

Abstract - University of Iowa Fault Detection & Diagnostics Program

In 2014, University of Iowa (UI) Facilities Management began an exhaustive study of a growing evolution in building systems management - Fault Detection and Diagnostics technology (FDD). After visiting Microsoft's Redmond Campus and seeing the substantial impact FDD had on their facilities operation, the UI embarked on a groundbreaking and large-scale effort to implement FDD in a campus environment. Thoughtful study and a methodical approach generated unique insight and innovative best practices, resulting in the successful implementation of FDD in 20 buildings across campus by March 2017.

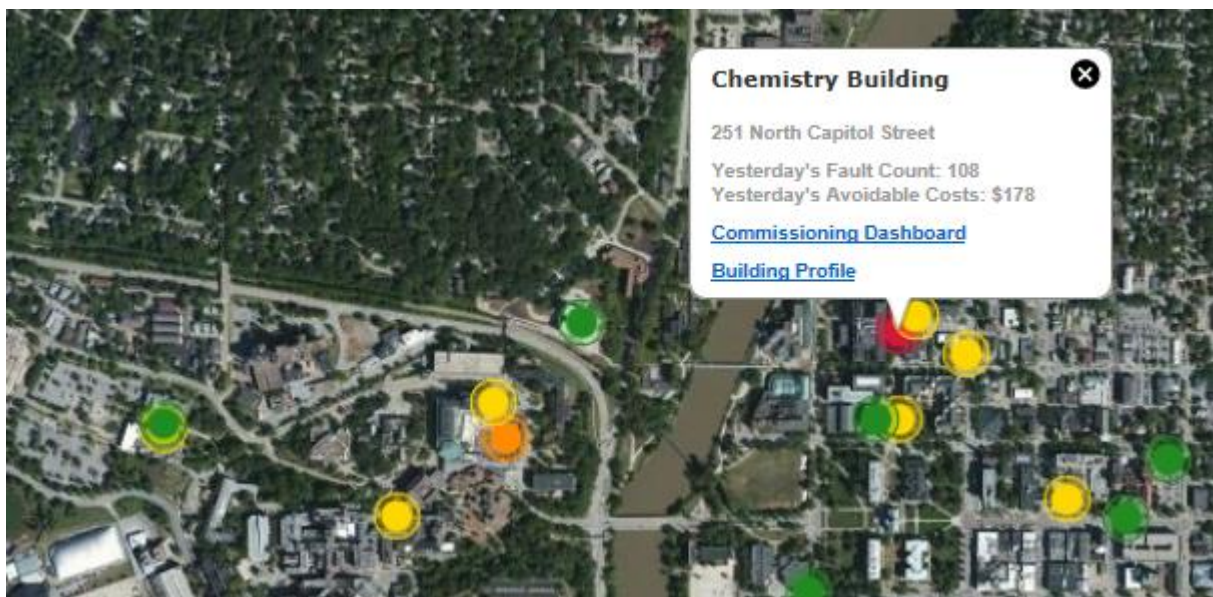
UI's FDD program at a glance:

- Twenty buildings onboarded including academic, lab, recreational and office spaces.
- All major HVAC equipment monitored with FDD.
- Four different Building Automation Systems (BAS) integrated.
- Time to onboard 20 buildings: three months.
- Work order integration with FDD software for performance tracking and transparent adoption.

UI's major FDD program achievements in first six months:

- Realized \$600,000 in energy savings.
- Shifted to 24 percent predictive quarterly work orders versus reactive
- Addressed issues related to energy: 117, occupant comfort: 171, maintenance: 304.
- Leveraged FDD on two newly constructed buildings and warranty punch lists.
- Exploring FDD for use in measurement and verification and performance-based incentives with utilities.

University of Iowa FDD Campus Monitoring



Institutional Benefit

Fault Detection and Diagnostics (FDD) catapults facilities organizations from reactive mode to a more planned, predictive approach. FDD collects and stores building data and then alerts operators and engineers when systems begin to drift out of optimal conditions. The result is early detection, diagnosis and correction of system inefficiencies.

In the first six months of the major FDD implementation, the University of Iowa discovered issues that normally would not be detected or may have taken significant time and expense before their discovery. The UI's execution of FDD led to the realization of the following institutional benefits, with demonstrable numbers and operational changes.

Unparalleled visibility into building and equipment performance

The UI's FDD software utilizes building data trends, at five-minute intervals, across a total of 50,000 points. The data feeds the diagnostics which offer opportunities and faults with suggested resolutions. In addition, diagnostics provide automatically calculated energy savings, comfort and maintenance impact details with graphics, so the work can be efficiently prioritized, planned and scheduled.

