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Implementing Computer-Based Procedures: Thinking Outside the Paper Margins

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ABSTRACT

In the past year there has been increased interest from the nuclear industry in adopting the use of electronic work packages and computer-based procedures (CBPs) in the field. The goal is to incorporate the use of technology in order to meet the Nuclear Promise requirements of reducing costs, and improving efficiency and decreasing human error rates in plant operations. Researchers, together with the nuclear industry, have been investigating the benefits an electronic work package system and specifically CBPs would have over current paper-based procedure practices. There are several classifications of CBPs ranging from a straight copy of the paper-based procedure in PDF format to a more intelligent dynamic CBP. A CBP system offers a vast variety of improvements, such as context driven job aids, integrated human performance tools (e.g., placekeeping and correct component verification), and dynamic step presentation. The latter means that the CBP system would be capable of displaying relevant steps based on operating mode, plant status, and the task at hand. The improvements can lead to reduction of the worker's workload and human error by allowing the work to focus on the task at hand more.

A team of human factors researchers at the Idaho National Laboratory studied and developed design concepts for CBPs for field workers between 2012 and 2016. The focus of the research was to present information in a procedure in a manner that leveraged the dynamic and computational capabilities of a handheld device allowing the worker to focus more on the task at hand than on the administrative processes currently applied when conducting work in the plant. As a part of the research the team identified type of work, instructions, and scenarios where the transition to a dynamic CBP system might not be as beneficial as it would for other types of work in the plant. In most cases the decision to use a dynamic CBP system and utilize the dynamic capabilities gained will be beneficial to the worker. However, tasks that are reliant on the skill of the craft or have a short set of instructions may not provide a way or even need to utilize all the advanced capabilities in a dynamic CBP system. Therefore, a hybrid CBP system that could handle all the classifications of a CBP would be the best solution to take advantage of all that a CBP system offers.

The implementation of a CBP system does not automatically improve the quality of procedures. Utilities should look into why each procedure is written the way it currently is on paper. Utilities should take the time before implementation to review, standardize format and update current procedures. Implementation of a CBP system can be a time to break out of traditional procedure writing processes and create new processes and procedures that take advantage of the capabilities a CBP system.

This paper summarizes the research on CBPs and provide suggestions to take into consideration when implementing a CBP system.

Key Words: Computer-Based Procedures, Electronic Work Package System

1 INTRODUCTION

Nearly all activities that involve human interaction with nuclear power plant systems are guided by procedures, instructions, or checklists. Paper-based procedures (PBPs) currently used by most utilities have a demonstrated history of ensuring safety. In the past year there has been increased interest from the nuclear industry in adopting the use of electronic work packages and computer-based procedures (CBPs) in the field. The goal is to incorporate the use of technology in order to meet the Nuclear Promise requirements of reducing costs, improving efficiency, and decreasing human error rates in plant operations.

Researchers, together with the nuclear industry, have been investigating the benefits electronic work package systems and specifically CBPs would have over current PBP practices. The authors of this paper are a part of a team of human factors researchers at the Idaho National Laboratory that developed and evaluated design concepts for CBPs for field workers between 2012 and 2016. The focus of the research was to present information in a procedure in a manner that technological capabilities of a handheld device allows the worker to focus more on the task at hand. The researchers conducted controlled studies in nuclear power plants' training facilities (e.g., flow loop, electrical laboratory, and instrumentation and control laboratory) [1-3]. In addition, the CBP design concepts were also evaluated in field studies where a set of procedures was converted to the CBP system and used by the field workers during normal operation for a couple of months. The field workers participating in the field evaluations provided feedback about the system's usability and potential areas of improvement. The field evaluations were conducted at nuclear power plants operated by APS, Duke Energy, Pacific Gas and Electric, and Southern Nuclear [4-6].

2 COMPUTER-BASED PROCEDURES

The nuclear industry is constantly trying to find ways to decrease human error rates, especially human error rates associated with procedure use. As a step toward the goal of improving field workers' procedure use and adherence and hence improve human performance and overall system reliability the authors have been investigating the possibility and feasibility of replacing current PBPs with CBPs.

