The Value of Adding Digital Print Technology to Existing IPDT Collaboration Systems

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Abstract. Timely and reliable information exchange is a hallmark of successful collaborative product development endeavors. The continuing challenge for organizations seeking to improve productivity is how to select and deploy technologies that provide the best return on their investment. This paper documents the process that LMMFC-D (Lockheed Martin Missiles and Fire Control Systems-Dallas) followed in selecting digital print technology to improve Integrated Product Development Teams (IPDT) performance across several programs. Cost benefit results are included.

INTRODUCTION

Document capture, access, retrieval, and conveyance are vital to IPDT communication across disciplines. For most of the 20th century, documents such as drawings, schedules and financial reports were constrained to being generated, archived and reproduced on some form of hard copy. This need for physical documents served to drive the evolution of product development processes.

But as the increasing number of INCOSE papers (Mackey & Bagg, 1999; Moulder and Reed, 2000; Myers and Verma, 1999; Pohlmann, 2000; Sampson, 1999, and Verma and Plunkett, 2000) attest, distributed computing using Internet technologies is redefining the boundaries of what one can and can not do in developing a more productive integrated product data environment.

The stimulus for modernizing existing product data management processes arrived in the form of a challenge from a U.S. government program manager. The year was 1996. He asked for a proposal to drastically reduce weapon system development costs through the innovative use of digital technology. This event, combined with Department of Defense digital data delivery requirements, set in motion a chain of events that continues to this day to alter the way one division of Lockheed Martin does business.

An earlier paper (Brown & Lavender, 1999) described how application of systems engineering processes shaped the development of a web-based collaboration tool from the perspective of one IPDT. This paper updates and expands on subsequent accomplishments from a division-wide perspective.

IMPLEMENTATION ENVIRONMENT

An apparent conflict between a longstanding corporate initiative and the initiatives of the LOSAT (Line-of-Sight Anti-Tank) weapons system program resulted in the forming of an ad hoc IPDT early in 1996. The corporate initiative was the result of U.S. government directives to improve the document delivery process. Work was underway to link an ongoing installation of SAP, software designed to integrate and improve company business processes, with the development of an integrated Product Data Management (PDM) information system. Conflict arose when the LOSAT program, needing immediate cost savings in response to funding cutbacks, began implementation of a program-specific INTRANET using COTS (commercial off-the-shelf) Internet technology to deliver data to the customer.

As shown in Figure 1, design and other product development data had to be delivered to several geographically dispersed sites. This is accomplished by using an operating rule that documents that are company proprietary or have DOD security rating or Confidential or higher are not placed in the electronic vault or transmitted via the intranet/internet.

OVERARCHING REQUIREMENTS

An IPDT was formed to resolve the apparent conflict between corporate and program objectives. A consensus developed on the eight overarching characteristics needed to improve the existing product data management system.

