


**Creating Smart Buildings with
Fault Detection and Diagnostics**

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Course Description

Discover how Big Data is finding its way into the facilities management profession and how our industry is increasingly positioning itself to harness and leverage the explosion of data collection and processing. At the center of this facilities-related Big Data revolution is the deployment of Fault Detection and Diagnostics or FDD. FDD holds the promise of moving our profession from a reactive service model to more of a predictive service model. Learn how employing a monitoring-based commissioning model, built on data analytics, holds the promise of providing more efficient building operations, retaining energy conservation gains, and lowering the risks to business continuity by using a predictive maintenance approach.

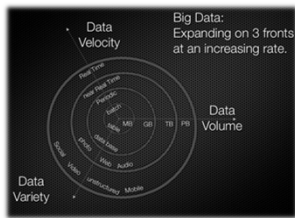
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Learning Objectives

- Define what we mean when we say "Big Data" in Facilities Management
- Discuss the Benefits of Leveraging Big Data
- Define Fault Detection and Diagnostics and how this technology leverages investing over spending
- Case Study: University of Iowa's Fault Detection and Diagnostics Program
- How to get started on your campus and measure success
- Questions and Answers

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Big Data in Facilities Management



<https://www.data-science-central.com/forum/topics/the-3vs-that-define-big-data>

The Three V's

Volume Data is generated by occupants, building operators, devices, sensors, etc. This makes it harder to put this data to action.

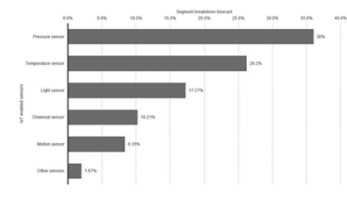
Variety Facilities data comes in the form of GIS location data, database and photo capabilities. Early adopters may be utilizing audio, video or social media input.

Velocity The delay between data generation, analysis and results is shrinking.

The explosion of data in buildings is driving us to make more data-based decisions and incorporate this information into our daily operations.

Big Data in Facilities Management

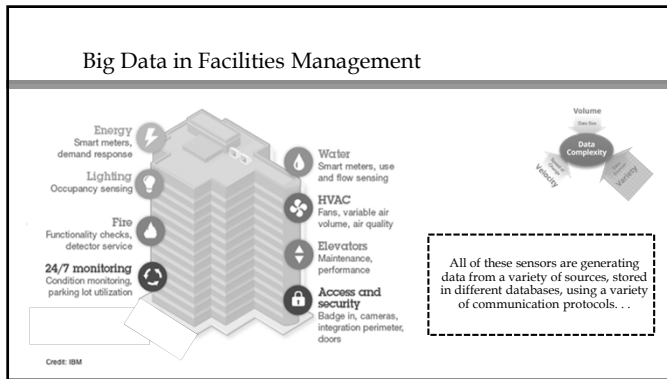
Global IoT-enabled sensors market (valued in \$ segment 2022)
Projected global Internet of Things enabled sensors market in 2022, by segment

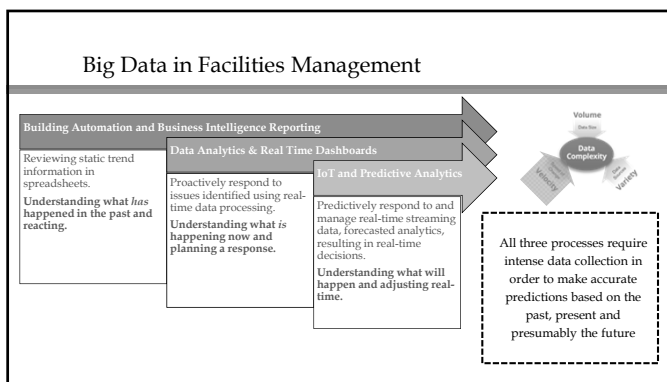


By 2022, Pressure and Temperature sensors will account for 62% of globally enabled IoT sensors.

statista

Source: Statista, Projected global Internet of Things enabled sensors market in 2022, by segment



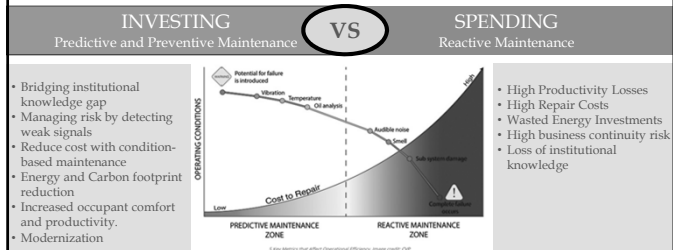




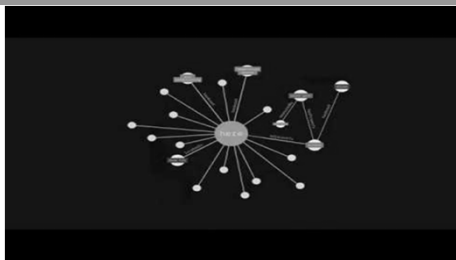
"If the rate of change outside your organization is greater than the rate of change inside your organization, the end is in sight."

