

**THE 4K MONITOR AS ZOOM STEREOSCOPE**  
A NEW PROCESS FOR AERIAL PHOTO INTERPRETERS THAT TREATS DIGITAL PHOTOGRAPHY  
LIKE IT WAS ANALOG.

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## **ABSTRACT**

As the photographic industry has been undergoing the transition from chemical/analog reproduction to digital-only reproduction, photo interpretation has become increasingly difficult to perform. Traditional zoom stereoscopes are quickly becoming an untenable solution due to a lack of available film-based reproductions. Achieving comparable results using stereoscopes with paper prints can require purchasing multiple enlargements or consuming more time by printing self-made enlargements. Using digital imagery directly has been impossible without costly and/or cumbersome equipment. All this has changed with the advent of relatively cost-effective 4K monitors and a new patent-pending process for manipulating digital imagery combining a conventional lens stereoscope, a 4K monitor, and image viewing software. It allows stereoscopic photo interpretation of historical aerial photography to be performed purely digitally. This new digital process closely matches the traditional zoom stereoscope method.

## **INTRODUCTION**

The use of digital technologies in the field of civilian Aerial Photo Interpretation (API) has been growing steadily for at least 25 years. At the core of this effort has been the Raster GIS, or Geographical Information System (e. g., ERDAS Imagine). This has been supplemented by standard Digital Image Processing (DIP) programs, such as Adobe PhotoShop, everywhere in the world. One of the common API applications for such photographic software has been historical studies of old aerial photography. For example, the histories of polluted industrial sites are under intensive study every day in all corners of the globe. Though the API efforts cannot answer all questions about the contamination of soil, water, or air, they can answer certain questions very confidently. This is important, for example, when investigating industrial sites which are currently coming under litigation, or have the potential for litigation in the near future.

Over the years, several companies have provided a service in which they conduct the necessary research to locate and obtain existing historical aerial photos for this kind of interpretation work. Typically, these companies create reports consisting of a series of photo enlargements—one per chosen year—of the target areas, spanning several decades. This has the benefit of quickly producing an overall view of the changes for a particular site through the passage of time. These reports can often be delivered digitally within 48 hours or less and can efficiently satisfy "Phase I" site assessments. However, these reports have two important drawbacks when it comes to conducting further API work.

First, the scan quality is not usually adequate enough to allow zooming in for the purpose of discerning small details in the features of a given site. Second, and equally important, there is no consideration for STEREOSCOPIC viewing in such reports. The stereo view is of enormous benefit to the analysis work. For those not already familiar with the concept and its importance: stereoscopic photography is the process of capturing different angles of target landscape features by taking a series of overlapping sequential photos as the plane passes over the site. When the stereo photos are properly viewed, the brain combines these different angles, producing the illusion of a three-dimensional perspective. In this way, even if one of the overlapping photos is substandard or out of focus, the brain tends to emphasize the better photo, producing a three-dimensional view which is optimal for interpretation.

However, the stereo approach to historical research is being disrupted by a shift in the aerial photography industry. This shift is caused by the move from the original analog acquisition of photography using chemical-based photographic

film to the newer digital acquisition that uses computer-based graphic files. The shift has in turn been forced upon the aerial photography industry due to the shrinking usage of film in mainstream photography. Film-based photo labs are going away—in fact, the majority are gone already. The impact of this on the photo interpreter is that he, or she, is finding it harder and harder to easily obtain a type of duplicate film reproduction product known alternately as “diapositives” or “film positives”. A diapositive is a print made from a negative but produced on a transparent sheet of film instead of photographic paper. The decline of diapositives in the industry is a significant problem because diapositives offer the highest quality reproduction of the terrain details captured in an aerial photo. The diapositive films are placed under a Zoom Stereoscope (see Fig. 1), where they can be comfortably viewed and magnified many times. The point of this approach is that it allows stereoscopic visual re-creation of former landscapes in which relatively minute details can be confidently interpreted and reported, even with photography at a scale of 1: 25,000/1"=2083'.



**Figure 1.** The traditional method: the Bausch & Lomb Zoom Stereoscope. The laptop on the right was only being used for monoscopic comparisons, as well as writing the report and producing the report's illustrations. Under the Zoom Stereoscope are two film “chips” trimmed out of 9x9 inch diapositives, one from the left photo and one from the right photo.