- Work from desktop computer monitor
- Reduce design documentation cycle time

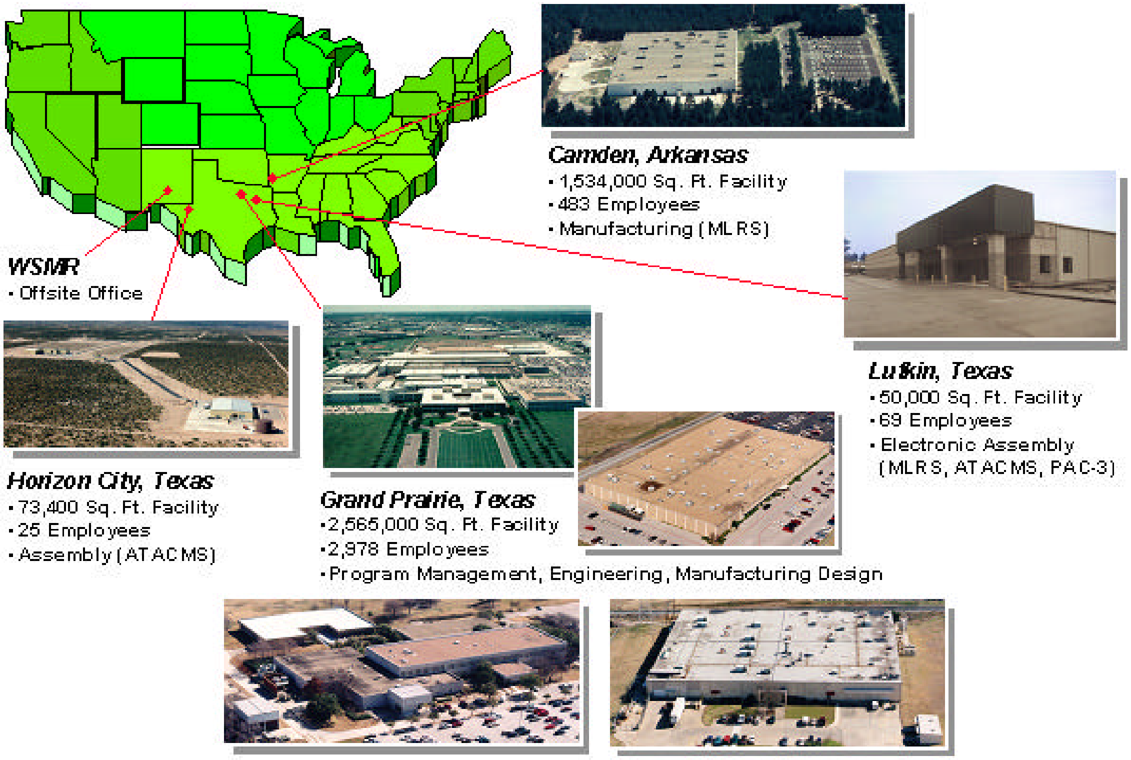

Figure 1. Geographically Dispersed Production Facilities Requiring Access to

- Maintain document integrity
- Portable document format for multiple read/print platforms
- Maintain design audit trail through use of existing document numbering and identification information
- Process changes must be evolutionary, because of large number of people involved and union constraints
- Customer needs documented design history
- Cost Benefits must be realized and recognizable

It also was noted that the bulk of technical data package deliverables were in the form of engineering graphics. This observation focused the search for a product capable of doing large-format, digital printing and copying for engineering applications.

DETAILED REQUIREMENTS

The push for the development of a capability to digitally produce, store, view and print on demand documents from the desk top comes from users (engineers, quality, materials, order/receipt processors) wanting to work with documents from their desk.

Fundamental to moving into the digital age is the ability to view at the desktop all documents. These documents include engineering drawings, parts lists, design specifications, materials procurement specifications, and materials receipt inspection and test reports. These represent the types of design information used to advance product development from the birth of an idea, to design maturation, to final end item production.

It is further necessary to be able to view documents digitally from any location. This means being able to print documents on demand either to a local laser-type printer or to a large format print system. The challenge is to capture these documents in such a manner that allows individual viewing and printing while ensuring that the document's integrity is not compromised.

New processes must maintain functional equivalence with manual processes being replaced. These manual operations ensure that documents released within the engineering cycle can be traced to the original signed source. This is signified by affixing an official release emblem to the document. The original is then held in a separate, secure location, and copies of the master circulated for review.

The process steps for the manual (paper) path from engineering to the shop floor were:

- Engineer completed design and design change actions, forwarded document package to design Release Group
- Release Group reviewed document package to ensure accuracy, logged document for tracking and control, affixed a release emblem (overlay appliqué) to the documents, then forwarded document package to Drawing Services
- Drawing Services received package, created a 35 mm silver film master (required by US Government for archival purposes), produced microfilm copies for distribution (called a diazo), produced multiple paper copies, and manually folded and collated paper copies for distribution to Engineering, Materials, Manufacturing Planning and Scheduling, and Quality Assurance
- Drawing Services then placed the document packages in the internal mail system to move documents

The time line to complete these actions would take from five days to thirty days. The processing cycle was effected by urgency of need. Consequently routine documents would often become urgent to ensure rapid processing, or would be handled as urgent as their time in the processing cycle grew. In some cases routine engineering changes would not reach the Manufacturing shop floor until after the part was manufactured, inspected and ready for installation. This resulted in a reject part, or a part that required modification prior to installation.

