Workshop on FDD for RTUs – Moving from R&D to Commercialization

Summary Report

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Executive Summary

The workshop on FDD for RTUs – Moving from R&D to Commercialization was held on Sunday, July 13 2014 in Rawls Hall, Purdue University. The primary goals were to review where we are with respect to commercialization of FDD for RTUs and to identify specific needs for moving this technology forward in the marketplace. The workshop was divided into 3 sections:

1) Review of Existing and Emerging RTU Diagnostic Technologies;
2) Policy Influencing Development, Adoption, and Evaluation of RTU FDD;
3) Evolution of Business Opportunities.

Participants in the workshop included researchers (university and government labs), industry developers, end-use customers, and policy makers (utility and government) with breakdown shown in the table below.

Breakdown of Workshop Participants

Participant Type	Number
University/Government Researchers	13
Industry Developers	9
Utility & Policy	5
Customers	4

A number of methods for FDD applied to RTUs have been developed over the past 20 years. However, commercialization has been relatively slow. The most commercially successful FDD products are generic tools for service technicians that apply to any packaged HVAC equipment and that are implemented in smart phones and/or through web services. However, recent performance evaluations of generic FDD tools have raised serious concerns about their ability to robustly diagnose faults across a variety of equipment without significant false alarms that can be costly and create credibility problems. There appears to be much greater potential for good FDD performance with continuous FDD where methods learn unit-specific performance characteristics under normal operation or when methods are integrated with equipment controllers and on-board measurements in the factory. Recently, FDD technology that provides continuous monitoring and diagnostics has been developed for commercial and residential packaged HVAC equipment and are being or will soon be offered as optional features. Examples include products by Lennox (integrated smart AirFlow and economizer diagnostics for RTUs), York (integrated FDD for York Predator RTU), and Emerson (cloud-based diagnostics for HVAC residential). However, it is believed that the marketplace will be slow to adopt these features for a variety of reasons, including:

1) although the national energy impact is high, the benefits for individual customer are uncertain and relatively low compared to other operating expenses;
2) there are limited federal and state government incentives and regulations to promote automated diagnostics for HVAC;
3) continuous FDD requires installation of additional sensors that can significantly increase the overall cost of the equipment;
4) most of the previous diagnostic R&D has focused on mainstream equipment and additional work is necessary to develop methods for higher-end equipment where automated FDD might be more economically deployed within OEM RTUs in the factory.

The bottom line is that RTU OEMs have been slow to invest the necessary resources to fully develop, deploy, and market integrated FDD because of difficulties in making a business case relative to other R&D projects. The principal exception has been in the development of integrated economizer diagnostics, which has been spurred by new California Title 24 requirements. Additional diagnostic requirements and/or incentives, such as for refrigerant charge or air flow FDD, would undoubtedly speed development and deployment. However, there needs to be FDD performance compliance mechanisms to guarantee minimum FDD performance. ASHRAE is currently involved in the development of standardized methods of test for FDD that could ultimately lead to approaches for FDD performance compliance. A Center for HVAC Diagnostics was proposed and discussed. In addition to developing the tools and approaches needed for development and assessment of FDD approaches, the center could:

1) collect, assimilate and share information, common tools and non-proprietary FDD technology components;
2) help develop a stronger market for HVAC products with FDD technology through better collaboration and integration;
3) develop a better understanding of customer opportunities including direct feedback from participating organizations (e.g. national retail)
4) leveraging public resources to address common issues that helps all associated organizations accomplish their goals quick and cheaper
5) promote awareness of emerging technology companies that could be potential partners or acquisition targets
6) provide independent 3rd party product testing/evaluations and field test assessments (appropriate targeted funding required)

The formation of a center at Purdue will be explored in the coming months with potential partners.

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1. Agenda

Workshop on FDD for RTUs – Moving from R&D to Commercialization
Sunday, July 13 2014,
Rawls Hall, Purdue University

Intended Audience: 1) commercial HVAC equipment and component manufacturers/engineers interested in developing and commercializing[g automated fault detection and diagnostics (FDD) for rooftop air conditioning units (RTUs); 2) policy makers and utilities interested in incentivizing the development and commercialization of RTU FDD

Goals: 1) review of existing and emerging technologies for diagnostic technologies applied to RTUs; 2) review of existing and emerging policy for development, adoption, and evaluation of RTU diagnostics; 3) review and discussion of the evolution of business opportunities for RTU diagnostics

