building, EB Cx Building. Built in 1997 Primarily full outside air and exhaust fan systems (Siemens, Phoenix and Aircuity)
Food Science	Research Lab/Classroom Lab	120,101	Primarily Lab Building, EB Cx Building. Built in 1966 Primarily full outside air and exhaust fan systems (Siemens and Phoenix)
Molecular Plant Science Add.	Research Lab/Classroom Lab	89,682	Primarily Lab Building, NC Cx Building. Built in 2012 Primarily Outside air and exhaust systems (with fan walls and multi floor pressurization) (Siemens and Aircuity)
Eli and Edythe Broad Art Mus.	Art Museum	46,236	Art Museum, NC Cx Building. Built in 2012 Environmentally critical Air Handler (Delta and Aircuity)

Michigan State University AFDD Pilot – Choices made During Development (1)

The biggest choice that we made during development involved creating a standard for how we were going to name everything – the vendor that we selected allowed for bulk templates to be created for equipment types.

These bulk templates would allow for quick deployment of an equipment class across many buildings and control systems, but also needed specific inputs which the native names of might differ from building to building – so defining exactly what a name means was important to us.

For instance, I may have systems that have a point called “heating coil control”

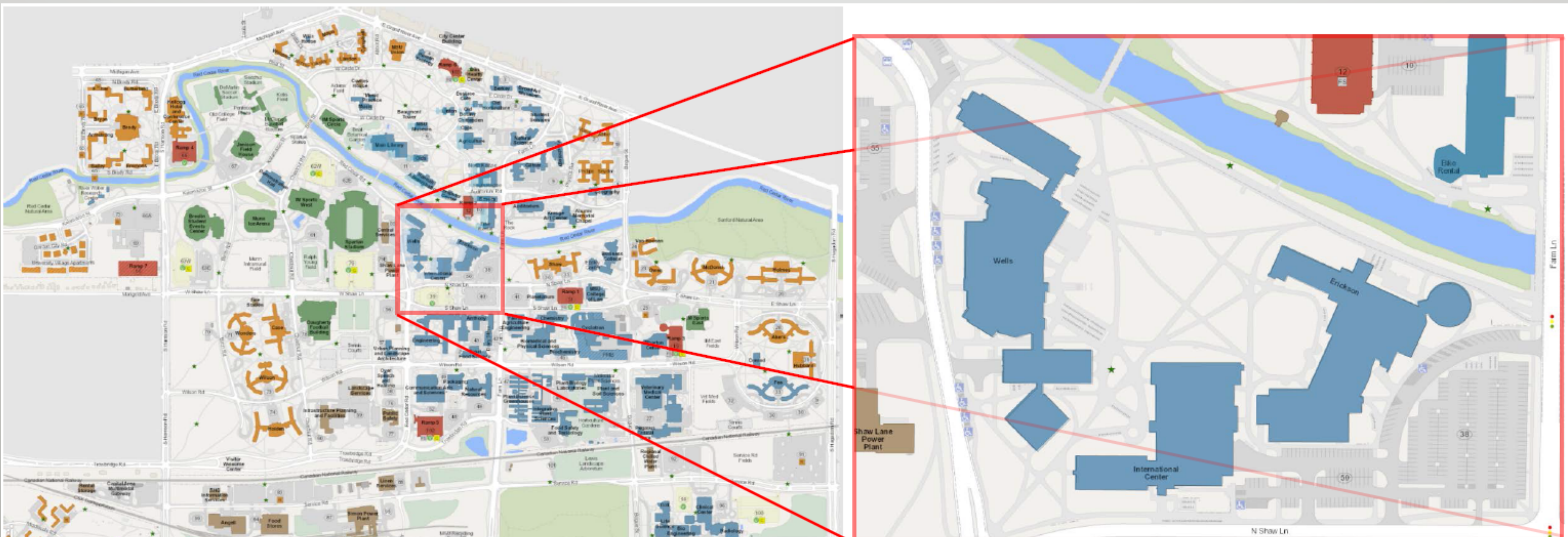
- on one system, this is a control loop for the heating coil valve to maintain a heating coil discharge temperature.
- Another system, the same point is used as a lower temperature control to have a minimum temperature.

When taken as single names, both could make sense, but when structuring a fault, one will trigger at a completely different time than the other.

Michigan State University AFDD Pilot – Where we are now

We are at the point now where we are finishing our first pilot building and have begin 2 other pilot buildings and also adding a new construction to the overall system.