Jack Welch - former CEO of General Electric

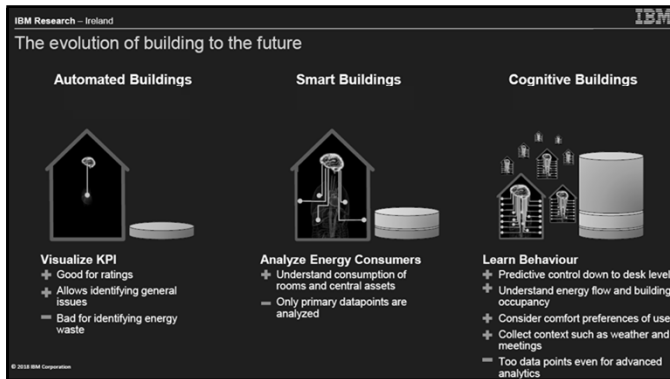
Benefits of Leveraging Big Data



Smart Building Enabled Operation



IBM Knowledge Graph for IoT: <https://www.youtube.com/watch?v=ebBTdH62yLg&feature=youtu.be>



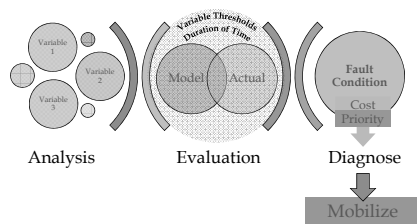
Fault Detection and Diagnostics

What is it?

A software **TOOL** used to **PROACTIVELY** discover building system problems and identify optimization opportunities **BEFORE** they lead to alarms, excessive waste of resources, occupant discomfort or system failure.

Not QUITE there on a scalable solution to Building IoT using machine learning...but it's coming and FDD gets us close

Fault Detection and Diagnostics



What is a fault?

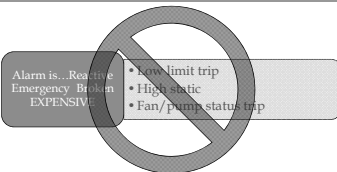
Validates System Performance vs Design Intent	<ul style="list-style-type: none"> Stuck cooling coil valve Supply temp higher/lower than setpoint Insufficient economizer
Identifies Opportunities for Efficient Operation	<ul style="list-style-type: none"> No night setback Low loop temp difference Unused free heating available
Points Out Potential for Future Catastrophic Failure	<ul style="list-style-type: none"> Valve short cycling Low mixed air temp Room air temp below min
Pinpoints Occupant Comfort Issues	<ul style="list-style-type: none"> Room air temp higher/lower than setpoint Zone occupied, AHU off
Detects Sensor Calibration & Controls Abnormalities	<ul style="list-style-type: none"> Flat sensor error Occupancy sensor on longer than expected Fan status mismatch



Prioritized Response

Planned, Scheduled,
Routine work

An Alarm is not a Fault



Why Fault Detection and Diagnostics?

"The Good Ol' Days"

- ✓ Three modes of operation
- ✓ Limited data points
- ➔ More room for intuition and institutional knowledge

2005

1. Termination of the system shall be initiated by the operator. The system shall be placed in a safe state and the operator shall be notified. The system shall be placed in a safe state and the operator shall be notified. The system shall be placed in a safe state and the operator shall be notified.

Why FDD?

2017

Room Control Operation Parameters for L3 Veeman Music Building

Today...

- ✓ More modes of operation
- ✓ More data points
- ✓ More “weak signals”
- ➔ Less room for intuition and institutional knowledge

Source: “The Intuition about how a machine is operating on a factory floor used to come from working there thirty years and being able to detect a slightly different sound signature emanating from the machine, telling us something is not exactly right. That is a weak signal. Now with sensors, a new employee can detect a weak signal on the first day of work – without any intuition.”

Thank You for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations
Thomas L. Friedman

Weak Signals

“The intuition about how a machine is operating on a factory floor used to come from working there **thirty years** and being able to detect a slightly different sound signature emanating from the machine, telling us something is not exactly right. That is a weak signal. Now with sensors, a **new employee** can detect a weak signal on the first day of work – without any intuition.”

Thank You for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations
Thomas L. Friedman

UI Facilities Management FDD Program

Improving Building Maintenance Practices with Data Analytics



“Experienced workers knew how to process **weak data**. But now with big data, with a much finer grain of fidelity we can make **finding a needle in the haystack the norm - not the exception**. And we can augment the human worker with machines so they **work as colleagues** and enable them to process weak signals together and overnight become like a thirty year veteran.”

Thank You for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations
Thomas L. Friedman

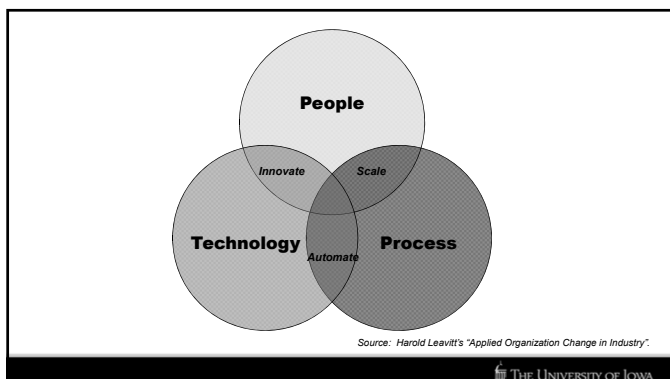


FDD at the University of Iowa

Key Tenants

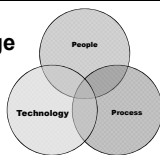
- ✓ Important that we leverage our internal expertise to prioritize and perform the majority of the work.
- ✓ Important that we use existing data infrastructure, mostly through our Building Automation Systems or OSISoft Pi.
- ✓ Always want to be good stewards of University money and resources.
- ✓ Must compliment overall FM goal to be more efficient with our work and support proactive and predictive maintenance.

