TRANSITIONING TO DIGITAL RADIOGRAPHY – WHEN DOES IT MAKE SENSE?

S.A. Mango, Aerial and Industrial Materials, Eastman Kodak Company, Rochester, USA

Abstract: The objective of this study was to identify the key issues faced by NDT organizations in their transition from analogue film radiography to digital radiography and to examine under what set of circumstances this transition makes good sense. Application examples of several customers who use flexible storage phosphor plates for computed radiography were studied, looking at how they coped with the transition and adapted to the new technology, highlighting both the successes and frustrations.

Introduction: Early History of Radiography. The use of penetrating radiation in radiography dates back to December 1895 when the German scientist Wilhelm Roentgen discovered X-rays while experimenting with high-voltage electricity in vacuum tubes. Within two months after Roentgen's announcement, hospitals throughout the world were using X-ray pictures to aid in surgery. It was not long before the same technology was applied in nondestructive examinations (NDE) in the industrial sector. Within a few years, the discovery that uranium ore and radium also emitted penetrating radiation gave birth to gamma radiography, although it would be a few decades before its use in industry became practical. Industrial radiography grew tremendously during World War II, as part of the US Navy's shipbuilding program, and was boosted further in 1946 with the availability of man-made gamma sources.

Modern Computed Radiography. The roots of modern CR can be traced to 1975, when George Luckey developed the flexible storage phosphor imaging plate at Eastman Kodak Company. In that same year, Kodak patented the first scanned storage phosphor system, giving birth to modern computed radiography. It was not until 1983 that the first CR system using storage phosphor technology was commercialised. Acceptance of these systems has grown steadily, first among the medical community in the late 1980s, and now in the industrial community.

New technology can be a wonderful thing. It can make life easier, provide improved productivity, and increased cost savings; and it can keep or make an organization competitive, among other things. The transition from film to digital radiography, however, is not always smooth – it can be fraught with pitfalls and obstacles for the unprepared. Nor is digital the best choice in every case. The size of the operation is a determining factor, but there may be other factors that come into play in making a transition successful. While many NDE organizations express a desire to transition to digital radiography, and many already have, their reasons are quite varied, as are their individual experiences. A variety of NDE professionals representing a cross section of the industry were asked why they made the transition, what their expectations and experiences were, and what issues they faced. Their experiences and insights are, indeed, food for thought and represent some valuable lessons for those yet to make the transition.

Results: The results show a successful transition depends upon a variety of issues ranging from regulatory to image quality to operational workflow and system flexibility. In some cases, these issues present significant barriers and make the transition, if at all, a difficult challenge. However, when it does makes sense to do so, the transition to digital radiography pays dividends in productivity, cost, and a big improvement in managing the images and information in the digital workspace. Those that have made the transition have learned, for the most part, that whatever fears or scepticism they may have had was unfounded. A number of issues were highlighted, none too surprising, and none too overwhelming.

Discussion: It is noteworthy that the overwhelming majority of NDE organizations that have gone digital are quite pleased with the outcome. First, we will define the scope of digital and computed radiography; next, we will take a closer look at some of the key drivers, expectations, and issues that make a transition successful or not.

What is Digital Radiography? Digital radiography encompasses a number of techniques in which a radiograph is created, not on conventional silver halide film, but with the use of another medium or device that allows the radiograph to be represented as an array of discrete digital intensity values, or pixels. For the purpose of this study, the digital applications examined were primarily computed radiography – employing storage phosphor imaging plates, and to a lesser extent, direct digital radiography – employing digital detector arrays, also known as flat panels. Radioscopy was not considered in the context of this study; while such systems produce a real-time electronic image, they generally do not provide for image post-processing and storage, hence, their applications are quite different from film radiography.

What is Computed Radiography? Computed radiography (CR) is a technique that captures a radiographic image in storage phosphors for later readout and display. Unlike "prompt-emitting" phosphors used in conventional phosphor-intensifying screens, these storage phosphors retain the latent image, which remains stable for a period of time before it decays to a level where image quality will be adversely affected. This period can range from minutes to days, depending on the screen phosphor material. During this time, the image can be read out with a scanning system, which, through the application of appropriate software, digitally reconstructs the radiographic image.

