

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

**Available for sale to the public, in paper, from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161,
phone: (800) 553-6847,
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/help/index.asp>**

**Available electronically at <http://www.osti.gov/bridge>
Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from: U.S. Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831-0062,
phone: (865)576-8401,
fax: (865)576-5728
email: reports@adonis.osti.gov**

Enhancing Facility Operations through Electronic Procedures™

Joe Temples
Process Control Engineer
Bechtel Savannah River, Inc.
Aiken, SC 29808

Chris Kourliouros
Process Control Engineer
Novatech Process Solutions, L.L.C.
Aiken, SC 29803

KEYWORDS

Electronic Procedures, Automation, Distributed Control System

ABSTRACT

Design of integrated solutions fusing existing facility practices with emerging technology is creating new platforms for enhancing operations. Review of current business methods uncovered several areas of improvement including; operating efficiency, document routing, accountability, reporting, records management, format standardization, and control system interaction. A new Defense Programs (DP) facility at the Savannah River Site (SRS) is implementing an electronic procedure environment to overcome these challenges.

Electronic procedures merge disciplines of design engineering, procedure writing, controls engineering, and operations into a central development platform for creating optimal plant processes. Users develop procedures through a combination of logical flowcharts, customizable properties, and Distributed Control System (DCS) functions resulting in the generation of static and dynamic operating procedures, software documentation, and automation code. Execution of developed procedures occurs in a single, uniform, procedure-oriented interface designed specifically for the operator in order to reduce process mistakes, present online information, list approved procedures, organize systems, launch audible alerts, and strengthen communications with automation. Creation of executed documents upon procedure completion and custom reports containing detailed shift turnover information are additional managerial benefits incorporated into the interface.

Initial and continuing application improvements from an evaluation of developer feedback, process configurations, and facility integration are reviewed. Incorporation of manual and automated electronic procedures into the Novatech D/3 Distributed Control System (DCS) and other sub-systems is also discussed with specific examples. A final analysis is performed on the results of meeting facility challenges and potential areas for new application expansion and growth.

INTRODUCTION

Procedures continue to remain central components of any industry determined to increase their productivity, safety, and operating efficiency. Without procedures, companies observe significant deficiencies in the areas of operations, maintenance, management, training, and safety. Successful implementation of procedures occurs through the standardization of writing guidelines, approval processes, and document control. Although these areas are often recognized elements of the procedure environment, developing optimal methods for managing these tasks becomes a challenge. Various types and levels of automation exist throughout the industry including distributed control systems, programmable logic controllers, and other computer driven controls. Despite the method of automation, the function is the same; to provide extended controls between the process and the operator. Although automation and procedures are traditionally developed through separate processes and review cycles, the two are integral to one another. Advances in technology are providing new methods for merging procedures and automation into a centralized platform. Facility analysis, interface design, and electronic procedure configuration in addition to potential application expansion are discussed with specific examples.

FACILITY ANALYSIS

Construction of a new Defense Programs (DP) facility at the Savannah River Site (SRS) prompted the review of existing operations in order to develop a comprehensive and interactive package for automation through the Novatech D/3 Distributed Control System (DCS). Current methods of automation comprise of a combination of dynamic graphics and batch programming alongside written paper procedures. Operator confusion and uncertainty often result from the use of multiple interfaces, which ultimately cause costly and untimely production mistakes. A process control team conducted a review of existing operational practices to determine a strategy for improving automation and expanding its controls.

Analysis began through comprehensive interviews and discussions with process control engineers, operation managers, operators, and procedure writers to gain an understanding of current facility strengths and weaknesses. Engineers, managers, and operators all recognized the primary area of improvement for operations to be communications with automation. For example, during sequence or batch errors, operators hesitate on the next appropriate step to perform. Their confusion results from a combined lack of understanding on the previous, current, and future actions to transpire from the DCS. As a result of their hesitation, operators develop a conception that once a sequence or batch program begins no further interaction is to occur on their behalf. On the contrary, automation requires repeated contact with operators in order for the program to continue its execution and completion.

Management identified reporting and accountability as the remaining areas of improvement. Deficiencies here include limited batch summaries and the absence of reports outlining running sequence programs. Several weaknesses were voiced and it was clear, the strength of operations was in procedures. All actions currently taken by operators occur through the interaction of steps written on paper procedures. Exceptions to this rule only occur during abnormal situations as directed by

management. Therefore, operators in conjunction with procedures are the essential piece to successful facility operations. However, the use of paper continues to be a constraint for the following reasons; assurance of current revisions filed by document control, capture of hand recorded information, and the turnover of procedures between shifts. The resulting analysis of operating practices generated the basis of a new design for operator interaction with automation and the DCS.