The limitations in paper-based systems do not allow them to reach the full potential for procedures to prevent human errors. Nuclear power plants consist of an environment that is constantly changing, depending on current plant status and operating mode. PBPs, which are static in nature, are being applied to a dynamic context. PBPs are written with the intent to cover many potential operating scenarios. Hence, the procedure layout forces the worker to search a large amount of irrelevant information for the pieces relevant to the task and situation at hand, potentially taking up valuable time when operators must be responding to the situation or leading operators down an incorrect response path. Other challenges related to use of PBPs are management of multiple procedures, place-keeping, finding the correct procedure for a task, and relying on other sources of additional information to ensure a functional and accurate understanding of the current plant [2].

A CBP is defined as a dynamic electronic presentation of a procedure that guides the worker seamlessly through the logical sequence of pre-determined steps [7]. In addition, the CBP system has the capability to utilize technology, such as incorporating computational aids, easy access to additional information (e.g., drawings, procedures, and operational experience), just-in-time training at the job location in the field, and digital correct component verification. The system, by incorporating modern technology, allows human performance improvement features to be integrated into both the procedure and the overall work process. A CBP system offers a more dynamic means of presenting procedures to the worker, displaying only the relevant steps based on operating mode, plant status, and task at hand. A dynamic presentation of the procedure guides the worker down the path of relevant steps based on current conditions and inputs made by the worker.

Context-driven job aids, such as corrective action documentation, drawings, photos, and just-in-time training are accessible directly from the CBP system as needed. The time spent searching for applicable documentation is noticeably reduced. Furthermore, human performance tools can be embedded in the CBP system in order to let the worker focus on the task at hand rather than the human performance tools. Some of these tools can be completely incorporated into the CBP system, such as pre-job briefs, place-keeping, correct component verification, and peer checks. Others can be partly integrated to reduce the time and labor required, such as concurrent and independent verification.

As a part of the CBP research, the team identified instruction sets and scenarios where the transition to a dynamic CBP might not be as beneficial as it would for others in the plant. In most cases the decision to use a dynamic CBP and utilize the dynamic capabilities gained would be beneficial to the worker. However, tasks that are reliant on the skill of the craft or have a short set of instructions may not provide a way or even need the advanced capabilities in a dynamic CBP. Therefore, a hybrid CBP system that could handle all the classifications (see levels of smart documents below) of a CBP would be the best solution to take advantage of all capabilities and benefits a CBP system offers to the industry.

2.1 The Nuclear Electronic Work Packages – Enterprise Requirements (NEWPER) Initiative

The team, together with utilities and vendors in the nuclear industry, formed the Nuclear Electronic Work Packages - Enterprise Requirements (NEWPER) initiative as a means to develop a vision of implementing an electronic work package (eWP) framework that includes many types of CBPs. The move to an eWP system that can utilize CBPs enables immediate paper-related cost savings in work management and provides a path to future labor efficiency gains through enhanced integration and process improvement in support of the Nuclear Promise [8-9].

The NEWPER members based their taxonomy on one defined by the Electronic Power Research Institute (EPRI) in "*Improving the Execution and Productivity of Maintenance with Electronic Work Packages* "[10]. Both EPRI and NEWPER based their taxonomies on levels of smart documents where a smart document is an electronic form with capabilities beyond a traditional paper form. The taxonomy consists of four levels of smart documents: (1) basic, (2) moderate, (3) advanced, and (4) adaptive. Table I summarizes each of the levels [9].

Table I. Summary of smart document levels.

Level	Summary
Basic (Active Fields)	The document has fields for recording input such as text, dates, numbers, and equipment status.
Moderate (Automatic Population of Data)	The document incorporates additional functionalities such as form field data "type" validation (e.g. date, text, number, and signature) of data entered and/or self-populated basic document information (usually from existing host application meta data) on the form when the user first opens it.
Advanced (Data Transmission)	The document provides the capability to transmit data entered into other data systems.
Adaptive (Dynamic/Variable Fields)	The document uses variable (i.e., dynamic) field options based on previously completed data entries or links to other electronic documents or media.