The image is read out by scanning it with a red or near-infrared light to stimulate the phosphor, causing it to release its stored energy in the form of visible light. This phenomenon is known as photostimulable luminescence. Like conventional intensifying screens, the intensity of this stimulated luminescence is directly proportional to the number of X-ray photons absorbed by the storage phosphor.

A key consideration in the use of flexible storage phosphor plates and CR systems is that any exposure source that can be used with conventional X-ray films can also be used with this filmless technology. More importantly, the flexible storage phosphor imaging plates can be directly substituted for film. They can be used in the same film holders and cassettes as those used for film and can be used in applications requiring a flexible medium, such as bending them around a circumferential specimen. This compatibility with existing sources and cassettes makes a transition from traditional film radiography to CR a fairly uncomplicated and inexpensive proposition.

Cost Savings. The potential for cost savings was a recurring theme among those asked about their expectations with transitioning to digital radiography. Analogue film users, of course, must keep buying consumables – film and chemicals. The higher the volume, the greater the expense. There are also film processors to maintain, and they generally take up more floor space and require more elaborate facilities (plumbing, ventilation, chemical collection, and treatment/disposal, etc.), which costs money. Furthermore, there are environmental and regulatory considerations related to effluent discharge, along with inspections, and sometimes, monetary fines.

Of course there is an initial investment required for the transition to digital – a CR reader will likely cost more than a film processor, but on the other hand, processors do not last forever and would have to be replaced periodically, so some of the expense of a CR reader would occur anyway. Did you just purchased several new processors last year? Oops! Obviously, the decision to go digital, along with an analysis of the pros and cons, should be made before such a major purchase, not after.

The greatest cost savings potential, by far, is the elimination of film and chemicals. Again, there is a tradeoff because a single CR imaging plate (IP) can cost a hundred times more than a sheet of film. The good news, however, is that the storage phosphor plate is erased after each use, allowing it to be reused for repeat exposures. The lifetime of a storage phosphor imaging plate varies as a function of environment, cleanliness, and handling; however, with proper care, a lifetime of thousands of cycles is easily attainable. In reality, the imaging plates will sustain physical handling damage in the normal use cycle and can be considered a consumable but only after paying for themselves many times over in cost savings. Digital detector arrays used in direct digital radiography are even more expensive, but they also last longer than storage phosphor IP.

In any event, the case for transitioning to digital, from a cost savings perspective, is an easy one. It is a fairly simple determination, taking into account the current and future film volume and associated costs and trading that for the expense of a digital system. There are a couple of pitfalls, however. In today's changing business environment it can be a challenge to forecast future production volume. One high-volume film user underestimated an impending decline in production. After calculating a reasonably favourable return on investment (ROI) and taking the plunge to digital, business declined, and years later, he is still waiting for his ROI. Another user reported that they were reluctant to make the transition 100%, so they retained their film radiography capability. Without the complete elimination of the expense for the operation of the processor(s) and purchases of film and chemical consumables, whatever savings they realized was not quite enough to pay for the transition to digital, and it became an incremental expense rather than a savings.

Workflow and Productivity. It is a given that digital imaging can save time over conventional silver halide imaging. Many of the NDE organizations that have transitioned to digital now boast much higher productivity. Consider a case in which a film radiography department performing first-article inspection exposes films, processes them, reviews the images in batch mode, writes a report, and sends it to production. This takes about 18 minutes for each evaluation cycle. Compare this to their post-transition scenario, in which it takes only one minute to expose, one minute to process, and they are evaluating the image two minutes after taking the shot. The 18-minute cycle time has been reduced to about three minutes. They do this 20 times a day; saving 15 minutes each cycle, and the savings are substantial. Not as obvious but still a real savings, is the labour and burden they now do not have to pay to someone for waiting for film to exit the processor. Now, some workers can take this the wrong way – they equate productivity gains with fewer headcount and the loss of their jobs. In reality, that is not the case. Most, if not all NDE organizations put the extra headcount to work on other tasks, boosting their productivity, and essentially, doing more for less. Furthermore, these organizations no longer need to hire or borrow extra personnel for periods of heavy workloads – they, in fact, have a more flexible workforce.

