Not your Father's Photogrammetry

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PHOTOGRAMMETRY

It's Not Just Your Father's Photogrammetry Anymore

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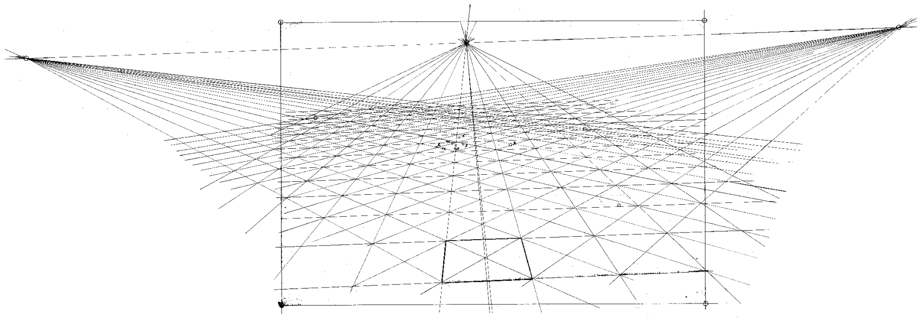
"Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment, through processes of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena *(American Society for Photogrammetry and Remote Sensing).*" For the surveyor, the most common application of photogrammetry is with aerial photography. Mapping performed with aerial photography dates back to World War I when the British Army mapped the Ottoman Turkish forts in the Palestine. Aerial photogrammetry became a common tool used in the United States, and the American Society of Photogrammetry was founded in 1934.

World War II saw the rapid development of high-volume photogrammetric mapping instrumentation and techniques. Although sophisticated instruments appeared in Europe before WWII as well as afterwards, the American emphasis on small-scale mapping of large geographic areas produced the most coverage of land areas. Periodic reflying of aerial photography for the inventory of agricultural lands as well as for topographic mapping has been the foundation of enormous data banks of archived aerial photography now available from the U.S. Geological Survey EROS Data Center in Sioux Falls, South Dakota.

Drunk driver and soft shoulder



Drunk driver and soft shoulder graphical solution

The imagery is available to the public in digital form for a nominal fee, and it is a superb source of historical data useful to the land surveyor for 2/3 of the 20th century. Many court cases concerning adverse possession rights have been easily proven with historical aerial photographs. Federally archived aerial photography is admissible in every state and federal court as physical evidence.

Applications

Useful information may be extracted from single images or from multiple images. The mathematics utilized for the restitution of single images are capable of locating objects with reference to each other when all locations are confined to a single plane. The most frequent application of single-image photogrammetry is in traffic accident reconstruction, and generally the major question asked of the photogrammetrist is "how long are the skid marks?" Or, "what's the radius of curvature of the skid marks?" The most common fallacy involved with single-photo restitution is attempting to "guess" a third dimension.

In rare cases when it is possible to develop a multiple vanishing point solution, some three-dimensional measurements may be derived under quite special conditions. The exception that allows this condition is when the plane of the imagery is not parallel to one of the three vanishing point planes. If the focal plane is indeed parallel to one or two vanishing point planes, the vanishing points then become infinite. Single-image restitution most commonly employs the eight-parameter projective transformation, which locates identifiable points in a single plane.

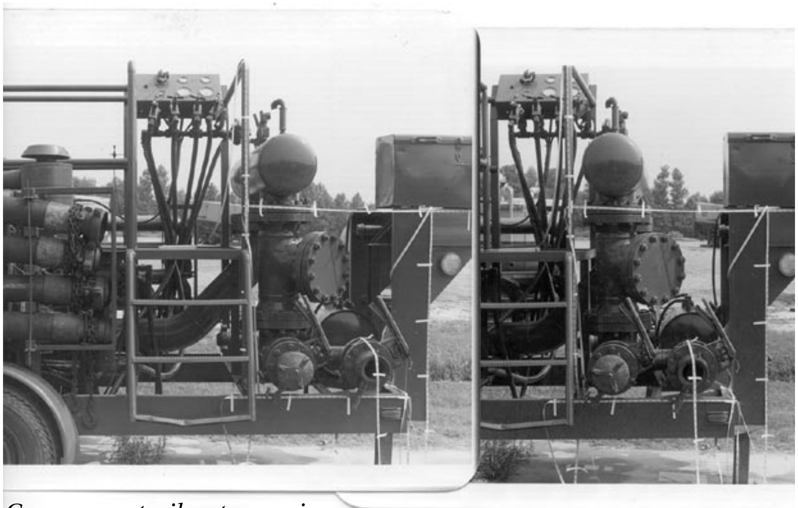
The "knowns" that must be present are at least four points where no more than two points are collinear. In other words, the 8-parameter projective transformation will transform one quadrilateral into another quadrilateral. If more than four visible points are measured in the image, then a least squares solution is possible. In least squares, we solve for an over-determined solution in which the sum of the squares of the residuals are minimized; the resultant residuals give us an indicator of "goodness of fit," or a check on our measurements. Just as the surveyor likes to *at least* compute a closure for a check, the photogrammetrist likes to compute a least squares solution!

