How to Modernize Your Paper Engineering Drawings

A White Paper From the *Paper to CAD* Experts

To compete in today's world, a company has to survive in a fast-growing, technologically driven environment to produce goods and services. How does a company deliver the best product or service to market at a fair price in the shortest time?

To maintain a competitive edge, a company must leverage its information assets, which includes a tremendous amount of engineering documents. Tools and processes to efficiently manage, distribute and modify these assets are essential.

International Data Corporation and *Document Management* magazine estimate that there are more than eight billion drawings worldwide, of which fewer than 15 percent are in a Computer Aided Design (CAD) format. This leaves an astonishing 85 percent of drawings maintained in non-electronic format, mainly paper-based engineering archives. Considering that each successive stage in a product cycle—design, production, support services—uses substantially more documentation than the prior stage, the benefits of integrating this information grows exponentially.

The need to capture, modify and distribute existing paper designs within the environment of today's computing technology predates CAD technology itself. The intent of this paper is to provide an insight into the issues and to present the benefits and strategies for capturing paper-based assets with CAD

The Hidden Costs of Paper

Manual methods of handling, storing and maintaining paper drawings are difficult, time-consuming and costly since most information is still in paper form. The following are some of the most obvious problems with maintaining paper archives:

- Paper drawings, mylar, bluelines and other media are susceptible to aging and damage over time.
- Manual-based revisions are costly, particularly with drawings requiring frequent updates.
- Paper is slow to distribute. It takes longer to copy and distribute a single piece of paper than it takes to distribute or reproduce several documents electronically.
- You may be fully modernized with a full suite of CAD software, but what about your contractors, subcontractors and business partners? Many transactions between companies are inefficiently conducted with manual archives, even when the originals may have been CAD files.
- Paper is cumbersome. It is often hard to find specific information in specific documents. Electronic searching is more efficient and faster.
- Paper is restrictive in format. It is limited to graphics and text, while electronic documents can contain hyperlinks, audio and video.
- Paper is static. It can be out of date even before it is distributed because of lengthy release cycles. The added concern of who has the most recent revision intensifies this problem.
- Facility costs for the storage and maintenance of paper archives can be substantial. Justifying a document management system should be based on significant reductions in facility costs alone.
- Paper gets lost. It is estimated that five to seven percent of technical assets are lost or misfiled using manual procedures for handling paper drawings.

Getting Started

It Starts With a Scan

Scanning is perhaps the most overlooked factor in the conversion process. Scanning archives into compressed raster format allows them to be enabled for faster revisions and improved distribution. This process can be painless and cost-effective.

Good separation of text, quality line representation and smooth raster geometry are also important aspects that should be considered in more detail when selecting a solution. Conversion to full vector CAD format is the most sensitive to a well-scanned image.

What Is a Scanner?

A scanner is a device that makes electronic images of documents. It is much like a photocopier, except that it produces electronic copies of drawings instead of paper.

How Does It Work?

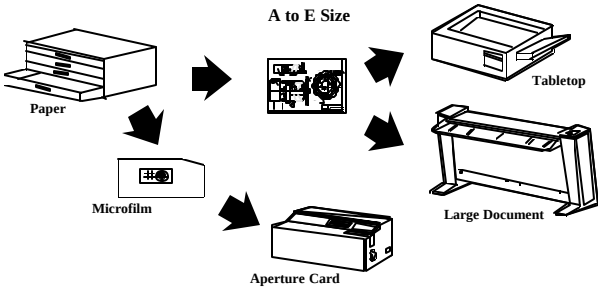
A scanner contains an electronic camera and a light source. The drawing is fed through the scanner and the details are seen by the camera which then creates an electronic file. This file is called a *raster* or bit-map file.

Much like a photocopier, a scanner has a threshold, or contrast setting. This is adjusted to produce the best electronic "copy." Usually a test scan is done to make sure that the threshold setting is good for the entire drawing, i.e., the faint lines are visible and the strong lines are not too dark.

The accuracy of the scanner is measured in Dots Per Inch (DPI). This is the number of pixels or dots that the scanner sees for every inch of paper. The higher the DPI, the more dots that are produced, and *the more accurate the scan is*. Typical resolutions are 200, 300 or 400 DPI. The higher the DPI setting, the larger the resulting electronic file will be.

Some scanners have the ability to interpolate or expand the scanned DPI to very high resolutions. It is important that the true optical resolution of the scanner is high enough for each particular project. Most archival and raster applications are best served at 200 DPI.

