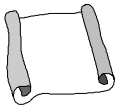
How to Modernize Your Legacy Engineering Archives

by
David J. Wilson



Raster Comes of Age

Raster scanning has proven itself as an initial bridge for moving critical paper engineering drawing archives into an electronic environment. The benefits begin with a scan but evolve and multiply as drawings are brought closer to a true CAD modeling environment.

The purpose of this paper is to provide an insight into the tools, benefits, and strategies for capturing and bridging your paper-based engineering assets into a true CAD modeling environment.

Certain issues regarding the use of paper based engineering drawings in a CAD environment have been discussed extensively during the last decade, and a consensus now exists regarding those issues. Rather than duplicate existing literature, these issues will be considered as "givens" for purposes of this white-paper:

1. The most effective process for bringing paper based engineering drawings into an electronic environment is the scanning process.

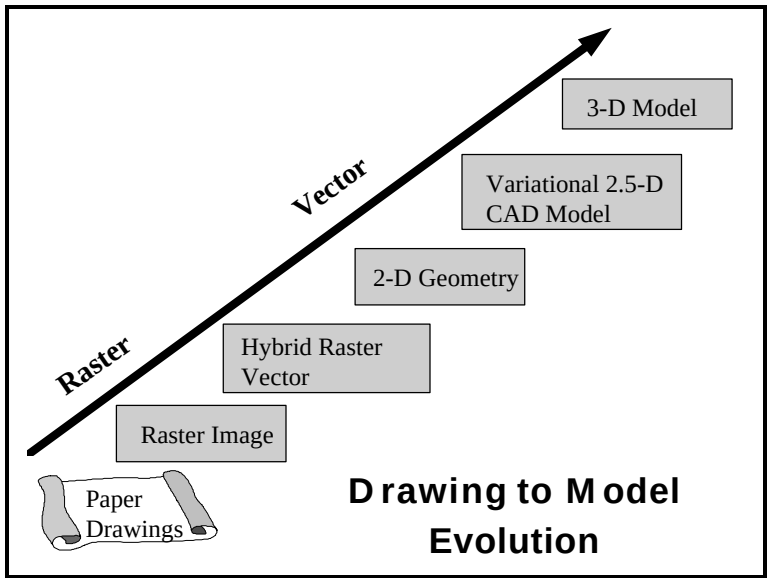
2. Substantial benefits like faster retrievals or improved revision cycles are obtained through the electronic archiving and distribution of scanned drawings.

3. Benefits increase when these drawings can be electronically edited.

4. Further benefits are obtained when these drawings are transformed into precise, complete and intelligent CAD models.

The vast majority of paper based drawings were created as static pictures with geometric and attribute intelligence contained in dimensions, notes and other annotations. The drawing picture is for visualization purposes only and, indeed, "NOT TO SCALE" is an annotation found on most standard drawing formats. Most of these scanned drawings do not yet fulfill their potential for providing complete and accurate information for engineering, manufacturing and other applications.

The electronic archiving, distribution, management, and update of legacy paper in a manner consistent with your company's objectives, provides a multiplier effect that can save tremendous time and resources.