In general, the goal is to have a campus map that users can search or navigate to points of interest and then be able to drill down for different views:



Example from the pilot (*Finally! Pictures*!)

MSU AFDD – Where we are now (Dashboards)

Navigation Buttons

Energy View

Fault View

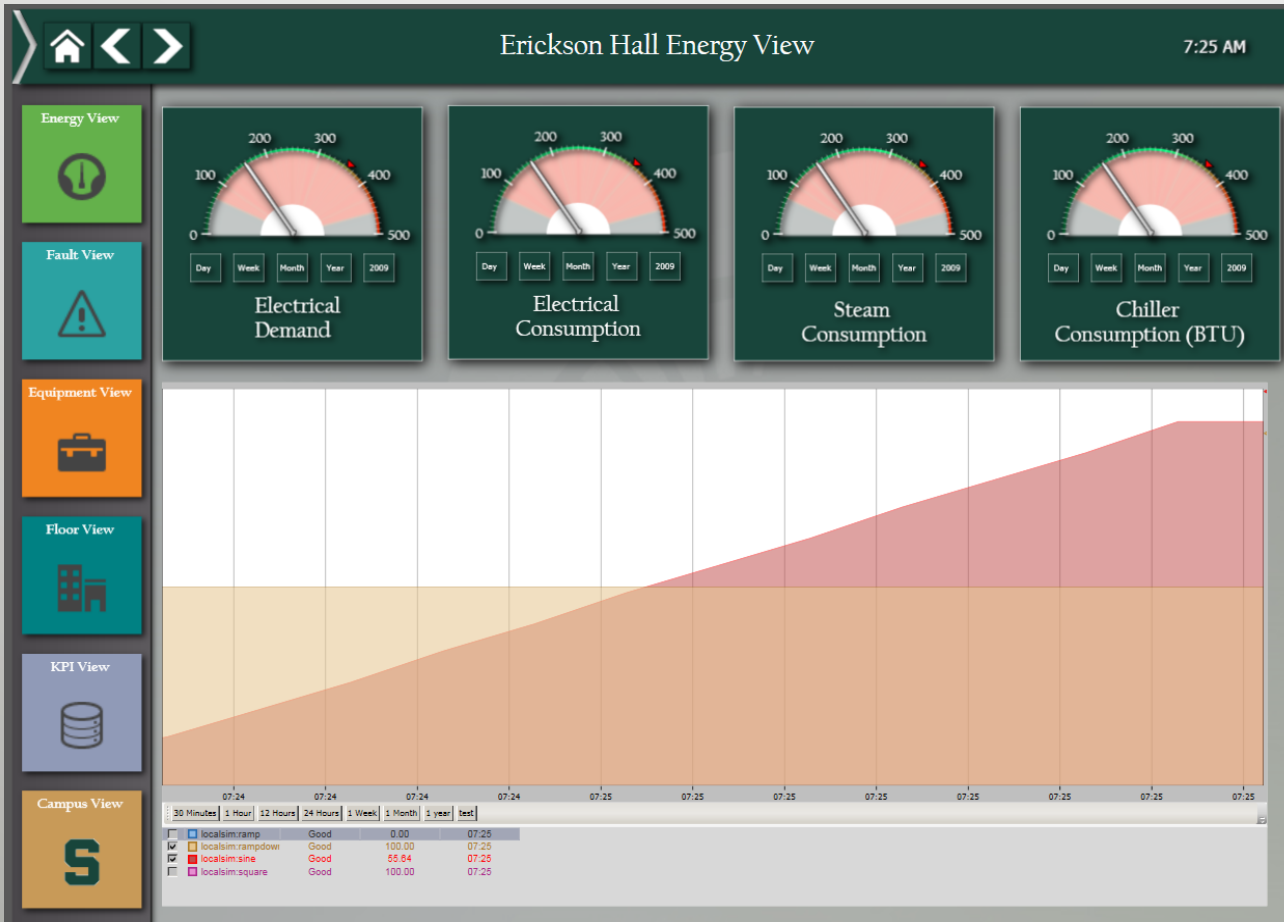
Equipment View

Floor View

KPI View

Campus View (back to the map)