There are many types of scanners that are capable of scanning A to E size paper (and larger) or aperture cards. When choosing multiple platforms, look for common user interfaces and for an intuitive look and feel.



Raster File Types

There is a wide range of standards and formats for raster files. File types can be split into two broad types: compressed and uncompressed. Some common file formats are Group 3, Group 4 and TIFF Compressed. Common uncompressed formats are PCX, RLC and TIFF Uncompressed. There are also several standards used by government and military organizations, such as the CALS standard created by the DOD and used through commercial industry. These standards are usually applied to existing formats, producing file types such as CALS Group 4.

Compression Methods

Data compression techniques have emerged in the market to allow raster-based drawings to be stored in less space than a three-dimensional CAD file. This is due to the use of two-dimensional compression that can reduce an eight MB uncompressed raster file to approximately 100KB without any loss of information. The most popular formats found in the market today are CALS Raster and TIFF format. Both use the CCITT Group 4 compression method.

Viewing

A viewer is a software package that allows you to look at documents without having to use the application that created them.

Viewing technologies offer a natural approach to integrating paper archives and CAD in a distribution function. In many cases, companies already maintain an active non-graphical database of drawing revisions. This database can be leveraged and "viewer-enabled" to provide the graphical link between paper and CAD-based designs. As progress is made toward EDM/PDM, the viewer can be integrated at an API level for direct communications with EDM/PDM systems.

Introducing a viewer is a simple and inexpensive way to link scanning with the ongoing build of a total solution. A small investment in a powerful viewing software package offers immediate benefits with little capital outlay and minimal training time. The

right viewer can help increase access to information, speed up time to market, streamline workflow, comply with ISO 9000 and OSHA standards and review and process change requests rapidly.

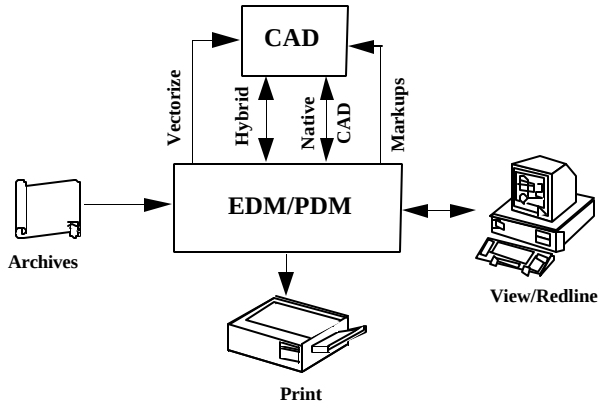
When selecting a viewer, look for speed, simplicity and the ability to view multiple formats.

The Engineering Change Order/Engineering Change Notice (ECO/ECN) process can be improved by introducing users to the concept of redlining and integrating redline annotations on all drawings (Raster and vector CAD-based) that are now contained on-line. More sophisticated editing systems can use the approved redlines as tools to facilitate accurate and timely revisions. As workflow is introduced, the process is enhanced further with a more controlled approval procedure.

Coming Together, Raster and CAD

With a scanned drawing, revisions can be made through raster or hybrid-enabled drafting within a CAD system. The result is increased value from CAD, even before a full EDM/PDM system is in place. As EDM/PDM is implemented, full management of the ECO/ECN process will be realized.

Paper Integrated CAD/EDM/PDM

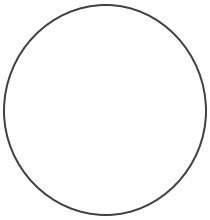


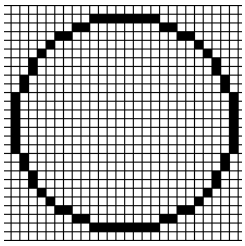
Raster Versus Vector

CAD Systems use vector files and scanners produce raster files. What is the difference? Raster files are fundamentally different than vector files.

A line drawn with CAD software is stored as a vector primitive. The software knows the starting and ending points and the line thickness. The line is "intelligent" because any part of the line "knows" that it is part of the line and what the rest of the line looks like.

When a drawing is scanned, it is broken down into row after row of dots or pixels. A scanned line is "dumb" because it is made of dots or pixels forming the shape of a line. There is no information or intelligence associated with the pixels. The dots do not "know" that they are part of a line. In order to modify scanned data as CAD data, it has to be made intelligent.