## **THE DIFFICULTLY OF USING DIGITAL STEREO PHOTOGRAPHY**

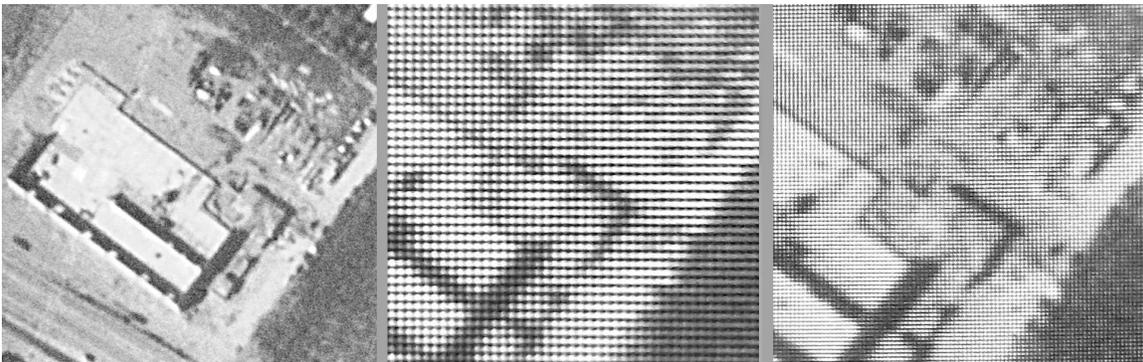
However, employing this same method by using scans of historical aerial photos viewed on a computer screen has not been easily accomplished without very expensive hardware and software systems that were designed for this purpose. Even with such systems, the photogrammetric and/or GIS setup effort greatly increases the cost of the endeavor. Thus, it has not been possible for environmental investigators to quickly and easily study stereo aerial photography acquired as digital imagery.

But just as the industry shift to digital imagery has made diapositives harder to obtain, the results of more recent innovations in the field of digital viewing technology are providing new options for using digital images. In the computer and digital entertainment industries, advancements in hardware for visual display have been moving forward rapidly. The computer gaming arena, for example, has constantly sought to create more realistic and detailed representations of virtual environments. Similarly, large-screen television sets and computer monitors have needed more pixels to present a more attractive, sharper picture. These new hardware products have appeared under various names, such as ultra-high definition TV, 4K monitor, 5K monitor, etc.

## EXPERIMENTS WITH NEW TECHNOLOGY

Our photo interpreter's attempts to apply these technologies to historical API began by experimenting with inexpensive smartphone stereoscopes, such as the Speck stereoscope and the Google "Cardboard". It was concluded, however, that the input digital image files, and the native resolution of the phone, did not permit a very satisfying or useful viewing experience.

Then something changed all this: experiments with Apple's "Retina Display" monitors on a laptop computer. Although these monitors initially seemed like an advertising and marketing ploy, they had a significant impact for photo interpretation work. The average laptop computer has a screen width of perhaps 1200 to 1800 pixels across its surface, from left to right. The new Retina Display screens boast a minimum of 2880 pixels across the screen—equaling 1.5 to 2.4 times greater resolution. Our photo interpreter's early experiments using a laptop's built-in Retina Display screen showed that scanned aerial photos could be very adequately viewed in stereo with a conventional stereoscope. It was awkward and uncomfortable, however, because of the ergonomics of trying to put a conventional lens stereoscope over a laptop screen that might, or might not, be able to be laid flat on the work table. The use of an external Retina Display monitor hooked up to the laptop solved this problem. The experiments also proved that selecting the correct monitor is not a simple matter of choosing the highest resolution available. As with the digital images themselves, the key factor is actually the size and density of the individual pixels, not just the overall quantity. This particular factor is, admittedly, somewhat subjective, but there is a definite point at which the pixel density is low enough to obstruct the clarity of the image even on 4K monitors. The external monitor used through the course of the experiments was a LG ULTRAFINE 4K 21.5" Display-CAF set to a resolution of 4096x2304 pixels. Figure 2 shows what a difference the higher pixel density makes compared to an average monitor.



**Figure 2.** The photo on the left is the target site as it appears to the naked eye on an average monitor. The middle photo shows the same site viewed on the same monitor through a 2X lens stereoscope. The photo on the right again shows the same site, only this time on a LG ULTRAFINE 21.5" 4K monitor through a 2X lens stereoscope. Note that while the middle photo appears very pixelated due to the 2X magnification, the right photo doesn't show much sign of pixelation even though it is also magnified 2 times.

The external monitor also has the advantage of freeing the photo interpreter from the need to use a specific setup, such as a laptop. Instead, any existing computer that is compatible with the external monitor can be used.

