



Fault Detection and Diagnostics Roundtable Summary

A group of 32 participants with a variety of interests and experience around fault detection and diagnostics (FDD) and related commercial building performance monitoring, met at the University of California, Davis on June 14, 2007, to discuss actions that could be taken to promote the further development and use of FDD in commercial buildings.

The Roundtable was organized by staff of New Buildings Institute and the Western Cooling Efficiency Center. Co-sponsors included the California Commissioning Collaborative and Architectural Energy Corporation. Funding was provided by the California Energy Commission's Public Interest Energy Program (PIER) through the Advanced Automated Fault Detection and Diagnostics Commercialization Program. www.archenergy.com/pier-fdd/

Background

Fundamentally, potential electricity energy and demand savings not only have to be achieved in new and existing commercial buildings, the savings must be held for a long time in order to meet California's power system requirements and global warming emissions mitigation goals. FDD in its variety of forms is one of a number of viable tools for building operators with which to manage ongoing energy and environment-related building performance.

Over the past several years, numerous developments in diagnostics have appeared via research and commercial channels with more activity on the way. Although there is increasing interest and activity around establishing and maintaining building energy performance, the commercial market for FDD appears not to be materializing due to a variety of factors that need to be addressed in order to bring the technology further along in the market.

The initial goal of the Roundtable was to develop a Roadmap with an Action Plan for California that would result in increased recognition and use of fault detection and diagnostics in HVAC equipment and systems in the state's commercial buildings sector.

The organizers hoped for the following outcomes:

- Development of Action Items that addressed the current barriers/challenges facing FDD in the marketplace, with commitments to followup.
- Identify opportunities for collaborative efforts on behalf of FDD in California and elsewhere to support FDD in a variety of commercial building markets.

The Roundtable was structured as a working meeting with a formal agenda and a facilitator. At the beginning, five participants were asked to speak for a few minutes on their perspectives on FDD from their experience. FDD vendors, users and researchers spoke. LBNL staff was asked to

provide a brief overview of the FDD market characterization study completed in 2006. No other formal presentations were made.

Vision for the Future

The Roundtable was structured in three parts: the first was a visioning exercise. The participants were asked to describe a future time when FDD was mainstream throughout the various market segments that would benefit from diagnostics. What would things look like if FDD was simply business as usual in commercial buildings? Plenty of comments came without hesitation. Some major issues emerged.

Integration with existing systems:

Several of the comments had to do with systems integration. It was acknowledged that FDD may not be an invisible feature of a system, similar to automotive diagnostics. They would have to be integrated with existing systems. This would require that FDD user interfaces (instrument clusters) are able to be universally understood, and the FDD would have to have standardized capabilities. There was some sense that today's control systems would "morph" into FDD since FDD requires control, and control should require FDD. Thus, FDD could enable or drive other advances in controls, operations and maintenance.

Value:

A key to the success of FDD is a more universal recognition of its value. This will be possible only if FDD benefits would be verifiable. The role of FDD should be expanded to identifying and characterizing performance, not just detecting faults. Once the value has been established, building operators can embrace available FDD tools with full buy-in as to role and value, senior managers can rely on the FDD system for decision-making and accountability, people's jobs depend on using it, and owners see a profit in using FDD.

Other drivers:

Some of the things that will drive the advancement of FDD to business-as-usual are the public seeing value in buildings operating correctly; full realization that comfort is the main driver for labor productivity; and an appreciation for IAQ and energy impacts. It was noted that limiting/managing emissions drove FDD in cars, and there may be other drivers for FDD. Incorporating FDD into retrocommissioning services for persistence will likely be an important driver. Utility adoption of FDD for persistence of savings and impact evaluation for large and small buildings and systems will also be an important driver.

Other observations:

- FDD should work in a range of buildings including those with no on-site operators.
- Deemed savings as an approach goes away with real data from FDD.
- FDD is already mainstream, just not universal.
- FDD becomes a requirement for all HVAC systems in the 2014 Standards revision of CA Title 24.

Industry Challenges

For the second part of the Roundtable, the organizers presented three lists of commonly acknowledged challenges that FDD faces. Participants were invited to add, clarify or revise the lists. One addition made was delineating FDD as appropriate at the whole building, system/sub-system, and device level. Another key addition was 'Value' to the Demonstrated Performance Challenges to clearly emphasize the need for understanding the benefits side of performance. Lastly, 'Cultural' was added to the Market Awareness Challenges to express the reality that exists in every building regarding management culture/structure, office politics at all levels, incentive structures, and more that can mitigate against achieving and maintaining optimum energy performance.