Introduction to and Evolution of RTU Diagnostics (Jim Braun); 8:00 – 8:45 am

Section I: Review of Existing and Emerging RTU Diagnostic Technologies: 8:45 am – 12:15 pm

Field Service Tools (Todd Rossi, FDSI)
Rooftop Unit AFDD: SMDS and Proactive Diagnostics (Srinivas Katipamula, PNNL)
Virtual Sensing to Enable Integrated RTU Diagnostics (Jim Braun, Purdue)
Lennox SmartAirFlow System for RTUs (Jon Douglas, Lennox)
Residential HVAC Cloud-Based Diagnostics (Fadi Alsaleem, Emerson)
Integrated RTU FDD System (Todd Rossi, York)

Section II: Policy Influencing Development, Adoption, and Evaluation of RTU FDD: 1:00 – 3:30 pm

RTU FDD in Title-24: Past, Present and Future (Martha Brooke, CEC)
Utility Incentives for RTU FDD in California (Mel Johnson, SCE)
Moving and Expanding the New York State Marketplace with NYSERDA (Ed Smyth, NYSERDA)
Standards for Evaluating RTU FDD Systems (Kristin Heinemeier, WCEC)
An Evaluator for FDD Algorithms (David Yuill, Purdue)

Section III: Evolution of Business Opportunities: 4 – 6 pm

Experiences Building a Business Centered on RTU FDD (Todd Rossi, FDSI)
Experiences Commercializing FDD in the Northwest (Danny Miller, Transformative Wave)
Discussion of Pathways towards Broad Commercialization (Rossi, all)
Do we need a Center for HVAC Equipment Diagnostics? (Rossi)

Optional Tour of the new Herrick Laboratories: 6:30 – 7:30 pm

2. Participant List

First Name	Last Name	Company	Title
Fadi	Alsaleem	Emerson Climate Technologies	Lead Algorithm Engineer
James	Braun	Purdue University	Professor
Martha	Brook	California Energy Commission	Senior Mechanical Engineer
Brock	Burkett	Target	Group Manager
Howard	Cheung	Purdue University	Graduate Research Assistant
Jon	Douglas	Lennox Industries	Principal Engineer
Bob	Drazovich	Cold Machines, Inc.	Vice President of Development
Mikhail	Gorbounov	United Technologies Research Center	Staff Eng/Sci, Res Engrg
Dale	Gustavson	Better Buildings, Incorporated	Principal Consultant
Kristin	Heinemeier	Western Cooling Efficiency Center	Principal Engineer
Andrew L	Hjortland	Purdue University	Graduate Research Assistant
Travis	Horton	Purdue University	Professor
Jia	Huang	PG&E	Program Engineer
Bonggil	Jeon	Purdue University	Graduate Research Assistant
Paul	Johnson	Target Corporation	Technical Lead Specialist
David	Johnson	Target Corporation	
Melvin	Johnson	Southern California Edison	Program/Project Manager
Srinivas	Katipamula	Pacific Northwest National Labs	Staff Scientist
Martha	Krebs	Consortium for Bldg Energy Innovation	Director
Yaoyu	Li	University of Texas at Dallas	Associate Professor
Ben	Lipscomb	PECI	Engineering Supervisor
Richard	Lord	Carrier	Fellow
Mark	Lowry	Western HVAC Performance Alliance	Chief of Staff
Danny	Miller	Transformative Wave	President
Hung	Pham	Emerson Climate Technologies	Mgr Systems Technology
Todd	Rossi	Field Diagnostic Services, Inc.	President
Edward	Smyth	DNV GL Energy	Senior Consultant
Jebaraj	Vasudevan	Purdue University	Graduate Research Assistant
Timothy	Wagner	United Technologies Research Center	Deputy Director, CBEI
Youngbo	Won	USGBC	
David	Yuill	Purdue University	Graduate Research Assistant

3. Summary of Presentations and Discussions

3.1 Introduction to and Evolution of RTU Diagnostics

This presentation provided background on automated FDD for RTUs, including requirements, history, overview of approaches, needs for additional R&D, and ideas for accelerating commercialization. R&D began more than 20 years ago with initial product offerings focused on hand-held tools that incorporate generic FDD approaches. Most of the approaches are based on comparing direct measurements (e.g., subcooling, superheat, condenser over ambient) with expected values and then applying rules to identify either normal behavior or individual faults. These approaches do not naturally handle multiple-simultaneous faults but are readily applied within hand-held tools to a range of equipment using generic expectations. For embedded diagnostics, FDD methods based on virtual sensors can enable handling of multiple-simultaneous faults with relatively low initial costs. Virtual sensors employ models to estimate expensive or difficult to measure quantities (e.g., refrigerant charge, flow rates) with low-cost measurements (e.g., temperature). A number of different virtual sensors have been developed and demonstrated, including refrigerant charge, refrigerant mass flow rate, compressor power, air flow, etc. The advantage of using these types of virtual measurements for diagnostics is that they are uniquely dependent on individual faults and therefore readily handle multiple-simultaneous faults.

