Bridging the Training Gap: Development of New Curriculum for the Commissioning Industry

Bradley Brooks, Kirstin Pinit, Lia Webster, PECI
Liz Fischer, Building Commissioning Association

ABSTRACT

The demand for energy-efficient buildings is increasing in both the public and private sectors and requires an increased workforce capable of meeting this demand. Currently available commissioning training opportunities do not address the full spectrum of duties and tasks required of a commissioning authority. The development of a comprehensive curriculum to prepare individuals for a career as a commissioning authority is needed. Upon completion of a comprehensive program, these individuals will be well-prepared to provide solutions and apply various strategies to achieve energy efficient, sustainable, and high performance buildings.

Developing a curriculum for commissioning authorities requires five critical elements: 1) a clear process for defining the job or occupation in the terms of duties and tasks; and knowledge, skills, and abilities; 2) development of learning goals and objectives; 3) defining of instructional topics, learning environments, and delivery methods; 4) development of training materials; and 5) outlining program evaluation methods.

This paper reports on the critical elements and activities undertaken by PECI to develop a commissioning authority curriculum with funding provided by the U.S. Department of Energy and other partners.

Introduction

Commercial buildings are energy intensive and a target for energy savings. In the U.S. alone, buildings are responsible for 36% of total energy use and 65% of electricity consumption (EPA 2012). Demand for energy efficient buildings is increasing, in both the public and private sectors. This increased demand for energy efficient buildings will require an increased workforce. Consequently, creation of this workforce will contribute to economic recovery and growth; improve the asset value of the nation's building stock; and produce sustainable environments. "Investments in building retrofits and energy efficiency can make a real difference in the American economy, by creating jobs, growing our industries, improving businesses' bottom lines, reducing our energy bills and consumption, and preserving our planet for future generations" (The White House, Office of the Press Secretary 2011).

The workforce required to create high performance energy efficient buildings will involve numerous distinct professions including architects, engineers, energy auditors, commissioning authorities, contractors, and building technicians and operators. Many of these professionals are currently in the workforce in sufficient numbers and possess the expertise to design and apply various strategies to achieve energy efficient, sustainable, and high performance building systems.

However, the commissioning industry does not have an adequate number of qualified commissioning authorities or a comprehensive training program to educate and train individuals entering this profession (Tseng 2005). Commissioning authorities are integral to the delivery of

energy efficient buildings and provide solutions to improve the performance of existing buildings. To address the lack of qualified commissioning authorities and bridge this gap, a comprehensive and widely accessible training program is required. This training program will entail development of curriculum to properly educate and train individuals interested in seeking a career in the commissioning industry.

Building commissioning requires a wide range of competencies including knowledge of building science, engineering, construction, and building operations (Heinemeier, Moore, Sellers, & Haasl 2006). Developing this curriculum will need to identify required competencies; define learning goals and objectives; identify the learning environment and delivery methods; and outline evaluation methodologies.

This paper reports on the critical elements and activities undertaken by PECI to develop a commissioning authority curriculum with funding provided by the U.S. Department of Energy and other partners including the New York State Energy Research & Development Authority (NYSERDA), the California Energy Commission (CEC), the Building Commissioning Association (BCA), the Northwest Energy Efficiency Alliance (NEEA), the California Commissioning Collaborative (CCC), and PECI. Overall funding for the project approached two million dollars.

Analyzing the Training Gap

The project team conducted a needs analysis to determine specific details of the gap between market demand for commissioning professionals and training opportunities available to provide job candidates the knowledge and skills necessary for performing commissioning activities. The main objectives of this needs analyses were to: 1) describe the workforce needs of the commissioning industry; 2) classify the current commissioning training opportunities; 3) determine specific training needs not currently provided in the marketplace; and 4) depict typical individuals seeking training in the commissioning industry. This needs analysis relied heavily on information gathered from experts in the commissioning industry, including commissioning service providers, educators and building owners, and relevant studies.