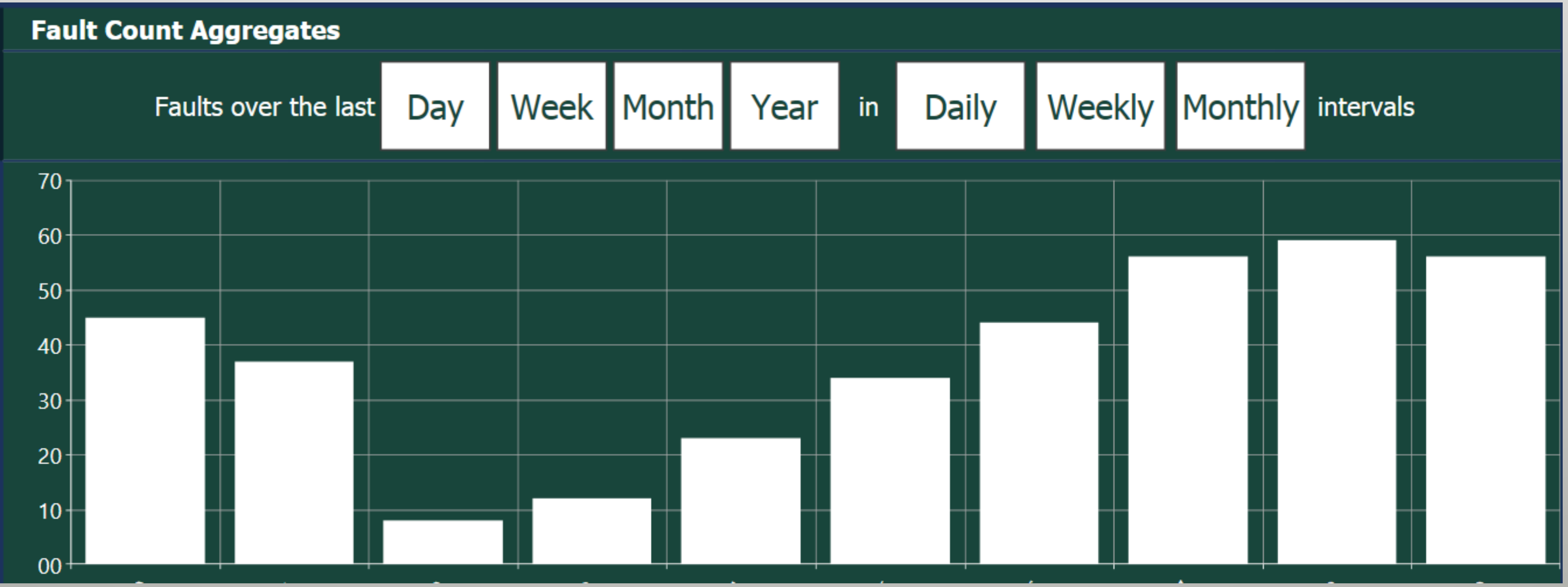
MSU AFDD – Where we are now (Dashboards)



Close up of the “Energy Widget™”

MSU AFDD – Where we are now (Dashboards)

Fault KPI View



Fault Trend View

MSU AFDD – Where we are now (Dashboards)

MICHIGAN STATE UNIVERSITY

Current Faults 0 Active 0 Active-Ack | Daily Fault Index -1578 % | Avg Fault Duration (Month) 2 Hours | Resolved Faults (Month) 3411 Faults