The Role of Drawings in the CAD Process

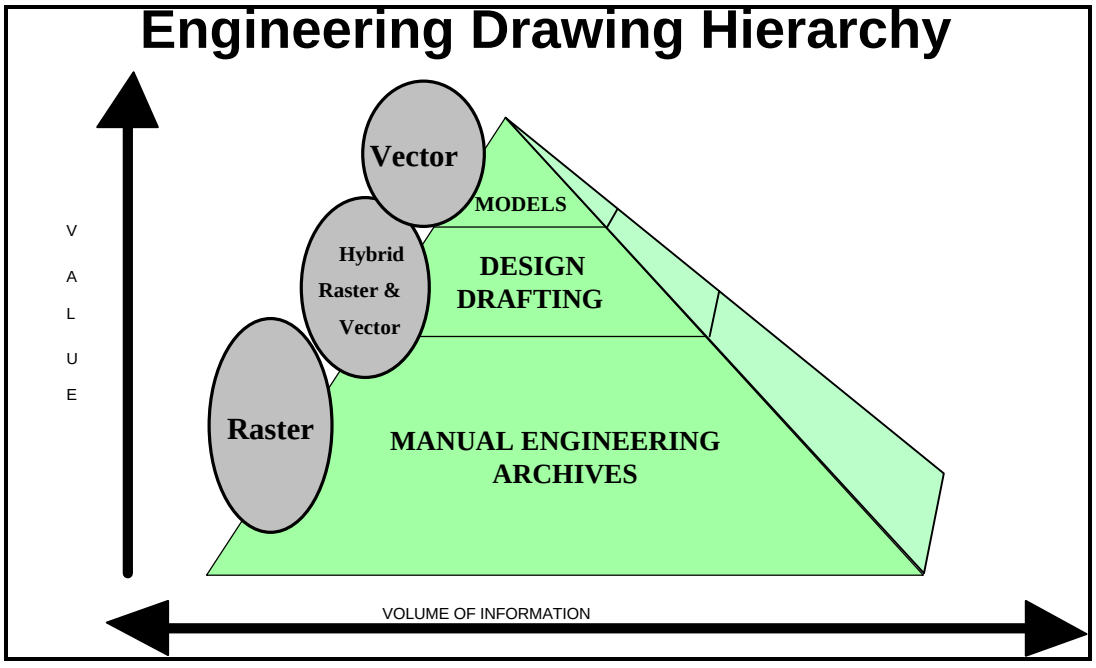
Drawings with the highest corporate value are found within the modeling and analysis environment using higher end CAD tools. These models require a geometric (vector) database in order to enable functions such as stress analysis, NC programming, parametric or variational modeling, automated mapping, and/or facilities planning.

There are different ways a drawing can be represented in CAD. The most common use of a revised drawing is a 2-D digital picture without computer readable intelligence. Geometry is for visualization only, and modifications are usually made to the drawings using erase and redraw methods.

Typical scanned drawings (picture based CAD) do not convey the complete part definition as a modeling system can. Scanned drawings may introduce part definition conflicts and discrepancies. The goal is to enable tools and technology that permit use of raster drawings in their "native" raster format, as well as convert raster drawings to intelligent CAD models for use in company critical engineering applications.

The archived drawing. It is common for many companies to have large quantities of designs which must be preserved throughout the life cycle of the product or service. Even though this archived information may only be needed for reference or contractual purposes, it is highly valuable. Archived documentation often exceeds the quantity of active information. At any time, a drawing can become active due to maintenance of an older design, or a new design may reuse information created in the past.

Drawing distribution. Circulation of active drawings within the conceptual or production cycle is often accomplished with physical hardcopy and digital CAD or raster data. The emergence of viewing software, internet and intranet services, e-mail, and EDM/PDM systems offers tremendous potential for companies to accelerate critical information throughout the enterprise.



Legacy CAD and paper drawings can easily be enabled into this process making them universally available to the user community. Since some of today's electronic distribution tools rely on a raster or vector only environment, it is common to only convert raster to vector or vector to raster. The result is increased value of both CAD designs and paper drawings.

The revised drawing. As companies move towards a digital archive and drawings evolve to CAD, the distribution advantages of EDM/PDM tools become available. Drawings within the revision cycle represent active changes or work in process. Integrating these older designs into CAD creates two potential editing solutions: hybrid raster CAD and vector CAD.

Newer designs are typically modified within the proven environment of CAD; however, a large portion of drawings are still based on paper archives and modified manually due to the initial costs associated with getting drawings into CAD. With today's tools, these drawings may now be updated and maintained within the CAD environment.