Action Plan

Following the second exercise, participants broke into three working groups where they were asked to consider an action plan framework that included description of the action or resulting deliverable, key participants including who might lead the action, resources required to achieve the action in terms of funding, facilities and personnel, and the approximate timeline for the completing the action. The three groups were: (challenge lists are provided below)

- a. Technical Challenges
- b. Demonstrated Performance/Value Challenges
- c. Market Awareness Challenges

Participants were asked to keep one key procedural driver in mind: time line for the revision cycle for the California Title 24 Building Standards. The next two revisions cycles are in 2011 and 2014. Diagnostics for unitary HVAC rooftop units and air handling units/variable air volume boxes have been proposed for the 2008 revision as Compliance Options. If FDD is going to be incorporated in the building standards as requirements, questions around energy/demand benefits, and benefit cost to consumers and the power system will have to be specifically addressed.

The specific action items that emerged included more or less detail depending on how far the group was able to get in their discussions.

Technical

Action Item 1: Develop an end-to-end Data Standard for FDD, for existing and new systems.

Work with ASHRAE through TC 1.4, 7.5, 7.9 & GPC13 + work with USGBC and BOMA toward a common Standard. The California-based BOMA Regional Manager and the Technical Chair of USGBC's Energy & Atmosphere TAG have indicated support for a common standard. Proposal development is underway. Will utilize existing standards where appropriate such as IEC 61850 and others. The following areas would be addressed by the Standard:

- Sensor: accuracy, frequency, drift
- Transducer: accuracy, bandwidth, storage

- Network: noise, bandwidth, storage
- Database: organization, format, what data, availability, frequency

Action Update: Since the Roundtable, discussions on technical issues have recognized the work completed at Lawrence Berkeley National Laboratory (LBL) on A Specifications Guide for Performance Monitoring Systems, <http://cbs.lbl.gov/performance-monitoring/specifications/pdf/pmsg-spec-draft.pdf> This Guide may represent a starting platform for establishing the details of some components of an FDD Standard. In addition, two Research Topic Acceptance Requests (RTARs) were submitted to appropriate Technical Committees at the ASHRAE annual meeting in June. They included: “*Closed loop control - problems, performance measurement, and alternative algorithms to PID*” and “*User Interface Design for Advanced Systems Operation.*” Both were supported by appropriate Technical Committees and are moving forward in the ASHRAE process. Taylor Engineering staff have established a web site to follow the progress of the RTARs: http://www.taylor-engineering.com/EMCS_Data_Standard/index.shtml It was also recognized that there are number of other efforts underway to develop data standards and visualization tools. An assessment of these other efforts will be necessary to avoid duplication of efforts and to encourage collaboration where appropriate.

An additional item was brought up by the group and tabled without further detail:

Action Item 2: Small Commercial Building Rooftop Unit Diagnostics

Action Item 3: Improved interface and usability of FDD information reported to user. This item had no further definition at the meeting, but has become one of the RTAR submissions noted above.

Demonstrated Performance and Value

Action Item 1: Investigation Best Practices.

Conduct a small number of in-depth case studies to identify the issues that are addressed by FDD tools currently on the market, and identify issues that need to be addressed. While an effort will be made to identify costs and benefits of the tools in these applications, this project will be a somewhat qualitative investigation, determining the metrics to be collected in the more statistically based research described in Action Item 2. It will be important to look beyond the technical issues addressed by the systems, and look into the organizational structure in which the tool is placed, and identify what works and what doesn't work within the organizational structures.

Objectives: Market segment comparison

Define what constitutes demonstrated performance

Understanding organizational issues for decision makers

Key players: FDD providers, owners/users, utilities

Resources: \$250,000+

Timing/Schedule: not detailed.

Action Item 2: Survey of Cost/Benefits of Existing FDD Demonstrations/Field Sites

Use a defined data collection protocol to collect cost and benefit data from a large number of buildings. A balance will have to be sought between level of detail and explanatory power of the data collected, and ease of data collection, to ensure a powerful dataset with a large sample.

Objectives: Develop data collection protocol, adapted from existing commissioning protocol
Encourage future additions of information to the database
Comparison of FDD buildings with control buildings
Understanding organizational issues for decision makers

Key players: FDD providers, owners/users, utilities

Resources: not detailed

Timing/Schedule: after Action Item 1 is completed.