The embedded control mechanisms of the manual process provided the starting point for a systems study to define how to reduce cycle time. A major consideration was the assurance of document integrity as the process evolved from manual to digital. The digital process had to meet or exceed criteria specified by the Government for document integrity, archival storage, change control, and configuration management while reducing cycle time.

Copies of released engineering documents are also distributed back to the originating agency and individual users within that design group. Documents are stored for reference as part of the product development process, for supply to co-contractors and for reference use during design and other reviews. During customer reviews, the customer representatives traditionally request a complete set of released engineering documentation since the start of product development.

Concepts for reducing cycle time required for moving documents through the release and distribution cycle were identified and analyzed. These analyses provided both cycle times and labor cost estimates as well as costs associated with the "as is" process. Analysis proved that these areas were prime areas for process improvement, with predictable results. Moving to a digital approach with an electronic vault provided the most efficient process and provided a capability to meet identified government requirements.

A digital approach enables:

- engineers to place the document package in an electronic vault
- the release group to access the document electronically, verify accuracy, affix an electronic appliqué
- drawing services to print documents in sufficient quantities to meet distribution needs (the demand for prints diminished over time as people became comfortable with digital documents), concurrently provide a copy for microfilm activity, and store the document digitally for in-house user access
- individual users can access the document insitu from their work location, print portion of documents to local printers or request complete copies be printed

The defined process improvement yielded multiple benefits:

- cycle time reduction
- open the bottleneck
- lower operating cost (The primary cost element is labor.)
- significant reduction in material costs (paper, toner (ink), equipment cost)
- instant access to documentation
- document portability

A primary bottleneck within the drawing services area was the government's requirement for silver microfilm as a deliverable product. Microfilm was required to provide government representatives a documented history of the design evolution. Adding equipment seemed like the simplest solution. However, within the environment that we operate the job function of filming engineering documents is an hourly, union position. To add one more microfilm camera would have created a requirement to add at least one more employee, but more likely two additional employees for best equipment utilization.

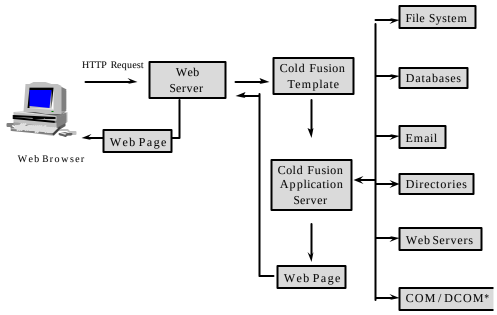

Figure 2. Data Warehouse Built on Open Standards

Manpower adds costs. Union manpower brings with it additional cost plus restrictive work practices. For example, when union personnel are not present, some tasks cannot be performed until the return of union employee. This has caused delays in processing documents, and in other cases resulted in a grievance being filed on management by union personnel.

These labor factors added impetus to the search for less labor intensive means to control documents and improve user accessibility by providing a capability to print on demand. A capability to view documents on a regular basis without the ability to change the document was another important consideration, one of great value for operational efficiency. Documents once released must be rerouted through the entire change cycle to ensure that all changes are correctly incorporated, that other documents that are affected by the change are addressed and that everyone who originally approved the document acknowledged the changes and the need for the change. Plus a mechanism must be in place to ensure that once the change is approved, released, and circulated that costs are properly documented and billed.

ENABLING TECHNOLOGY

With the introduction of the desktop computer and distributed computing, their use of to process and store vast amounts of information began to be work. However, the process for authenticating documents and assuring document integrity (what was released is what you get), the need for easy access coupled with the need for low cost viewing (viewer), and the ability to print a variety of document sizes on multiple print systems. These were items specific to the drawing release cycle that needed a system solution. Several file format types were examined, such as HPGL, HPGL2, TIFF, CALS, and PDF. With the exception of PDF, all file formats were changeable (compromising document integrity), required costly viewers and were difficult to use by the target viewing audience.