One such tool is hybrid raster vector. This tool allows both raster and vector data to be maintained within the same drawing file. This hybrid raster vector environment offers significant payback to users who must revise drawings but only require a digital picture or archive. Selected areas of scanned drawings can be converted to vector for ease of updating and editing. The result is increased value from legacy drawings and CAD without the need for total conversion to vector.

When the requirement is for a true CAD model with precise geometry, a critically important revision must be made to a scanned drawing. That critical revision includes not only the conversion of geometry from raster to vector, but also the update of those vectors from hand drawn precision (typically +/- 1/32) to CAD accuracy. Parametric CAD and Variational Geometry, discussed below, provide excellent tools for this purpose.

It starts with a scan. Scanning is perhaps the most overlooked factor in the conversion process. Today's scanners provide advanced image enhancement features to produce better quality raster files. Conversion to full vector CAD format is most dependent upon a well-scanned image.

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.* Typical resolutions are 200, 300, or 400 DPI. Resolution should be based on your needs with the images. While 200 DPI may be fine for viewing and distribution, 300 or 400 DPI will produce more accurate raster to vector conversion results.

Compression methods Data compression techniques have emerged to allow raster based drawings to be stored in less storage space than a 3-D CAD file. This is due to the use of two dimensional compression which can reduce an 8 MB uncompressed raster file to approximately 100KB without any loss of information. The more popular formats found in the market today are the CALS Raster and TIFF format, both utilizing the CCITT Group 4 compression method.

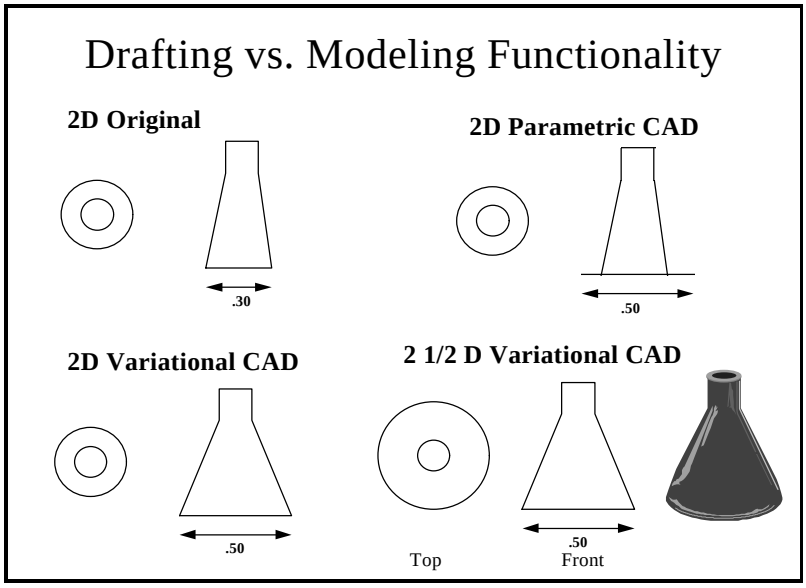
Utilize a service bureau. Outsourcing to service bureaus is a common method for handling small jobs, pilot projects, or quick turnarounds. You save on resources, realize fixed costs, and have little to no capital outlay for equipment. These services, however, may not meet the security or design needs of your company.

Scan in-house. A variety of affordable and high quality scanners are available in the market to address a range of throughput needs. An in-house approach can be effective when implementation is incremental and resources are readily available.

Intelligence at last. Engineering models are established when geometry and attribute relationships are contained in application readable form. This can be either 2-D or 3-D. More advanced CAD systems offer parametric and variational geometry models. These offer truly intelligent environments where engineers can analytically and dimensionally drive design concepts.

dimensions and notes. In Parametric CAD, the dimensions and geometric elements are "associated." Changes made to a dimension will update the associated geometric element, but do not update elements of the drawing not associated to the dimension.

Parametric CAD is an excellent aid for updating CAD drawings. For example, it is easy to update a circle from its .300 as-



drawn radius to its intended .500 radius. Although effective, it requires that the shape be changed element by element. Let us next consider a technology to ease the process.