- In its first six months, UI's FDD program delivered approximately 1,800 unique analyses which resulted in \$600,000 in realized energy savings.

Measurable shift toward predictive from reactive maintenance

FDD's ability to prioritize and distribute work immediately enables the UI to create a daily workflow of verifying and submitting predictive work orders. Using FDD, the UI is able to perform root-cause analysis within the FDD program, and provide greater direction to the maintenance team. To date, the FDD team has:

- Generated 253 predictive work orders driven by FDD between March and September of 2017.
- Addressed 117 energy issues, 171 comfort issues, and 304 maintenance issues.
- Demonstrated a shift to 24 percent predictive work order generation rather than reactive or corrective work orders.

"The integration of the CMMS system with FDD is pivotal. It allows the group to go from diagnosis straight to planning and scheduling of the corrective repair."

Tom Moore, Manager of Building Operations & Maintenance

Enhanced infrastructure and productivity, without duplication

By leveraging the UI's existing Building Automation System and meter data infrastructure, no additional capital was invested in data collection hardware. The data trending and analysis occurs in the cloud, which prevents fault detection from slowing down the critical and essential building HVAC controls processing.

This FDD solution also integrates with the UI's current CMMS (work order system) so as not to duplicate efforts and create more work for the end user. The FDD-CMMS integration embeds analytics into the daily FDD meetings and institutes a clear workflow for assigning maintenance and reporting progress. This integration provides measurement for identifying time and resource needs.

Leveraging FDD for more sustainable practices

FDD helps identify funding opportunities outside of the traditional funding model.

- Captures items under warranty and obtains commitment from the vendor to correct FDD-identified issues.
- Assists in capital and deferred maintenance project identification, prioritization and "go-no-go" decision making.
- Future plans to explore the use of FDD alongside utility incentive programs.

Innovativeness, Creativity, and Originality

The University of Iowa FDD initiative fits into a broader innovative vision for the future of building operations and management on the UI campus. UI's Integrated Building Operations program represents an organization-wide transformation towards a data-driven, systematic, symbiotic work management style. A Building Operations Center acts as a central hub to help reshape and redefine not only how the UI will manage physical assets in the future, but how the higher education facilities management profession will transform itself through emerging technology.

As this shift takes place, FDD is driving sweeping cultural change throughout UI Facilities Management, such as moving from employing mechanics to employing technicians, from component diagnostics to systems diagnostics, from systems drift to systems hold, from reactive responses to predictive responses, from valuing institutional knowledge to shared knowledge and from investing in repairs to investing in FDD cost-avoidance tools.

From the outset, the UI's implementation of FDD stands out from other programs because of the cross-functional team commitment to advancing operations and the evaluation of FDD as a tool for planning and scheduling of predictive work. The following characteristics outline this unique approach:

"FDD helps our team come up with solutions to larger systemic problems rather than putting out fires at the component level. This inherently moves us towards efficiency and optimization in how we do our work and how our buildings operate."

Katie Rossmann, Manager of Data Analytics & Commissioning

- **Commitment to the advancement of our building operations professionals**
 - Nurturing in-house expertise and exposing teams to emerging technology at APPA and partner organizations; such as visiting the Microsoft Campus to investigate FDD.
 - Creating award-winning initiatives such as our Energy Control Center and Energy Hawks Program, recognized by APPA in 2010 and 2012 respectively.
- **Commitment to the next generation of building intelligence and technology**
 - Conversion of all building controls to DDC and metering all major university buildings.
 - Creating design standards, integrating existing systems, and leveraging data historians.
 - Developing a planned, prioritized and predictive work management style and Building Operations Center.
- **Thorough evaluation of FDD in the field and developing lessons learned**
 - The UI began its evaluation of FDD in 2014 with a pilot to self-perform an on-premise FDD implementation in a newly constructed and highly complex building. By 2015, the UI recognized FDD's potential and started evaluating solutions for a campus-wide deployment. In 2016, an RFP for a 20-building scope was issued, and by the end of 2016 the UI selected an FDD provider and began its implementation. In early 2017, FDD was live at the University of Iowa.
 - This methodical approach created a specialized learning environment that helped the team avoid potential pitfalls. The UI was able to leverage these lessons learned to implement FDD quickly and confidently.
 - In three months, the UI onboarded 20 buildings—2,685,000 square feet!