DESIGN OF THE OPERATING INTERFACE

Dynamic graphics and batch programming presently link operators to automation. Graphics consist of smart graphical objects displaying active sequence statuses along with interactive prompts and queries. Batch applications reflect a more engineering-oriented display with cryptic acronyms and confusing transitions between subroutines. Consequently, a preliminary design of several new possible interfaces was performed each focusing on the integration of procedures, automation, and the operator, as seen in Figure 1.

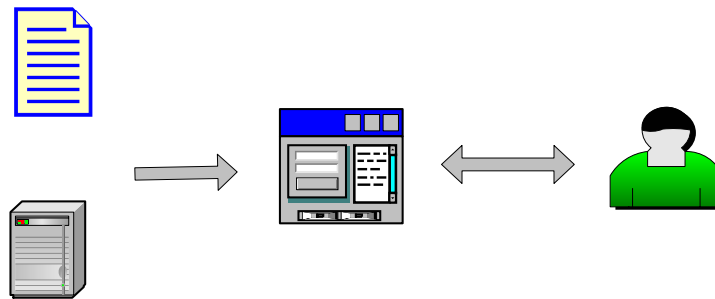


FIGURE 1: AUTOMATED PROCEDURE TO OPERATOR RELATION

One proposal involved using an existing graphics application combining all sequence and batch programs into a single, dedicated group of graphical displays. Previous configurations distributed the interaction with automation onto multiple process graphics rather than centralizing the information. Although the graphical application was already familiar to operators, its limitations comprised of lengthy, excessive configuration and maintenance times and a lack of connectivity to external data sources.

A second proposal focused on the use of Visual Basic in order to create a customizable display meeting the requirements of a single, unified display. Visual Basic offers the ability to create custom controls and connect to multiple data sources through object-oriented programming, all aspects not available through the current facility graphical application. Any object-oriented programming language provides the same capabilities and functions as Visual Basic; however, extended knowledge of this language throughout the facility prompted its selection. Through research and repeated reviews, a single procedure-oriented operator display emerged integrating all aspects determined from the facility analysis. Instead of splitting the operator focus between written paper procedures and dispersed through multiple graphical displays, the three were combined into one, as seen in Figure 1.

The interface contained dedicated windows displaying running procedures and procedural steps mirroring those written previously on paper. A message area provided a single point of contact for operator responses with audible procedure alerts, once unachievable with other application packages. Additionally, a system toolbar enabled the organization of procedures into facility areas. With backend data storage of procedure information, reporting deficiencies no longer existed.

DESIGN OF THE PROCEDURE DEVELOPER

After an initial examination of operating procedures, several recurring patterns became apparent. Aside from formatting and background sections, the heart of every procedure is divided into five basic types of steps; actions, transitions, control logic statements, informational messages, and queries. Actions mainly comprise of verbs and objects. Transitions are special actions steps merged with conditional statements. While control logic statements dictate the flow of the procedure, informational messages provide background information to the operator during procedure execution. Queries are used to input information into the procedure, make decisions, or archive data. Recognizing every procedure is actually a batch process (i.e. a definitive beginning and end), the decision was made to model the procedure developer after the most successful standard ever produced by the ISA, the S88 series of batch standards.

Microsoft Visio was the preferred medium to construct the procedures. MS Visio is a unique application enabling users to flowchart procedural steps using graphical shapes onto a virtual canvas, versus the conventional method of typed words and phrases. Each flowchart shape contains custom properties configured by the user to define how the procedure interacts with the operator. Extraction of information entered by users is also used to generate a formatted paper procedure.

Restricting the procedure into a flowchart format allows for some other significant advantages. For instance, the intent of the procedure is observed quickly and easily through the visual inspection of connected graphical shapes representing each step. Users no longer are concerned with formatting issues but concentrate on the flow of the process. Additional properties within each shape provide users the ability to configure underlying DCS automation code while others generate quality assurance (QA) documentation.

A direct link now exists between the operator interface and the procedure developer. Disciplines of system engineering, process control engineering, procedure coordinators, and operations are able to interact together through one common development platform for creating procedures and automation, as seen in Figure 2.