A picture is worth 1000 words but a model is worth 1000 pictures. When updating a drawing in an environment in which a true model is not required, hybrid raster vector editing is effective. However, when intelligence of a model is required, all geometric data must be transformed into vector form. This process has often been called raster to vector conversion or vectorization. This technology helps to move beyond the unintelligent picture or raster role into a more intelligent vector drawing and editing environment.

2-D Parametric CAD. The classic 2-D CAD model consists of geometry,

2-D Variational CAD. A Variational Geometry model allows for the establishment of relationships (tangency, mutual relimit, etc.) between geometric elements. When a geometric element is updated, the figure will "hold shape" by maintaining those relationships.

After these relationships are applied to scanned and converted drawings, the update of just a few dimensions can bring all geometric elements of a shape to the desired CAD precision.

2 1/2-D Variational CAD.

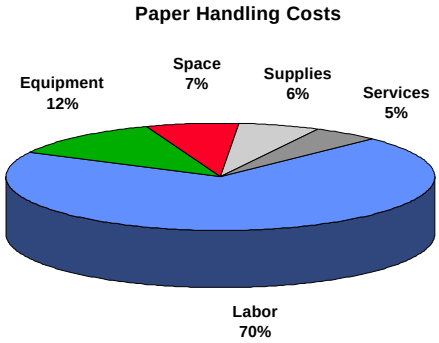
2 1/2-D CAD, which may also be parametric and variational, contains view intelligence that understands the relationship between Front, Top, Right, and other views. Although a 2 1/2-D model does not contain an internal 3-D solids representation, it contains the 3-D intelligence to allow easy generation of a 3-D solid when the model is transferred to a 3-D system.

The use of a 2 1/2-D CAD system to create a precise CAD model from your 2-D paper drawings provides more than an upgrade from 2-D paper to a 2-D CAD model. Changes made in one view are reflected through all other views. An avenue is created to move from paper to solids and a significant step towards an accurate 3-D CAD model.

Real Costs of Paper

Manual methods for handling, storing, and maintaining paper drawings are difficult, time-consuming, and costly. The following are some of the most obvious problems with maintaining paper archives:

- Paper drawings are susceptible to aging and damage over time.
- Paper is not geometric or accurate in nature.
- Manual-based revisions are costly, particularly with drawings requiring frequent updates. Drawings maintained as variational or parametric models offer significantly lower costs to modify further.
- Paper is slow to distribute.
- Paper driven design environments require more costly change order cycles and more time to prototype than modeling based approaches.
- Many transactions between companies are inefficiently conducted with paper 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.
- Paper is restricted 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 exacerbates this problem.
- Facilities costs for the storage and maintenance of paper archives can be substantial.
- It is estimated that five to seven percent of technical assets are lost or misfiled.



Source: U.S. Department of Labor

How Does It Work

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

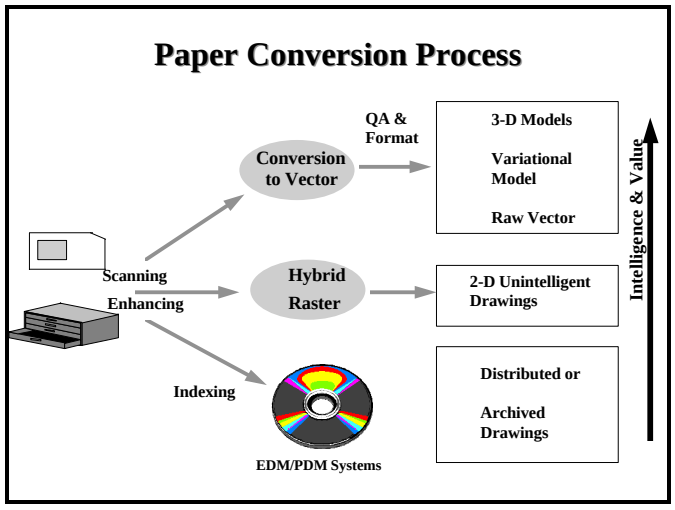
Deteriorated drawings can be scanned, cleaned up, and stored in raster. Modifications can be made to the drawing in raster or areas of the drawing can be converted into CAD vectors as it becomes necessary. This combination of raster and vector can be plotted as well as stored within more advanced EDM/PDM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

