How to Evaluate a Scanner

By Derek Jenkins

Introduction:
The main focus of this paper is to provide an introduction to the complex issues of evaluating and choosing a Book or Microfilm scanner for use in a library, conversion bureau or archival work place. There is no right or wrong answer, but being educated allows you to make a more informed decision. This report is primarily aimed for the non-technical user, but does introduce some technical issues that I will cover as simply as I can. For more detailed and technical information on evaluating scanners IImage Retrieval, Inc is available to assist. We can also connect you to experts like Don Williams (ex-Kodak), the staff at NARA and the archival staff at the Library of Congress for more assistance.

The issue:
Choosing a scanner to scan books or microfilm documents can be a daunting task. The industry has scanners available from a few thousand dollars to over a hundred thousand dollars. All of these systems can scan, but is the way that they scan going to meet your project objectives? Is the scanner a practical choice within your budget? Is the scanner even within your staff's technical capability? In many ways the budget drives the selection, but buying the wrong machine could prove to be a waste of money and cause the project to be both late and with unacceptable image quality.

Below is a list of my evaluation criteria in order of decreased importance. However, the points are interrelated so selection is commonly a compromise among all the points.

> **Image Quality:** This is the main topic in this paper and, in my opinion, the most important factor when buying a scanner. If you can not produce a good image then why do the scanning?
>
> **Reliability:** If the scanner is always failing and needs constant maintenance then it will not be available for the task it was intended. The first year may be covered by a warranty but frequent failures could force you to purchase other yearly maintenance support contracts just to be able to use the machine.
>
> **Performance:** If the time the scanner takes from one scan to the next is too long, then scanning more than a few pages or frames at a time is not practical. At the other end of the scale: Why buy a scanner that will do 500mph when paper handling requirements or the output image size slows you down to 70mph?'.

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Functionality: Knowing how you will be scanning will help define the functionality required in the system. Are you scanning on demand or are you converting in volume? Do you want a finished product from the scanner or will you post process it into your final formats?

Cost: Cost is a trade-off between quality, reliability, performance, and functionality. Only you can make this determination. Buying a scanner that does not deliver the quality and quantity required is a waste of, not always readily available, money.

Background:

1. At the basic level, all scanners capture images in either color or grayscale. The associated hardware and software defines what image is finally delivered you.

2. All scanners capture an uncompressed data stream that when viewed in two dimensions creates and image.

3. Scanners DO NOT scan in PDF, JPG or TIFF. These are the output formats from the software that is running the scanner.

4. You can only evaluate the quality of a scanner by looking at an uncompressed image. You can not evaluate the quality by looking at an image that has been compressed, because the image suffers degradation during compression.

5. Images from a “SIMILAR” model should never be used to evaluate a scanner. Different models use different cameras, electronics, lighting and scanning methods. This is why it is sold as a different model.

Image Capture:

When images are scanned they normally arrive in the memory of the PC in either 8 bit (grey scale) or 24 bit (color) depending on the camera being used. They may have come from the camera at 12bit or 36bit, but for practical reasons scanners tend to handle then at the 8bit or 24bit levels. From this point on in the scanning process any output images are a ***derivative*** of the original scanned image.

For instance, a bi-tonal image is made by converting an image from its original grayscale or color format to a 1 bit mono-chrome representation. This can be done in many ways. The simplest way is a simple static thresholding. A better approach, is the more sophisticated dynamic thresholding method. But at the end of the day it is still a software mathematical algorithm that produces the output.

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This algorithm has nothing to do with the quality of the scan originally captured by the scanner.

On the same basis a 24bit color image can be converted to an 8bit (or even 4 bit) grayscale representation of the original. This is also a tampered version of the original scan unsuitable for quality evaluation.

Compression:
Once in the PC's memory, the captured image is normally then compressed for storage. The most common method for storing a bi-tonal image is called CCITT-G4 compression. This "Compressed" image is then wrapped in a TIFF header that contains basic image information like width, height, bit depth and even basic meta-data. This image is commonly known as TIFF-G4 or sometime Group 4 or even just TIFF, although the label "TIFF" can be very misleading. It can be confused with the term Group IV, uncompressed, mutli-page or other "TIFF" file format.

Some of the typical compression schemes for color and grayscale images are JPEG, JBIG or JPEG-2000. They take an image, compress its size with a mathematical algorithm and store it on disk. In most cases these formats achieve their savings in size by introducing a "loss" in the image quality. The higher the loss is, the smaller the file size. This savings in disk space comes at the expense of increased image degradation and at times a loss of image quality.