The best solution available on the market was the provided by Océ. We prepared procurement documents and acquired their system. The initial Océ system was optimized to work with TIFF file format and would not print PDF documents. And although TIFF posed some problems, specifically the assurance of document integrity, it was determined to be a better avenue to pursue than no avenue at all. Initially we could meet some of our requirement goals but not all of them, hoping for future capabilities that allowed us to continue toprogress.

We wanted to use open source standards and felt that the Internet technologies represented the most enduring solution. Figure 2 illustrates the layered approach of interacting with a data-enabled web site. Some of the standards pertaining to this area are:

- HTML (Hypertext Markup Language) for a device independent display mechanism and somewhat separating the processing from the presentation.
- HTTP (Hypertext Transfer Protocol) for defining the interaction between the client and server.
- TCP/IP (Transmission Control Protocol/Internet Protocol) defining a robust computer-to-computer information packet exchange system.
- SQL (Standard Query Language) forms a rigorous language for selecting, inserting, updating, and deleting data from a persistent store.
- ODBC (Open Database Connectivity) is a programming mechanism to interact with a persistent store.

An often-overlooked Internet standard of great utility is MIME (Mail Internet Multimedia Extensions). This allows the client to identify the data stream that will follow. This in turn allows the browser to launch an application for processing the data with little user interaction. This technology allowed Adobe to create a plug-in to display PDF documents. The Adobe distribution model accelerated the acceptance of this format. The PDF reader was free, and you pay only for document creation. This successful business model is now being used to introduce additional new technologies .

PDM IMPLEMENTATION PROCESS

Figure 3 traces the evolution of events culminating in the capability to deliver digital prints to the shop floor. This timeline also represents the pace of progress made by the ad hoc IPDT in collecting

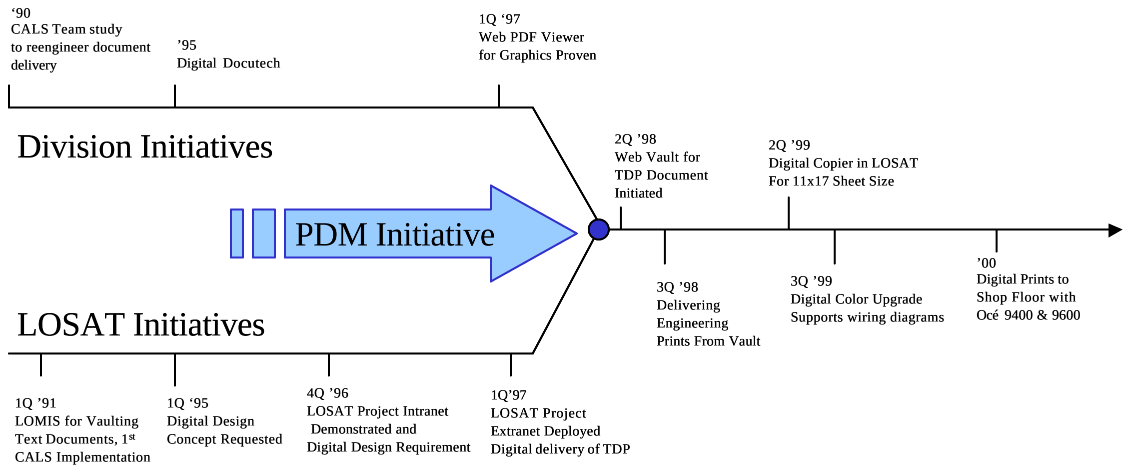

Figure 3. PDM Drove LMMFC-Dallas to a Unified Solution

requirements, synthesizing solutions, testing progressively more capable systems and adjusting the system architecture to insert new technology as it became available.

The continuing challenge faced by the development team was to assemble a fully integrated PDM solution, linking the internal silos of document management while maintaining document delivery service. This was solved by creating an internet based document storage system. This vault supported the PDM effort by providing a common repository to collect information.

The second key decision involved the choice of document format. The first choice was to use a TIFF format. But the TIFF format did not resolve the problem of different formats being used by both document creators and users. The solution arrived in the form of the PDF format used to link the document generation process on the LOSAT program. Out of this success came the requirement for print hardware to have software capable of working with the PDF format.