Portability and Sustainability

The University of Iowa has built a knowledge-base of FDD practices and experiences, which it is currently sharing with other facilities organizations and design professionals across the country to aid them in their successful adoption of FDD. These lessons are portable and will help others reduce time and cost of implementation, while maximizing the FDD solution they choose.

There are a number of vendors that provide FDD systems. Each provider approaches this technology differently but the common thread is continuous monitoring of the operating status and conditions of the building systems and notification when the tool detects the building systems are operating outside of selected parameters. Therefore, proper due diligence is required to learn about offerings from the various providers and to discuss internally how this technology can be most effectively leveraged by your organization.

It must be emphasized that this technology is a tool to be used by a building technician like a hammer is a tool for a carpenter. The FDD system itself does not fix systems. FDD provides critical information to the building technicians in order to help them more effectively manage building systems. However, it remains the responsibility of the team to take appropriate action.

In order to effectively leverage the FDD tool, UI Facilities Management suggests that a facilities team evaluate their organization and systems for the following:

- DDC (Direct Digital Control) system that monitors and controls the building heating and cooling systems, and communicates with other software systems via a common communication protocol (like BACnet).
- BAS (Building Automation System) and the protocol employed (e.g. BACnet, OPC, etc). Consult the BAS technician or partner if needed.
- FDD champion/lead that facilitates communication with IT personnel, FDD provider and other vendors if necessary (e.g. BAS).
- Enthusiastic commitment from the facilities organization and especially the IT Department to drive onboarding of the solution, then adoption and maximization of FDD technology, which includes improvements to work operations.

Following this initial checkup, organizations can start on the path of evaluating and selecting their FDD solution.

The University of Iowa valued the following capabilities when selecting an FDD partner:

- Tracks the organization's top-line and team goals so that the solution and services can be counted on to deliver results in alignment with what matters most to the university.
- Offers high quality customer service in onboarding the team, which includes assisting with gathering equipment information, working with the IT department, and asking many clarifying questions ensuring FDD is properly commissioned for the campus buildings.
- Possesses steep knowledge in HVAC design and/or maintenance.
- Provides an FDD solution that is flexible to integrate with existing technologies and easy to use, so as not to duplicate work or expenses. An FDD solution that plays well with other systems will future proof the investment.
- Provides solutions beyond alarms. Analytics should be accurate and optimizable based on the operation of the facilities—each building on campus is unique.

The UI believes organizations that employ these basic lessons will set themselves up for tangible success and be rewarded by their management and occupants.

Management Commitment and Employee Involvement

As with any major organizational change, the University of Iowa recognized the biggest challenge to the implementation of FDD hinged upon the successful adoption of a new data-driven culture, not the technology itself. UI administration was in a unique position to support the groundbreaking program based on the following factors:

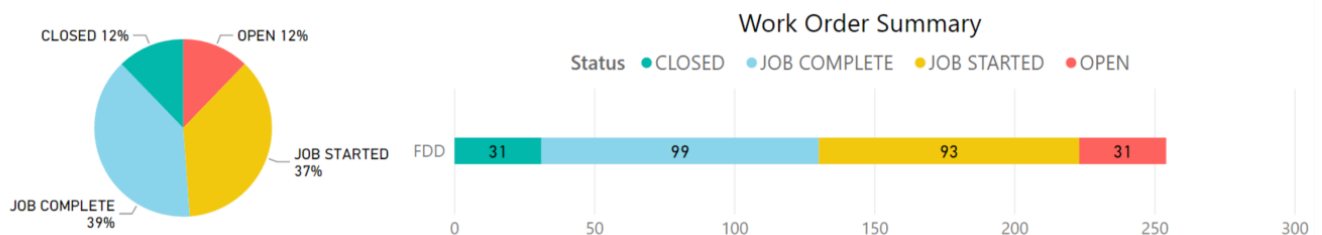
- Recognized partner Microsoft Corporation had already successfully implemented FDD on their campus.
- Big Data had emerged as a proven business asset in other industries.
- The UI had already made commitments and investments in informatics and data analytics in campus research and academic programs.
- The UI is committed to providing the very highest value to our students, faculty, and staff by ensuring that university operations are effective and efficient.
- FDD provided the opportunity to pivot our energy management program from one historically based in project-specific energy reduction to a new, progressive program grounded in continuously improving and optimizing building operations (i.e. continuous commissioning).
- FDD mitigates impending failure, and by preventing that failure, we minimize risks to business continuity and avoid more costly failure mode repairs.
- FDD reduces the communication barriers between various FM units (energy engineers, building control engineers, building technicians, etc.). Having access to this tool allows everyone to recognize that each team member is working for the common goal and each team member brings different strengths to make the implementation successful.

