CarestreamNDT

WHITE PAPER

# Non-Destructive Evaluation using Imaging Plates for Field Radiography Applications

Practical advice to improve Computed Radiography Image Quality While on the Road.

# INTRODUCTION

At Carestream NDT we want to share not only our technological developments and product portfolio, but also the knowledge and practical experience that our staff obtains by working shoulder-to-shoulder with customers like you. We aim to share this knowledge and experience in a straightforward fashion so that our readers may find practical applications in their everyday activities.

**This series is directed but not limited to NDE professionals in the following industries:** Oil & Gas, Nuclear, Construction, Foundry and Castings, Energy Generation, Aerospace, Transportation, Automotive, Military and Defense, Agriculture, Art Restoration & Museum Artifacts, and NDE Services Companies.

CarestreamNDT

150 Verona Street
Rochester, NY 14608

www.carestream.com

Film radiography has been employed for non-destructive evaluation of welds on pipelines for over eight decades. Typically, small crews of radiographers operate out of the back of a truck, often in remote and extreme conditions. Pipeline environmental conditions can be extreme for temperature, moisture, and cleanliness. The radiography crew follows the welders as the pipeline is assembled. Field radiography utilizing film has remained viable because it follows well-established procedures and meets applicable code requirements for a very diverse set of industries and operating conditions. It is easy to perform, and people are comfortable doing it. There is an extensive history of results for specific methods and techniques. Intensification from front and backside lead screens inside flexible cassettes enables a large degree of amplification at high energy, which allows for good image quality at short exposure times.

Nevertheless, at present time we live in a world that has been profoundly transformed by digital technologies, and where many people are easily sharing digital images every day as part of professional and personal interactions. For nearly two decades Imaging Plates (IPs) have been replacing film for portable outdoor Computed radiography (CR) applications.; nevertheless, CR technology adoption has been contingent upon achieving acceptable image quality to truly become a suitable replacement for film and also getting enough IPs use cycles in order to obtain an adequate return on investment (ROI).

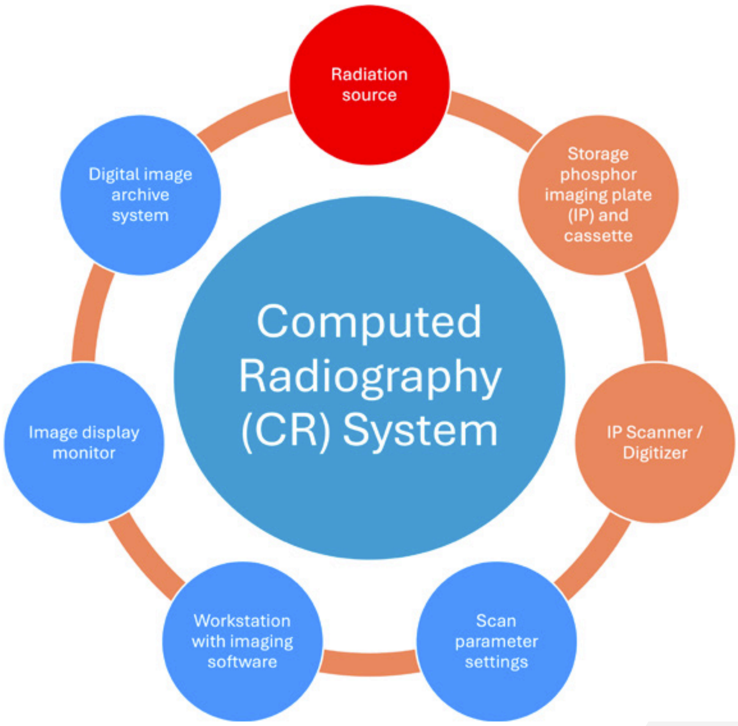


**Figure 1:** Elements of Hardware and Software that constitute a Computed Radiography System, as described in ASTM E2033-17 [1].

Figure 1 describes in a single image the hardware and software that constitute a computed radiography system. Technological advancements in microelectronics and software engineering have allowed not only to fuse in a single device four of those elements (indicated in color blue) but to develop lightweight portable digital systems, such as Carestream's INDUSTREX HPX-PRO,  designed to deploy and produce high-quality images utilizing a single-pass scan/erase protocol in rugged NDT environments.