Another way of looking at productivity is the dramatic reduction in the safety exclusion zone made possible by the storage phosphor IPs used in computed radiography. The high sensitivity of IPs allows exposure time reductions up to 90%, and their increased latitude makes possible the examination of complicated specimens of varying thicknesses with fewer shots, compared to film. Shorter and fewer shots translates to lower dose, which translates to a much tighter 2 mR exclusion zone around a work area. For example, one NDE organization reported a reduction in exclusion zone for a typical examination from 100 feet for film to 25 feet for CR. In a petrochemical plant, this means less down time; and in a nuclear plant, there is less need to shut down the floors above and below the work area. Instead, the exclusion zone is confined to a much smaller area on one floor. This translates to increased productivity when the workers outside the smaller exclusion zone can still go about their business.

Performance and Image Quality. While improved performance and image quality is not necessarily an expectation or key driver in the transition to digital, it is an area of concern. The expectations of NDE managers who were involved in transitions from film to digital was that the performance and quality level of their new digital systems would approach that of film but not necessarily be superior. For the most part, these expectations were fully met, with some users actually reporting improved performance of their CR systems over their previous film techniques. Still, there are purists who profess that it will be a long time, if ever, before digital techniques can completely replace film because a discrete pixel simply cannot compete with a continuous-tone film. Well, yes and no – where high-speed films are concerned there is a tradeoff in resolution; and often, such applications can be accomplished with the even faster storage phosphor IPs, at an image quality level equal to or better than film. In some cases, the digital systems are considered an alternative to film, complementing film systems when appropriate. This can be a good strategy, but as mentioned earlier, the highest potential for cost savings cannot be realized when the transition is less than 100%.

Interestingly, some users do not want improved quality in a new system, digital or otherwise. There is already some apprehension among NDE technicians that the appearance of a digital image could be different than film; however, even more unsettling is the potential disruption if the image is better or of higher quality. Seeing something new or different in an evaluation could create uncertainty in interpreting the results and could lead to additional effort and expenditures. One organization pointed out a worst-case scenario in which they build a very large and complicated part and maintain a two-year inventory for their prime customer. If a new, improved digital NDE system suddenly allows them to detect indications previously undetectable, it would "indict" the entire inventory, forcing them to go back and re-inspect it all. So their position is that they "cannot accept worse but do not want it any better."

Regulatory Issues. Regulations, codes, and standards have always been an integral part of the NDE industry. While a good portion of the industry need not be concerned with anything other than in-house approved techniques, alternatively, there are strict specifications by the cognizant engineering organizations (CEO) requiring a particular film class or technique. Even more formal standards (ASME, EN, ASTM) and codes (NRC) either favor the use of traditional film radiography or specifically disallow digital techniques. This aspect is cited by many as the reason for "proceeding cautiously" into the digital world, as these formal codes and standards often take years to change or replace with digital versions.

But in the real world, rules are meant to be broken. For example, formal code approval can take years by the NRC, but the industry has adopted a shorter route. By developing a "code case", the NRC will allow a digital technique for a limited number of years, subject to renewal and finally adoption or cancellation. In the meantime, the technique is allowed for up to ten years, so the transition to digital has begun, despite the regulatory bureaucracy. Besides, formal standards addressing the classification and qualification of digital radiography systems are already drafted and even in the balloting process, so removal of this impediment is imminent, and many view this as an "opening of the floodgates" after which digital radiography will become mainstream.