Most of the discussion centered on issues related to accelerating commercialization. Equipment manufacturers will build what people will buy, but are limited in being able to stimulate the marketplace for FDD. Providing incentives and/or requirements can help push the market for FDD such as is occurring for RTU economizer diagnostics through California Title 24 requirements. However, the current economizer standards lack accountability for testing/evaluating performance. Filling out the form saying the feature exists can be enough for regulatory compliance. Better compliance mechanisms are needed if diagnostic features are to have real value since manufacturers tend to be secretive about methods and performance. FDD development projects within OEMs must compete against other projects for resources and it has been difficult to successfully make a business case thus far. One of the important needs is to develop a better understanding of the benefits of FDD. We need data before and after service for range of equipment to help build the case. The technical and management workforce is not sophisticated enough yet to motivate people. Contractors/technicians are happy to jump in if the business is there – chicken and egg problem. Although the long-term solution may be diagnostics that are embedded in equipment from the factory, there still is a need for handheld devices or add-on continuous monitoring solutions for the existing equipment base and work force.

3.2 Review of Existing and Emerging RTU Diagnostic Technologies

Field Service Tools (Todd Rossi, FDSI): Field service tools developed by FDSI were presented within the context of an integrated cloud-based platform for: 1) maintaining "as designed" performance; 2) upgrading technology and replacing units when appropriate; 3) addressing distribution system and envelope problems when needed; and 4) addressing adjacent issues (e.g. lighting controls) as needed. A number of different end uses were described based on utility incentive programs, national account preventative maintenance, and field support. Future developments will include integration with embedded data systems to better support field service technicians and integration into scalable SaaS solutions for small/medium commercial buildings. The discussion included a desire by policy makers to have standard applications for M&V with open diagnostic methods with performance that is well understood. There also was a desire to develop a better understanding of benefits so that customers know what to expect and where the changes are well demonstrated. It is felt that these are needed to lead a market transformation.

Rooftop Unit AFDD: SMDS and Proactive Diagnostics (Srinivas Katipamula, PNNL): This talk described two technologies developed at PNNL related to RTU FDD. The Smart Monitoring and Diagnostic System (SMDS) is a fault detection methodology. It does not include diagnostics that isolate the cause of a fault. The method involves the use of a correlation of the power consumption of the RTU with ambient temperature determined under steady-state conditions and normal operation. The model must be trained when the unit contains no faults. Expectations from the normal model are compared with outputs from another model that is trained with recent measurements to detect performance degradations beyond a threshold and to estimate overall energy use penalties for the faults. It is a relatively low-cost approach that can be retrofit on existing units or it could potentially be factory integrated and use virtual power measurements to further reduce costs. The Proactive Diagnostics technology actively controls economizer dampers to facilitate some specific AHU diagnostics, including stuck dampers, sensor faults, and economizer control problems. Both active and passive diagnostics algorithms have been released as open source (http://github.com/volttron) that meet current California Title 24 requirements.

The discussion centered on a few technical issues and concerns. For instance, there was concern about how the SMDS would help if the unit wasn't initially performing properly. Also, the Proactive Diagnostics might provide continuous fault indications under "normal" operation for certain economizer designs, such as: 1) damper design is such that there is some significant leakage when fully closed, which is not uncommon, 2) the building intake could be close to the exhaust such that there is some recirculation (also not uncommon for RTUs).

Virtual Sensing to Enable Integrated RTU Diagnostics (Jim Braun, Purdue): As a result of a lot of discussion during earlier talks, the workshop fell behind schedule and a decision was made by the organizers to skip this presentation. The slides provide a description of the use of virtual sensors for fault detection, diagnoses, and fault impact evaluation. A virtual sensor uses low cost sensors (e.g., temperatures) and models to estimate quantities that are difficult or expensive to measure and that are needed as independent features for FDD. Example virtual sensors that have been developed and validated include RTU capacity, refrigerant mass flow rate (3 ways), refrigerant charge, compressor power, evaporator air-flow rate, condenser air-flow rate, supply fan air flow rate, supply fan power, outdoor-air fraction. The use of virtual sensor outputs that are uniquely dependent on individual faults (e.g., virtual charge for charge faults) enables handling of multiple-simultaneous faults in a straight forward and relatively low-cost manner. A complete FDD demonstration for an RTU was developed and evaluated in the laboratory.