Vector Data		**Raster Data**
Center Point:	5,5	DPI: 300 dots per inch
Radius:	5"	
Thickness:	0.1"	

The Revision Cycle

Raster Drafting

Raster editing or drafting is the simplest and most productive way to modify scanned paper drawings. It is the lowest cost method to bring drawings into a format to modify or make changes to the data. This is supported by the availability of many scanning service bureaus and the recent price breakthroughs of large-format scanners. Raster drafting works best when simple updates are required in nondimensioned or analysis-oriented drawings.

There is significant differentiation within the software products found in today's market in terms of features, functionality and positioning. The more advanced products are capable of snapping to or selecting and manipulating raster "entities" just like vector CAD entities.

Conversion To Vector

Drawings with the highest degree of corporate value are those used within Analysis and Modeling systems. These drawings need to be in a fully vectorized format. Some examples include; a company that needs to develop a three-dimensional

model from an old drawing and run FEM or interference checks within the model; or a city planner that is developing a new building and needs to use three-dimensional terrain models from old paper drawings. Both environments require vector CAD models in its purest form and consequently require full conversion to vector.

The process of automatically converting the scanned image into a CAD drawing is called raster-to-vector conversion, or vectorization. Tools are available to perform this function in an unattended batch manner, or operator-assisted with line following or selective conversion processes. Conversion software will not produce an unattended 100 percent conversion. It is best used as a component of the conversion process rather than as a total solution.

The tools used to vectorize are:

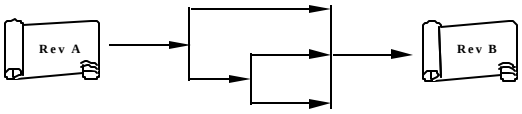
Overlay Tracing

This is often referred to as heads-up digitizing. A scanned image is loaded into the CAD system as a backdrop and the image is "traced" over with CAD entities. This is very similar to the digitizing except a digitizer table is not needed.

Overlay tracing is quicker than a complete redraw, but is still labor-intensive, tedious and time-consuming. It is a good option when working with poor-quality drawings. Raster snapping and heads-up digitizing improve throughput and accuracy over traditional hand-digitizing methods which are still widely used.

Batch Conversion

Batch tools work with a set of predefined rules to recognize unique settings such as text classification, width separations and geometrics. This works best when drawing quality is very good, drawings are consistent and the desired result is basic primitives. Results of batch systems will often require clean-up to ensure the converted drawing meets the needs of the user.



Selective or Interactive Conversion

This is the most promising of the CAD conversion techniques. It combines the intuitive knowledge of the user with an interactive line-following or selective conversion process. These tools allow an operator to isolate selected geometry and text, then work within the limiting factors of the technology.

As an example, a topographical map is converted by selecting a raster contour, then the software traces it to an intersecting or gap position, converting the pixels to CAD geometry. This process is repeated for the entire trace. Then an elevation is assigned, creating a three-dimensional model for the GIS system to take over.

Hybrid Process

A fully hybrid approach is where scanned archives and CAD systems are maintained for a drawing. The term hybrid in this case means a combination of both raster (scanned) and vector (CAD) drawings. Hybrid editing means using both raster data and vector data simultaneously. Changes can be made within either environment. Information can be exchanged back and forth between two distinctive formats, thus offering the most efficient method for modifying the old within the new.

Calibration between the raster database and vector drawing model is typically provided with a reference or resource file. This file contains scaling and coordinate transformations to provide a real-world coordinate system on an otherwise unintelligent raster database.

Deteriorated drawings can be scanned, cleaned up and stored in raster. Modifications can be made to the drawing in raster, or areas of the drawing can be converted into CAD vectors as it becomes necessary. This combination of raster and vector can also be plotted and stored within more advanced EDM/PDM systems.

Working in a hybrid environment allows use of the scanned drawings immediately. Decisions to modify, plot or vectorize can be made as needed. Investing time and money to convert existing drawings can be accomplished on a "just in time" basis.

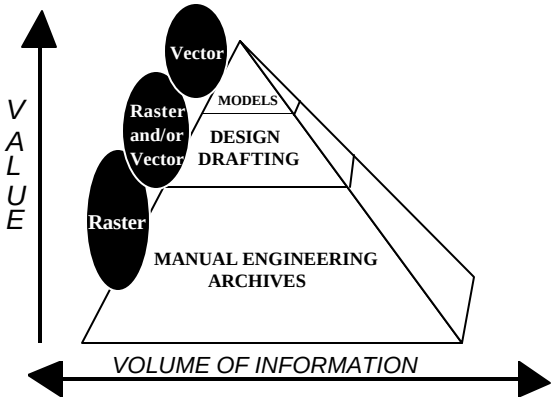
With reduced labor costs and improved usage of CAD, the benefits of revising drawings electronically are clear. What may not be clear is the trade-off of investing in the up front conversion to full CAD versus taking advantage of lower cost hybrid and raster CAD systems.