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Technology helps us adapt to the rate of change

- ✓ 49 Buildings
 - Academic, Lab, Office, Recreational, etc.
- ✓ Over 87,000 Points, 9700 Analyses applied
 - Schneider Electric Building Analytics FDD Software
 - 5 min interval collection
- ✓ All Major HVAC Equipment (11,900 pieces of equipment)
 - AHUs, HW/CHW Systems, Pumps, VAVs
- ✓ 3 Building Automation Systems
 - Andover Continuum, Schneider StruxtureWare, JCI Metasys
- ✓ Onboarding planned for new construction
 - Laying the groundwork for onboarding Pharmacy and PBSB upon construction completion



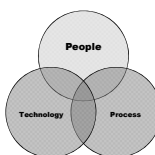
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People help to scale and innovate

Analytic Response Group



Multidisciplinary team
Meets 4 mornings per week
Prioritizes, plans & coordinates response



First Responders

- Experienced HVAC technicians
- Interact with tool full time
- Field troubleshooting and part person for maintenance team

2 FTE



Controls Support

- Experienced controls programmers (1 part person)
- Assist with analytics issues & troubleshooting, adjust programming as needed

1 FTE



Analytics

- B.S. Managers
- Technical support for FDD
- Review metrics and report successes

As Needed



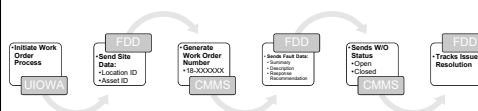
Priority and Planning

- B.S. Managers
- Prioritize and plan ARG activities
- Coordinate and plan FDD projects

As Needed

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Process integrates with technology to help us automate



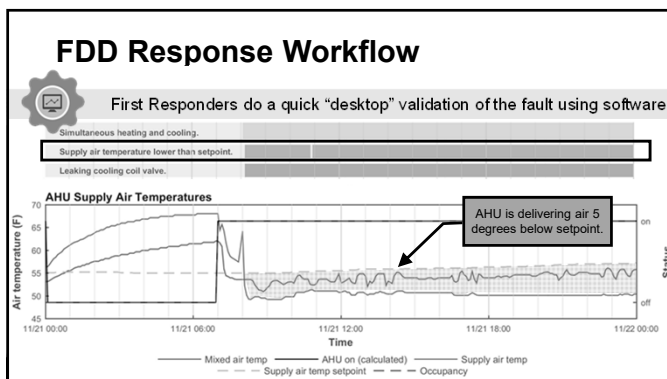
Use the tools you already have. Enhance, don't duplicate!

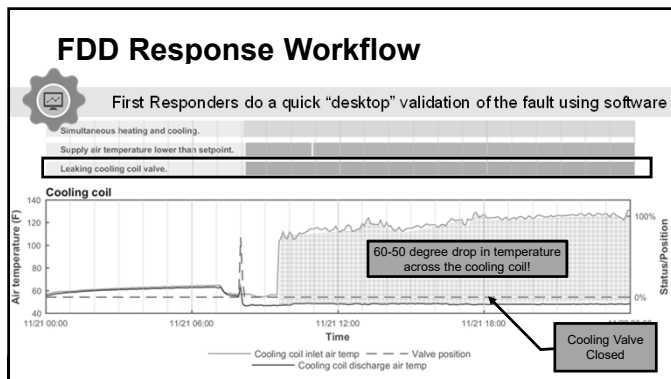
- 2-Way communication between CMMS and FDD software using Web API
- Leveraged FDD integrator and our CMMS integrator to do the programming
- Utilized static IP to communicate between the FDD information in the cloud and our CMMS database hosted within our firewall