The University of Iowa views FDD and Big Data analytics in the broader context of the fundamental tool for managing building operations; including managing energy consumption, occupant comfort, research productivity and risks related to business continuity.

Strong support from UI Facilities Management leadership allowed for broader acceptance of a new planned and predictive work management style. Upon onboarding of the 20 buildings, a multidisciplinary team was comprised to form the Analytic Response Group. This group consists of building technicians, controls engineers, an energy engineer and maintenance management representatives. A daily meeting guarantees a regular touchpoint with the analytics and a continuous process improvement cycle to encourage success of the program. UI Facilities Management is invested in utilizing this tool on the journey to becoming a more predictive, planned and scheduled maintenance organization.

Figure 1, below: The UI has already completed 51% of work orders generated by FDD and initiated work on an additional 37%. This highlights the team's focus on responding to and resolving issues, not simply generating work orders.

Work Order Summary March 2017 – September 2017



Documentation, Analysis, Customer Input, and Benchmarking

Big Data and FDD hold the key to effectively managing our increasingly complex and sophisticated building systems. In an ideal world, building occupants are unaware of the technology behind-the-scenes. However, they benefit greatly from reduced occupant disruptions due to catastrophic equipment failure, unplanned work or unfavorable building conditions. The UI has benchmarked using automated data collection to capture positive momentum in areas including, but not limited to, efficient work order management, reduction in energy consumption, and more effective troubleshooting techniques. We have experienced tremendous results to date as noted in the two examples below. Additional documentation, analysis, customer input and benchmarking is available upon request.

Figure 2, below: The shift from reactive (corrective) to proactive (FDD) maintenance is demonstrated by tracking our Work Order categories. Since adopting FDD across campus in 2017, we have been driving toward 25 percent all of work driven by FDD and proactively managing our equipment before emergencies.

Twenty-Building Work Order Performance: January – September 2017

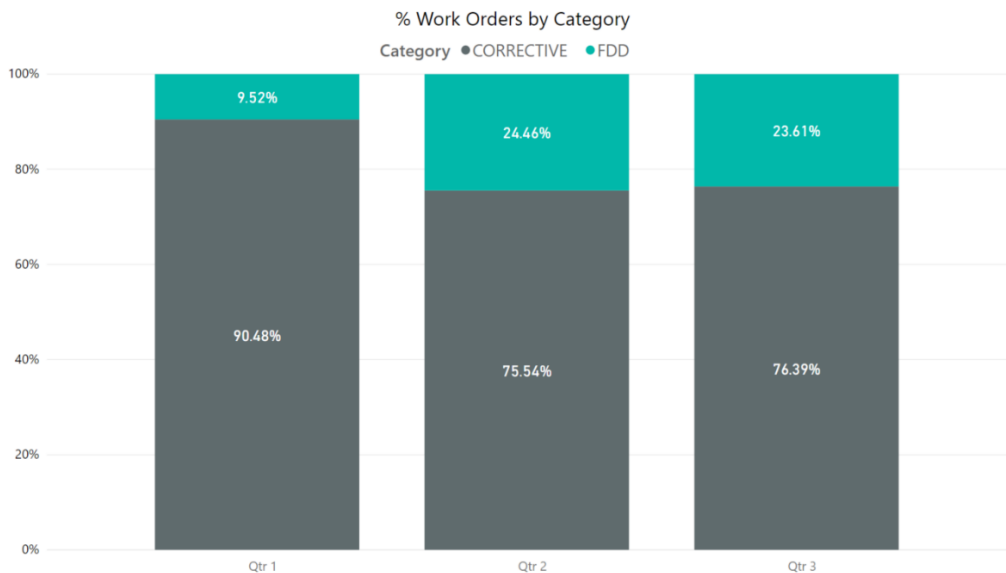


Figure 3, below: Over a quarter million in energy savings to date realized in one UI campus lab building. Many discoveries were difficult to find without utilizing FDD to review how numerous data points behave over time and in certain conditions.

Medical Laboratories Energy Performance: March – September 2017 compared to previous years

Major Findings

- Optimized heat recovery setpoints
- Recalibrated and/or replaced faulty temperature and humidity sensors
- Removed unnecessary heat sources from the AHU airstream
- Cleaned plugged strainers
- Replaced leaking valves