The implementation of the Web Vault in mid '98 and the delivery of PDF capable digital print hardware produced the desired convergence between Corporate and LOSAT project initiatives. Digital prints have been delivered to the shop floor since mid-year 2000.

IMPLEMENTATION DETAILS

The document vault was an outgrowth of the work done on the LOSAT program (Brown & Lavender, 1999). The basic requirements to catalog, store and retrieve documents were unchanged from the original design.

The WEB vault requires two types of persistent storage: information about what is being stored (a.k.a. meta-data) and the actual document. We chose to use the file systems to store the vaulted document. This method improved system portability and scalability. Collecting meta-data about the document is the difficult part to achieve. The challenge is to store what you need to subsequently locate the document.

The distribution of the Printers/Scanners on the network, as illustrated in Figure 4, allowed us to provide a separation between logical use and physical layout on the network. This gave users across the enterprise direct access any printer in system. Networking standards and an established enterprise network permitted us to readily integrate new support into the system without the need to write specialized interface software. These printers and scanners supported input and output to the web vault.

The vault was designed to be portable and grow as required. It was initially created using Microsoft Access for the persistent data store. This was adequate for the first six months of use. The system is accessed for retrieval far more than information is uploaded. This circumvented the table locking slowness of using MS Access for this purpose. As the vault grew in number of documents and users, the meta-data was ported to Oracle to improve reliability and access speed.

COST BENEFITS

The value of new technologies and re-engineered processes is measured by the benefits that accrue to an organization's operations. In this case, benefits flowed from significantly revamping a cumbersome document processing operation and opening new opportunities for improving employee productivity.

Print-on-demand from an electronic Web vault was key to opening entirely new avenues to afford access to design information by all. It enabled the end user to print on-demand those engineering documents