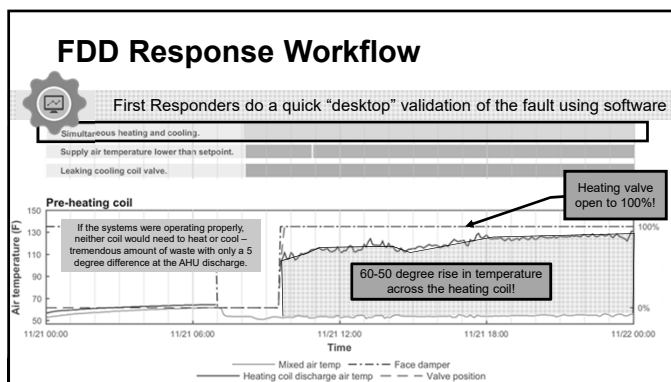
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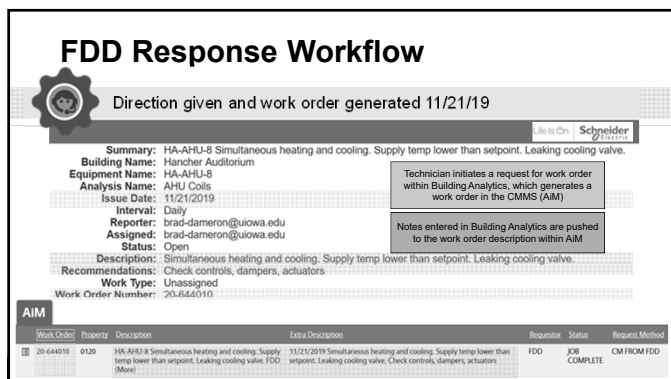
Fault Detection and Diagnostics Demo									
Building	Equipment	Analysis	Start Date	Notes Summary	Tasks	Cost	E	G	M
Yorban School of Music	VOLARC Loop (Heating System)	HW Loop	11/5/2019	Low loop temp difference. Diff pressure lower than setpoint. Flow sensor miscalibration.	1	\$31	10	10	10
Visual Arts Building	VAB-Stab HW Loop (Heating System)	HW Loop	11/5/2019	Minimal load across loop. High supply temp.	1	\$28	10	10	10
Medical Education Research ...	MERF-GEN AHU-2 (Air Handler)	AHU Coils	11/5/2019	Simultaneous heating and cooling.	1	\$27	10	10	10
Medical Education Research ...	(Air Handler)	AHU Coils	11/5/2019	Simultaneous heating and cooling.	1	\$27	10	10	10
Wendell Johnson Speech and ...	SHC-WJSH400 System Loop (Heating System)	HW Loop	11/5/2019	Minimal load across loop. Supply temp higher than setpoint.	0	\$17	10	10	10
Van Allen Hall	VNH-Penthouse AHU (Air Handler)	AHU Coils	11/5/2019	Possible simultaneous or excess heating and cooling. Return RH lower than minimum. Supply temp higher than setpoint. Supply temp reset error. Out of range sensor error (high).	0	\$14	10	10	10
Medical Education Research ...	MERF-LAB AHU-1 (Air Handler)	AHU Coils	11/5/2019	Simultaneous heating and cooling.	1	\$14	10	10	10
Medical Education Research B.	EMRB-CHHS (Cooling System)	CHW Loop	11/5/2019	Low loop temp difference.	0	\$14	10	10	10
Medical Laboratories	ML-LAB AHU1_Supply (Air Handler)	AHU Coils	11/5/2019	Excess heating. Supply temp higher than setpoint. Leaking heating valve.	1	\$12	10	10	10
Chemistry Building	CB-AHU-4 (Air Handler)	AHU Coils	11/5/2019	Simultaneous heating and cooling. Stuck cooling coil valve.	0	\$12	10	10	10
Medical Research Center	MRC-ERU-1 (Air Handler)	AHU Heat Recovery	11/5/2019	Unused free heating available.	0	\$12	10	10	10
Iowa Memorial Union	IMU-Chilled Water East (Cooling System)	CHW Loop	11/5/2019	Low supply temp. Diff pressure not tracking setpoint.	0	\$11	10	10	10
University Medical of Iowa	UOI-ERU-01	AHU Heat Recovery	11/5/2019	Unused free heating available.	0	\$11	10	10	10

Hancher Auditorium Example									
Issue identified and troubleshooting begins 11/21/2019									
Building	Equipment	Analysis	Start Date	Notes Summary	Tasks	Cost	E	G	M
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/17/2019		1	\$0	10	10	10
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/18/2019		1	\$0	10	10	10
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/19/2019		1	\$0	10	10	10
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/20/2019		1	\$0	10	10	10
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/21/2019	Simultaneous heating and cooling. Supply temp lower than setpoint. Leaking cooling coil valve.	1	\$103	10	10	10









Closing the Loop

Work completed and Work Order closed 11/9/17

AIM Notes Log KATHLEEN About Logout

Entry Date	Created By	Name	Note Type	Notes
Dec 06, 2013 08:53 AM	THMOORE	THOMAS MOORE	CLOSEOUT	This is complete.
Nov 22, 2013 02:30 PM	DAMIRON	BRAID DAMIRON	GENERAL	Found cooling valve actuator failed. Replaced actuator. BS, RM 11/22/13

Analytic is no longer flagging

Building	Equipment	Analysis	Start Date	Notes Summary	Tasks	Cost	E	G	M
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/19/2019		1	\$0	0	0	0
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/20/2019		1	\$0	0	0	0
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/21/2019	Simultaneous heating and cooling. Supply temp lower than setpoint. Leaking cooling valve.	1	\$93	10	0	0
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/22/2019	Simultaneous heating and cooling. Supply temp lower than setpoint. Leaking cooling valve.	1	\$41	10	0	0
Hancher Auditorium	HA-AHU-8 (Air Handler)	AHU Coils	11/23/2019		1	\$0	0	0	0

Measuring Value

Difficult to quantify this energy benefit...