The NEWPER initiative published a utility generic set of functional requirements for basic and moderate smart documents in December 2016 [11]. Functional requirements for Advanced and Adaptive smart documents will be jointly published as a Procedure Professional Association standard in 2017.

The smart document taxonomy helps to determine the level of functionality and dynamic nature of a CBP. CBPs can range from a straight copy of the PBP in PDF format to a more adaptive (i.e., dynamic) CBP. The smart document levels can be used to classify which CBP type is being used. Procedures may not always lend themselves to be converted to a more intelligent level, such as advanced or adaptive CBP. A less complex and/or short procedure will most likely be a perfect candidate for a basic document.

3 IMPLEMENTATION CHALLENGES AND CONSIDERATIONS

During the years of CBP research the researchers have encountered multiple different arguments for why it will not be possible or feasible to implement a CBP system. Some of the most common arguments are related to user needs and limitations, the conversion and authoring of procedures, other technology limitations, and cost.

One of the arguments often voiced by utilities is that people are resistant to change. This on its own is not a false statement. As humans we do not like the unknown and hence have a tendency to be hesitant to change familiar processes, but using such blanket statement as a reason to not improve work processes is poor business logic. The researchers expected that in general the older work force in the nuclear industry to be quite hesitant to transition from using paper to dynamic procedures on handheld devices. However, the researchers found that the few individuals who initially expressed their hesitance became great advocates after just a short familiarization period (usually less than 30 minutes). It was also concluded that the risk of individuals rejecting change from a traditional paper process to a digital and dynamic format is greatly reduced if the new system is well-designed from a user perspective. In other words, if the system is easy to understand and use even for novice users then the risk of rejection is minimal.

Another item identified to greatly impact the user experience with the new system, and hence the user acceptance, is the availability of different sizes of handheld devices where the size needed depends on organization or nature of the task. For example, a field operator who climbs up ladders and crawls in tight spaces would most likely prefer a smaller sized handheld device than a maintenance technician who brings a cart out to the work location and who does not need to move around too much in the plant during the execution of the task.

The NEWPER initiative brought up the concern of the constantly being monitored in the field. The field workers were concerned that the CBP system's ability to log performance data, such as step completion times and paths through the procedure, would be used against them. The main purpose of logging this type of performance data should be to identify quality issues with the procedure or planning rather than individual workers' performance. Information such as certain steps that always tend to take a longer time than expected to execute is valuable when both revising the procedure and when planning for future work using the same procedure. It will be up to each utility to manage how the performance data will be used and to protect the privacy of its workers. Field workers expressed that logging the procedure execution will give them some piece of mind too. For example, if an audit is conducted due to a valve that should be Open was found Closed the field worker will have an easier time proving that the valve was in fact Open during a previous valve line-up (i.e., the worker correctly followed the procedure) and that someone else may have unfortunately bumped the valve after the line-up.

A utility has tens of thousands of procedures and instructions which all need to be converted into a digital format. The complexity of the conversion process depends on which level of smart document the utility decides to use for the majority of the procedures. A basic smart document does not require much more than adding some input fields to the PDF while adaptive (i.e., dynamic) smart documents will require more effort. The researchers found that the utilities will get most out of their transition from paper to smart documents if they choose a combination of different levels of smart documents.

Not all procedures gain an advantage when they are converted into CBPs. Simple procedures (e.g., procedures that do not collect data, do not require branching, or are very short) can be left as a straight copy of the PBP in a PDF format. This allows for their use within the CBP system and gains the benefits of the more streamlined work process, increased traceability, and reduced paper-costs.

A hybrid CBP system that allows for all levels of procedures ranging from simple PDF through the adaptive level of smart documents is an ideal choice for utilities looking to take advantage of the benefits such a system has to offer.