Integrating Paper with CAD

The earliest implementation of CAD was conducted in the 1950s to solve one simple problem: Modify existing drawings electronically. A flying spot scanner converted microfilm data into an electronic image. While scanning remained a cost-prohibitive option, interactive computer graphics and CAD evolved into an enormous tool for creating newer designs.

With the emergence of standards for storing drawings in raster format, and the emergence of cost-effective scanning hardware and services, the raster environment came of age in the early 1990s. Today, there is a number of available options to obtain paper archives or "BC" (Before CAD) designs into the design and drafting environment of a CAD system.

Engineering Drawing Hierarchy

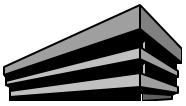


Manually Redrawing

Manual redraw means exactly that: just place your drawings on the desk by your CAD system and redraw them from scratch. A complete redraw of the original drawing is, and will always be, the most accurate method of conversion. It requires little capital outlay and can be useful to convert small numbers of simple designs. However, it is extremely time-consuming and a poor use of the CAD system as the investment in CAD will be used to create designs which already exist.

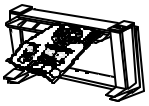
Digitizing

Digitizer tablets are a common CAD peripheral and involves placing a drawing on the tablet and using the puck to trace over the original design using a CAD system. This method is faster than just redrawing the design, but it is prone to errors and is still labor-intensive and slow.



Using a Service Bureau

Outsourcing to service bureaus is a common method for handling small jobs, pilot projects or quick turnarounds. There is a savings on resources and little to no capital outlay for equipment. Bureaus typically use one or all of the methods listed here. These services, however, may not meet the security or design needs of a company. Be sure to choose a partner based on their experience and knowledge of your design practices and needs. Remember, the cost of conversion is directly related to the quality of the end result.



Scanning

Scanning paper drawings to work within the proven environment of CAD and the emerging environment of EDM or workflow offers the most control in the transition from paper. The scanning process can be customized to fit the individual drawing or its application. Scanning has been successfully implemented in both large and small companies to solve integration problems between paper and CAD.

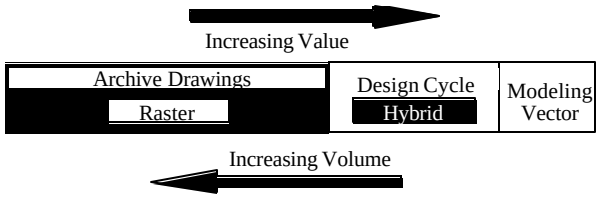
Once drawings have been scanned, their value increases because of the three principal ways to use the newly scanned design in a CAD system. The following section outlines three revision methods available:

Re-engineering the Paper Trail

Seven to ten percent of companies' operating expenditures are spent on manual document management processes, re-engineering the flow of information or paper trail. An organization will realize tremendous savings by re-engineering the paper trail. Not only is design production more efficient, but customer support is expanded and rightsizing demands are met through leverage of information assets and reinvestment strategies.

The Archiving Advantage

Through the implementation of a managed engineering archive, searching time as well as re-engineering time becomes past history. This translates into real dollar savings. Substantial savings can also be realized in a managed revision process. The reliance on manual drafting and control of drawing revisions on older documentation can be put to rest.



The CAD Advantage

CAD has already proven itself as a tool to design and maintain product and service documentation. Applying this tool to archived resources allows the CAD advantage to be applied completely. These electronic drawings can then be quickly revised, modified, plotted or copied in a fraction of the time it takes to modify paper designs. The design process can become highly streamlined, providing substantial cost savings, improved product quality and faster time to market.

The Document Management Advantage

Once files are in electronic format, document management can be used to further increase and enhance productivity. Options range from a simple file storage system with limited revision tracking to a system that securely controls viewing, editing and distribution of all engineering-related information.

Many organizations are required to comply with standards and regulations that virtually necessitate electronic document management. According to the British Standards Institute, 47 percent of ISO certification failure is due to poor documentation control. Cost and time justification can be realized by improving the ECN/ECO process and achieving ISO 9000 certification. In addition, AEC firms are feeling regulatory pressures for process safety management, and OSHA 1910 regulations are demanding improved management of document control processes.