Operational deficiency that would have been caught eventually

\$3000 Calculated Short-Term Avoidable Cost

Operational deficiency that would not have been caught

Long-Term Avoidable Cost

Calculated Value

Optimization of existing operations

Energy Savings

Data Validated

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Biology Building Example

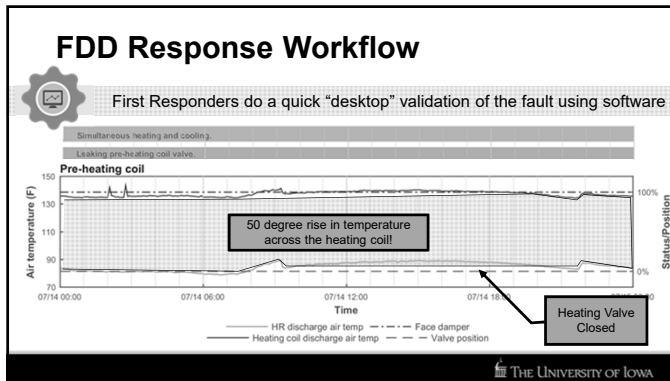
Issue identified and troubleshooting begins

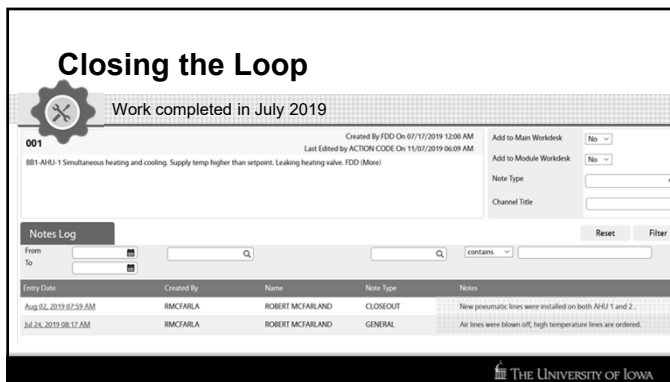
Started to see slight indicators of a problem

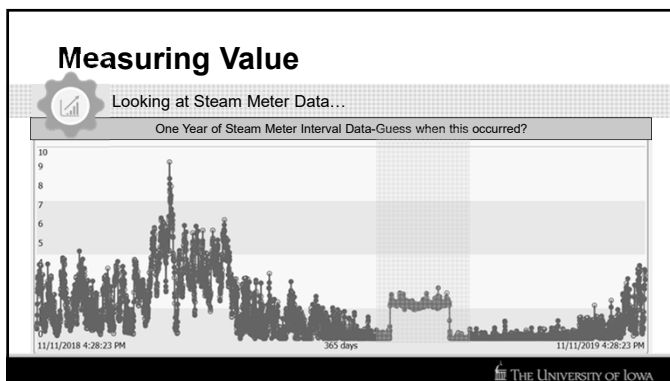
Energy waste indicator increased 6/18/19!

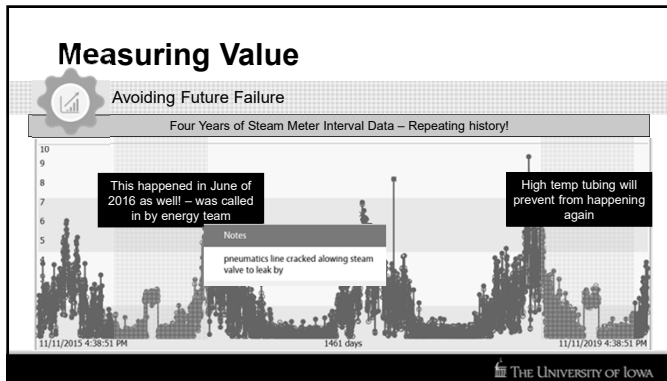
Building	Equipment	Analysis	Start Date	Notes Summary	Tasks	Cost	E	G	M	Actions
Biology Building	BB1-AHU-1 (Air Handler)	AHU Coils	6/15/2019	Excess heating.	0	\$3	1	0	0	
Biology Building	BB1-AHU-1 (Air Handler)	AHU Coils	6/16/2019	Excess heating.	0	\$3	1	0	0	
Biology Building	BB1-AHU-1 (Air Handler)	AHU Coils	6/17/2019	Excess heating.	0	\$3	1	0	0	
Biology Building	BB1-AHU-1 (Air Handler)	AHU Coils	6/18/2019	Simultaneous heating and cooling. Leaking heating valve.	0	\$981	10	0	0	
Biology Building	BB1-AHU-1 (Air Handler)	AHU Coils	6/19/2019	Simultaneous heating and cooling. Leaking heating valve.	0	\$1,736	10	0	0	
Biology Building	BB1-AHU-1 (Air Handler)	AHU Coils	6/20/2019	Simultaneous heating and cooling. Leaking heating valve.	0	\$1,736	10	0	0	