The NEWPER members expressed concern over the cost and level of work required to convert all of their procedures into electronic format. Most of the utilities want a system that has the capability to support the fully adaptive CBPs, as discussed previously, but not require them to spend the time to convert all the procedures at once. The researchers recommend the utility identify groups of procedures to convert. The groups should be small to allow control of training processes needed for the procedure writers and workers to fully utilize the new functionality the smart document would bring. The groups can either be categorized by organization, type of task, level of smart document, or a combination of these. Converting groups of procedures verses all procedures at once allows the utilities to show progress and early returns on investments.

It is not only the workers in the field who are affected by the transition from PBPs to CBPs. Other roles such as planners, procedure writers, supervisors, and archivers are also impacted. When designing the CBP system all these roles need to be assessed to ensure all user needs are adequately addressed. Related to the conversion of PBPs to CBPs the procedure writers' specific requirements and needs should be kept in mind. Currently, most procedure writers use templates (often home-built) in either Microsoft Words or other legacy text editors to revise existing procedures and to write new ones. The researchers identified that the procedure writers were both concerned that they would have to become software developers to manage more advanced smart documents and that the transition might eventually render the procedure writers out of their jobs.

In order to gain full advantage of the technological advancements inherent in CBPs, there must be a translation layer between the procedure writer and the underlying data structure needed to support the different levels of smart documents. A procedure authoring and editing tool would be such translation layer [12]. The authoring and editing tool should be designed to be used by individuals that have no prior programming skills, such as most procedure writers. Hence, to ease the transition from the traditional approach of composing and revising procedures in a text editor the user interface should be intuitive and easy to use.

As mentioned, the authoring and editing tool must be designed with the end-users (procedure writers) in mind. In other words, users who are more comfortable with using text editors than more advanced or complex systems. One example of design decision to consider is to use functions such as drop-down boxes, input boxes, lists, and options to add the dynamic branching capability in the smart documents. This will eliminate the need for the user to write logic statements to describe the conditions in which the branching will occur. Using these types of elements in a tool to create the procedure will mitigate errors that might otherwise be introduced into the document.

Such tool should allow the procedure writer to easily create a procedure for a specific task by selecting the components and actions required from sets of predefined components and actions. The CBP system authoring and editing tool must be able to handle relationships between steps (e.g., decision points, input fields, and marking steps not applicable). In short, the authoring and editing tool should provide a mean for the procedure writer to identify the appropriate level for the new smart document and add the functionality needed to create the smart document.

It will also allow a user to create a future CBP document in less time. As procedure steps are created they will be stored in a library where they can be accessed and reused as needed in the future. When creating a new procedure the procedure writer would access the library and select the steps appropriate for the specific task or procedure. This will decrease the time needed to revise and author procedures as the library grows.

The conversion of the original procedure to a data format that can be used by the CBP system should not require much more user interaction than simply selecting which files to be converted. The conversion process itself should take place in the background, while the procedure writer works on other procedures. The conversion tool should ensure that relevant steps are identified and sequenced in their proper order and that as much logic as possible is added to the converted procedure. However, the conversion tools currently offered to the nuclear utilities are not capable of automatically generating all the dynamic functionality needed for CBPs. Hence, the procedure writer will still be needed to ensure that functionality such as branching between steps and/or procedures, access to additional information and job aids, and calculations are correctly represented in the procedure after conversion.

Another concern identified through the NEWPER initiative is the need of rugged mobile devices to be used by the workers in the field. The driving factor for using rugged devices is that they will last longer in the particular work environments in a nuclear power plant. More specifically, the concern is that the device needs to work properly even after being dropped from high heights, exposed to both hot and cold environments, or used outside. However, rugged devices are most often quite expensive compared to none-rugged versions. For the price of one rugged device one could potentially purchase five to ten normal devices. Hence, the device is not too expensive to replace if it breaks.

The use of any mobile devices also brings up the concern about how to ensure the work will not be lost if the device is broken. Two examples of how to mitigate this are; 1) with available Wi-Fi coverage the CBP system automatically synchronize data to the system database upon completion of each step in the procedure, or 2) the CBP system stores the recorded procedure on a Secure Digital (SD) card which can be swapped into a new device if needed.