The Workflow Advantage

Workflow tools provide even greater value in meeting OSHA and ISO demands. Cost benefits of workflow products are far greater than those provided by document management tools alone. Workflow is the final enhancement to a paperless environment, enabling company-wide document management from scanning the document, to viewing, redlining, tracking and archiving.

Cost-Benefit Analysis

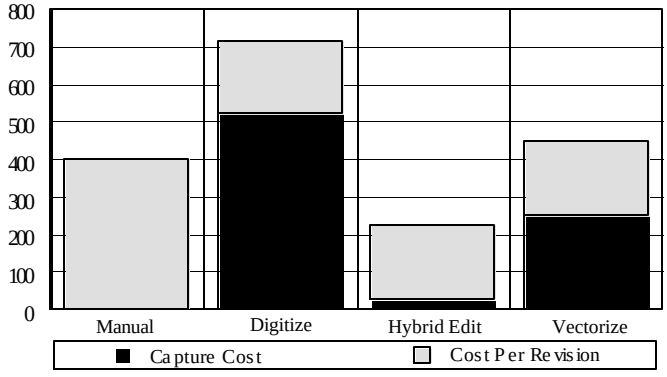
Scanning drawings to digital raster form is essential to realizing the benefits from the methods provided in this analysis. The justification for scanning to a raster image can be easily made by reviewing the value of document management, savings in facilities costs and improved document accessibility throughout the organization.

Cost justification of the various technologies described in this paper is easily measured when based on labor savings in the revision process and improved information access and management.

Revision Cost Savings

The costs associated with revising drawings are dependent on the method and solution used. The four methods presented here include manual, CAD digitize, hybrid raster/CAD and full vectorization to CAD.

Costs are incurred with each individual revision and include the cost associated with capturing the document to a digital form unless the manual method was used. Therefore, the true cost is calculated by combining labor rate and time spent on each revision plus the digital transformation expense.



Action	Times Per Month	Manual Hours	Raster Enabled Hours	Burdened Rate	Savings
Find a Drawing	100	1	.05	$50	$4,750
Find related ECO	20	1	.05	$50	$950
Approve ECO	20	4	.5	$50	$3,500
Update to Rev B	20	3	.1	$50	$2,900
Confirm Changes	20	1	.1	$50	$900
Distribute Latest Rev	20	3	.1	$25	$1,450
				Monthly Savings	$14,450 per month

In an article first appearing in Document Management magazine, the inherent costs to recreate and revise a complex drawing, using each of the methods we have discussed, were compared. The comparison considered both the initial capture time, various labor rates and the time associated with making revisions to the drawing once it had been captured. The hybrid raster/CAD approach, which eliminates the redraw, cleanup and verification processes, offers the greatest immediate cost-benefit for the first revision and beyond. Drawings required in a vector CAD environment are best served by full conversion methods.

A simple cost-benefit example in which a company has 100 drawings with 20 ECOs to perform each month can be used to give an example of the benefits of the raster-enabled approach presented in this paper. Various labor rates are used for each discipline. Actual numbers should be determined for individual organizations.

Business Reinvestment

Companies spend seven to ten percent of their expenditures on a manual document management process. A business reinvestment strategy involving the technology presented here can help reduce the overall costs a company incurs with managing, revising and distributing information.

Time to Market and Lead Time Benefit

Manufacturing companies often survive based on getting quality products to market sooner than its competition. Doing so helps increase mind share and therefore, market share. Greater market share creates more revenue on the invested technology already completed for the product.

Project-oriented companies, such as utilities and construction, effectively develop a product at a greater scale. Contracts are awarded based on accurate and detailed proposals that require project cost and time estimates. A paper-enabled and intelligent modeling system at the front end yields faster design times and more accurate bidding efforts.