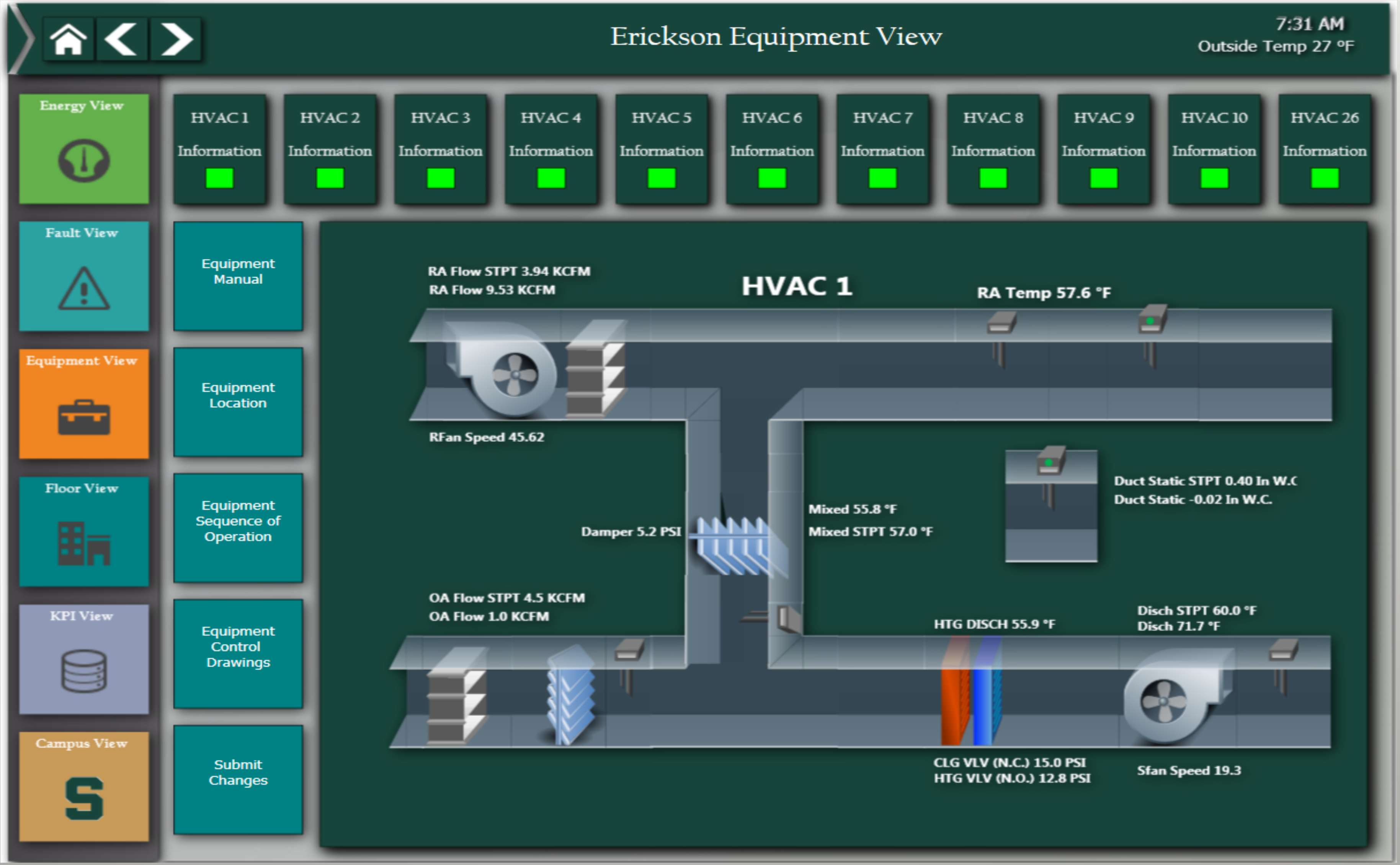
2/16/2016 7:27 AM

Drag a column header and drop it here to group by that column

Building	EquipmentType	EquipmentName	Fault Name	Fault Active Time
ERICKSONHALL	AHU	HVAC10	Regular Operation Not Economizing when it should	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Leaking Heating valve	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Outside Air Flow Mismatch	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Return Air Flow Mismatch	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Supply Air Flow Mismatch	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC5	Regular Operation Not Economizing when it should	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC6	Regular Operation Leaking Heating valve	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC6	Regular Operation Not Economizing when it should	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC7	Regular Operation Not Economizing when it should	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC8	Regular Operation Not Economizing when it should	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC9	Regular Operation Leaking Heating valve	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC9	Regular Operation Supply Air Flow Mismatch	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC9	Regular Operation Not Economizing when it should	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Not Economizing when it should	2/16/2016 7:26:46 AM
ERICKSONHALL	AHU	HVAC7	Regular Operation Reported Air Flow Invalid	2/16/2016 7:10:11 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Supply Fan VFD not meeting Command	2/16/2016 7:01:34 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Outside Air Flow Mismatch	2/16/2016 6:58:49 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Return Air Flow Mismatch	2/16/2016 6:54:50 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Supply Air Flow Mismatch	2/16/2016 6:54:50 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Leaking Heating valve	2/16/2016 6:48:45 AM
ERICKSONHALL	AHU	HVAC8	Regular Operation Reported Air Flow Invalid	2/16/2016 6:46:47 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Not Economizing when it should	2/16/2016 6:45:34 AM
ERICKSONHALL	AHU	HVAC2	Regular Operation Reported Air Flow Invalid	2/16/2016 6:45:34 AM
ERICKSONHALL	AHU	HVAC10	Regular Operation Not Economizing when it should	2/16/2016 6:45:23 AM
ERICKSONHALL	AHU	HVAC10	Regular Operation Reported Air Flow Invalid	2/16/2016 6:45:23 AM
ERICKSONHALL	AHU	HVAC6	Regular Operation Reported Air Flow Invalid	2/16/2016 6:44:59 AM
ERICKSONHALL	AHU	HVAC6	Regular Operation Supply Fan VFD not meeting Command	2/16/2016 6:41:44 AM