Achievable image quality is dependent upon shot conditions, imaging plate type, reader settings, and scatter control measures. Likewise, the number of achievable use cycles is dependent upon the IPs design for durability, the operating environment of the IPs and the user's adequate care measures for them. This White Paper reviews the basic principles of storage phosphor imaging plates including a comparison between film and computed radiography imaging plate technology. Actionable and practical usage criteria and guidelines for optimum image quality and maximized overall use cycles for various IPs types are shared with our readers.

## The ever-increasing viability of using imaging plates at field inspection environments.

CR is a mature technology that was first introduced for medical imaging nearly 40 years ago but which at present time shall be viewed as a viable replacement technology for film in an increasing number of industrial applications where IPs can be utilized inside of flexible or rigid cassettes. Technology advancements in the portability of CR readers and improvements in imaging plate overcoat technology have made it viable to expand the established fixed CR imaging laboratory setting to an expanding set of viable field imaging applications, such as pipeline radiography, that were not considered feasible in the past. Digital images obtained from IPs processed through a DICONDE-compliant software can effortlessly be shared with remote offices for image analysis and interpretation;  also, if required, DICONDE-compliant digital images are suitable to be integrated into digitalized imaging workflows.

Because CR uses similar flexible cassettes, the imaging process feels familiar to those who have previous experience with film-screen systems and provides more flexibility than many DR systems. The main drawback perceived for CR compared with DR is the need for an IPs scanning process and therefore a perceived delayed display of the image after capture.

## The fundamentals of imaging plate construction and usage

Although it is not a prerequisite reading, this white paper builds on the principles of CR and IPs technologies discussed in our previous white paper "Imaging Plate Use for Radiographic Nondestructive Evaluation - Best practices directed to achieve the best quality image possible derived from our hands-on practical experience".

Figure 2 is a cross-sectional comparison of a typical industrial film versus two specific industrial imaging plate types at the same magnification. Film is duplitized, which means that the photosensitive imaging layer is coated on both sides of the plastic support. As studied, film imaging layers were approximately 8 μm thick, with a 1 μm protective overcoat. Imaging plates were much thicker. High-resolution (HR) plates were 160 μm thick for the phosphor imaging layer with a 4 μm overcoat, and general purpose (GP) imaging plates were 290 μm thick for the phosphor imaging layer with an 11 μm overcoat.

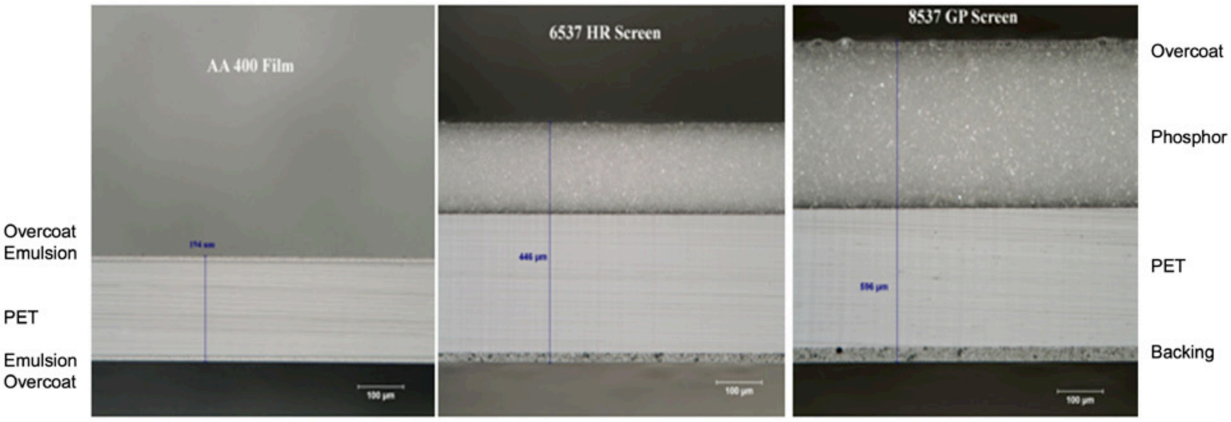


**Figure 2:** Cross Sectional Comparison of Film and Imaging Plate Technology, from White [1] [2].

Because imaging plates are thicker than film, they are more prone to exposure from scatter and therefore appropriate scatter control measures such as the use of metallic screens and the collimation of the radiation beam should be adopted.

