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Paper Session III-A - Design of a Portable Data Collection Procedure System for Processing Space Shuttle Payloads and Main Engines at the Kennedy Space Center

Darcy Miller
NASA, Kennedy Space Center

John Lekki
Nasa, Kennedy Space Center

Kevin Jackson
Sentel Corporation

Mike Kappel
Sentel Corporation

Loretta Moore
Auburn University

Design of a Portable Data Collection Procedure System for Processing Space Shuttle Payloads and Main Engines at the Kennedy Space Center

Darcy Miller and John Lekki
NASA, Kennedy Space Center

Kevin Jackson and Mike Kappel
SENTEL Corporation

Loretta Moore
Auburn University

Abstract: The Portable Data Collection (PDC) Procedure System is currently being developed to allow Work Authorization Documents (WADs) to be run electronically at the Kennedy Space Center (KSC). WADs are used throughout KSC to perform various tests, maintenance, and integration tasks, including processing of Space Shuttle Main Engine hardware and Space Shuttle Payloads. The PDC system is targeted for use in the Space Shuttle Main Engine Shop, and for Space Station Resupply and Return ground processing, in 1998.

With the PDC system, the work procedure is converted from a word processor document to a database. It is then executed using standard work stations and portable computers. All data is entered electronically and stored in the database. This includes quality stamps, signatures, notes, and task data. The system immediately distributes entered data to all other terminals viewing the same document. The current ink stamp is replaced with an electronic stamp.

System Benefits:

- All task team members see changes to the document instantly. This provides greater assurance that all team members are properly informed and that data is accurate.
- Accuracy of the procedure is improved as changes are incorporated directly into the appropriate sequence of the procedure. This eliminates the change sheets that are presently appended to the document. The process of approving and distributing a change has also been streamlined.
- Information availability is improved because procedure information is stored in a database. This data can be searched and retrieved through standard database queries for management reporting or incident investigations.
- The need to print and distribute paper copies of a procedure prior to a task is eliminated.
- The need to scan the procedure for storage is eliminated.
- Emergency procedures can be accessed immediately.

Existing Process*:* Work Authorization Documents (WADs) are procedures that are used throughout KSC to perform various tests, maintenance, and integration tasks, including processing of Space Shuttle Main Engine hardware and Space Shuttle Payloads. Currently these work procedures are created electronically using a word processor template. The procedure is approved and stored via an electronic Technical Documentation System. When the procedure is ready to be executed, it is printed, copied and distributed to members of the task team. To document procedure execution, a single record copy is kept up to date by using a pen to record task data and notes, and by using quality and technician ink stamps to signify the performance of work steps. Task team members also maintain their own copies. Changes to the work instructions that occur during the execution of the procedure must be documented on a paper form. These change forms require approval signatures. Once approved, the change form is then copied and distributed to the task team. The completed record copy of the work procedure, including deviations, is scanned into a computer and stored electronically.

PDC Process: The objective of the Portable Data Collection (PDC) Procedure system is to automate the procedure process. The system is targeted for use in the Space Shuttle Main Engine Shop, and for Space Station Resupply and Return ground processing, in 1998. With the PDC

system, not only is the procedure created, approved and stored electronically, it is also executed electronically. This provides the final piece to make the procedure process completely paperless. Once the procedure is ready to be executed, the PDC system is used to extract information from the document and place it into a database. It is then executed using PCs, laptop computers or pen based computers that are networked together. Task data is entered electronically, by using either a keyboard or handwriting recognition on a pen based system. The PDC system instantly distributes this data to all other terminals.

The ink stamp that is currently used for quality, technician and engineering approvals is replaced with an electronic stamp that meets the form, fit and function of the old ink stamp. A programmable memory chip inside the electronic stamp stores a unique identifier. The electronic stamp is used to add a secure mark to a work step, identifying who performed that step, along with the date and time the step was performed. The electronic stamp is read using a stamp reader that is connected to the serial communication port of the computer. The system provides protection mechanisms to assure data and stamp integrity. Once the procedure has been worked to completion, a report is stored in the Technical Documentation System and can be retrieved in portable document format (PDF). The data from the database is also stored and available for queries.

System Description: The main hardware components of the PDC System are the Central Data Server and the Portable Data Terminals. The Central Data Server (CDS) is the main computer that serves as the network host and database server. The CDS is a server with Windows NT Server operating system. The Portable Data Terminals (PDTs) display procedure steps and enable users to collect task data and apply stamps. The portable data terminals are standard personal computers with Windows 95 or Windows NT Workstation operating systems. Various Personal Computers (PCs) are used as PDTs, including desktops, laptops and pen based tablets.