Lennox SmartAirFlow System for RTUs (Jon Douglas, Lennox): This talk described the algorithms and development behind a new option for RTUs that provides embedded virtual air flow sensing for supply and outdoor air streams. The virtual air flows are inputs to economizer diagnostic algorithms that meet new California Title 24 requirements. In addition, this capability facilitates direct control of ventilation air flow rate to meet ventilation requirements and also could allow real-time capacity estimates. The virtual air flow sensor for the ventilation stream uses a correlation between air flow and two inputs: 1) damper position and 2) differential pressure measurement across the damper. There was one question regarding the application of this technology in combination with power exhaust. The current SmartAirFlow product does not support power exhaust. However, it does not appear to be a difficult problem since power exhaust should only operate with 100% outdoor air.

Residential HVAC Cloud-Based Diagnostics (Fadi Alsaleem, Emerson): An add-on product for residential HVAC equipment diagnostics was described. It combines local measurements with cloud-based analytics and a web interface. The required sensors include return air, supply air, refrigerant suction and refrigerant liquid line temperatures. It appears that the FDD method involves comparing current measurements with "expectations" based on previous measurements obtained under normal conditions. Some examples of refrigerant charge loss and evaporator filter fouling were provided. However, it is not clear from the presentation the range of faults that can be diagnosed and how well the overall method works. In the discussion it was learned that the business model is based on a combination of an installation fee ($100 to $300) and a monthly fee (~$10/month). It takes about 1 hour to install the product. The contractor / channel partner determines the type of offering to the end user and could provide free installation. There was a question about who owns the data: Emerson owns the collected data.

Integrated RTU FDD System (Todd Rossi, York): This talk described the development of a FDD product for RTUs that is soon to be offered by York. It includes refrigeration cycle diagnostics for small to medium size units (3 to 40 tons) covering the York, Sunline, Predator, and Millennium lines with multistage (but no circuit unloading) capacity control. The faults considered include: 1) high and low side heat transfer; 2) compressor efficiency and flow restrictions, and 3) low or high refrigerant charge. The system also provides real-time efficiency and capacity assessments associated with faults using virtual sensors. The required measurements include: 1) outdoor dry bulb temperature; 2) return wet bulb or dry bulb/relative humidity; 3) suction pressure; 4) liquid or discharge pressure; 5) suction temperature; and 6) liquid line temperature. An automated test rig was developed to test the FDD method in the laboratory. Testing included different indoor and outdoor driving conditions, all single fault scenarios at multiple levels, and multiple simultaneous fault scenarios. The product is expected to be released in late 2014. FDSI is working with national accounts and utilities to integrate embedded FDD solutions into maintenance and service workflows. PG&E has an Emerging Technology (ET) program to demonstrate the performance and benefits of integrated FDD in 15 units at 5 sites. It was noted that the two most important driving factors for development of OEM-based FDD solutions are competitive pressures and regulation (e.g. Title 24). During the discussion it was noted that faults can be isolated based on available data. There was a comment by an end-user that there is a need to link product outcomes to customer value. This is a difficult problem, but essential in building a business case for FDD.