Aerial photography is normally flown in order to provide a continuous stereoscopic view of the ground. That is accomplished by providing for a nominal 60 percent forward overlap such that one view provides the imagery to be used with the left eye, and the next view is used with the right eye. Normal stereoscopic acuity then allows one to perceive the third dimension or depth. Appropriate instrumentation and software then is used by the photogrammetrist to reliably map the terrain in all three dimensions. When doing topographic mapping of small areas of a few acres, the cost-effective method is to use GPS RTK and/or a total station. However, when the topographic mapping area is significantly larger, the normally cost-effective method used is aerial photogrammetry.

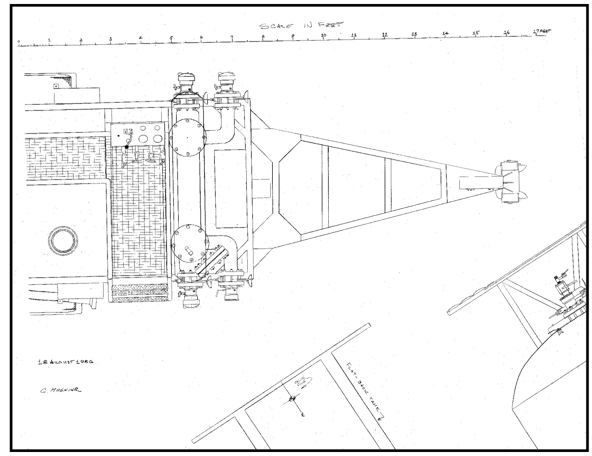
In past decades, there was always a need for surveyed ground control to properly orient and scale the aerial mapping. Today, large areas are commonly controlled by in-flight high-precision GPS RTK in the airplane, obviating the necessity for extensive ground control. The decision to employ aerial photography and photogrammetric mapping services is normally based on the cost to the landowner of land-based "topo" surveying versus aerial photogrammetric mapping. Figuring into the equation includes time of year, tree cover, and presence of underbrush—all factors that can make aerial photogrammetry impossible. Occasional statements by snake oil salesmen that photogrammetry is going to replace the boundary surveyor are just pure foolishness.

As photogrammetric mapping utilizes stereo imagery, so do terrestrial photogrammetric applications. However, much of the terrestrial and close-range work that utilizes multiple images does not use stereo imagery as much as using highly convergent views to maximize the certainty of positioning. In aerial photogrammetry, we design the photographic coverage for an optimum "base/height" ratio such that the intersecting rays of conjugate imagery meet at a nominal 90º. With aerial photography, the overlapping imagery is also flown such that the orientation of the photos are nearly parallel in order to simplify the viewing with the human eye for stereovision. When conjugate imagery has a relative convergence angle of more than approximately 30º, the human eye is normally unable to fuse the two images into a stereoscopic view. Nevertheless, terrestrial and close-range photogrammetry commonly employs such extreme convergent views to maximize the mathematical solution. The inability to view in stereo is not considered a hindrance because artificial targets, stickers and reflectors can provide for positive monoscopic measurement of conjugate imagery points.