Radiographers are advised to utilize their film techniques as a starting point for CR gamma radiography. Many gamma shots are under-exposed; therefore image quality can generally be improved by increasing the dose.

For a given radioisotope, the source energy and activity are fixed, so exposure time is the only variable that can be lengthened to increase the dose. Scatter should always be controlled for gamma radiography by utilizing front or backside leads. Weld quality images can be achieved with HR imaging plates.

| Energy Type | Radiation Source | Energy Level | Suitable Imaging Plate Type |
|---|---|---|---|
| X-Ray | Linear Accelerators | 2 – 15 MeV | GP |
| | Betatron | 2 – 10 MeV | |
| | Tubes | < 450 kVp | HR |
| | | < 80 kVp | XL |
| Gamma | Cobalt 60 | Peaks at 1.17, 1.33 MeV | GP |
| | Iridium 192 | Seven peaks between 200 and 600 keV | HR |
| | Selenium 75 | Nine peaks between 66 and 401 keV | |

**Table 1:** Imaging plate selection as a function of energy level and energy type, adapted from White [3].

Table 1 has plate recommendations as a function of energy level. The GP imaging plates should be utilized for very high energy applications, or for profile shots. The ultra-high resolution (UHR) blue plates should not be utilized for gamma radiography because of their higher noise level.

# Increasing the number of achievable use cycles on imaging plates

The durability of imaging plates has been an issue for artifact formation, and it determines the number of achievable use cycles. It has been shown that both film and imaging plates have similar physical properties; however because imaging plates are utilized for more than one use cycle, artifact formation becomes an issue over time. There are several potential sources of radiographic imaging artifacts: scratches, abrasion, dust, fingerprints, yellowing from moisture and or cleaners, and cracking.

Figure 3 provides an example of two imaging plate structures, each employing different overcoat technology. The function of the overcoat is to protect the phosphor imaging layer from damage that can potentially cause radiographic imaging artifacts. Imaging plate manufacturers utilize either chemical or laminate overcoat technology. The chemical overcoat technology is a polymer or polymer blend that may or may not be radiation hardened to promote cross linking of the polymer. The laminate overcoat technology is a thin sheet of polyethylene terephthalate (PET) that is adhered to the phosphor layer with an adhesive. Figure 3 provides a cross sectional comparison of the two overcoat technologies.