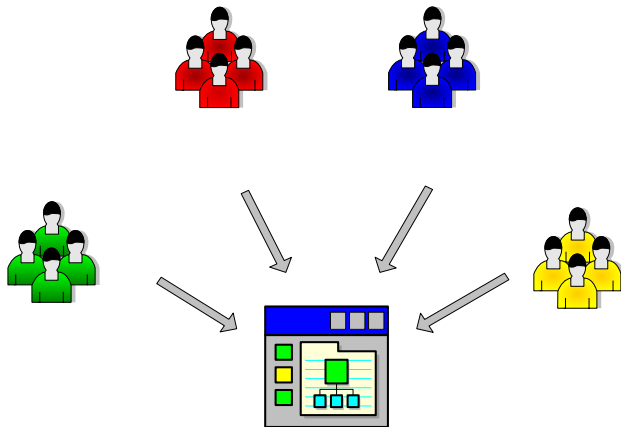


FIGURE 2: TEAM CONTRIBUTIONS TO PROCEDURE DEVELOPMENT

Through the developer display each group contributes their unique perspective into a single display. System engineers flowchart the system-specific operational processes through use of graphic symbols, text entries, and custom properties. Process control engineers map DCS parameters for automation, matching the process outlined by the system engineers. Procedure writers review the procedure steps entered by system engineers to ensure if standard writing guidelines are met. Finally, operations determine if both the procedure and underlying automation meets their specific requests. Decreased procedure development time and enhanced revision control between the procedure, QA documentation, and automation sequence code result. Therefore, the procedure developer facilitates the complete relationship between the various procedure development groups and the operator, as seen in Figure 3.



FIGURE 3: DEVELOPMENT TO EXECUTION OF PROCEDURES

DEVELOPMENT OF ELECTRONIC PROCEDURES

After the design of the procedure developer and operator interface, the need arose to determine the different pieces of software to be generated from each application. First, the Portable Document Format (PDF) was selected as the medium for the formatted documents resembling traditional paper procedures. PDF is ideal due to its cross-platform compatible files which are viewed with an easily readable free reader. File sizes are small versus typical word documents and consequently highly resistant to viruses. The most vital benefit of PDF documents is the preservation of the original record

System
En

which plays an important role in complying with 21 CFR Part 11 security regulations. Second, the generation of electronic procedures is created from the flowchart of shapes and configuration of custom properties. Each of these properties and shapes electronically dictate the interaction between the procedure and the operator. Third, expansion of the application advanced into generation of DCS code required to execute the electronic procedure automatically. Common sequence actions and general functions were identified and incorporated into custom property fields for each shape. Configuration and extraction of each DCS parameter, in turn, generated a functional table of the procedure, which translated into DCS code. The result is DCS code interaction in conjunction with the electronic procedure. And fourth, certain shapes provide users the ability to outline requirements necessary for software QA documentation. Each requirement is extracted for possible use in other QA applications. As seen in Figure 4, the procedure developer application enables users to configure a variety of custom properties in order to create several pieces of software vital to the electronic procedure environment.

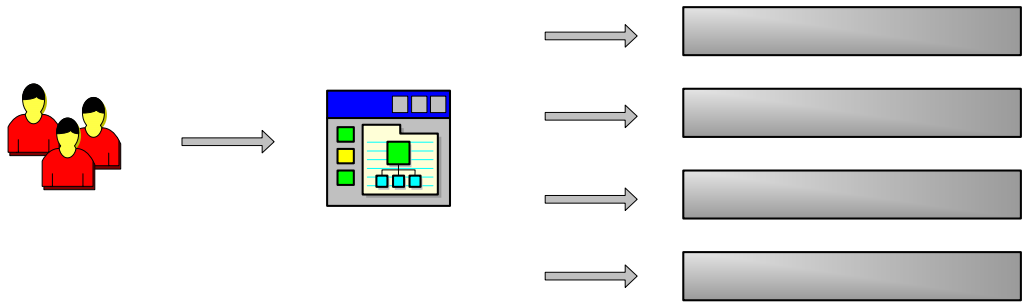


FIGURE 4: PROCEDURE DEVELOPER SOFTWARE DESIGN

Next, the electronic procedure and corresponding automation code became the principal files for execution in the operator interface, as seen in Figure 5.



FIGURE 5: OPERATOR INTERFACE SOFTWARE DESIGN

From these two innovative pieces of software, the procedures contained all the necessary properties for either manual or automated execution. The choice of which procedure type to run was left to operations. Execution of each procedure results in an executed record retained in another PDF document. The executed PDF file resembles the existing procedure except with detailed recordings of execution times and operator entries through queries, comments, or DCS interactions. Next, audible procedure sounds through the interface alert the operator of message prompts or queries, automation errors, procedure statuses, or DCS malfunctions. Each type of alert is configured with a separate sound file while other settings allow for repetition interval and delay times. Custom reports such as

shift turnover reports are generated from the display. The shift turnover report outlines procedures currently in-progress or completed procedures during the shift. Also, prerequisite actions and operator comments are readily available for review of procedures prior to transition between operators. Therefore, the design of each piece of software facilitated the complete integration between the procedure developer and operator interface, as seen previously in Figures 4 and 5.