Management of Information and Images. The speed and efficiency in managing electronic information is a marvel of the modern age, and not surprisingly, this is a common expectation in the transition to digital. Original data are captured are stored in proprietary formats to maintain data integrity, but standardized formats (JPEG, for example) allow for swift and widespread dissemination of those data and images to a wide audience of designers, technical colleagues, managers, and other stakeholders, with no geographic boundaries. Users are reporting a marked reduction in turnaround time, shorter design cycles, quicker decision making, and elimination of travel otherwise required to move film images around. Do so many people really need to review the images and make decisions? Perhaps not – one user admitted that with so many people viewing the results, some of them suddenly became "experts", second-guessing the radiographer's decision, possibly making the wrong decision! It is a digital world – we can easily drop those experts from the electronic distribution list.

Further efficiency is evident in the storage and retrieval of digital radiographs. Retrieval of a film radiograph typically involves stacking and unstacking boxes, pulling an envelope, and sorting through multiple sheets of film. By contrast, a catalogue of digital radiographs on a DVD can be accessed more quickly and displayed on a monitor for selection of image(s) and subsequent evaluation or dissemination. An average timesaving is five to ten minutes per image (add one to two days for an off-site archive), along with a tremendous reduction in required floor space. Again, time is money, and so is real estate.

Scepticism and Fear of the Unknown. Perhaps the most intangible aspect of the transition to digital radiography, and one that is difficult to assess, is the inherent scepticism and fear of the unknown. Change is sometimes uncomfortable, and this transition represents a big change. True, in the very early days of digital radiography there was some basis for such fear. The early adopters jumped in with high hopes but did not always get what they bargained for. Early IPs were more difficult to erase, often requiring two passes, negating any productivity gain. There was sometimes a disconnect between the sales promise and engineering reality. What were essentially "R&D units" lacked the modular architecture to allow upgrades to newer technology, resulting in very costly upgrades. The viewer did not match the image format, requiring strange orientations or split images. Computers were incompatible with the task, often overloading and crashing, resulting in costly downtime. One early adopter hoping for a five year ROI was still hoping after ten years!

Internal resistance is not the only barrier. Even after demonstrating a clear case to make the transition, with all the due diligence of financial and operational analyses, demonstrations, testing, and qualifications, there sometimes lies a final challenge to convince the external customer or CEO to accept the change. One particular NDE organization with such a sceptical customer had little difficulty in overcoming this obstacle. They simply adapted existing standards for "Controlling the Quality of Industrial Radiographic Film Processing" to their CR operation in every way possible. Their customer, who had already decided that there was "no way a digital system can come in and replace film," arrived on site to view a comparison. What they saw were complete and convincing records of system performance, stability, and sensitivity, with the image quality indicators showing, in most cases, that the new CR system was outperforming the previous film system.

Today there is little to fear but fear itself. Modern CR systems have addressed all of the above shortcomings and much more. Today's radiographers are much better rounded, possessing a mix of interpreter and computer skills, and they make short work of the learning curve. Although some still are sceptical and initially will not trust "on-board tools", this scepticism is very short lived with the realization that modern digital radiography is not the beast it once was, and it actually provides a multitude of benefits in terms of cost, productivity, workflow, efficiency, and better decision making.

Conclusions: The transition from film to digital radiography is gaining momentum, driven by expectations of cost savings and improved productivity. Clearly it is not for everyone, as the relatively small NDE operation may lack sufficient justification to make the initial expense, or it may require a much quicker ROI. But where it does make sense, the benefits are many. Those who have made the transition, and have successfully sidestepped some of the pitfalls, are already ahead of the curve and poised for success well into the future.

Webster's dictionary defines transition as "a passing from one condition, form, stage, place, etc., to another." Throughout this paper, the transition is treated as a decision – a choice to be made by the NDE organization. Today this is very true – it is a choice, based on careful consideration, financial analysis, and individual circumstances. In the long run, however, it will ultimately be viewed not so much as a choice, but rather, the inevitable evolution of the NDE industry.

References: The following organizations shared their experiences and insights during the preparation of this paper. Their cooperation and assistance is greatly appreciated.

1. ATK Thiokol, Brigham City, UT
2. AutoLiv Automotive Safety Products, Ogden UT
3. Boeing Helicopter, Mesa, AZ
4. Parker Aerospace, Kirtland, OH
5. Tennessee Valley Authority, Chattanooga, TN