The software system components are:
Form Conversion software module - Prior to executing the procedure, this module is used to extract the data from the Procedure (Microsoft Word Document) and inserts it into the database.

- Stamp Utilities software module - This administrates the electronic stamps. It associates the electronic stamps with the data in the database, including the user's name, phone, fax, office, and ID number. It also associates the stamp with the image that indicates who performed an activity.
- Report Generator software module - After executing the procedure, this module creates the procedure in report format, which includes all of the information from the original document plus the stamps, data, notes, and other information that was entered while executing the procedure. The report is put into portable document format (PDF), which is a read-only document with search capabilities.
- Portable Data Terminal (PDT) software module - The Microsoft Windows based graphical user interface displays the work procedure that contains the steps numbers, the task descriptions, and the locations where stamp images are applied when team member buy off steps. Team members enter task data, stamps, notes, etc., using keyboard, mouse, or pen based data entry. The work document is retrieved from the database and user inputs are stored back into the database. The user is permitted to alter the procedures through a change form where the user can electronically edit the document and obtain approvals. As information is entered into a PDT, it becomes immediately available on all other PDTs.

Project Development: The project began as a Small Business Innovative Research (SBIR) contract that was initiated by the Safety and Mission Assurance Directorate at the Kennedy Space Center. They teamed with the Payload Processing Directorate to jointly develop the project with SENTEL Corporation, which was awarded the SBIR contract. The result of the SBIR was a working prototype of the PDC Procedure System. This prototype was tested and determined to be a viable option. After the contract was completed, SENTEL and NASA formed a partnership through a "Non-reimbursable Space Act Agreement" to develop the operational version of the system. NASA is developing the form conversion, stamp utilities, and report generator software which are applications that are more specific for NASA requirements. SENTEL is responsible for developing the Portable Data Terminal software module. This piece of software holds the greatest commercial potential to be marketed in other work environments such as the aerospace and aviation markets.

In order to ensure the usability of the PDC system, two approaches were taken. The first was to include representatives from diverse backgrounds, including engineers, quality assurance personnel, and technicians. They provided initial requirements and feedback about the design as it was developed. The second approach was to conduct a Formative Evaluation study which resulted in improvements to the design. This is a systematic approach to obtain usability metrics and to identify areas for improvement. During the study, potential users were given a list of tasks to perform. The list only provided information on what tasks needed to be completed, but no direction as to how to perform the task. Quantitative data was collected such as the time to perform the task and the number of errors. This was compared with the performance of an "expert" user. Results indicated that most tasks were performed by the users at an acceptable level. The tasks that were not performed at an acceptable level indicated areas for redesign. The study was directed by a professor from Auburn University.

Future Development:

- The system was modeled after the existing paper system, using the existing business rules. Control features could be added to validate work practices. Many suggestions have been given by users during testing and demonstrations of the system.
- Body wearable computers could be used in confined spaces or areas where the user needs to be mobile, or have their hands free to work. This includes head-mounted displays of the computer screen, computers worn around the waist, and data entry using small screens, keyboards, or voice recognition.
- Barcoding could be incorporated into the PDC system.
- SENTEL is currently marketing the product to be used by other government agencies and private corporations in areas such as aircraft and highway maintenance.

Key Accomplishments:

1993: Completed Phase I Study for SBIR.

1996: Completed Phase II of SBIR. The proof of concept for this system was demonstrated.

1996: Received NASA SBIR Technology of the Year Award in the Computer/Software category.

1996: Completed Pilot study #1. The first Pilot study was conducted using the PDC electronic system in parallel with the paper system.

1997: Formative Evaluation (User Study) of the PDC

1997: Upgrade system from proof-of-concept to an operational system.

Key milestones:

1998: Test and implement PDC System in KSC Space Shuttle Main Engine (SSME) Shop.

1998: Test and implement PDC system for use in Space Station Processing.

1999: Enhance operational system. Include interface to Payload Data Management System; Provide internet access to PDC.

Contacts:

Darcy Miller, Lead Project Engineer	darcy.miller-1@ksc.nasa.gov
John Lekki, Lead Technical Engineer	john.lekki-1@ksc.nasa.gov
Payload Processing Directorate	http://www.ksc.nasa.gov/payload/projects/qapdc
Kennedy Space Center, FL	407/867-3523
Kevin Jackson, Chief Technology Officer	kjackson@sentel.com
Mike Kappel, Lead R&D Engineer	mkappel@sentel.com
SENTEL Corporation	http://www.sentel.com
Alexandria, VA	703/739-0084
Loretta Moore, Ph.D.	moore@eng.auburn.edu
Computer Science and Engineering	334/844-6330
Auburn University, AL	http://www.eng.auburn.edu/~moore