Image Quality Evaluation:
Most compressed image formats are images that have been mathematically manipulated and degraded to achieve a smaller storage foot print. Therefore, these images are not valid to be used for scanner quality evaluation. **The only true representation of the scanner's image quality is an uncompressed, unenhanced, color or grey scale image that is typically stored in a RAW or 'Uncompressed' TIFF format.**

For evaluation, it is important to scan some of your proposed work. However, this still provides a very subjective and limited review. Later projects may have an entirely different type of material or media (i.e. film stock). Testing with one project in mind may not show inherent scanner weaknesses that could be an issue later on. A better method is to scan a known entity like a standard scanner target. These targets simulate the basic components of all images to allow an unbiased evaluation of a scanner's quality (s*ee Applied Image at the end of this paper).* These targets are available in many different layouts and most will do an excellent job of demonstrating the strengths and weaknesses of the scanner. Working with this known entity allows removal of the personal feelings about the documents and brings the evaluation to a more technical level.

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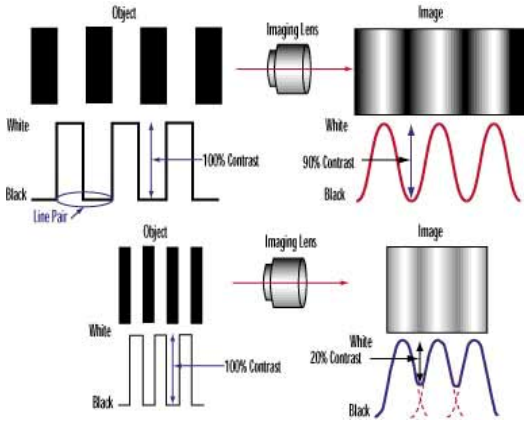
Don Williams, an Image Quality and Calibration Consultant, formerly a research scientist in the Imaging Science Division of Eastman Kodak has been working with NARA and the Library of Congress to produce an improved mathematical method to evaluate both film and book scanners. This process started with the "SFT targets" that evolved into the "SFT II targets" and have now progressed to a new version of target specifically for book scanners. It will be available to the market very soon. Considering the type of work that most institutions are doing this target may be little overkill, but it is the ultimate method in the market for scanner evaluation.

Without going to extremes, scanning any of the commercially available film or paper targets will allow you to evaluate many of the basic functions of a machine. However, you must insure that the images being evaluated were produced on the exact model with the exact lens, lighting and camera that you are considering purchasing. As stated earlier, allowing samples from "something similar" will make the comparison totally invalid.

Modular Transfer Function:

A scanner consists of multiple components like camera, interface boards, lens, lighting and a transport that, when used together, produce an image. One of the evaluations of a scanning system is to view the sharpness or focus of an image before any enhancements. The finer the details that are viewable in the image then the better the scanner's precision. In optical terms this is called the MTF or Modular Transfer Function.

In the example below, taken from the Edmund Optics technical support Web site, an image with black and white lines is evaluated. When the size of the line is large the black to white contrast can be seen. As the size of the lines get smaller and the number of lines increase, the edges turn into a blur and image definition is lost.



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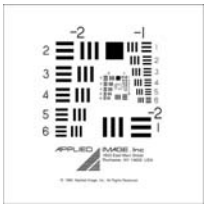
Quantitatively measuring MTF takes a special program but a simple evaluation can be made by looking at certain parts of a scanned target. When evaluating these images they should all be viewed on the same monitor at a 1:1 ratio or 100% zoom. Other levels of zoom scale the image up or down and do not provide a true representation of the original scan. Another thing to remember is that the monitor must be at its native resolution or again you will be distorting the image.



Line Pair per Millimeter (LPPM) Target. These are read by looking for the highest numbered line pair on the target where an observer can distinctly see the black and white lines. The higher the number the better the image *at the resolution scanned*. Don't compare 200dpi on one machine with 300dpi from another.

Fan Wedge Target. This is a fan shaped series of lines that are thicker at the bottom and thinner at the top. This is used like the LPPM and the user looks for the highest number where the distinct difference between the black and white lines can be seen. The higher quality scanner will have the higher line delineation. In addition to this simple numeric reading one can also compare the straightness of the target lines to evaluate the scanner.