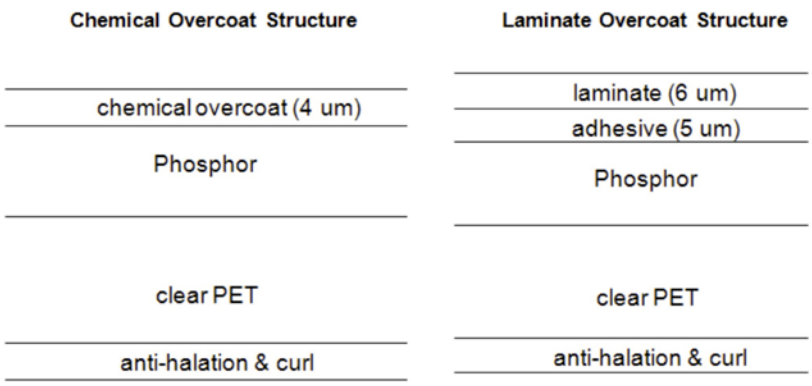


**Figure 3:** Chemical Overcoat versus Laminate Overcoat Plate Structure, from White [2] [3].

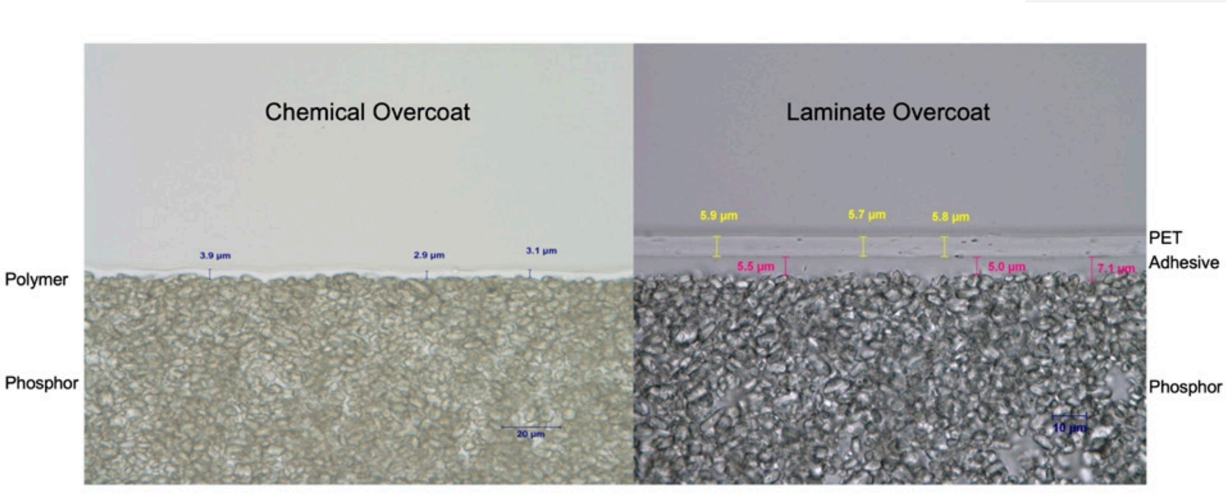


**Figure 4:** Cross-Sectional Comparison of Chemical Overcoat versus Laminate Overcoat, from White [7] [8].

Laminated overcoat imaging plates have been developed specifically for applications that encounter rugged environmental conditions and extensive handling. The laminate overcoat (as shown in Figure 4) produces fewer radiographic artifacts as a function of time, which extends the achievable number of use cycles. The advantages of the laminate overcoat imaging plate over the chemical overcoat imaging plate include improved abrasion resistance, ability to clean, chemical and moisture resistance, and cracking resistance.

There are usage criteria and guidelines for maximizing field radiography imaging plate lifetime (See actionable items at the end of this white paper). When not in use, plates should be stored flat, in dark and dry conditions, and they should be handled by the edges with cloth gloves. They should not be creased or kinked because permanent and irreversible cracks can be created. Extreme humidity or wet conditions should be avoided because this can shorten lifetime. Refrain from surface temperatures greater than 212°F (100°C), and plates should only be used in the temperature range of –22°F (–30°C) to 120°F (49°C). Clean only with a manufacturer-recommended solution and a lint-free cloth.

Figure 5 provides radiographs of a 0.37 inch steel weld coupon for four different imaging plate types. The plates were placed inside a flexible vinyl cassette with a 0.010″ backside lead and a 0.005″ backside copper. An iridium plus radioisotope source was used to expose the imaging plates. The source-to-detector distance was 12″, and the plates were exposed for 1 minute 47 seconds for an exposure factor of 7R, read at a 100 µm pixel size. The best weld quality images were obtained with the HR and HR laminate imaging plates.

