2009 BFRL Project Description

Project Title: Virtual Cybernetic Building Testbed

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BFRL Program: Cybernetic Building Systems

Objective: To create and maintain a whole building emulator capable of reproducibly simulating normal operation and a variety of faulty and hazardous conditions in order to serve as a testbed for investigating a wide range of issues important to the development of cybernetic building technology including commissioning, fault detection and diagnostics, optimization strategies for interacting building systems, aiding emergency responders, and extending communication protocols.

Problem:

What is the problem? The dynamic interactions of integrated control systems in a cybernetic building are not well understood. Building owners and operators are increasingly demanding integration of historically separate building automation systems in order to reduce operating costs and better manage their facilities. These demands are reflected in recent industry technology roadmaps.[1] Building owners need standards, performance metrics, and best practice guidelines to achieve their goals. Ideas are emerging about new ways to make use of the information rich environment that cybernetic building systems can offer and conservative economic estimates indicate the potential for $1.1 billion per year savings in office buildings alone[2]. Research to advance these ideas to the stage of commercialization depends upon tools that can reliably and reproducibly test and evaluate alternatives. Building automation system manufacturers and service providers need assistance in developing, testing, and certifying new products.

Why is it hard to solve? The problem is hard because comprehensive testing cannot be conducted in real buildings. In a real building it is necessary to maintain a comfortable and safe

[1] U.S. Department of Energy, *High-Performance Commercial Buildings: A Technology Roadmap,* http://www.eere.energy.gov/buildings/info/documents/pdfs/roadmap_lowres.pdf
[2] Benefits and Costs of Research: A Case Study of Cybernetic Building Systems, R.E. Chapman, NISTIR 6303, 1999.

environment for the occupants at all times, weather cannot be controlled or reproduced, and hazardous events like fires cannot be introduced and repeated under controlled conditions. There are no simulation tools that can realistically capture all of the necessary details of a complex cybernetic building system.

How is it solved today, and by whom? The problem is not solved. There is no comparable tool elsewhere with the capability to carry out the broad range of investigations needed. A building emulator has been built by Lawrence Berkeley National Laboratory using different simulation tools as a base and includes only HVAC controls. In that case the emulator is best suited to investigating long term energy performance of control strategies but it does not have the capabilities of the Virtual Cybernetic Building Testbed (VCBT) to emulate faults, commissioning problems, fires, and other hazardous conditions. The VCBT has already enabled collaborative research efforts with many outside partners including Pacific Northwest National Laboratory, Natural Resources Canada, CSTB, and a number of building automation and control product manufacturers.

Why NIST? The VCBT is aligned with the BFRL mission of anticipating and meeting the needs of the U.S. building industry, and with the vision of creating critical solution-enabling tools. The VCBT also enables research addressing three of the BFRL Core Competencies: Measurement Science for Building Energy Technologies; Information, Communication and Automation Technologies for Intelligent Integration of Building Design, Construction and Operation; and Fire Protection and Fire Spread Within Buildings and Communities. NIST has a long history of helping industry through testbeds with unique capabilities. The HVAC, fire, and building modeling expertise present in BFRL, and the ability to combine them with real controllers, gives BFRL a unique ability to do this work.

Approach:

What is the new technical idea? BFRL has successfully built a Virtual Cybernetic Building Testbed that combines the flexibility and reproducibility of simulation tools with networks of commercial building automation and control products to create a laboratory environment that realistically approximates actual building performance. The new idea is to expand the capabilities of the VCBT to emulate a wider range of buildings and operating conditions. The eventual goal is to have a facility that can emulate a variety of commercial buildings in any climate under both normal operating conditions and a range of fault or hazardous conditions. It will become a key resource for developing commissioning tools, fault detection tools, decision support tools for emergency responders, enhancements to the BACnet standard, performance metrics for commercial products, and best practice guidelines for building owners and operators.

Why can we succeed now? BFRL has a long track record in developing and advancing building emulator technology. A first generation VCBT has already been created and it has produced significant positive results. This provides an excellent base from which to expand the capabilities of the testbed. Collaborative work through CRADAs indicate both a growing need for such a tool and industry support for this work. With the increased demand for FDD and

commissioning tools, integrating building systems, and optimizing energy performance while improving safety and environmental quality, there is more need than ever for such a testbed.

What is the research plan? NIST has already built an operational VCBT with assistance and cooperation from industry partners through cooperative research and development agreements. Both the simulation capabilities and the real building automation system components will be expanded to enable realistic emulation of larger and more complex buildings and a greater variety of normal and abnormal operating conditions. New types of building automation systems will be added to the virtual building and the ability to reconfigure the building design and operational details will be improved. The nature of the improvements will be driven by the research objectives of the users of the facility and by the needs of collaborating industry partners.

Several new capabilities will be added to the VCBT including simulation and control hardware to emulate central plant equipment, extended features of the Network Entity Simulator to make virtual controllers visible on the BACnet network allowing the scalability of commissioning tools to larger buildings to be tested, new HVAC terminal equipment types, and increased fire modeling capability. New BACnet functionality will also be added to bring the VCBT up to recent addenda to the standard. In addition to these improvements, a variety of emulation runs will be created to meet program objectives for testing new commissioning and fault detection tools, to the Sensor Driven Fire Model, and new emergency first responder tools.

Future expansions will include adding capabilities to track and monitor energy consumption implications of control strategies for short or long time scales to support the BFRL strategic priority in Measurement Science for Building Energy Consumption. The vision is to make the VCBT into a tool to develop a method of test for energy performance of building control systems.

Recent Results:

- **Output**: Creation of a first generation VCBT using control products from seven cooperating companies for HVAC control, lighting control, physical access control, and fire detection. These devices are interconnected using a BACnet internetwork that uses all networking technologies defined in the BACnet standard.
- **Output**: Park, Reneke, Galler, Bushby, Davis, “Enhancement of the Virtual Cybernetic Building Testbed to include a zone fire model with HVAC”, NISTIR 7414, 2007
- **Output:** Park, *HVACSIM+ User’s Guide Update*, NISTIR 7514, 2008
- Allowed all many other areas of research to proceed. Enables testing of FDD tools, commissioning, first responder, and all other projects.
- **Outcome**: A fault simulation library was developed to serve for testing HVAC FDD and commissioning tools.
- **Outcome**: The ZFM-HVAC simulation tool was developed to emulate building fires with interacting HVAC systems.
- **Outcome**: New interfaces to the simulation tool were developed to speed the configuration of building emulation runs.

Standards and Codes:

BFRL staff are already participating in the following standards committees that will be directly impacted by this work: ANSI/ASHRAE 135, ANSI/ASHRAE 135.1, EN ISO 16484-5, EN ISO 16484-6, and NEMA SB 30. There is a possible future standard method of test for building control system energy performance that may result from this work.