Pestrecov Star Sector Target. This is a circle of lines, thicker on the outside and thinner at the center. This is evaluated by looking to see how close to the center you can still see the distinct black & white lines. Again, the more precise scanner will show distinct lines closer to the center.

Text Size Targets. This is the alphabet in upper and lower case printed in ever smaller type fonts. The evaluation is performed by comparing which lines of text can be read. The best scanner will render the smallest fonts clear and legible. This is very important when scanning books. Footnotes, especially, may require a scanner that can scan smaller fonts than some scanners can provide.

Straight line Test. This test is valid for both book and film scanners. This test involves the evaluation of a diagonal line scanned on a book scanner or filmed and then scanned on a microfilm scanner. This evaluation is simple and just reviews that straightness of the reproduced line is. A significant wave distortion in the line indicates major issues with the scanner.

Color Separation Test. This test is normally only used on a color book scanner and is my favorite test because it tells so much about the scanner and is so easy to see. All one need do is to look at any part of a target with a solid black vertical

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or horizontal edge. This could be a line or text edge or anything that has a good transition from black to white. Look at the line at 100% and see if you can see any color shadow or halo. Continue this same process by viewing the image at 200%, 300%, 400% or more to check color shadow is ever revealed. Look on both sides of the line or character. Color halos at the default 100% reveal a low quality scanner or a defective array. Average quality scanners will not show a color halo until 400% or so. The best scanners will not show any haloing at all.

Full area Scan. This is also a test for book scanners. Five identical targets are placed in the maximum scan area, one in each corner and one in the center, and the full area is scanned. The evaluation is done by examining each target for optical distortion. The poorer quality scanner will exhibit a higher distortion when between each of the targets.

Image target evaluation. Target evaluations must be done at different resolutions to optimize the analysis. Some scanners like the i2s Digibook and the nextScan Eclipse have a variable optical system. This means that the operator moves the camera and refocuses the lenses to achieve different resolutions. Other scanners like the Book-eye 3 and the Wick & Wilson RS 300 have a fixed optical resolution. This means that the camera and lens are fixed at a given resolution, like 300dpi. The image resolution is then scaled up or down to achieve the desired resolution. Scaling down can be an acceptable image as it is a derivative of the original but scaling up involves interpolation and adding pixels that were not in the original scan. This is not acceptable if a precise image representation is required.

Image Resolution:

Image resolution can be loosely defined as how many dots or points are found within one linear inch of the scanned image of an original document. This is can be any number, but 200, 240, 300, 400 dpi or ppi (dots or points per inch) are normal for the scanning industry. But what is a dot or a point? From the notes on MTF, the measurement of image quality is judged on how well an observer can resolve (see) a transition (dot).

An simpler explanation of this statement is: If we scan a document and can see 200 dots per inch then we have a 200dpi image. If we scan a document and can see 300 dots per inch then we have a 300dpi image. If we scan the same image at 400dpi but cannot resolve (see) any more detail than at 300dpi, then we only have a 300dpi scanner. The scanner may say it's a 400dpi scanner, the image header may say it's a 400dpi images but if you can't "see" 400dpi then you do not have a 400dpi scanner.

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If the scanner is not resolving (allowing the observer to see) more detail as the resolution increases then it has hit its MTF ceiling. This can also technically work against the scanner's evaluation. If the scanner is resolving more detail than it is supposed to (200dpi scan can see 100dpi for instance) then the final image may include extraneous image results (noise) that are not really part of the original material. However, this could also be considered a good problem to have as changing the f-stop will lower the MTF and reduce the noise.

Color Evaluation:

For book scanners I have stayed away from true color evaluation because there are many more steps involved than just scanning a color target. If a scanner has the ability to use an ICC profile, and most book scanners can, then color variances can be corrected. I am not saying that scanning a GretagMacbeth® color target is not useful. I am saying that true color evaluation is only possible under very controlled circumstances with special calibration tools. This requires the scanner and monitor to both be calibrated and an ICC profile generated. This final profiling step insures that the monitor is reproducing a perfect replica of the scanned original. You would only be able to confirm that the monitor is doing this perfect replication if you view the original document in a special calibrated light box. This detail is beyond what most people can practically do. Entities like NARA or OCLC that have goals for Pristine Archival scanning buy the equipment and search out the expertise and training to do this type of "full" color evaluation. As long as the scanner produces decent eye discernable color and has the ability to use ICC profiles then this is generally all that you should need in most cases.