Other Benefits

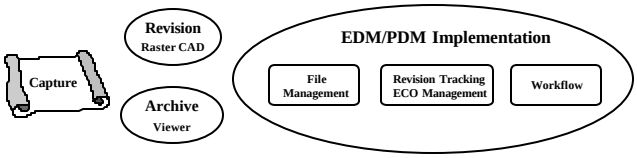
The direct benefits of integrating paper within EDM/PDM and CAD are based on labor savings in the revision cycle. However, there are many intangible benefits:

- An increase in the value of CAD by eliminating its use for tedious redraw. CAD can now be used for productive design and analysis functions
- A common electronic database
- Reduced retrieval and print times for documents with a document management solution
- Improved information flow with workflow and E-mail tools
- Improved conformance to the ISO 9000 or OSHA regulations by instituting better document control procedures.
- Increased value of paper drawings through integration with CAD and EDM/PDM tools
- Fewer lost, damaged and misfiled documents
- Immediate availability of accurate information
- Streamlining of the change process
- Improvement in time to market
- Increased quality

Add Value to Drawings

The overall benefit to organizations that scan paper drawings is to increase the value of the company's most valued asset, information. Once captured into electronic form, drawings can be used for many functions, such as maintenance and material

control, project management, quality assurance and purchasing.



Making it Work

Once the implementation decision is made, how do you ensure the success of enabling your paper drawing archives or EDM/PDM system?

With long implementation cycles in the enterprise-wide EDM/PDM system, payback and user acceptance can drag and stall throughout the initial stages of a full-scale implementation. The integration of manual paper-based archives as a first step can help companies to successfully implement such a system. An incremental approach can produce a more immediate payback and end-user satisfaction with its implementation.

Plan Globally, Invest Incrementally

This simply means looking at the broader business issues related to the life-cycle of paper drawings. Select the most critical business issues and implement the appropriate technology while planning for the bigger issues of document management and workflow systems.

A paper-enabled approach incorporates elements of EDM/PDM before deploying a full-blown system. This step-by-step process allows payback benefits to be realized while addressing the integration of the vast amounts of paper designs within CAD and introducing an electronic distribution environment. The value of the drawings increases along with existing drafting systems by implementing hybrid or raster CAD systems. This allows scanned archives to be manipulated within the same tool set used for newer design work.

A more critical evaluation of the EDM/PDM backbone can be accomplished by enabling the initial conversion process. Users have more time to model workflow, design ECO/ECN processes, define security requirements and determine other control issues best handled by EDM/PDM.

Paper-Enabling PDM

Companies using progressive implementation strategies may have already taken the approach to implement PDM to help manage the existing CAD/CAE environment. Most PDM systems can be expanded by adding raster-literate viewers and hybrid raster-editing systems to allow the vast amounts of paper archives to be contained in the same system managing CAD.

Use a Value Added Resellers (VAR) or a Consultant

Consultants can offer a company a broad range of expertise that comes from working with other similar companies. VARs have broad expertise with products and can provide needs analysis, implementation and training services. Look for VARs that have specific experience with the paper-enabling issues. A consultant can help with needs analysis, training, selection process and implementation. Ask for reference accounts with needs similar to yours.

Include the User

Include your user community through the various phases of implementing this technology. This will improve the acceptance of the technology and the overall payback to your company.

Select Proven Suppliers and Products

Today's software market is covered by too many products that are fragile and offer poor support. Your selection and relationship with a manufacturer is critical and goes beyond the product. Look for companies with a historical and ongoing investment in the technology, worldwide operations, proven customer satisfaction and good training programs to ensure optimal use and payback of your investment.

Evaluate the Software

The software should provide a full compliment of conversion approaches. Each and every drawing will have an optimal payback approach and the resulting systems should incorporate hybrid raster and vector editing for the simple changes, selective conversion for moderate changes and full two-dimensional parametrics and three-dimensional modeling for the higher valued drawings.

Also look for ease of use, compatibility with other software and hardware and support of standard formats. These features will ensure compatibility now and in the future. The software features should benefit a list of key requirements scaled on their value to your organization to help in the evaluation process. This needs to include careful attention to file formats that you need and that the software supports.

About the Author

David J. Wilson is principal of Open Archive Systems, OASys, specializing in paper-enabling consulting services and proven solutions for companies implementing document management and raster/CAD systems. OASys clients include Reseller partners, manufacturing firms, utilities, state and local government, and architectural firms that require raster enabled solutions.

Currently, Mr. Wilson works with major accounts including NYNEX, General Dynamics, Cummins Engine, Southern New England Telephone, Dresser Rand, IBM, GE, Bell and AEG/Modicon, providing consulting and technological services. He frequently lectures and writes on integrating paper within the CAD and EDM/PDM environment.

Mr. Wilson can be reached at:

Open Archive Systems
5 Jefferson Rd.
Windham, NH. 03087
Telephone: (603) 890-5314
Fax: (603) 890-5342

e-mail: dwilson@openarchive.com
homepage: www.openarchive.com