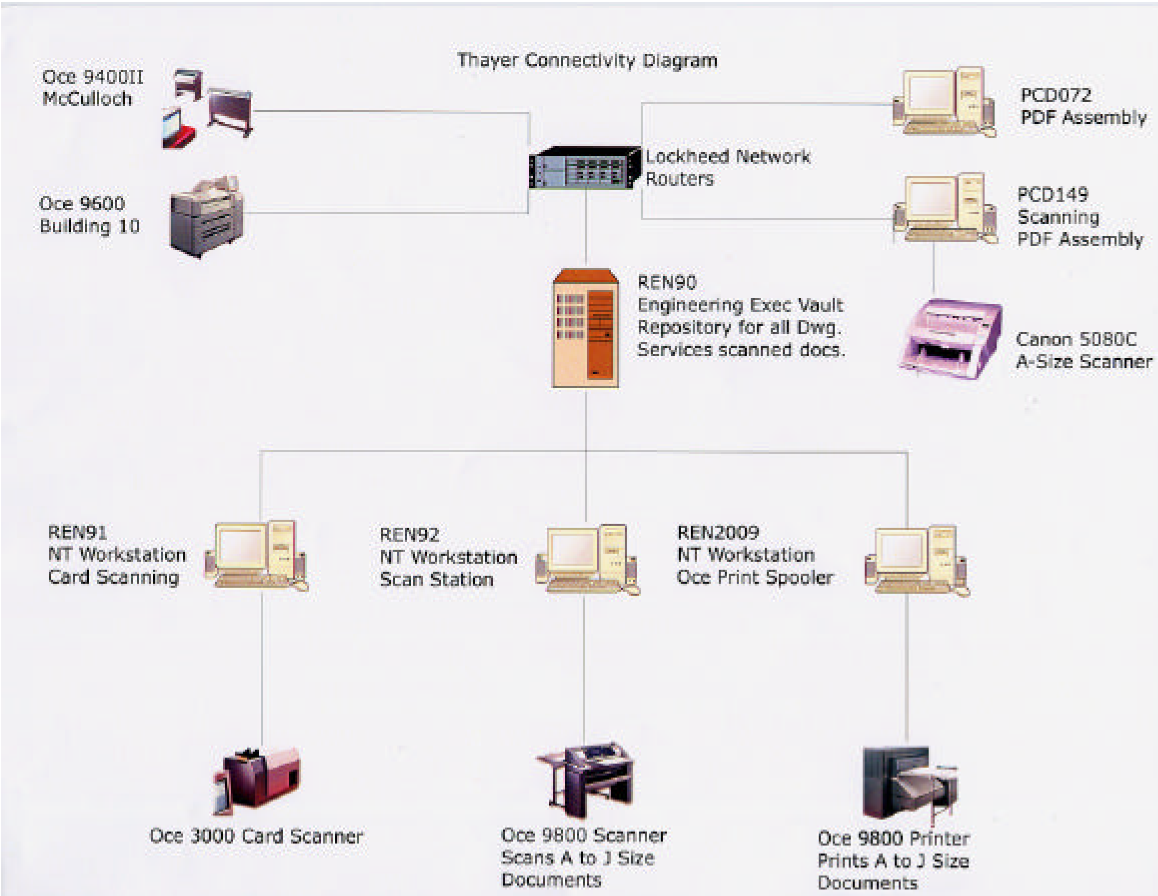

Figure 4. Digital Scan and Print Technology Readily Integrates into the Enterprise Information Systems Structures

deemed important or needed. This also enabled the end user to print a section of the document, or the whole document at their local printer, versus having to print the entire full-scale document to a large format printer/plotter. The Web vault provides the user instant access, local control of the print process, to include requesting full size prints from the centralized print area when needed. Web use avoids costs associated with multiple reproduction and distribution of engineering data to a distribution list of individuals.

The ability to scan a document and capture the data digitally reduced the time required to file, store and retrieve the information for use or reproduction. The most significant savings are realized from the ability to transport the document via the Web versus via manual distribution. Authorized users now have on-demand document accessibility.

Reducing paper reduces cost. The advent of digital documents offered new scaling opportunities. These opportunities were non-existent with paper or other traditional materials. With digital document creation, even the scaning process can be eliminated, unless needed to capture some information. Digital documents can be scaled any desired. The original document size represents a form of scaling that enables the document originator to present data in a format and size that enhances readability, view-ability and comprehension. In most cases at Lockheed Martin, engineering documentation was prepared on the 36" x 44" format, 11 square foot of paper. Depending upon the amount of detail placed on the sheet, most users could work from an 18" x 24" sheet size, 3 square feet. That size reduction represented a saving of 8 square feet per sheet. These savings existed prior to digital documents, but the Web based digital document presented a true print on-demand capability enabling the user to print the document to an 8 ½x 11 sheet, 0.65 square feet. And print only the page(s) needed at printer located near the desktop.

Documents, either produced digitally or scanned to an electronic file, are easier, cheaper, and faster to store, retrieve, transmit and reproduce. Moving to a digital Web based product provided significant cost savings because documents became more quickly available to manufacturing planning, scheduling, and the shop floor. A nominal seven-day turnaround time has been reduced to a one and one half-day for paper copies. Digital documents are now available instantaneously

Initially a majority of the Web based users were receiving the documents as hard-copy distribution and viewing the same document on the Web. As confidence in the electronic document availability grew, the demand for hard-copy distribution decreased. This represents a true cost saving in time and money.

Reducing the demand for printed documents produces a long list of small-cost items, that when multiplied by the number of copies not being printed becomes a significant cost avoidance. Examples of these small-costs are: materials (paper, microfilm, data cards, toner, developer, machine meter charge); equipment maintenance costs; labor costs (camera operator, keypunch operators and distribution personnel, file clerks); and environmental impact items (chemicals, personnel exposure to toxic materials).

Reducing and eventually eliminating the need to store hard copies of documents in multiple formats provides long-term cost benefits. Bulk storage of data requires enormous amounts of physical space, security, and environmental controls. In a paper society masters or copies of documents are stored because these documents provide the history and evidence of the design, design criteria, and associated specifications for items to be manufactured. Hardened storage ensures survivability of documents from natural and manmade disasters. In large companies such as Lockheed Martin several organizations could be storing and maintaining the same paper documents. The availability of documents digitally allows controlled access to one location, maintained with minimum human intervention.