ColorChecker® SG

Film scanners can be evaluated according to the 256 levels of grey that they capture. If we scan in a certified calibration strip then we can look at the grayscale patches and read the density. This can then be compared with the known density of the strip. Most scanners will allow the end used to adjust the lamp on a film scanner to set correct the white levels. If the black levels do not align to the correct values then you will need to adjust the scanner using gamma correction.

When calibrating any scanner, do not believe your eyes. Use the tools and read the numbers.

Reliability:

If the scanner is constantly failing and needs frequent maintenance then it will not be available for the task it was intended. These ongoing repair costs and production delays will effectively increase the purchase price of the scanner. What appeared a good buy suddenly becomes a burden to the operational budget.

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Performance:
A manufacturer's documentation may state that is takes one second to scan an image. It may state that it scans at a rate of 300 pages per min. These numbers can be deceiving and may not tell the whole truth. Check carefully what the production ratings assume and mean.

Book Scanners:
There are several elements to the action of scanning. A scanner may take just 1 second to do the scan but it also may take additional time to set the exposure, correct the curvature and save the image to disk. The time that should be looked at is not the scan time but the full cycle time that takes all these steps into account. *The cycle time is the time from the start of a scan to the time you can start the next scan,* ***repeatedly***. Depending on your goals (the volume of materials you have to scan and the amount of time you have to complete the project), this cycle time could be too long. Scanning more than a few pages at a time may not be practical.

Let us look at this from another angle. If I am scanning a book using a glass plate, how fast can the operator release the glass, turn the page, close the glass and then press the scan button? If that time is less than the time the scanner takes to save the last page then the operator we will be waiting for the scanner. If the operator's actions take longer than the save time then the reverse is true and the scanner is waiting for the operator.

Performance is not everything, but it is important. I would much prefer that the scanner is waiting on me to finish turning the page than me waiting for the scanner to finish saving the image file. I have seen a scanner run at 12 scans per min or about 24 pages per min. This is about as fast as an operator can work for any extended time.

Microfilm Scanners:
These scanners are normally rated in pages per minute. However, the definition of a page in microfilm terms can vary.

- In the US we use 8.5 x 11 inches to rate scanning speed in most cases. In Europe they use A4 which is 210mm x 297mm or 8.27 x 11.69. This is a full ¼ inch smaller then the US.
- What is the size of the pull-down or inter-frame gap? The smaller the gap the faster the frame rate.

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- What reduction ratio was used to scan the documents? The higher the reduction ratio the larger the inter-frame gap will be when the measured in document inches.

So a scanner in the US rated at 300 pages may run at the same speed as European one rated at 310 pages. The page size and inter-frame gap significantly affects how many pages will be scanned per minute. It is not only the scanning speed.

But now let us consider the full system. I may be able to scan at 300ppm but can I process, compress and output those images at the same rate? If I can't, then the scanner has to be slowed down. If I have to slow it down then I don't need a 300ppm scanner. This is especially evident when scanning newspapers. The images are very large and are normally stored as uncompressed (RAW) TIFF images. This means that the PC that runs the scanner is trying to write to disk between 50 and 70 megabytes of data per scan. This is on the upper limit of the average disk drive. Most drives are only capable of between 40 and 50 megabytes per second. So the scanner has to slow down to a rate that can be saved to disk. As a result of this throughput delay even though the scanner is rated at 300ppm, in practical terms the operator will only achieve between 40 and 50 RAW scans per minute.

Now let us look at film handling as part of the equation. To set a simple base line for consideration, on an Eclipse 300 a 100ft roll of 24x film scanned at 200dpi takes about 7 minutes to scan. Then the roll has to be rewound, dismounted and the next roll loaded, tested, index data entered and then the scanner restarted. Assuming that this takes 3 minutes then we have, **for the mythical perfect roll of film,** a 10 min per roll production time or 6 rolls per hour. This is 42 minutes of scanning and 18 minutes of "scanner management". From direct experience, one operator can run 2 high speed scanners and keep them going; but it is hard work.

Now let us consider the same production environment with an even faster scanner, say 500ppm scanner. The roll takes about 5 minutes to scan. We still have the 3 minutes of overhead making the cycle time 8 minutes. This works out to be 7.5 rolls per hour or 37 minutes scanning time and 23 minutes management.