2/9/2016 7:27:10 AM - 2/16/2016 7:27:10 AM

MSU AFDD – Where we are now (Dashboards)



Equipment View

Michigan State University AFDD Pilot – Lessons Learned

I think the biggest lesson learned for us (*and I feel like I can not stress this enough*)

- **Make sure that you fully understand the responsibilities of the vendor, the integrator and yourself.**
- **If you are going to invest in a program, make sure that you are prepared to spend what is needed to make it successful – this is not the initial cost, but addressing faults.**
- **Know your scope – identify exactly what level of depth you want, if you aren't sure, make sure that the solution you pick can be expanded in stages, you may even want a price lock.**
    - **"Mile wide, Inch deep look or an Inch wide, Mile deep look?"**
- **Be Ready to clean up your control system – we found a lot of inconsistencies in point names within a single controls vendor, and naming between vendors and generations of systems can make things very confusing.**

Michigan State University AFDD Pilot – The Future (what now short term)

One of the biggest questions that we have is “what now?”

There are many things that we can do with what we have selected – and honestly this comes right back to the discussion of what problems are we NOT trying to solve … that is to say, we are trying to reconcile what tools we have, what they are best at, and where they fall short.

Some of the things that we know we want to accomplish with our FDD solution are –

- **Campus wide FDD deployment (where DDC is sufficient for it to make sense) this would include 3 stages of deployment**

    1. **Basic FDD – “inch deep, mile wide” faults common to all units – “is it supposed to be on”; “is it supposed to be heating/cooling/economizing”; “is it overcooling/overheating”; etc.**

    2. **Basic Dash-boarding (concurrent to FDD *ideally*) – Show FDD statistics, show utility information, show BMS/FIS information, etc.**

    3. **Advanced FDD/Dash-Boarding – (we honestly don’t know specifically what this will look like)**

Michigan State University AFDD Pilot – The Future (The Long View)

Our "Ideal Long View" would involve a much larger scale deployment of FDD with a dashboard/workflow management system that allows the following flow:

1. **The FDD system detects a problem**

2. **That problem will be assigned a priority and classification and based on the priority and classification it will be forwarded on to a technician, controls operator or commissioning manager for addressing or further investigation as needed by "the system" creating a work order with all of the appropriate details and contact information in it from our GIS/FIS systems**

3. **Technician/Operator accesses the work order, drawings, manuals, etc. via mobile "any glass" platform and diagnoses and repairs/replaces/passes on issue (this mobile platform will also track status, allow for ordering parts and equipment and allow technicians/operators to enter time to a work order**

4. **Due to the Workflow tracking we produce equipment health and building health KPI's etc.**

5. **Lather, Rinse and Repeat as required.**

Discussion

Next Steps

- Registration now open for BBA Summit
  - http://betterbuildingssolutioncenter.energy.gov/summit
  - EMIS Summit session “From Numbers to Action: Using EMIS to Detect Problems and Fix Them” scheduled for May 10th, 2:00-3:15pm ET
- Visit Ask-An-Expert at BBA Summit
  - Jessica Granderson available to answer questions at Summit
  - Tuesday May 10th, 4:30-5:30pm and Wed May 11th, 10:30-11:30am
- Join the Campaign – “Soft” launch at Summit
- Next EMIS team meeting
  - Summer 2016

BBA EMIS Team Resources

Resources	Description
EMIS framework and crash course	Introduction of EMIS family of tools
Energy information handbook	How to analyze meter data and identify energy-saving opportunities
EIS business case	Costs and benefits of energy information system
EMIS utility incentives guide	EMIS utility incentives and financing programs across the US
EMIS specification and procurement support	RFP template, technology specification (minimum functionality is highlighted), RFP evaluation criteria
Primer on organizational use of EMIS	How to plan, implement, and use EMIS

eere.energy.gov/betterbuildingsalliance/EMIS

THANK YOU

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