Results of the Needs Analysis

The investigation yielded the following findings on the commissioning workforce, current training, and absent training opportunities in the commissioning industry:

- Organizations and individuals in the commissioning sector have identified a shortage of well-trained applicants for job openings;
- The demand for commissioning services far exceeds the capacity of qualified firms because of growing interest in energy efficiency and sustainable buildings (Tseng 2005);
- Current training opportunities offered by many organizations target experienced commissioning professionals and focus on providing certification exam preparation or continuing education units;
- A large amount of the commissioning training available focused on the commissioning process;
- The training available provides a limited amount of technical information and few hands-on or applied training experiences;

- The duration of most available training ranges from a few hours to several days;
- University engineering programs do not provide the required field and hands-on experience working with building systems and equipment; and
- Cost concerns prohibit employers from providing training opportunities to employees due to lost work productivity and travel expenses.

Additionally, the needs analysis uncovered information that described a typical individual who is seeking training in the commissioning industry. A need exists to provide training to three specific groups: 1) entry-level commissioning professionals seeking technical and hands on training; 2) recent college graduates with engineering degrees seeking specific training in commissioning; and 3) professionals seeking to transition into the commissioning industry from related engineering disciplines. The project team concluded that to meet the need for increased capacity and skill in the commissioning field, the target audience for training is those individuals who come to the field with an engineering degree or previous experience in building operations combined with a solid understanding of engineering fundamentals obtained through equivalent training and work experience.

Defining Desired Outcomes through Occupational Analysis

Successful curriculum is developed from a solid understanding of the job or occupation to be addressed in the training program. Without a clear understanding of the job function and the knowledge, skills, and abilities (KSAs) required for a specific job, any curriculum or training program runs the risk of inadequately preparing a participant for the job (Norton, Moser 2008). An occupational analysis results in an exhaustive list of major functions, key activities, KSAs, and technical supportive enablers.

To conduct the occupational analysis, the project team implemented a modified DACUM method. DACUM (Developing A Curriculum) is an innovative and widely-used process to determine competences to be addressed in a training curriculum (Norton, Moser 2008). The DACUM methodology is based on three premises: 1) expert workers describe their job better than anyone else; 2) jobs can be effectively described in terms of competencies or tasks and duties; and 3) the specific knowledge, skills, and abilities required to correctly perform job tasks can be described (Norton, Moser 2008). The required steps to complete the DACUM process include development of a DACUM chart; validating and ranking results; analyzing validation results; and selecting instructional topics. This phase of curriculum development is consistent with other well-known instruction development models such as ADDIE (Analysis, Design, Development, Implementation, and Evaluation).

The typical DACUM process employs a trained facilitator to guide a committee of experts through the process. The committee convenes in one location from one to several days to perform the occupational analysis that typically results in development of a DACUM chart. This chart lists job function duties and related tasks for each duty. The development of KSAs results from the identified job tasks.

To expedite this process, the project team developed a draft DACUM chart and facilitated a review with selected subject matter experts. The team relied on its own subject matter expertise and referred to previously published reports and other sources during the development of the draft DACUM chart. These documents included several commissioning guidelines and standards from the American Society of Heating, Refrigerating, & Air Conditioning Engineers (ASHRAE),

the Building Commissioning Association, the National Institute of Building Sciences (NIBS), and the National Environmental Balancing Bureau (NEBB). (ASHRAE 2005, 2007, BCA 2008, NIBS 2006, NEBB 2009)

Commissioning providers recruited from the Building Commissioning Association formed the expert panels. Two panels were formed, one panel to address new construction commissioning and a second to address existing building commissioning. These experts participate in industry associations, perform commissioning services, and employ commissioning personnel.

Through a series of teleconferences, the panels reviewed the draft DACUM charts. The panels clarified and revised the job duties and tasks and assigned specific requirements describing the KSAs for these tasks. Once the panels reached consensus on elements, the DACUM data charts were revised and prepared in their final form.

Table 1 is an excerpt from the DACUM chart with correlating KSAs to illustrate the level of detail achieved through the process.

Table 1: Sample DACUM Chart & Related KSAs

No.	Duty	Task	KSA
L	L1.Write Functional Performance Test (FPT) Procedures	1. Develop/update FPT list 2. Examine drawings, diagrams, & specifications 3. Examine control system diagrams, point lists, & control sequences for test scenarios 4. Develop draft FPT procedures 5. Revise FPT incorporating review comments 6. Perform integration testing	Knowledge of: Mechanical & electrical equipment and system operation, BAS control diagrams, points, sequences and configuration, TAB process and procedures Skilled in: Writing detailed step-by-step procedures Ability to: Determine testing requirements of specific systems and equipment.