The introduction of CBPs on mobile devices into the field requires an environment capable of supporting the data needs of the CBPs. This environment, defined as a digital architecture (DA), is a collection of information technology capabilities needed to support and integrate a wide spectrum of real-time digital capabilities for performance improvements of nuclear power plants, such as a CBP system [13]. The DA can also be thought of as the integration of the separate instrumentation and control systems and information systems already in place in nuclear power plants, which are brought together for the purpose of creating new levels of automation in power plant work activities.

Implementing a DA may bring up concerns of and challenges with items such as bandwidth capabilities, cybersecurity and Wi-Fi availability. While these concerns are not trivial, they can be addressed in an efficient manner. The benefits of the level of system integration available with a well-designed DA will outweigh the resources it takes to address and resolve the potential technical challenges. Benefits such as real-time updates of critical path schedules based on task progression, updates of equipment databases based on actions taken in the plant, access to additional information and just-in-time training from the work location, and live video streaming of critical task will ensure both safer and resources efficient operation of the nuclear power plant. Below are suggested approaches to resolve potential bandwidth capabilities, cybersecurity and Wi-Fi availability challenges.

As more devices are introduced onto a network, bandwidth requirements can become challenging. Capabilities such as load balancing and distribution can be enabled on existing equipment to increase their existing efficiency. Redundant paths of traffic should be added to reduce the risk of the chance of a single point of failure. A process for resolving issues and implementing changes should be put in place such as a systematic management and evaluation process of the ever-changing bandwidth demands. Capacity-related information should be collected to evaluate performance and trending information should be used to evaluate the available bandwidth capacity utilization as the system grows.

A cybersecurity plan to mitigate any possible attacks should be implemented by following the Regulatory Guide 5.71 [14] which defines the cybersecurity defense development process through the following main steps: 1) Develop a cybersecurity plan in compliance with 10 CFR 73.54, 2) Establish and implement a cybersecurity program, 3) Maintain the cybersecurity program, and 4) Retain and handle records.

Wi-Fi availability can be mitigated with the introduction of more hotspots and access points to increase coverage. In the cases of controlled areas the CBP system should be able to function in an offline mode by downloading the required information before entering such an area. As the mobile device is once again within Wi-Fi coverage or connected through a kiosk, the CBP can be synced with the system to provide updated information.

The last consideration related to CBP implementation important to highlight is that a CBP system does not automatically improve the quality of procedures. In fact, as the researchers converted procedures in their research activities, many procedures were found to have unique issues needing attention. Utilities looking to implement a CBP system should look into why each procedure is written the way it currently is on paper and should take the time, before implementation, to review, standardize format and update their procedures. Implementation of a CBP system can be a time to break out of traditional procedure writing processes and create new processes and procedures that take advantage of the capabilities a CBP system.

A CBP's main building block can be boiled down to a step in the procedure. A more focused approach on how each step is written can improve the procedure because each step in a CBP is what the worker will interact with. Each step instructs the worker to perform a single action. These individual actions lead to the completion of the overall task. By maintaining focus on what a step is instructing the worker to do and how that step affects the overall task outcome is what defines procedure flow. How the procedure flows determines the quality of the resulting CBP.

4 CONCLUSION

This paper discuses some of the major challenges or arguments a utility will have to address while moving forward with implementation of a CBP system. These challenges can be summarized as user needs and limitations, conversion and authoring of procedures, technology limitations, and cost. Although there are challenges inherent in implementing a CBP system, research has shown that there are options available to the utilities to meet and overcome the challenges. CBPs provide a means for reducing costs, improving efficiency and decreasing human error rates of plant operations. In order to take advantage of these benefits, utilities should take the time to develop their implementation strategy of a CBP system. The strategy should allow for groups of procedures to be updated or converted to work in the CBP system. This reduces the upfront time and cost before seeing the return on their investment.

Utilities looking to implement a CBP system should look into why each procedure is written the way it currently is on paper and should take the time, before implementation, to review, standardize format and update their procedures. Implementation of a CBP system can be a time to break out of the paper margins of traditional procedure writing processes and create new processes and procedures that take advantage of all the capabilities a CBP system will provide.

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