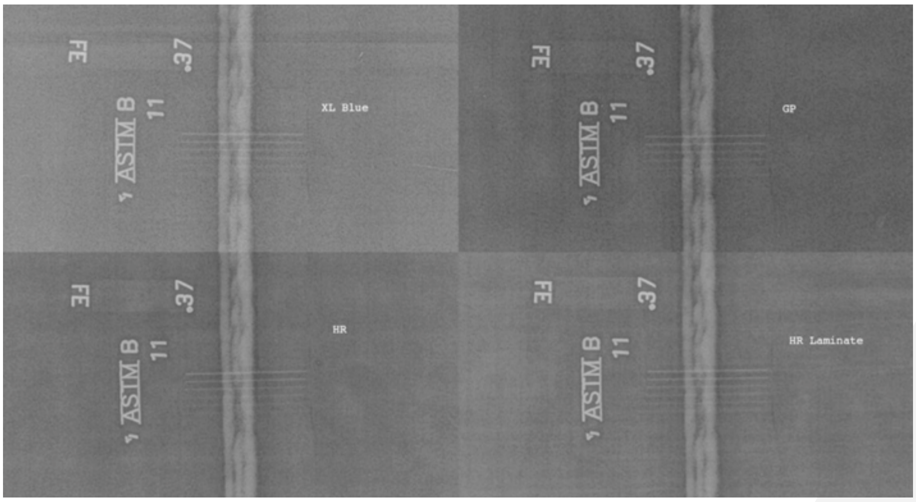


**Figure 5:** Weld Coupon Radiographs with Iridium Exposure, from White [2] [3].

Figure 6 provides radiographs of a 4″ schedule 80 pipe with 0.337″ (8.6 mm) walls for four different imaging plate types. The plates were placed inside a flexible vinyl cassette with a 0.010″ backside lead and a 0.005″ backside copper. An iridium plus radioisotope source was used to expose the imaging plates. A double wall contact shot was executed, with the plates exposed 42 seconds for an exposure factor of 7R, read at a 50 µm pixel size. The essential wire Number 5 could be detected with HR, HR laminate, and the GP imaging plates. The best images were with the HR and HR laminate plates.

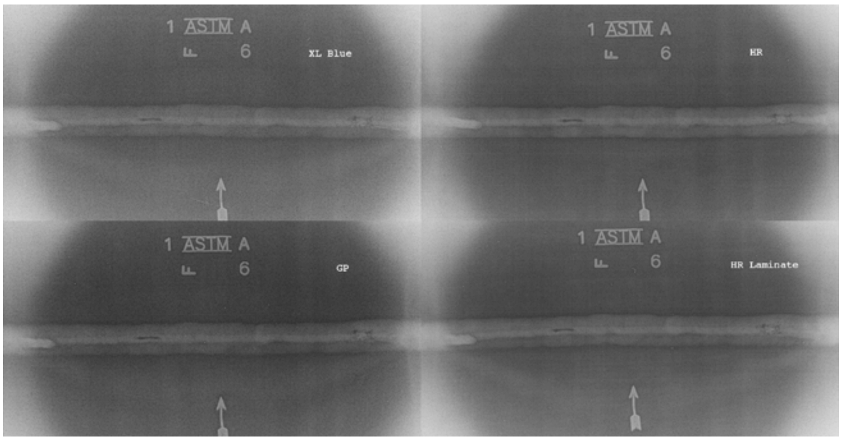


**Figure 6:** Four Inch Schedule 80 Pipe Weld Radiograph with Iridium Exposure, from White [2] [3].

Figure 7 provides a comparison of the fast scan interpolated basic spatial resolution (iSRb) utilizing a duplex wire gauge for four different imaging plate types.

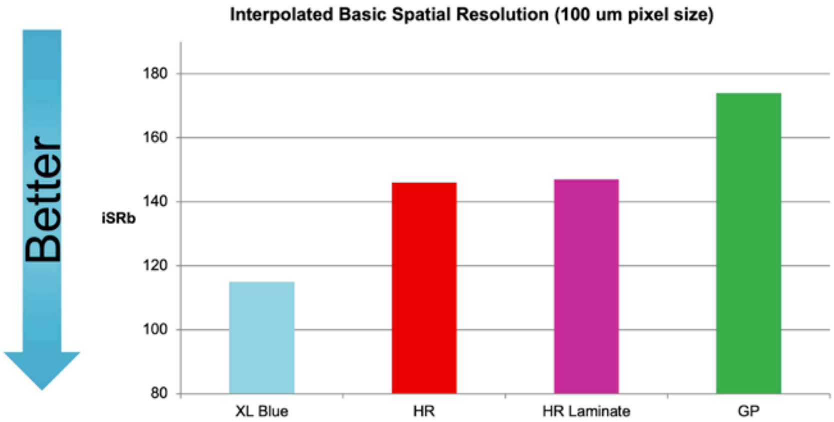


**Figure 7:** Interpolated Basic Spatial Resolution, from White [2] [3].

The plates were placed inside a flexible vinyl cassette with a 0.010" backside lead and a 0.005" backside copper. An iridium plus radioisotope source was used to expose the imaging plates.

The source-to-detector distance was 12 inches, and the plates were exposed for 1 minute for an exposure factor of 3.5R, read at a 100 µm pixel size. The XL Blue plate yielded the best sharpness, followed by the HR and HR laminate plate, and then the GP plate.

## Actionable approach - Guideline to integrate IPs into your field pipeline imaging process and to achieve optimum CR image quality.