SCALABILITY

The original document distribution solution was implemented for a single engineering project team. That solution worked well for a group of about 100 individuals and around 2000 engineering documents. At the conclusion of that effort, there were concerns about the scalability of the implemented concept.

The expanded vault is now division wide for more than 2000 people and over 10,000 officially released documents, and four geographically dispersed facilities. This established the inherent scalability of the WEB vault concept.

SECURITY

The Internet is insecure (Schneier, 2000). Adequate security for this initial implementation is presumed by restricting transactions to users within the Lockheed Martin firewall. The risk inherent in this policy hinges on the effectiveness of internal company security processes developed and enforced by the computer department. More overt actions will be required in the future to assure users that documents represent the most recent information approved for release by the product development team. Security solutions must also be applicable for extending the use of this digital print technology to vendors and customers outside the firewall. Issues to be addressed include privacy, identification, authentication, document integrity, and transaction audit ability. Many models exist for how different industries and organizations protect Internet transactions and data transfers. These models are becoming more sophisticated to reflect technology advances and the need for more capable security systems to ward off would-be intruders. The next step in realizing additional benefits from the digital print technology is to devise tailored protocols and processes mimicking legacy manual procedures while providing the required security.

SUMMARY

This case study illustrates how early emphasis on bringing stakeholders together in the form of an integrated product development team and attention to developing system requirements produced a high-value solution. That is, a digital print system automating processes formerly done manually. Use of systems engineering practices for improving processes were a key element in the success of this endeavor

The bulk of the savings were the result of reducing touch labor and slashing process cycle time. These savings quickly became real as the user community embraced this new way of processing documents.

The ease with which new print technology was inserted into the open standards framework provided by the Internet raises serious questions about opting for proprietary solutions such as those provided by vendors like Microsoft. These open standards, when combined with design simplicity, produced a system of almost unlimited extensibility and scalability. Open standards also make the system amenable to technology refreshment process.

The range of applications for the implemented print-on-demand technology appears quite large. An example would be installing a print/scan system at a flight or other test site to improve the transmission of data to and from the home office.

The ad-hoc cross-functional IPDTs most certainly accelerated the process of identifying and reaping the benefits of innovative digital technologies.

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BIOGRAPHIES

Phil Brown is a principal in Systems Engineering Associates. He is a licensed professional engineer (PE) with more than 30 years experience in complex system development. Most of this experience was acquired leading systems engineering teams in the aerospace industry. Professional society memberships include the Texas Society of Professional Engineers (TSPE) and the International Council on Systems Engineering (INCOSE). He has authored several technical papers on systems engineering applications and served as a theme editor for INCOSE's quarterly magazine. He is President of the Mid-Cities (DFW) Chapter of the Texas Society of Professional Engineers, Texas Engineering Foundation state scholarship chair, and co-chair for INCOSE's Education and Research technical committee.

Frank Kuchelmeister is Manager of Reprographic Services at Lockheed Martin Missiles and Fire Control – Dallas. He is responsible for the identification, evaluation and procurement recommendations of analog and digital reproduction, microfilm and associated computing equipment and software, plus implementation of support service required to ensure the distribution of documents throughout the company and retention of released engineering data. Before that he managed Integrated Logistics Support for division space programs. He joined Lockheed Martin after a distinguished career in the United States Air Force. During his Air Force career he was responsible for the control, maintenance and delivery of the U.S. Nuclear Weapons Stockpile located on various military installations.

Jack Lavender is Chief Technical Officer for Systems Engineering Associates. He recently complete work for an Internet startup developing a system for consumers to compare and select an electricity provider in deregulated environments. Before joining Systems Engineering Associates, he was a Systems Engineer at Lockheed Martin Missiles and Fire Control. One of his major accomplishments was creating a collaborative extranet to enhance a major weapon system program's IPDT development activities. Prior to that he worked Information Technology research projects such as non-linear information browsing and neural networks. Other activities include selling web hosting services and developing new internet applications.