Raster drafting. Raster editing or drafting is the simplest and most productive way to modify scanned paper drawings. This is supported by the availability of advanced clean-up and editing features contained in some of today's products. Raster drafting works best when simple updates are required in non-dimensioned or unintelligent picture oriented drawings.

There is significant differentiation within the available software products in features, functionality, and positioning. The more advanced products are capable of working with raster "entities" just like vector CAD entities. Complex entity oriented changes can be made while preserving the integrity of other intersecting geometry. New additions can be made using your present CAD system and *added* or "burned" into the drawing with ease. This process is called rasterization or vector to raster conversion.

Hybrid process. A fully hybrid approach is one where raster and vector CAD data coexist within a drawing. The term hybrid in this case means a combination of both raster (scanned) and vector (CAD) data within a drawing. 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 the two distinctive formats. This approach offers the most efficient method for modifying the old within the new.

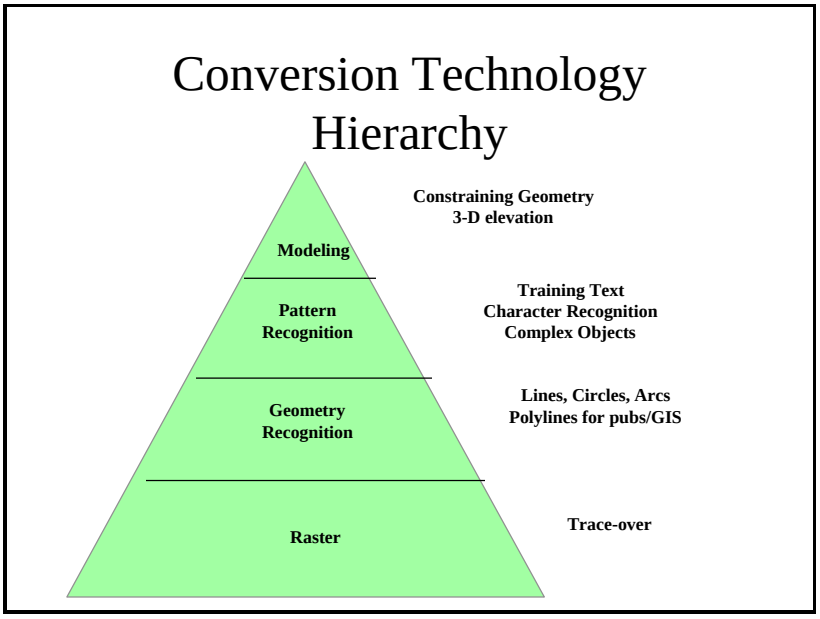
Two approaches exist for managing the hybrid databases. One approach separates the raster and vector models. It then introduces a third calibration file to define positioning, scaling and orientation of the imbedded object. This approach introduces more management burden on the user.
A more integrated approach treats the



scanned raster data or multiple images as a CAD drawing. No additional management or operator burden is required.

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 done on a "just in time" basis.

Conversion to vector. Drawings within Analysis and Modeling systems have the greatest corporate value. These need to be in a fully vectorized CAD format. Some examples: a company may need to develop a 3D model from an old drawing and run FEM or interference checks within the model; or variational and parametric modeling is required to test various design concepts for a complex part or assembly. Both situations require vector CAD models in their 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. Conversion software will not produce an unattended 100 percent conversion. It is best used as a component of the conversion process rather than a total solution.