Technically this will work with one scanner but two would be nearly impossible to run smoothly at the same time. As soon as the rhythm of scan/mount/scan/mount is disrupted then a scanner goes idle and the productivity is reduced. A 500ppm scanner may not be the best production

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solution. Also one should consider the practical issues of interruptions for telephone, bathroom, lunch, etc etc etc and suddenly faster may not be better. It is important to look at the whole scanning environment not "just the scanning speed" to get the fastest production scanner for ones production goals.

Functionality:

Again we have a divergence between functionality for book scanning and film scanning, although some points are common to both.

What ability do you want your scanner to have? Is this functionality a part of the scanner or part of the software tool that is driving the scanner or is it a post process? Why and when does this matter to you?

Book Scanning

1. Are you doing On-demand scanning?

2. If the majority of your books and documents that you are going to scan are 8.5x11 or 11x17 inches do you really need to have a scanner that will scan the occasional 22x34 inch map?

3. Do you need a book cradle or is most of your work flat?

4. Do you need a glass platen to hold the work?

5. Do you need a vacuum table?

6. Do you want the scanner to just scan and then you will post process all the images later with other software like Photoshop®, BookRestorer® or some other software program?

7. Do you want the scanner to deliver finished work at the expense of speed?

8. Do you want the scanner to be portable?

9. Are you scanning for pristine archival work?

10. Do you have operators that are capable of operating a complex optical/lighting system?

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Microfilm/fiche Scanning

1. Are you doing volume production scanning or are you doing on demand scanning?

2. Will a trained operator be using the scanner or will it be open to the public?

3. Do you want to process the images as they are scanned or will you post process them using other tools later?

4. Are you scanning for archival work or is this for simple monochrome retrieval?

5. Do you want the scanner to be portable?

6. Do you have the infrastructure in place to manage a complete production system?

Cost:

This is a complex topic. On one hand, you need a scanner to do the work required. On the other hand, you may have budget/funding constraints. Therefore, I see a two step approach to evaluating the cost of a system. The first is focusing in on the type and volume of work you are going to do. The second is the capability of the system. Common to both is the reliability, training and support offered by the vendor.

Again we have different questions depending on whether you are scanning books or microfilm.

Common Question

1. What is the equipment's warranty period?

2. What is the cost of an extended warranty?

3. Is support onsite or telephonic? Remember you are paying a premium for on-site support.

4. Does the system being purchased need a PC and/or monitor? Or is it included?

5. Is freight included in the quote or is it billed later? Note: A lot of the equipment is made overseas so freight can be high.

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6. Is the entry level scanner's capability being exaggerated so that it fits your budget? Should you practically be looking at the next model up to meet your goals even if it does cost more and may not be in your current budget?

7. If the price seems too good to be true then there is a reason. Is this the end of a model's production life? Are the last ones being liquidated? Will it be replaced with an improved version? Should you wait?

8. Is the model a new model with no proven track record? Should you let an experienced user work the kinks out of the system before you purchase it?

9. What happens if the scanner is delivered and it is DOA?

10. Is the scanner a true optical resolution scanner or does it scale up or down to achieve the requested resolution?

11. What is the reputation of the manufacturer?

12. What is the re-sale value of your used equipment?

13. Should you consider used equipment?

Book Scanners

1. Does the scanner have a book cradle?

2. Is it mechanical or electric?

3. Does the system have a glass? Can you add it later?

4. How does the color scanner scan grayscale? Does the scanner do grayscale at a native level or does it generate the grayscale from a color scan?

5. Does the system have operator exchangeable cameras for higher (or lower) resolutions, upgrades, and easier repair?

Microfilm/fiche Scanners

1. Does the film scanner scan both 16mm and 35mm film?

2. What reduction ratios can be handled and are they handled with true optics?

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3. Does the fiche scanner scan mixed mode, 16mm & 35mm, fiche?
4. Can the film scanner handle 1000ft reels?
5. How fast is the scanner's rewind speed?
6. How long does it take to setup?
7. What level of training is required to operate the scanner?
8. What is the cycle time when scanning jacket fiche? Cycle time is the time from the start of one scan to the start of the next scan.
9. How does the scanner handle 96frame COM fiche? How does it handle 297 frame COM fiche?
10. How does it handle the different resolutions & reduction ratios?
11. Is the scanner a true optical resolution scanner?

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Any purchase is a compromise of quality, performance, cost and functionality. What compromise are you prepared to or need to take for the project that you are thinking of taking on?