Results of the DACUM chart development effort were verified through a survey to rank the importance of each KSA. An electronic survey was sent to 7,555 commissioning authorities, contractors, owners, design engineers, and others listed in the databases for the National Conference on Building Commissioning and the Building Commissioning Association. One hundred and ninety-four individuals responded to the survey representing a response rate of 2.5%.

The survey results were analyzed and ranked by the mode – the highest value that occurs most frequently. This ranking of the KSAs helped the project team identify and prioritize certain topics while discarding others. When finalized, the commissioning authority occupational analysis had documented 115 specific job tasks in 18 duty categories and included a catalog of the knowledge, skills and abilities required for this occupation.

Designing Comprehensive Curriculum

After completion of the occupational analysis, the next step in the process is the design of the curriculum. The KSAs developed in the occupational analysis were used as a guide for the curriculum design. This phase includes development of a curriculum outline, instructional topics

and learning objectives; definition of the learning environment; and determinations of delivery methodologies that best convey the instructional content. The project team continued to follow sound instructional design methods described in the ADDIE model to design the comprehensive commissioning curriculum.

Curriculum Outline

The project team analyzed and grouped each KSA into broad instructional areas. This process was iterative, until the most logical flow was determined. The curriculum outline indicates progression through sequential topics areas. These high-level topics group large categories of information into components within the curriculum. The highest level in the curriculum is a module, which contains courses. Courses contain lessons, which are the lowest level of instruction. These groupings are made by considering the:

- Most effective way to address the full breadth of the KSAs;
- Logical flow of content from the perspectives of instructor and participant; and
- Eventual packaging of content to be offered to the market.

Participants move through the program sequentially by completing the required lessons in a course, courses in each module, and all modules in the curriculum.

Learning Goals and Objectives

Learning goals are broad statements that describe the result achieved by completing a particular course of study. In this case, the primary goal of this instruction would be the reduction of energy use in buildings. Other goals include preparing individuals to gain employment in the commissioning industry.

Learning objectives are more specific, relate to each instructional topic, and describe specifically what the participant should know or be able to do after completing training. Each learning objective has three core components: 1) an observable action or behavior, 2) conditions of the performance, and 3) a measureable level of acceptable performance. Five hundred and seventy-eight (578) learning objectives were developed to address the KSA's for commissioning authorities.

Verbs describe the observable action or behavior within the learning objective, for example "describe the benefits of commissioning" or "calculate the energy loss." Conditions under which the action or behavior are performed may include the instructional environment, materials, tools, and resources that are used to perform the observable action. Measurable criteria define the acceptable performance required by the participant and may be evaluated with several methods. For this program, the condition under which the action is performed includes the interaction with learning materials and learning environment. The measureable criterion for acceptance is a passing score of 70% on the module assessments. Figure 1 shows examples of learning objectives that meet these requirements.

Figure 1: Example of Well-Developed Learning Objectives

- Describe the operation of a water heater by reviewing the manufacturer's literature in thirty minutes.
- Identify the correct efficiency ratings using equipment data provided prior to end of the design phase.
- Calibrate a temperature sensor using a multimeter to NIST specifications.

Delivery Methodologies

The format within which training is conveyed must provide a successful path to completion of the program. The most important consideration is providing the educational experience best suited to convey the specific instructional content. Another controlling factor in determining the delivery of instruction is consideration of issues related to the target audience. The participants' preference, familiarity, and experience with alternative learning methods such as e-learning and self-study are an important consideration.

The project team studied traditional independent self-study, face-to-face classroom lecture, distance education, e-learning, and hands-on situational training. The proliferation of online educational formats offers many options for training to adult learners. Research has demonstrated that adults learn best by self-directing their learning process; applying concepts directly to their requirements; relating their own experiences into the learning process; and learning concepts through solving problems rather than absorbing content (Knowles 1984). E-learning formats are compatible with all of these requirements.

Ultimately, a blended learning approach that combines asynchronous e-learning and hands-on situational laboratory instruction was selected. E-learning is less expensive for participants than onsite training which requires travel expenses and time out of the office during business hours. Asynchronous e-learning allows participants to control the time, location, and pace of instruction and permits the use a variety of instructional methods to satisfy the different learning styles of participants. Hands-on situational instruction in a classroom laboratory environment provides real life experiences testing systems and equipment similar to what is found on the jobsite.