The tools used to vectorize are:

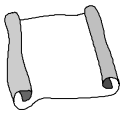
Overlay Tracing. This is often referred to as heads-up digitizing. A scanned image is loaded into the CAD system as a backdrop and the image is "traced" over with CAD entities. This is very similar to the idea of digitizing but a digitizer table is not needed.

Automatic Vectorization. Conversion of scanned drawings to intelligent CAD models has long been the desire of companies. There are numerous approaches presented by products found in the market.

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 effective 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.

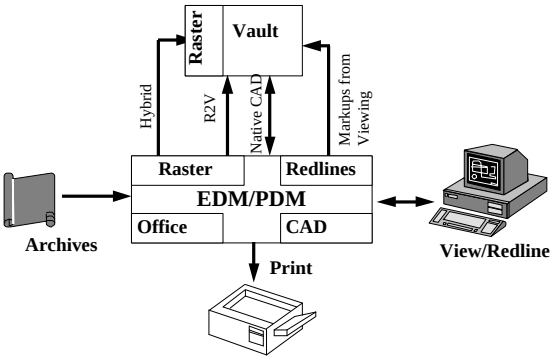
As an example, a manufacturing firm needs to make modifications to a part design. Advances in new materials and related cost savings demand that the part be redesigned to meet new structural requirements. Variational modeling is needed to optimize the design process. Rather than convert the entire drawing, only the appropriate geometry is selectively converted. The resulting relationships are defined, making future parameter driven design easy and in a sense, automatic.



Integrating Paper with EDM and PDM

While implementing task-oriented tools like CAD or word processing have improved individual productivity gains, scanning paper assets and implementing EDM/PDM enhances the business process. Reduced product cycle times, ISO 9000 support, and lower cost of goods represent the kind of measurable issues impacted by implementing EDM/PDM systems.

Integrated Paper CAD/EDM/PDM Environment



Viewing and redlining tools play an important role within this environment as they allow for quick and easy visual access and commenting (redlining) of the drawings. The ultimate viewer is one that supports your native CAD modeling format, raster formats and common office formats (word processing, spreadsheets, etc.), and is tightly integrated with your EDM/PDM Vault.

Tightly Integrated CAD/EDM/PDM. A tightly integrated system is one in which the revision, release, and review cycles are all controlled from a common database environment of EDM or PDM. Drawings earmarked for update are flagged for checkout and launched into the appropriate editing tool.

Scanned drawings, now electronic files, can be managed and edited by the same tools used for vector files. More advanced CAD tools allow you to work on these electronic archives in their scanned raster format. This makes it possible to use a single editing environment for all drawing revisions, both in CAD and raster. Managing these raster or hybrid files is easiest with systems that store the raster files as part of a CAD drawing file.

Raster vs. Vector

CAD systems use vector files; scanners produce raster files. What is the difference? Raster files are fundamentally different from vector files. If you draw a line within your CAD software, it 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 "knows" 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, and the dots do not "know" that they are part of a line. Intelligent Hybrid CAD tools apply Artificial Intelligence techniques to treat the raster as if it is vector geometry thus immediately giving it editing efficiencies similar to 2D CAD. For scanned data to be used within the full CAD modeling world, it must be made intelligent and converted to vector format.

Redefining the ECO Cycle. Tightly integrated systems also link the viewing tool and its' redlining capabilities. These systems can concurrently allow viewing and simultaneous redlining of drawings throughout the enterprise.

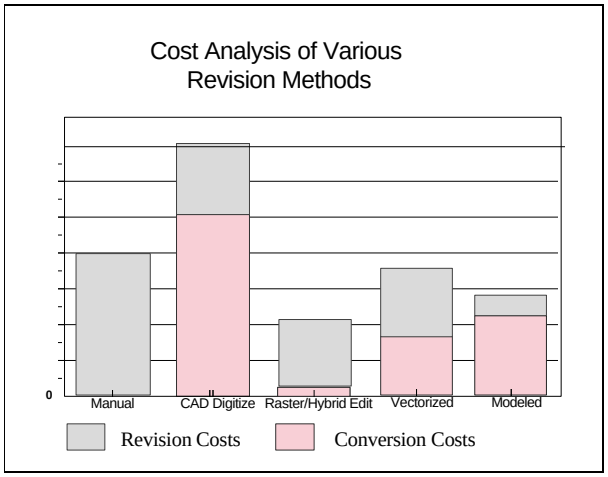
As the drawing approaches approval, all redlines can be consolidated into a single approved file that can make its way into CAD. The resulting raster or vector drawing is updated and a final electronic comparison performed to verify completion of the task.