Brian White resumes his perspective on the viability of CR imaging processes outside a fixed laboratory setting an into imaging field applications: "Digital imaging is ready for outdoor pipeline radiography. Advancements in reader portability and laminated plate technology enable CR as a replacement for film. Laminate overcoat imaging plates have equivalent image quality relative to legacy imaging plates, and they can achieve a higher number of use cycles as a result of reduced image artifact formation,making CR both accessible and profitable for pipeline firld applications."

Once you have made advancements in the decision to integrate CR technologies to your field imaging process often it is difficult to identify a support element that systematically identifies the fundamental factors that have a significant impact in CR image quality and that also provides useful information about their control. ASTM E2023 "Standard Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)" may be a useful starting point which provides a series of requirements that are intended to control the quality of computed radiographic examinations.

This standard practice may be the starting point to establish an adequate field pipeline CR written procedure that addresses the specific requirements and tests that the radiographer shall face in CR field inspection processes.

Additionally, Table 02 compiles key elements that can have a positive impact in your everyday CR field imaging practices using IPs:

| | |
|---|---|
| **Summary of the key ideas in this White Paper** | Remember that sharpness is not the best indicator of image quality; IQ is a function of brightness, sharpness, and noise; all three work together. |
| | Imaging plate selection, dose level, and scatter control determine the radiographic image quality for computed radiography. |
| | Plate handling and use determine the artifact level in the radiograph as a function of time; this results in how many use cycles can be achieved. |
| | Follow best practice guidelines above to maximize the overall image quality and the number of imaging plate use cycles. |
| **General guidelines to handle IPs** | Good radiographs are images that are free from artifacts! |
| | Imaging plates can be utilized for many cycles. |
| | Anything that blocks light at the surface of the IP will manifest as white spot artifacts in the image. |
| | An imaging plate is no longer usable when an artifact can potentially hide an indication in the radiography's zone of interest. |
| | The number of use cycles for the IP is determined by the artifact level and the tolerance for artifacts. |
| **Guidelines to achieve optimum CR image quality** | The CR radiographic technique can closely match the film technique. |
| | The best way to improve image quality is by increasing dose. |
| | Scatter must be controlled to achieve the best possible image. |
| | The pixel intensity must be related to an image quality level. |
| | Select the proper imaging plate for your application. |
| **Guidelines to prevent artifacts in Computed Radiography Imaging Processes** | Store IP in dark and dry conditions; avoid extreme humidity or wet conditions. |
| | Handle by the edges and use gloves to avoid fingerprints; use manufacturer-recommended cleaner with a lint-free cloth. |
| | Do not crease, kink, or drag across surfaces. |
| | Avoid surface temperatures > 212ºF (100ºC) |
| | Temperature range for use; -22ºF (-30ºC) to 120º F (49ºC) |
| | Completely open flexible cassettes before insertion or removal of a plate when front side leads are used. |

**Table 2:** Best practices in Computed Radiography Imaging Processes, adapted from White [4]and [5].

For readers interested in exploring how computed radiography (CR) can be integrated into your pipeline and other field inspection processes:

- https://www.carestream.com/en/us/nondestructive-testing-ndt-solutions

Here are some supplementary information resources and white papers from Carestream NDT's products and services portfolio:

## Products

- HPX-PRO Portable Digital System
- INDUSTREX HPX-1 Plus Digital System
- INDUSTREX Flex GP, HR and XL Blue Digital Imaging Plates
- HPX-1 Diagnostic Tool & HPX-1 Digital Plate Carrier
- INDUSTREX Digital Viewing Software
- Advanced Industrial Radiographic Training Academy
- NDT Archive Solution
- Virtual NDT Showcase
- Resource Center

## Services - Training and Supplementary Resources:

- Digital Detector Array Radiography - 40 Hour Online Course
- Digital Imaging - 40 Hour Classroom Training

References:

1. ASTM (2017), ASTM E2033-17, "Standard Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)" ASTM International.

2. White, Brian S. "Nondestructive Evaluation Utilizing Imaging Plates For Field Radiography Applications." In Digital Imaging 2016, pp. 64-70. 2016..

3. White, Brian S. "Imaging Plate Use for Radiographic Nondestructive Evaluation." In ASNT Annual Conference 2015, pp. 137-142. 2015.

carestream.com/ndt

**CARESTREAM NDT AND YOU.
WE'RE BETTER TOGETHER.**