Thus, the image processing software, and the report writing software, would operate on the computer's normal monitor, and the display of the aerial photos would occur exclusively on a 21-inch Retina Display 4K monitor sitting flat on the desk with a simple lens stereoscope sitting on top of it. Figure 3 shows this configuration in use for comparing two different years of aerial coverage.

The mechanics of making this system come together comfortably took some experimentation. It did succeed, however, and a number of months-long environmental investigations have been completed almost exclusively based on this technique. An operating procedure has now been defined that is not only acceptable to use as a digital substitute for the traditional diapositive process, but relatively inexpensive with regard to the essential equipment required.



**Figure 3.** The new photo interpretation workstation: a 21" 4K Monitor using Adobe PhotoShop to display digital stereo pairs for analysis using a common 2X pocket stereoscope. The monitor is being controlled by the laptop in the upper right corner. While viewing, shifting the head from one stereoscope to the other proved more effective than trying to move the stereoscope each time.

## OPERATING PROCEDURE

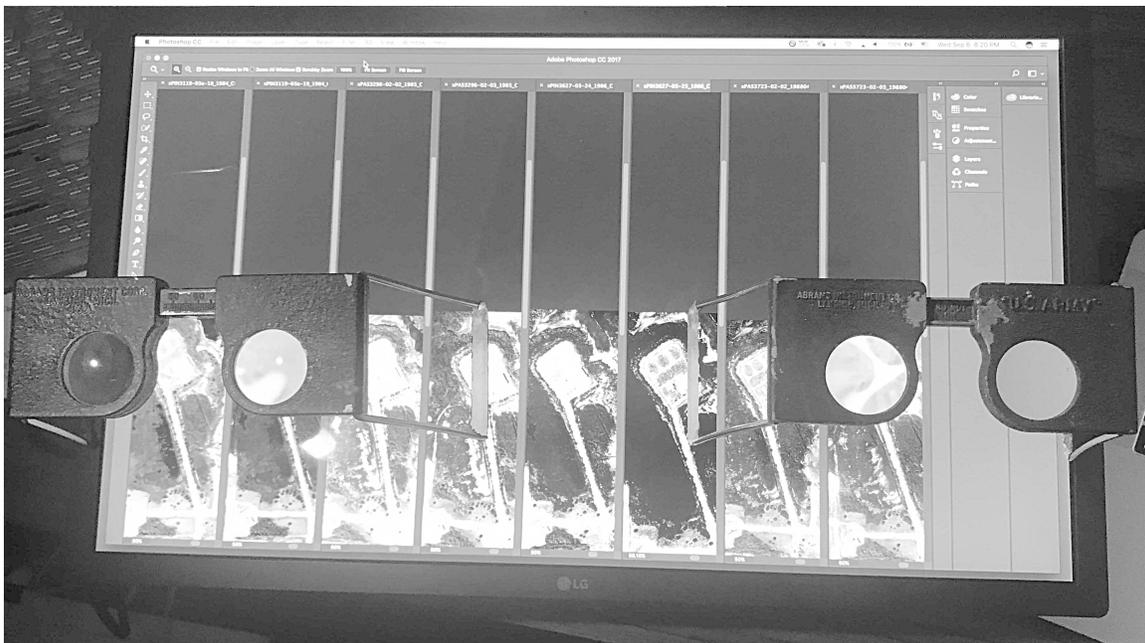
1. Obtain the highest quality, highest resolution scan images of the target area for the time periods needed.
  - Scan resolution should be at least 12 microns, but 7 microns is much better.
  - Scans should be done from the original negatives if possible.
  - Stereo pairs (or triplets) should be ordered; also, coverage from adjoining flight lines can often be beneficial.
2. Pre-process the individual frames of photography for optimal viewing.
  - Clip out the target area from each of the exposures, carefully labeling each.
  - Use DIP techniques to enhance and match the target chips.
  - If they are from the same flight line, rotate each image 90 degrees and save this version of the photo.  
(Note: Shadows pointing down-screen is best, if possible.)
3. In the DIP software, pull up two of the corresponding stereo images on the external monitor.
  - Position the photo windows correctly for stereo viewing.
  - Zoom and reposition the images until you see the left and right photos side by side.
  - Position the two photos so that corresponding images are about 55mm apart.
4. Place a 2X lens stereoscope over the external monitor and adjust until the stereo viewing is comfortable.
  - If reverse stereo is encountered, swap the positions of the 2 photos on the external monitor's screen.
  - If little or no stereo is observed, the rotation of the images may need to be changed.
  - Zoom and reposition the two photos individually, as appropriate.
5. Begin interpreting the stereo pair. All report writing is done on the computer's main screen.