3.3 Policy Influencing Development, Adoption, & Evaluation of RTU FDD

RTU FDD in Title-24: Past, Present and Future (Martha Brooke, CEC): This talk provided some history and future expectations for RTU FDD the CA building energy code. The California building code is within Part 6 of Title 24 and is called "Building Energy Efficiency Standards (BEES). In the 2008 BEES, there was a 5% energy performance credit given to systems with FDD. There also were inspection requirements for new construction to ensure compliance with requirements for presence of an economizer and other features along with required sensors. In addition, there were prescribed FDD functional testing requirements for new construction that considered: 1) sensor drift, 2) sensor failure; 3) damper/actuator fault; valve/actuator fault, 4) simultaneous heating, cooling and/or economizing. In the 2013 BEES, FDD for air-side economizer operations is mandatory for all air-cooled unitary DX equipment with cooling capacity >= 54,000 Btu/h (4.5 tons). It can be stand-alone or integrated into the RTU controller, but must be capable of displaying values of each sensor and report a minimum of the following system conditions: 1) free cooling available; 2) economizer enabled, 3) compressor enabled; heating enabled; 4) mixed air low limit cycle active. It also must be able to manually initiate each operating mode to independently test component operations. The 2013 BEES includes the FDD construction and functional testing requirements from the 2008 BEES. Currently, there is no plan to add any additional diagnostic requirements in the 2016 BEES. The refrigerant pressure sensor requirement is likely to be removed, but reporting requirements could be added. In the discussion, it was noted that economizer diagnostics are "a no brainer", while it is not clear that other diagnostics are cost effective. More work is needed to evaluate the benefits of other diagnostics. It was noted that the small/medium commercial building is the lowest common denominator in the commercial buildings space and typically has worse performance than residential buildings. Generally people who work there cannot affect change. It was mentioned that the market is driven towards the lowest cost products. Also, rebates are linked to linked to EER and not controls.

Utility Incentives for RTU FDD in California (Mel Johnson, SCE): This talk described past, present, and future activities at a California utility related to HVAC FDD, including discussion of utility strategic directions, action plans for on-board and in-field diagnostic evaluations and promotion, industry involvement, understanding and communicating the utility business base for FDD, research programs supported by utilities, review of previous and current CA utility diagnostic programs including field and embedded FDD, and regulatory and technical challenges in achieving widespread adoption of FDD. Some of the challenges in adding regulatory requirements for FDD arise from: 1) added benefits of FDD are not recognized by established savings claim mechanisms; 2) the application of Title 24 "FDD protocols" has led to questionable benefits; 3) it is difficult to leverage public funding for development of proprietary technology. A technical challenge is that it is very difficult to achieve good performance of generic (e.g., handheld) FDD tools because of the wide variety of system types, efficiencies, and configurations, the wide range of operating conditions where it could be applied, and the difficulty in obtaining accurate field measurements. The needs for future work include determining the immediate and ongoing value of FDD over current standard practice and traditional program approaches and quantifying and mitigating the impact of measurement uncertainty on FDD performance.

Moving and Expanding the New York State Marketplace with NYSERDA (Ed Smyth, NYSERDA): In order to support and sustain the development of FDD for HVAC, NYSERDA supports marketplace education and end-user development, demonstrations and verification projects, technical analyses, and performance-based and prescriptive incentives. Approximately every 6 months, NYSERDA offers solicitations under the Advanced Buildings Program with about $25M in funding for research, product development, and pilot demonstration funds for technologies, strategies, and practices that advance the energy performance of residential, multifamily, and commercial buildings. This includes support of FDD for HVAC. NYSERDA also provides performance-based and prescriptive incentives. Performance-based incentives require verified savings supported by engineering calculations with minimum incentives of $30,000, up to $2M. Prescriptive incentives could be developed for specific technologies that are applicable to a wide number of sectors where savings have been established and verified by known third party. Some specific performance-based include demand response ($100/kW upstate and $200/kW downstate) and monitoring-based commissioning ($.05/kWh)

Standards for Evaluating RTU FDD Systems (Kristin Heinemeier, WCEC): ASHRAE is currently developing a standard method of test for RTU FDD to ensure that manufacturer's claims are substantiated. This is sorely needed because FDD systems are appearing in the marketplace with no understanding of how well they work. Even the Title 24 economizer diagnostic requirement does not have a 3rd party performance compliance mechanism. It is up to the manufacturer to certify that the diagnostics function and perform properly. There are currently 48 economizer diagnostic products from 9 manufacturers that are certified by the manufacturer. It is unknown how well these products really work. The goal of the ASHRAE standard SPC-207C is to provide a method of test for evaluating whether an FDD system meets the manufacturer's claim of performance, whatever that claim might be. It is meant to apply to integrated FDD, strap-on FDD, remote monitoring, and hand-held solutions. During the discussion it was noted that CEC expects to support ASHRAE 207P. However, the CEC is worried that using the standard as part of some regulatory requirement for FDD performance on specific type of equipment (e.g. RTUs) puts them at a disadvantage versus other types of equipment. It was reiterated that the standard is only a "method of test" to verify the manufacturers' claim and there will be no absolute performance requirement.