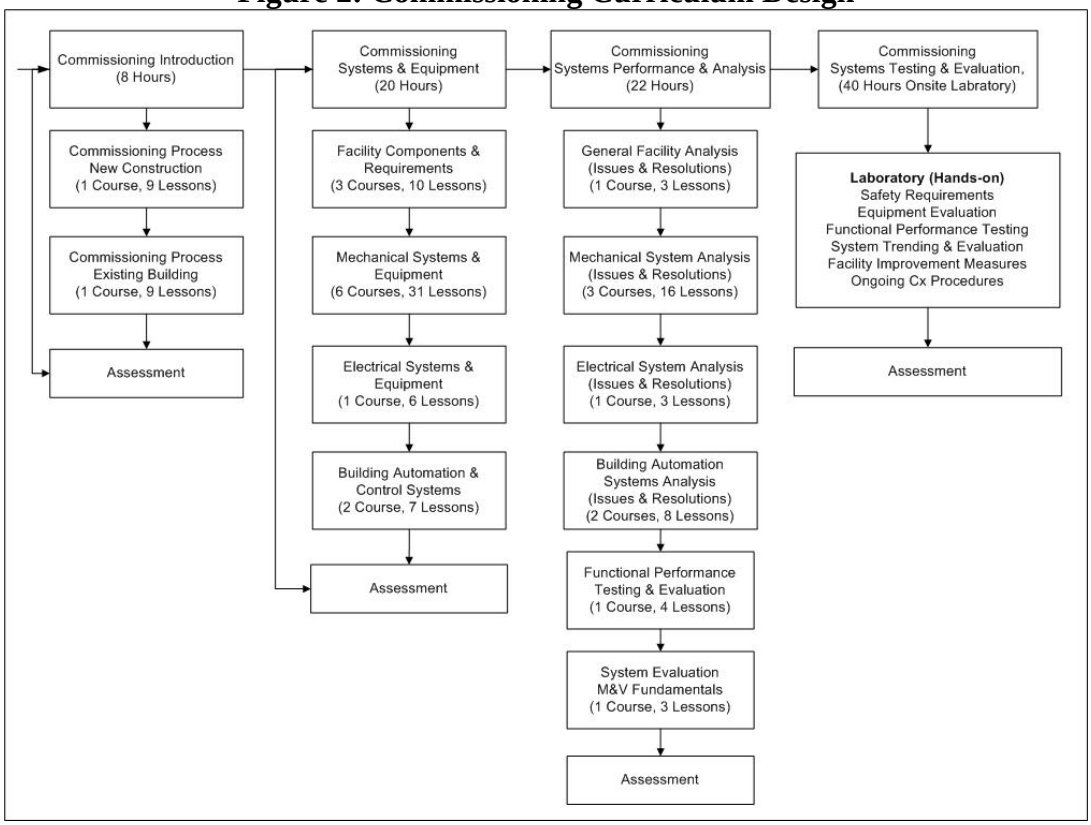
Final Curriculum Design

The curriculum design is the culmination of the elements described above and encompasses the organization of instructional content and the outcomes to be achieved through completion of the course of study. The rationale for the commissioning curriculum design (Figure 2) is based on four principles:

1. Understanding of the commissioning process, which includes project phases, activities, and deliverables, is fundamental to the delivery of commissioning services;
2. Operational knowledge of the individual systems and equipment components provides a foundation for advanced coursework;
3. The development of analytical skills is required to determine proper system and equipment operation to optimize building energy performance; and

4. Observation and manipulation of the actual systems, equipment, and instrumentation provides the opportunity to apply knowledge to real life situations in an engaging learning environment.

Figure 2: Commissioning Curriculum Design



The commissioning curriculum was organized into four modules that address the four principles sequentially. Each module builds upon prior instruction and culminates with actual hands-on commissioning activities to functionally test and evaluate a building's energy performance. Initial estimates indicate the total commissioning training program will take approximately 90 hours to complete.

Development of Training Materials

The development of the content for this project was completed in two phases. Instructional content was first developed to fulfill the learning goals and objectives within the framework of the curriculum design. Subsequently, this raw content is prepared for delivery via e-learning and site-based laboratory activities according to the selected blended learning approach. Participant and instructor manuals will be developed for the laboratory module. These materials will be finalized through an alpha review of the final content. An online learning management system (LMS) will be developed to deliver e-learning content and to manage participant engagement in both online and laboratory portions of the program.