## SOME WORKING GUIDELINES

Of course, the success of this approach depends on having good quality images to begin with. The importance of scan resolution was stressed above for situations in which small details are necessary to the investigation. If photos from adjoining flight lines are used, then no rotation of the images is necessary. In general, a good procedure has been to cut out the target area from a stereo pair and save those files with an “X” attached to the end of the filename, then rotate each of the two images 90 degrees and re-save the files with a “Y” attached to the filename. In this way, the Y-files can be used for standard observation along one flight line, and the X-files for observation across two flight lines. This is mentioned because it is often very helpful to have a variety of stereo views available for comparison when interpreting small details—such as processing equipment on the ground—or very subtle features, like ground stains from pollutants.

Only a lens stereoscope of 2X should be used for this procedure. Even a 4K or 5K monitor's resolution is not high enough to allow stronger stereoscopes such as either the 4X reflecting stereoscope or the typical zoom stereoscope with its minimum magnification setting of 7X. In fact, the 2X stereoscope is mainly being used only to produce the stereo effect. Magnification is now predominantly accomplished by the zoom-in feature of the DIP software.

The use of a 21 inch monitor with this 4K screen methodology also easily accommodates comparison of different years of coverage for a target site. The procedure would be to get the first year of coverage displayed as described above, then simply open the two photos from another flight year in the same way. After doing this, make the DIP re-tile the windows again. At this point you can zoom in and move the images around until you have two stereo pairs displayed side by side. These comparisons are most easily made by positioning two stereoscopes over the monitor and simply shifting your head from one to the other. In this same fashion, further stereo pairs can be opened for comparison at the same time, and very easily viewed together on a single screen. Our photo interpreter has done this for up to four years of photo coverage simultaneously on the same external monitor screen (as shown in Figure 4).



**Figure 4.** The stereo setup for comparing four different years of aerial coverage of a target. For each year of photography, there is a left photo and a right photo placed and zoomed appropriately for the specific subsection of the site under study.

## POSSIBLE FUTURE IMPROVEMENTS AND REFINEMENTS OF THE PROCESS

The authors see this procedure as merely the starting point for a more complete equivalent of the traditional zoom stereoscope. At the moment, the process, while workable, is far from automated. For instance, magnification on an actual zoom stereoscope is simpler than zooming in with standard DIP software. With the zoom stereoscope, each photo is magnified at the same time, while they must be zoomed in separately with the software. As another example, if the target

area is too large to view all at once through the lens stereoscope, the DIP software requires individually panning each photo to a new section. This often requires re-adjusting the photos to recreate the stereo effect.

In addition, the process mainly serves to transfer the stereo viewing capability to digital photography at an acceptable level of usability. Little additional functionality for the interpreter is gained through the process using un-customized, off-the-shelf software. But, with the proper software customization, the above problems should be able to be solved and new functionality added.

One of the features the authors are hopeful to add through customized software is a so-called "blink mode" that provides the ability to switch back and forth between 2 years of photography. This would allow the interpreter to dramatically see the changes in detail between the two years, since features will seem to move or disappear and re-appear with each flip back and forth. This would also remove the need to have two stereoscopes and both stereo pairs displayed on the 4k monitor at the same time. It would even make it possible to use a smaller, more portable external monitor for viewing photography in stereo, which would be a great benefit when working in the field or meeting with clients.

## **CONCLUSION**

This procedure (Patent Pending) allows the detailed interpretation of industrial scenes in good stereo from digital input materials. Though the process is a little more involved, both technologically and procedurally, than using a zoom stereoscope and diapositives, it closely approximates the same procedures and results. But, while this new process is very usable, the level of zooming, and the quality of the stereo image, is still not as effective as diapositives made from the original negatives. Since actual film reproductions are still available, albeit on an increasingly limited basis, the well-equipped Photo Interpreter must be able to use either method to compare images in stereo, side by side, from different media.

With diapositives becoming increasingly scarce and digital cameras gradually being adopted for taking aerial photography, this new 4K viewing process will become increasingly important in the decade ahead. But along with digital imagery's advantages, it also has drawbacks, some of which have already been stated above. Others include the fact that the increased complexity of the necessary equipment leads to less reliability/more downtime; another is the inherent ephemeral nature of digital storage; and the limitations of existing technology to completely capture all the information existing in the historical aerial photography archive. These problems, too involved to explore in this article, suggest that API would best be served by maintaining an analog process as well as adopting a new digital one.