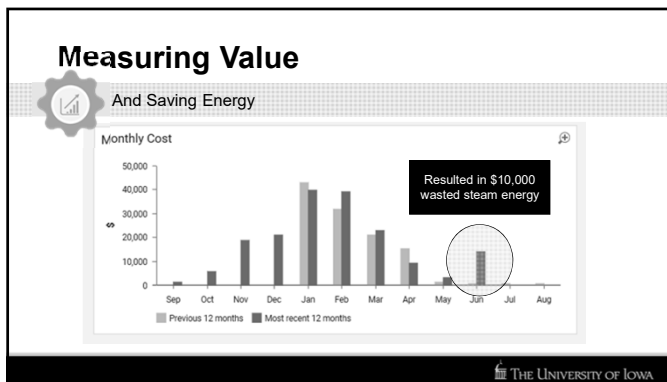
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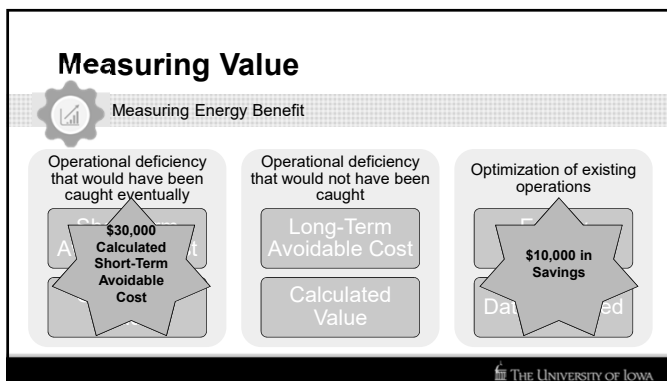




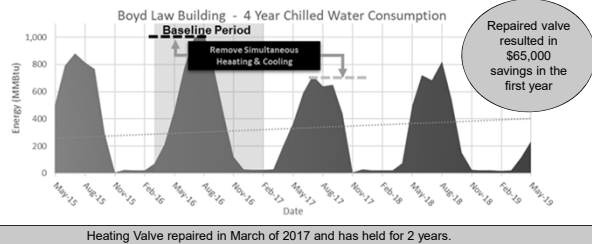






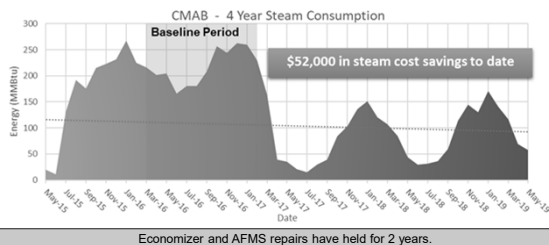


Energy Trends – Boyd Law Building



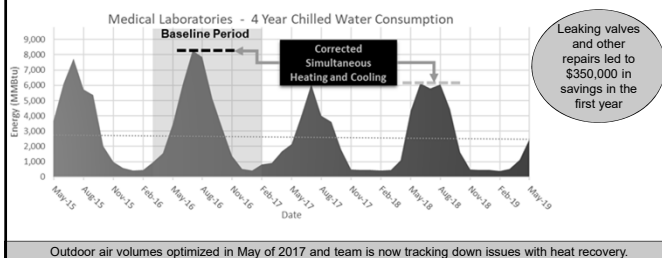
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Energy Trends – Calvin Hall



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Energy Trends – Med Labs



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What's Next?

Current State...

- ✔ Completed onboarding of additional 29 buildings to the Schneider Building Analytics platform.

Ongoing improvement...

- ✔ Always improving our processes to build Fault Detection into our existing maintenance practices through expanded training and workflow improvement.
- ✔ Looking at ways to utilize the tool to identify larger capital investment projects and the associated workflow for implementation

Coming Soon...

- ✔ Implementing FDD in a new construction environment for improved commissioning outcomes and warranty management

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Implementation Tips & Measuring Success

Implementation Tips

FDD Implementation Tips



University of Iowa FDD Implementation Timeline

- ✓ **September 2014**
Started FDD pilot
- ✓ **September 2015**
Worked with an integrator for FDD solution development
- ✓ **February 2016-June 2016**
Issued an RFP for 20 General Fund Buildings
- ✓ **October 2016-January 2017**
Selected an FDD solution and on-boarded 20 buildings
- ✓ **March 2018-July 2018**
On-boarding additional 29 buildings
- ✓ **Present**
Preparing to On-board two new construction projects upon substantial completion (Pharmacy and PBSB)

FDD Implementation at Ulowa

1

September 2014

Started a pilot to self-perform an on premises FDD implementation in a newly constructed lab building

- Partnered with Microsoft at their Redmond, WA campus
- On-boarded Iconics Software at Pappajohn Biomedical Discovery Building
- Data and software lives on premises
- All software framework developed and maintained in-house:

Point Mapping	Data and Software Maintenance
Writing Analytics	Cost Savings Calculations
User Interface	Custom Prioritization

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FDD Implementation at Ulowa

Pappajohn Biomedical Discovery Building FDD Pilot

11	Air Handling Units
5	AHU Equipment Classes
500	VAV Boxes
25	VAV Equipment Classes
104	Additional Systems
615	Total Assets



- "Walk" through the building 60 times every hour
- See real-time faults
- Leverage templates to make solution flexible, on-boarding faster, maintenance simpler.

Tool required a hefty amount of data combing, mapping, maintenance and in-house expertise.