Cost-Benefit Analysis

Creating an open environment for drawing archives requires a one-time cost for scanning paper drawings into an electronic environment. Once implemented, savings are realized throughout all phases of the product life cycle.

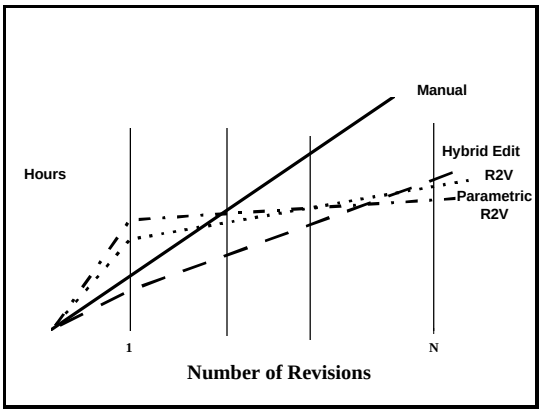
Considering that the amount of technical information grows exponentially throughout each successive phase of a product life cycle, the savings can easily accumulate. This can provide a substantial return for the maintenance, archiving, and revision of paper assets.

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 between investing in the upfront vectorizing to raw vector CAD, conversion to intelligent variational models, or taking advantage of lower cost hybrid raster CAD system.



Revision Life-Cycle Cost Savings. The costs associated with revising drawings are dependent on the method and solution used. The methods presented here include manual, CAD digitize, hybrid raster CAD, full vectorization, or conversion to intelligent models.

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 projected on each revision plus the digital transformation expense.



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/vector approach, which eliminates the redraw, cleanup, and verification processes, offers the greatest immediate cost benefit for non-model oriented drawings. Drawings required in a vector CAD environment are best served by full conversion to intelligent variational modeling systems.

Business Reinvestment. Companies already spend 7-10% of their expenditures on manual document management processes. A business reinvestment strategy involving the technology presented here can help reduce the incurred costs of managing, revising, and distributing information.

Market/Lead Time Benefits. Manufacturing companies often survive based on

getting quality products to market sooner than its competition. Doing so helps increase mind share and hence market share.

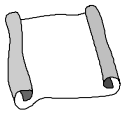
Project oriented companies, such as utility and construction companies develop a product at a greater scale. Contracts are awarded based on accurate and detailed proposals which must include cost and time estimates. A paper-enabled and intelligent modeling system at the front end yields faster design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

Other Benefits. The direct benefits of integrating paper within EDM/PDM and CAD can be attributed to labor savings revision cycle. However, there are many other 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.
- Improved product quality. Getting it right the first time reduces downstream costs significantly.
- 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 the time to market.

A simple cost-benefit example in which a company has 100 drawings with 20 ECOs to perform each month illustrates some of the 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.

Action	Times Per Month	Manual	Raster Enabled	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/month



Selecting Vendors

When purchasing software, a relationship is established with the manufacturers and their resellers. Here are some points to consider when selecting a business partner:

Evaluating a company

❑ **Historical Longevity:** Market experience helps to ensure that your software manufacturer can deliver the best tools.

❑ **Investments in Research and Development**: Look for a consistent history of investment in the development of technology.

❑ **Integration Services:** Companies with strong integration services can assure full implementation of their technology with investments you have already made into databases and applications software.