Photogrammetric applications include topics in medical research such as last year's column (September 2005) on shooting monkeys and sailors out of ejection seats. At that one Navy laboratory, stereo X-ray photogrammetry was used along with highly convergent high-speed photography filmed at the rate of 500 frames per second! Both of these



Compressor trailer stereopair

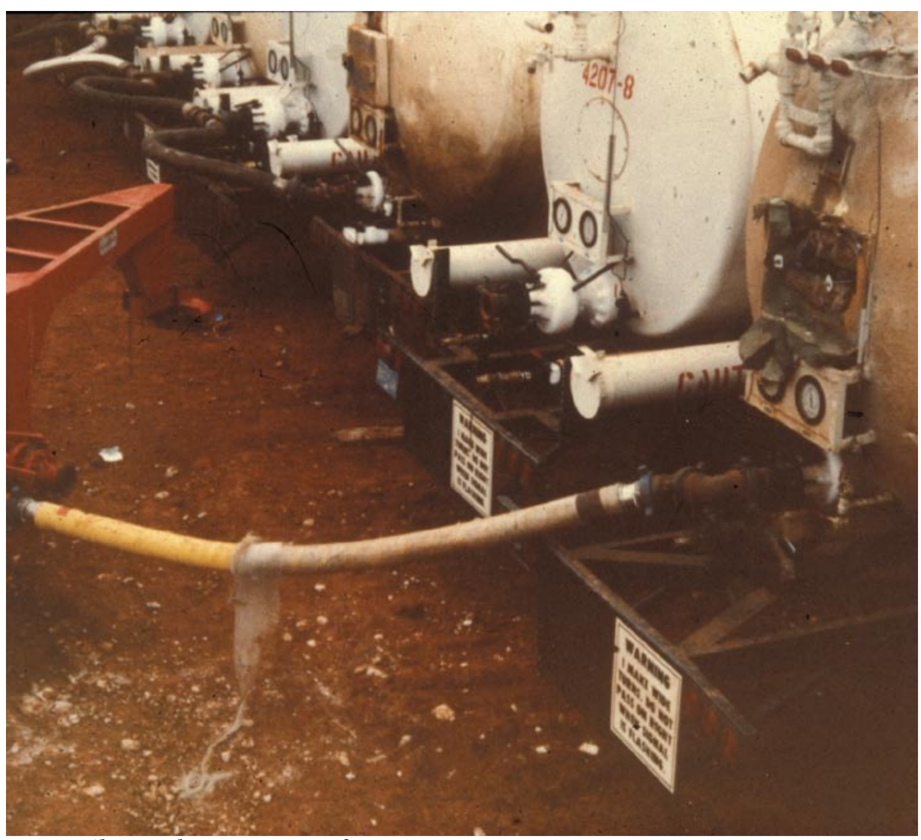


Compressor trailer plan view in pencil

applications used photogrammetry because no other technology exists that could perform the measurement job! Photogrammetry is commonly used to calibrate parabolic antennae for radio telescopes as well as for use in space. Classical surveying techniques are too time-consuming for the level of precision necessary for extreme accuracy in these cases.

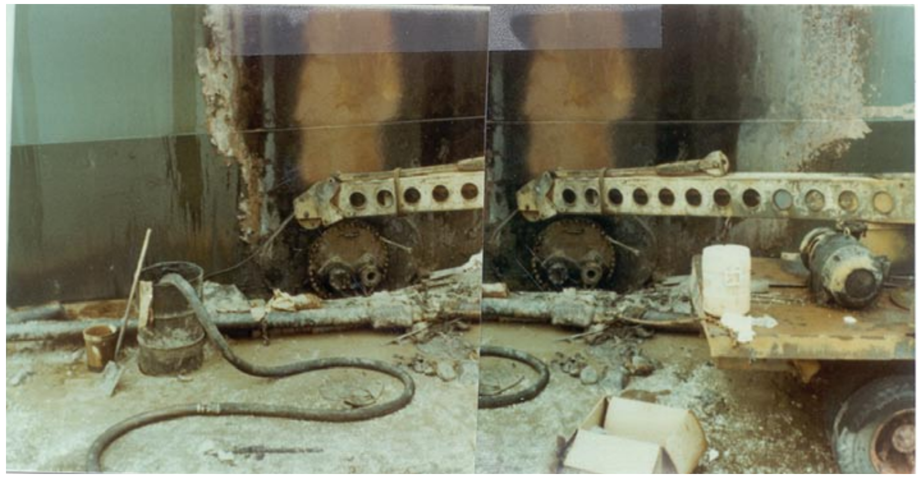
Accuracies exceeding one part in 250,000 of the camera to object distance are routine accomplishments with off the shelf photogrammetric systems. Such systems are commonly used for optical tooling applications in many aircraft factories and U.S. Navy shipyards that need cutting-edge measurement technology. Photogrammetry is commonly used in some fit-up applications in shipbuilding, particularly when modular construction is employed. The level of accuracy required for many commercial shipyards is such that it is a common crossover solution with terrestrial LiDAR scanners. As long as the object of interest is static, scanning is a simpler procedure. On the other hand if the object is moving, then photogrammetry with multiple cameras that image in sync are the only solution.