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FDD Implementation at Ulowa

- 1 **September 2014**
Started a pilot to self-perform an on premises FDD implementation in a newly constructed lab building
- 2 **September 2015**
Investigated working with an integrator for a campus-wide FDD solution



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Pilot Lessons Learned

- ✓ Management Champion is key
- ✓ IT involvement is critical
- ✓ Enhance existing infrastructure-Don't duplicate!
- ✓ Understand the skills available to you in-house and partner with an integrator or software provider to supplement the rest.
- ✓ The software is only a tool-Process and People are equally important
- ✓ Capturing the maintenance "story" is instrumental in measuring success and maintaining sustained optimization

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FDD Implementation at Ulowa

- 1 **September 2014**
Started a pilot to self-perform an on premises FDD implementation in a newly constructed lab building
- 2 **September 2015**
Investigated working with an integrator for a campus-wide FDD solution
- 3 **February 2016-June 2016**
Issued an RFP to select an FDD solution for 20 General Fund Buildings



Writing an RFP or Selecting a Solution

Determine what is important to your team

- ✓ Analytics customizable by the UI team
- ✓ In-house analysis and troubleshooting
- ✓ Transparent cost over a 5 year period
- ✓ Availability of Training
- ✓ Experience in FDD and HVAC design and/or maintenance
- ✓ Ability to integrate with other UI systems (e.g. CMMS)
- ✓ Ease of use – both on the “Developer” and “User” side

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FDD at the University of Iowa - Today

- 1 **September 2014**
Started a pilot to self-perform an on premises FDD implementation in a newly constructed lab building
- 2 **September 2015**
Investigated working with an integrator for a campus-wide FDD solution
- 3 **February 2016-June 2016**
Issued an RFP to select an FDD solution for 20 General Fund Buildings
- 4 **October 2016-January 2017**
Selected an FDD solution and on-boarded 20 buildings with a software as a service, cloud-based solution.
- 5 **March 2018-July 2018**
On-boarding additional 29 buildings with the same software as a service, cloud-based solution.
- 6 **Present**
Preparing to On-board two new construction projects upon substantial completion (Pharmacy and PBSB)

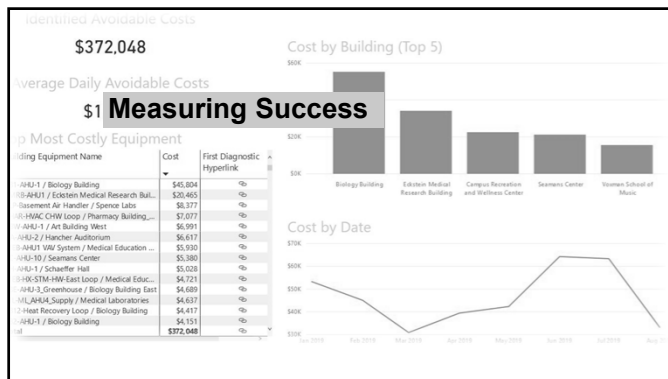
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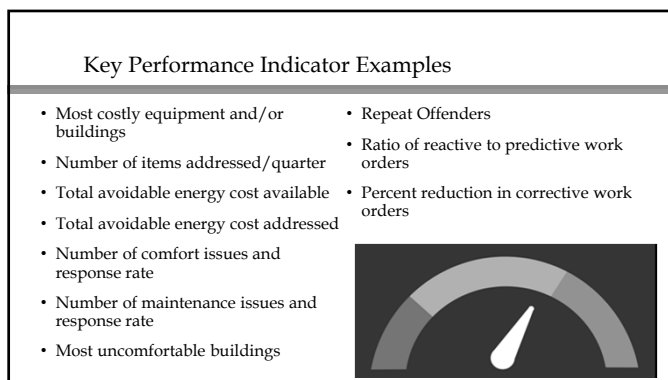
Other Quick Tips

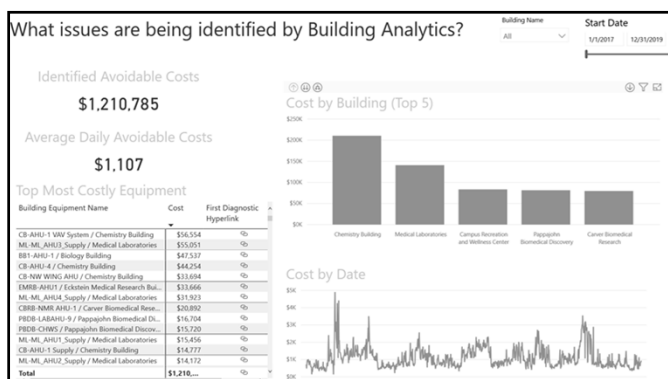


- ✓ Find a balance between mitigating risk and never getting started
- ✓ Fail Fast and don't be afraid to change course
- ✓ Could spend an eternity on data clean up – work backwards from the solution to determine what data is important and how “clean” it needs to be
- ✓ Make sure you can measure your success