❑ **Industry Partner Relationships:** A good indication of a quality software manufacturer is when their product is recommended by vendors of related technology.

❑ **Satisfied Customers:** Are there any "big name" accounts on the client list? References are always worth a check.

❑ **International Operation**: Worldwide usage can be a good indication of the maturity of a company. Foreign language versions can be helpful for your future or current applications.

❑ **Training and Support Services**: Proper training and support can be the difference between success and failure when implementing new technologies.

❑ **Market Leadership or Dominance**: Your investment in paper tools is a long term one and should be backed by a vendor with proven leadership in its field.

Evaluating the software

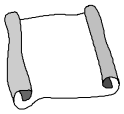
❑ **Offers Full Compliment of Conversion Approaches**: Each and every drawing will have an optimal payback approach and the resulting system should incorporate hybrid raster/vector editing for the simple changes, selective conversion for moderate changes, and full 2-D parametrics and 3-D modeling for the converted drawings of higher value.

❑ **Easy to Use**: Menu structure and commands should be consistent and logical with easy integration into your existing system. On-line help and a good reference manual are also necessary.

❑ **Features that Benefit**: A list of key requirements scaled on their value to your organization can help in the evaluation process. Key requirements include:

1. Automatic Raster to Vector Conversion: ease of editing and a necessary first step toward creation of a true CAD model.
2. Automatic Vector to Raster Conversion: improved distribution of drawings through company-wide imaging systems.
3. Intelligent Raster Editing: cost effective simple updates of electronically archived and distributed scanned drawings.
4. Hybrid Raster Vector: update options tailored to your particular objectives.
5. Parametric CAD: easy update of CAD geometric elements.
6. Variational CAD: easy update of CAD geometric shapes.
7. 2 1/2-D CAD: a paper-to-solids path.

❑ **Support of standard formats**: Make sure that the software you select supports industry standards including CALS and TIFF.



Making It Work

Once you've made an implementation decision, how do you ensure the success of enabling your paper drawing archives within your CAD or EDM/PDM system?

Evaluate your Paper Trail. Evaluate and model the life of a drawing within your company. This will help you and your staff understand the areas needing improvement and helps in the justification of scanning, document management and hybrid systems.

Categorize your drawings: With the various technologies presented in this paper, it is clear that a number of options exist to modify them. Determine the modeling needs of the drawings throughout their projected life. Drawings without modeling needs can be scanned at lower resolutions and modified using hybrid raster and vector solutions. Modeling targeted drawings should be captured at slightly higher resolutions and converted to vector format.

Evaluate the quality of your drawings and determine the enhancement needs. Drawings that have excellent to moderate quality will work best. Poor quality and faded drawings can be improved with traditional photographic equipment and high end scanners but will likely result in limited benefits from the technology presented here.

Evaluate your resources and scanning urgency. This will help you to determine if scanning services or in-house resources will work best for you.

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

Plan globally, invest incrementally. An incremental implementation can produce a more immediate payback and faster end user buy-in.

Convert Incrementally. When considering the revision cycle and paper archives, use the incremental conversion approach. Hybrid raster offers increased leverage of your CAD productivity while allowing the integration of paper archives. When drawings are being modeled, only convert the necessary geometry.

Quantify the Benefits. Determine the strategic and practical value of the technology being introduced. Lower operating costs, time to market, and improved quality all provide the benefits required to justify the investment.

Educate your staff. The benefits of the technology presented in this paper are far reaching but are only as effective as the staff and its understanding of the technology. Include in your investments, product and procedural training seminars to ensure that user acceptance is maximized.

Conclusion. The value of capturing paper based drawings within a CAD system have long been acknowledged, but cost effective and practical tools and methods to accomplish this have only recently become available. Depending on the objectives of your organization, your goals may include the archiving, management, distribution, and updating of your paper drawing legacy.

This white-paper has described the tools and technology currently available for turning a paper legacy into today's and tomorrow's valued data asset.

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 who require raster enabled solutions.

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

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