Development of Instructional Content

Developing successful instructional content requires both domain knowledge of the subject matter and expertise in instructional design. The project team worked closely with experts from the commissioning field to develop the instructional content. The domain of knowledge these subject matter experts (SMEs) provide in the development of the instructional content ensures that the instruction meets the learning goals and objectives desired and brings an element of reality to the content through real-world examples and images. The team also engaged the expertise of professional instructional designers to ensure that content is presented in the appropriate manner and appeals to participants in the training program.

Subject matter experts were members of the Building Commissioning Association. The selection criteria included depth of knowledge on the subject matter to be developed; teaching and/or training experience; and examples of presentations. Eleven SMEs participated in the development of the instructional content.

Following the learning objectives defined for each lesson, the SMEs began development of the instructional content. The development process included three steps: 1) development a draft PowerPoint presentation of the lesson with bullet point and images; 2) revision of the lesson based on comments provided by the project team and capture of audio narration; 3) review of audio transcripts and development of a glossary of terms.

The project team used a web-based document management system to manage the development of 123 lessons by 11 SMEs. This system allowed the SMEs and reviewers to check documents in and out for reviewing and editing. The document management system addressed version control issues, enabled access control through roles and permissions, and facilitated workflow with notifications and alerts.

Development of E-Learning

Content developed by the SMEs became the foundation for development of the e-learning modules. An instructional design process was applied to each lesson to incorporate images, video, animation, interactive elements, and quizzes. The project team reviewed a matrix of the entire curriculum which conveyed the diversity of instructional elements. Detailed design documents for each course were reviewed to ensure technical accuracy was maintained throughout the curriculum. During production, image enhancements, video clips, professional audio narration, interactive quizzes, animation, and lesson navigation were implemented.

The New Jersey Institute of Technology's Center for Building Knowledge received funding under the same U.S. Department of Energy project and teamed with PECI to produce sixty percent of the e-learning content. PECI contracted with Building Media, Inc. to develop forty percent of the e-learning content.

Development of Laboratory Instructional Materials

Preparation of laboratory instructional materials included development of an instructor manual and participant manual. The instructor manual contains the information required to coordinate laboratory activities and configure the laboratory systems and equipment. The participant manual describes the laboratory exercises and step-by-step procedures to complete each exercise.

The initial step in the development of the laboratory documents was the identification of laboratory systems and equipment. From a review of the KSAs, curriculum topics, and learning objectives the project team selected the following systems for inclusion in the laboratory: Chilled water system (Water or Air Cooled Chiller); Hot water system (Hot Water Boiler); Air handling unit with air distribution system; Packaged HVAC units (Heat Pumps, Spilt-Systems, Gas/ Electric); Interior lighting system (Fixtures, Lighting Control Panel and Occupancy Sensors); Domestic hot water with circulation pump; and Building Automation System (Direct Digital Control System)

For each system, the participant will experience typical commissioning activities performed in the work environment. These activities include observing and documenting the installation of equipment; functionally testing of systems; system trending; and performance evaluation. Participants will be assigned to teams comprised of three members to complete six laboratory activities. Each team will be work on different laboratory exercises during the same period ultimately completing all the laboratory exercises. The laboratory configuration can accommodate a maximum of 18 participants.

Evaluation of Training Program

Program success will be measured in several ways: participant knowledge assessment, post-training participant assessment, and program evaluation. Data collected through tests and surveys will provide insight into participants' increase in knowledge and skills and their satisfaction with the program.

Perhaps the most important indicator of success – and the most difficult to measure – is reduction in energy use in buildings as a result of an individual attending the training program. Determining whether the program had a measurable impact on energy use is difficult to determine, as many factors affect a building's energy use.

Participant Knowledge Assessment

Participants will complete both informal and formal knowledge assessments throughout the program. "Test Your Knowledge" quizzes offer self-checks within each lesson to informally check for comprehension and reinforce learning. The modules were designed to be completed sequentially; therefore participants must pass a knowledge assessment for each module before moving on to the next. This assessment will be administered electronically and a 70% pass rate will be required to continue. A certificate of completion is awarded after successfully passing the final module exam with a 70% pass rate.