Here are my suggestions:

- Verify the information given in the advertising literature or provided by the salesperson.
- Check all the numbers in a real world setting like at trade show or at another known installation.
- Sit down at the scanner and use it like you would, if you had purchased it.
- Be wary of statements like, “the scanner was damaged in shipment” or “I am not qualified to demonstrate the system” if the performance is not as advertised.
- Ask for multiple references and call them all. Better still try and find a user with the scanner that was not a reference, since a company is not likely to give out the name of a site that had problems.
- Ask the reference site probing questions to explore and compare how you are planning to use the scanner.
- Ask the references about the scanner’s reliability, vendor’s responsiveness and the post sales support.
- Ask the salesperson for samples to be done on a machine that is exactly like the one you are considering. If possible, be present when the samples are done. Try to do them at an onsite demo or at a trade show and take the images away with you.
- **For a book scanner**
  - Ask for targets like the Kodak TL5003 “Old man target” to be scanned in both Color and grayscale and at different resolutions and save them as uncompressed TIFF images.

  - Ask for a scan of the GreTag color patch target at different resolutions and saved as uncompressed TIFF.

  - Scan an area the full size that can be handled by the system. Scan it multiple times moving a target to each corner.

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- **For a Microfilm scanner**
  - Obtain a standard target like the Kodak Old Man Target. Have it filmed 2400 times on a silver negative and processed by a reputable company.
  - Send a 20ft segment to the scanner manufacturer and ask them to scan it at 200, 300 and 400dpi in grayscale and monochrome.
  - If possible, be present to see the scanning and then take the images away with you.
  - Scan a clear strip of 16mm film and also 35mm film and look at the exposure from one side of the film to the other.
  - If a document is 8.5x11 at 200dpi then the image should be very close to 1700 pixels x 2200 pixels. Also the ratio between the width and the height should be very close to 1.29 (2200/1700=1.294).

All this information will let you know the capabilities and limitations of the scanner.

Summary:
Scanner and image evaluation is a very, very broad topic. I have tried to stay with the core points that can be looked at by most people. There is so much more that I have not even touched on like lighting, color temperatures and optical systems. I have also not covered the image distortion and its required mathematical correction that is inherent in some scanner designs.

This outline has been produced as a source of information for you. I have tried to be as generic as possible and not slanted in any direction. I am very willing to spend time and discuss this with you to help you produce good evaluation criteria.

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Company Background:

IImage Retrieval, Inc (IIRI), was founded in 1990 by CEO and President, Derek Jenkins and has been involved in the microfilm digitizing and document scanning industry since its inception. Coming from a systems software and R+D background Derek allied his new company with the fledgling scanner manufacturer called SunRise Imaging® and participated in the development of a new microfilm scanner. Over the years SunRise® became the leader in the film scanning industry and IImage Retrieval was its largest and most experienced reseller and repair facility worldwide.

In 2002, IImage Retrieval severed ties with SunRise® and its principles formed another company called nextScan. They developed a new line of microfilm scanners and applications that set new quality and performance standards in the film scanning market.

Driven by IIRI's customer's requests, they expanded its products to include the i2s line of rare book scanners. The introduction in the US of the DigiBook™ archival scanners was heralded by the Harry Ransom Center at the UT in Austin digitizing their pristine two volume edition of the Gutenberg Bible. Since then, many other establishments have purchased scanners to digitize their special collections and archives including the Library of Congress (LC), NARA, the University of Pittsburgh and the University of Florida. The University of Florida at Gainesville has seven CopiBook systems scanning a massive collection of Caribbean newspapers. The Church of LDS also has eight CopiBooks installed at various sites across the United States.

Recently, we installed DigiBook scanners in Cairo and another Arabic country with the LC, as part of the World Digital Library project. We have also just completed installing a system in Doha, Qatar with Carnegie Mellon and the Qatar Foundation.

The i2s line of high resolution scanners were designed for the archival industry but also fill a very flexible roll scanning any large flat objects from museum displays, tapestries and pictures to maps drawing or newspapers.

Reference:

Applied Image, Inc www.AppliedImage.com Luke Hobson (585)482-0300
Image Calibration Targets
Image Science Associates, LLC Don Williams (315)573-4782
Image Quality and Color Calibration Consultant
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Edmund Optics www.edmundoptics.com
Optical equipment supplier

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