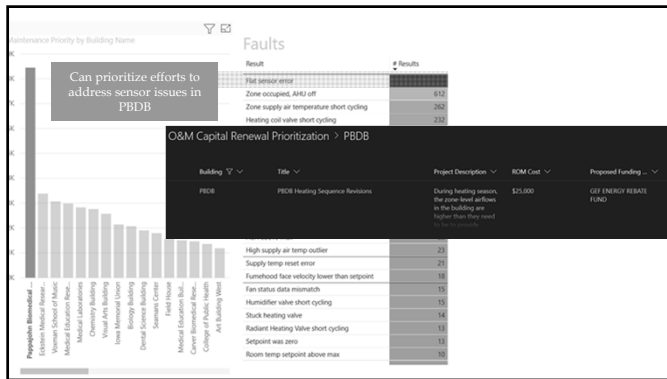
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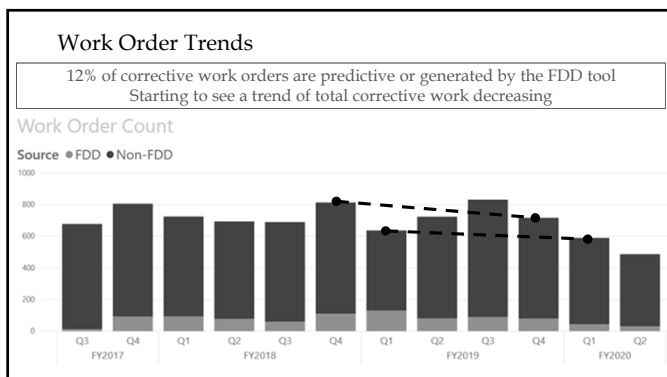












What types of issues are found?

Common Air Handler Faults		Common Zone Faults		Common Heating System Faults		Common Cooling System Faults	
Result	Air Handler	Result	Zone Equipment	Result	Boiler - Heating System	Result	Chiller - Cooling System
Outdoor air damper below minimum	1	Room air temp higher than setpoint	1	Missing information utility rates	1	Diff pressure lower than setpoint	1
Supply static pressure smaller than setpoint	1	Room air temp lower than setpoint	1	Supply temp not tracking setpoint	1	Low supply temp	1
Supply temp higher than setpoint	1	Occupancy sensor on longer than expected	1	Low loop temp difference	1	Supply temp higher than expected	1
Out of range sensor error (low)	1	Locking heating valve	1	Pump status data mismatch	1	Out of range sensor error (high)	1
Heating temp difference across cooling element	1	Flat sensor error	1	Missing information utility rates, pump HP, rated H&W flow	1	Chiller/CRH on, CH&W pump off	1
Possible simultaneous or excess heating and cooling	1	Zone supply air temperature short cycling	1	Supply temp reset error	1	Missing information CH&W pump HP	1
Gas status data mismatch	1	Zone occupied, AHU off	1	Missing information pump HP, rated H&W flow	1	Out of range sensor error (low)	1
Pressure sensor drift	1	Supply air flow lower than setpoint	1	Diff pressure lower than setpoint	1	Stuck zone supply damper	1
Reset air temp higher than setpoint	1	Out of range sensor error (high)	1	Pump(s) on, boilers off	1	Stuck heating valve	1
Missing information rated flow	1	Heating coil valve short cycling	1			Exhaust flow lower than setpoint	1
Out of range sensor error (high)	1	Stuck zone supply damper	1			Zone air while unoccupied	1
Stuck cooling coil valve	1	Stuck heating valve	1			Supply fan short cycling	1
Supply temp reset error	1	Exhaust flow lower than setpoint	1			Supply air velocity pressure sensor drift	1
Energy information available (see details)	1	Zone air while unoccupied	1			Out of range sensor error (high)	1
Supply air temperature short cycling	1	Supply fan short cycling	1			Chiller/CRH on, CH&W pump off	1
Gas air while unoccupied	1	Supply air velocity pressure sensor drift	1			CH&W pump(s) on, chiller/CRH off	1
H&W effectiveness info available	1	Out of range sensor error (high)	1			Diff pressure higher than setpoint	1
Stuck pre-heating coil valve	1	CH&W pump(s) on, chiller/CRH off	1			Low loop temp difference	1
Flow imbalance	1	Stuck cooling valve	1			Missing information CH&W pump HP	1
No supply temp reset	1	Cooling coil valve short cycling	1			Out of range sensor error (low)	1
Sensor error or flow reversal	1	Missing information AHU fan rated HP/flow	1			Pump status data mismatch	1
Missing information fan HP	1	Sensor error or flow reversal	1			Missing information pump HP, rated CH&W flow	1
Reset air temp lower than expected	1	Stuck zone primary damper	1			Negative temperature difference across loop	1
Flow sensor error	1	Stuck zone primary damper	1				
Stuck heating coil valve	1	Stuck zone primary damper	1				


Resources


- Department of Energy Smart Energy Analytics Campaign
<https://smart-energy-analytics.org/>
- COGfx Study on the Impact of Green Buildings on Cognitive Function
<http://naturalleader.com/thecogfxstudy/why-you-should-care/>
- Your peer institutions!

Recommended Reading/White Papers

- Accenture Energy Smart Buildings:
czgbc.org/energy-smart-buildings-whitepaper.pdf
- Forbes article on Data Scientists:
[https://www.forbes.com/sites/gilpress/2016/03/23/data-preparation-most-time-consuming-least-enjoyable-data-science-task-survey-#67d4e2ef6f63](https://www.forbes.com/sites/gilpress/2016/03/23/data-preparation-most-time-consuming-least-enjoyable-data-science-task-survey/#67d4e2ef6f63)
- IBM research on Machine Learning:
<http://www.research.ibm.com/labs/ireland/#projects>
- Thank You for Being Late: An Optimist's Guide to Thriving in the Age of Accelerations* Thomas L. Friedman

This concludes The American Institute of Architects Continuing Education Systems Course





Questions?

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