Participants completing the program will be surveyed at three month, six month, and one year intervals to assess both short-term and long-term knowledge retention. The survey will also gather data on participants' job status to determine whether participants were able to secure work in a job related to their training or in another field. Measurement of reduced energy use will require more sophisticated evaluation methodologies that have not yet been determined.

Program Evaluation

Participants will be asked to complete program evaluations to measure the success of the program and to inform future program improvements, updates and enhancements. At the

conclusion of each course, participants will be asked to complete an electronic survey to evaluate their experience. Questions will focus on the participant's satisfaction with the delivery of training; perceived value of instructional content; suggestions for improvement. A similar evaluation will be used to gather feedback on the laboratory module.

In addition to participant surveys, PECI will use data collected from the learning management system that will be used to deliver e-learning content to perform further analytics on participation including time spend completing courses and performance on test-your-knowledge quizzes.

Lessons Learned

For parties interested in developing instruction to meet goals that are similar to the goals of this project, the following findings and insights can provide assistance and allow others to learn from this experience.

Occupational Analysis

It is critical that the expert panel members are committed to the project and that they have the time needed to prepare for and contribute during working sessions. During the occupational analysis phase, the project team faced the challenge of panel members who could not attend scheduled meetings, were unable to review documents prior to meetings, and who did not fully participate during meetings. The use of teleconferencing made it difficult to achieve desired levels of collaboration.

To address these challenges the project team recommends the following actions: solicit members that are extremely interested in the outcomes of the project; be clear about the amount of time required; and hold face-to-face meetings to keep members engaged in the discussion.

Subject Manner Experts

The SME's developing instructional content need training and support to ensure they develop the content as required. The project team held a kick off and several teleconferences to explain the project requirements; however, early drafts of some content did not meet expected results in terms of adherence to learning objectives, inclusion of images, and other factors.

Working one-on-one with SME's addressed many of these issues but required unanticipated resources from the project team. Several of the SMEs communicated excellent instructional concepts during one-on-one exchanges; however, the development of the actual instructional content to convey these concepts was challenging.

The project team recommends the following actions to effectively engage SMEs in transferring their expertise into high-quality instructional content: 1) whenever possible, select SMEs with proven success in developing the expected quality of instructional material prior to contracting for services; 2) plan and budget to work individually with SMEs prior to and during the development of any instruction content, and set expectations by providing examples of completed high quality work product; 3) clearly communicate scheduling requirements and build in periodic check-ins to ensure content development progresses as expected.

Next Steps

The development of e-learning and laboratory materials is expected to be complete in August 2012. In parallel, a Commercialization and Sustainability Plan and a Certificate and Accreditation Plan will be developed.

The Commercialization and Sustainability Plan describes how the training will be brought to market. The plan covers program administration, costs and pricing, and program enhancements and updates. A detailed marketing plan describes the target market, marketing strategy, and methods to measure results.

The Certificate and Accreditation Plan discusses how the program will address industry needs and expectations related to accreditation of the training program and professional certification of individual practitioners. Accreditation from a reputable accrediting body helps establish the program's credibility. The project team has taken initial steps required to obtain International Organization for Standardization (ISO) Standard 29990: Learning services for non-formal education and training. Regarding professional certification, the program will support individual participants' pursuit of certification or maintenance of certification.

Conclusion

This curriculum was developed to change the landscape of available commissioning training and to expand the workforce capable of providing solutions to meet the demand for energy-efficient buildings.

Most currently available commissioning training offerings focus only on the commissioning process rather than the application of knowledge, skills and abilities required of a commissioning authority. This program addresses the gap with instructional content that encompasses the extensive breadth of knowledge and skills required by the commissioning authority occupation, and it incorporates hands-on activities to provide an immersive and transformative learning experience.

The full spectrum of knowledge required includes understanding of the commissioning process; knowledge of the individual systems and equipment; development of analytical skills to determine system performance; and the observation and manipulation of the actual systems, equipment, and instrumentation to apply knowledge and use new skills in the actual real-life setting. A blended learning approach allows for on-demand self-study combined with hands-on situational experiences, which is consistent with the adult learning principles.

As of spring 2012, the project is in the final stages of development. PECI plans to work collaboratively with the Building Commissioning Association to launch the program in the fall of 2012. The two organizations will continue to work together to promote the program to the market and to monitor ongoing needs for updates and enhancements.

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