Action Item 3: FDD Model Specification

Objectives: Develop a generic FDD specification that can be adapted.
Guidelines for building owners. Guidelines for utilities
Link with CA Title 24 Standards
Develop standard FDD scopes
Develop acceptance tests and related criteria

Key players: FDD providers, owners, ASHRAE, non-profits (as drivers).

Resources: not detailed.

Timing/Schedule: near term

Market Awareness

Action Item 1: Target and Sell FDD to Market Leaders in a Given Sector.

Objectives: Demonstration projects built on existing relationships with multi-site owners and their current maintenance providers.

FDD suppliers partner with Roundtable participants to identify Market Leaders.

Key players: FDD suppliers, O&M providers, referrals from Roundtable participants, owners.
NBI, AEC, CCC and WCEC could participate.

Resources: \$150,000 for three demonstration projects

Timing/Schedule: Immediate, with one year to complete.

Action Item 2: Engage Industry Leaders on FDD.

Objectives: Outreach to owners associations BOMA, IFMA, PRSM, SMACNA, ACCA, NAEASCO, AIA, ASHRAE, USGBC, others.

Key players: NBI lead. Could be part of NBI's *Billion Square Foot Initiative*.

Resources: \$75,000 from CEC

Timing/Schedule: 24 months

Action Item 3: FDD Model Specification.

Objectives: Develop a generic FDD specification for automated embedded FDD.

Key players: FDD providers (Jay Santos-lead-Facility Dynamics, Field Diagnostics, others), owners, ASHRAE, non-profits (as drivers).

Resources: *Pro bono*

Timing/Schedule: 90 days.

Action Item 4: Case Studies, 3rd Party Reviewers, Web Site and Articles

Action Item 5: Get Programs Like LEED to Embed FDD to Create Market Pull

Action Item 6: Form an FDD Industry Group

Action Item 7: Cultural Issues including: Accountability, Motivation/Incentives/Rewards, Identifying the Key Entry Points to a Given Market.

Action Item 8: Work with Industry Associations to Set Minimum Codes and Standards for FDD

As noted, each of the working groups came up with an action item for developing parts or all of an automated embedded FDD specification/standard. This is clearly a direction that FDD has to move in.

Industry Collaboration

Finally, the group discussed opportunities for collaborative efforts. There was broad agreement that there was value in collaborative efforts, and shared goals. A list of potential partnerships was generated. A concern was raised, however, that more formal collaboration would necessarily slow the process down. Institution-building is an overhead expense that this industry can't afford right now, since the need to advance tools is too pressing. While at the meeting, several individuals identified actions that they were interested in pursuing, and have subsequently started moving forward as noted in the Action Items. Perhaps this group meeting will provide enough of a Roadmap, that significant advances can be made on multiple fronts without external organization required.

There was recognition that some public funding was going to be necessary to ensure that the benefits of this group decision making would move forward in an organized way. Support from organizations such as CEC (PIER), US DOE, ASHRAE, and BOMA should be sought.

The group was generally interested in follow up meetings, if they were held by teleconference.

New Buildings Institute is continuing to maintain a mailing list of 87 individuals invited to the Roundtable or added subsequently. This is the first national FDD mailing list of its kind. To be added to the list, please contact: [markc at newbuildings.org](mailto:markc@newbuildings.org)

Observations

Overall, the Roundtable was judged as a success in terms of establishing several concrete action items, with individuals and organizations agreeing either to lead an activity or be actively involved with others.

Discussion was lively throughout the meeting. Most participants were actively involved in the discussions throughout. During the flow of a meeting, themes emerge; ideas come and go; questions are posed with no answers. From this Roundtable, there are a few things from the discussion worthy of mention:

1. The use of and benefits of FDD cut across several major market segments including: building owners, building managers, facility operators, HVAC service companies, O&M contractors, the commissioning industry, utility companies, carbon emissions agencies, and probably others. It is vital to get the message about FDD across these markets since FDD application and benefits have specific appeal depending on the market.
2. There was a surprising sense of common cause and not much disagreement.
3. There is no national champion (individual/organization) *per se* that is leading efforts to move FDD further into the market. It is not clear where such a champion might come from, if one were to emerge.
4. While there was a lot of common interest, there was less a sense of moving forward together. Participants had interest in specific follow up activities, but not another Roundtable unless it was topical. Email or teleconference would be appropriate for future communication especially on the Action Items that are moving forward.
5. There appears to be no specific interest in establishing a national organization to represent FDD in a variety of stakeholder venues. Yet without a person or organization at the center of FDD, collaboration/cooperation in support of FDD is left to enterprising interests and is generally a random event.
6. FDD developers and researchers still have to live in a world that takes integration of design, controls and ongoing operating performance into consideration only on rare occasions.
7. The working groups did a good job of prioritizing and documenting the most important topics and ended up with a coherent list of priority actions.
8. An FDD work plan could be developed for the California Energy Commission and the California utilities that would potentially address the Roundtable Action Items as well as related activities. This might provide a more effective and consistent approach to providing timely responses to the known technical, performance/value demonstration and market awareness challenges.
9. FDD practitioners have had a rough time as they have worked over the years. Lack of recognition, market interest, building owner support have left some participants feeling somewhat battered. Because of this, at times it is difficult for the practitioners and researchers to reach outside the limited space they have created and begin to create momentum around FDD in a more effective manner.
10. Given that FDD is an integral part of building controls, operation and maintenance, ongoing commissioning functionality, and vital to maintaining energy efficiency and related environmental benefits, it seems that trying to establish FDD as a separate discipline is not the way to go. There appears to be no interest in and rationale for establishing a national organization (non-profit or industry association) dedicated to promoting FDD as a standalone building operations-related tool. Rather, it appears far more important for FDD to be broadcast into existing building operations. FDD needs become as envisioned: a business-as-usual tool in the building energy performance marketplace.

Additional Material

Overall Barriers/Challenges to FDD in the Buildings Market

The following challenge lists were summarized from a variety of published assessments of what is keeping FDD from faster market entry, as well as added to by Roundtable participants.

A. Technical Challenges

1. Data Acquisition including bandwidth and storage
2. Data sufficiency
3. Data standards
4. Open standards / Interoperability
5. Data visualization
6. Data usability including reporting of information, presentation of information
7. Data integration
8. Sensors including number needed, accuracy, calibration, drift, cost
9. Durability
10. Performance standard (s) --benchmark (s)
11. Control system variability
12. Operational Sequence
13. Point naming convention
14. Fundamental approach including qualitative, quantitative, other
15. Whole building level, system level, device level.

B. Demonstrated Performance and Value Challenges

1. Case study project design: which FDD tool, research design options, modeling, M&V.
2. Building type and quantity.
3. FDD Level: whole building, system level, device/unit level.
4. kW/kWh/carbon impacts.
5. Building operating impacts: labor productivity, maintenance
6. Indoor air quality impact.
7. Costs of FDD tool: purchase, setup/commissioning, ongoing.
8. What is working and why?
9. What is not working and why?
10. Whole building level, system level, device level.

C. Market Awareness Challenges

1. Little awareness across the market including building owners, operators, and controls vendors/specifiers.
2. Lack of cost (ROI, capital, etc) and performance information/data.
3. Varied customer needs: owners, managers, operators, design community, HVAC contractors. Internal politics always plays a role.
4. Cultural: accountability; work expectations; workplace hierarchy
5. Fragmented market.
6. Market transformation is needed.
7. Who can you talk to about FDD? Who are the advocates? Who has the information?
No national organization or point of contact or website. *[NBI will be establishing an FDD*

Web site September 2007].

8. Controls companies: why so little interest?
9. ESCO's: should be a natural ally.
10. Market perceptions of FDD are few and likely not favorable.
11. Owner interest.
12. Training/usability of the FDD tools.
13. Commissioning of FDD tools.
14. Non-energy benefits.
15. Utilities role: big demand response benefit potential.
16. Current cost of energy is not a sufficient driver in many places.
17. Predictability of results.
18. Building owner/operator response requirements when FDD finds problems.
19. Codes and Standards.
20. Whole building level, system level, device level.

Roundtable on Fault Detection and Diagnostics for California
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University of California - Davis, CA

Participants

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Kristin	Heinemeier	Western Cooling Efficiency Center	(Co-Chair)
A.Y.	Ahmed	Semptra Utilities	
Steve	Blanc	Pacific Gas & Electric Co.	
Michael	Brambley	Pacific Northwest National Laboratory	
Martha	Brook	California Energy Commission	
Mike	Day	Ice Bear	
Terry	Egnor	New Buildings Institute	
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Chuck	Frost	Lawrence Livermore National Laboratory	
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