As with any new procedure development, the question of back fitting existing paper procedures became apparent. From the review, another application development ensued tying paper procedures to the procedure developer. Users import text files, such as MS Word, and automatically generate procedure shapes in the developer display. A detailed flow of text document to procedure flowchart is seen in Figure 6.



FIGURE 6: TRANSFORMATION FROM PAPER TO ELECTRONIC PROCEDURE

CONFIGURATION OF ELECTRONIC PROCEDURES

A board of engineering, operations, and project managers reviewed the applications potential advantages and decided for implementation into the new DP facility currently under construction. All standard operating procedures (SOP) were scheduled for completion using the applications. Training sessions immediately ensued for system engineers, procedure writers, and process control engineers, each of whom contributes their own portion to the electronic procedure. System engineers started development of the first procedures with some hesitation. As the engineers became more familiar with the procedure developer, progress of the development cycle increased. Likewise, procedure writers felt the same growing pains as the system engineers. User feedback continues regularly resulting in many application improvements including: document formatting to meet facility guidelines, new shapes for custom tables, new pages for monitoring condition during procedure execution, windows for viewing recorded information entered into the procedure, switches for disconnecting procedures from automation for manual execution, and a host of others. As application development continues, new versions of the applications are released to the users. Version upgrades help avoid timely and cumbersome rework. Since the application is based on procedures, the impact to the new facility is reaching into every department, forcing all groups to work more closely together in the creation of effective procedures. However, any change or modification to established business practices requires time.

CONTINUING IMPROVEMENTS

As with any new application, areas of improvement, expansion, and growth emerge. Since the procedure developer, operator interface, and procedure converter involve operating procedures, the potential is apparent for inclusion of other types of procedures including alarm response procedures, abnormal operating procedures, emergency operating procedures, and many more. Further reviews of facility practices reveal the need for online or immediate changes to executing procedures. Support for tablet PCs also began to surface. Parts of a procedure are downloaded into the tablet PC for manual execution of steps. An operator now is able to complete and acknowledge lengthy series of steps while in the field. After execution of the steps, the procedure on the tablet is merged back with the original document executing on the DCS. Routing techniques to document control, archiving of historical documents, new electronic procedure writing guidelines, and reporting are all other areas which may also increase operations efficiency and capacity.

CONCLUSION

Creation of the first procedures began in January of 2004 by system engineers. So far, approximately 40% of the scheduled procedures for completion are within their initial revisions. Ten to fifteen procedures are under the review cycle moving toward the validation stage, where operators alongside engineers will execute the procedures on simulated training stations. Initial preparations by process control engineers are underway for configuration of automated procedures on the DCS.

In conclusion, the development of an electronic procedure environment is leading the way for improved operations in DP facilities at SRS. Operation in existing DP facilities, after witnessing the impact to the construction of the new facility, has scheduled the implementation of electronic procedure into two systems by 2006. Therefore, an electronic procedure operating environment is only the start of a continuing improvement process for optimizing plant process.

REFERENCES

1. Center for Chemical Process Safety, "Writing Operating and Maintenance Procedures", Guidelines for Writing Effective Operating and Maintenance Procedures, Center for Chemical Process Safety/AIChE, New York, New York, 1996.
2. Parshall, Jim and Larry Lamb, Applying S88: Batch Control from a User's Perspective, Instrument Society of America, Research Triangle Park, North Carolina, 2000.
3. Adobe Systems Incorporated, PDF Reference, 4th Ed., Adobe Systems Incorporated, San Jose, California, 2003.

4. The Society for Life Science Professionals, "Risk based approach to 21 CFR Part 11," <http://www.21cfrpart11.com/pages/library/index.htm> via the Internet, 2004.
5. Xcert International, "Meeting the FDA's Requirements for Electronic Records and Electronic Signatures (21 CFR Part 11)," <http://www.21cfrpart11.com/pages/library/index.htm> via the Internet, 2004.
6. Liberty, Jesse, Programming Visual Basic.NET, 2nd Ed., O'Reilly & Associates, Inc., Sebastopol, California, 2003.