An Evaluator for FDD Algorithms (David Yuill, Purdue): This talk presented a general methodology and case study results for evaluating the performance of handheld FDD tools that apply to packaged air conditioning equipment, including RTUs. The method uses measurements or simulation data to evaluate generic FDD tools that have been developed and are available in the marketplace as aids to service technicians. The case study demonstrated that a number of the available methods perform poorly in that they have high false alarm and misdiagnosis rates. During the discussion it was noted that it is very difficult to have a single generic FDD method that works well over the wide range of equipment and conditions experienced in the field. It is much easier to design an FDD system with good performance for specific units as either a factory embedded system or an add-on system that continuously monitors performance and can track changes. For handheld tools, it makes sense to only consider extreme faults to avoid false alarms.

3.4 Evolution of Business Opportunities

Experiences Building a Business Centered on RTU FDD (Todd Rossi, FDSI): As a result of a lot of discussion during earlier talks, the workshop fell behind schedule and a decision was made by the organizers to skip this presentation. The slides describe the business model and offerings associated with a small company located in the northeast that offers FDD products and support to commercial clients. They are building a SaaS technology platform to support solutions across the broad utility and small/medium building markets that is scalable, standardized, configurable, and low cost. Their tools include: 1) Synergy, an analytics platform; 2) SA Mobile, a smart phone / tablet based field technician interface; and 3) the Service Assistant, an automated data collection for a/c diagnostics. The platform and tools have been successfully applied to a number of retail chains across the country.

Experiences Commercializing FDD in the Northwest (Danny Miller, Transformative Wave): A small company located in the northwest is offering online monitoring and diagnostics for small commercial buildings that utilize RTUs. The focus is on RTU efficiency and performance from a whole–unit perspective with outputs annunciated via smart phones, tablets, & browsers. FDD features include: 1) controller-level "real-time" faults (sensors, motor drives, communication faults, inadequate airflow, lack of cooling performance, lack of heating performance, economizer actuator and damper failure, fan belt slippage); 2) time-based degradation faults using historic data (improper schedules, excessive use of after-hours override functions, disproportionate runtime between RTUs, changes in the economizer performance, degraded cooling output comparative RTU energy use analytics for outlier identification); and 3) economizer faults that are CA T24 compliant (air temperature sensor failure/fault, not economizing when it should, economizing when it should not, damper not modulating, excess outdoor air). Some key findings were 1) the condition of equipment was worse than we thought but most problems are preventable; 2) not much better condition for those paying for a facility monitoring service; 3) majority of deployed RTUs lack advanced features such as FDD; 4) customers are rarely interested in investing in features that cannot be cost justified in the short term. Recommendations are to: 1) promote tools that "make smart – simple" to deal with the information overload that currently exists; 2) invest more into validating and quantifying the cost of "not knowing" (need to demonstrate an accumulated value for the FDD); 3) consider radical alternatives such as having utilities take on the cost and management of FDD for ratepayers if the benefit is so great and the resistance so formidable and/or require major national and regional accounts to invest in the deployment and use of FDD by retrofitting and/or replacing existing equipment.

Discussion of Pathways towards Broad Commercialization (Rossi, all): Much of the discussion of pathways to commercialization occurred throughout the workshop. Currently, it is tough to make the business case for FDD because the benefits are difficult to measure and haven't yet been adequately quantified. The best technical solution to achieve good performing FDD is factory embedded products that include unit-specific performance expectations. The major drivers for RTU OEMs to develop embedded diagnostics are thought to be are competitive pressures, regulation (e.g. Title 24), or incentives. Some of the recent OEM developments are in response to the Title 24 economizer diagnostic requirements. Some of the OEM developments are going beyond those requirements and perhaps are creating some competitive pressures for others to follow. However, additional regulations and incentives would surely speed up the development process.

Do we need a Center for HVAC Equipment Diagnostics? (Rossi): The idea of a Center for HVAC Equipment Diagnostics was proposed with strong interest from many participants. The center/consortium could be a collaboration between private and public organizations to support their common interests in HVAC FDD technology with the potential to:

- Reduce product marketing and R&D costs by collecting, assimilating and sharing information, common tools and non-proprietary FDD technology components
- Help develop a stronger market for HVAC products with FDD technology through better collaboration and integration - driving end customer value quicker
- Better understanding of customer opportunities including direct feedback from participating organizations (e.g. national retail)
- Leveraging public resources to address common issues that helps all associated organizations accomplish their goals quick and cheaper
- Promote awareness of emerging technology companies that could be potential partners or acquisition targets
- Provide independent 3rd party product testing/evaluations and field test assessments (appropriate targeted funding required)

Purdue will work to develop such a center in collaboration with industry, utilities, government agencies, and other research organizations.