The newest special application group within the Photogrammetric Applications Division of the American Society for Photogrammetry and Remote Sensing (ASPRS) is the LiDAR Application Group. LiDAR is continuing to make extraordinary strides in both aerial and terrestrial applications as evidenced in current aerial mapping projects and terrestrial use by surveying and engineering firms. Aerial mapping of topography by LiDAR is quite efficient; it is commonly flown at night since the systems generate their own energy that is detected, and the air turbulence is normally much quieter. The technology has recently emerged with great success not only because of the LiDAR sensors but also by the combination of GPS RTK and ultra-high precision inertial platforms that record orientation data at high rates. This combination of sensor packages is termed "Direct Georeferencing," and is beginning to be used in

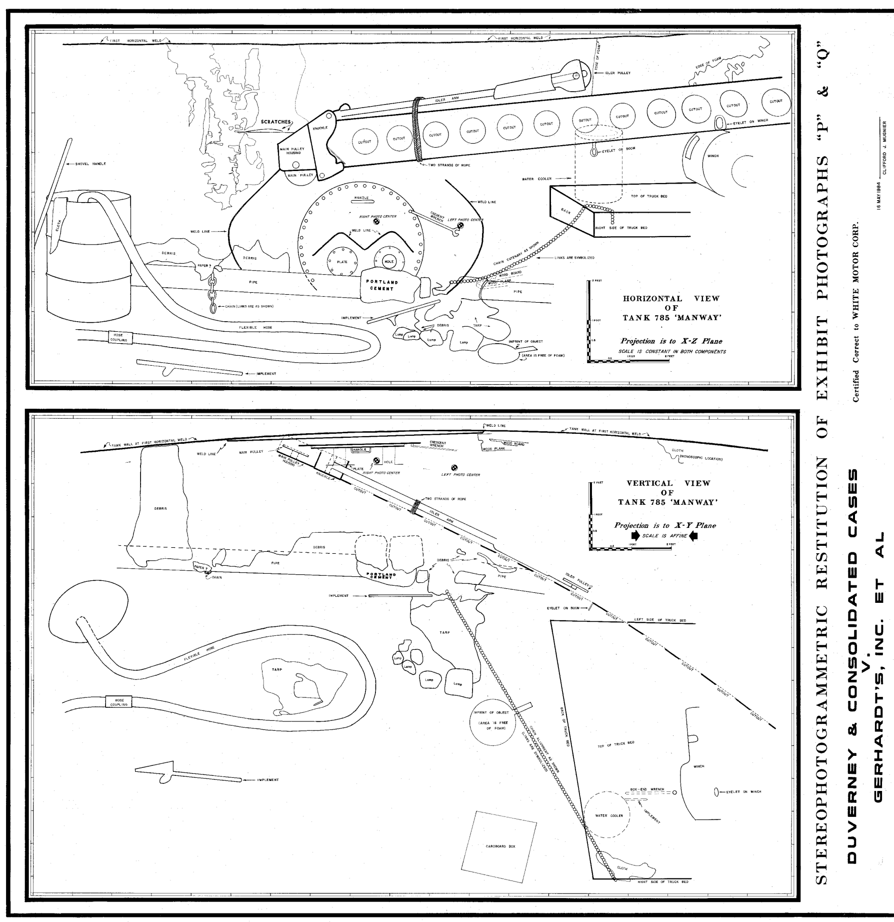


CO2 trailers and compressor A-frame tongue backpacks (without LiDAR) for mapping in areas of dense forest canopies. This is a more reliable method than what I wrote of in my *Photogrammetric Engineering and Remote Sensing* column (June 2000) on Ghana where they used to map forest trails with the "rope, pig, and compass" system!

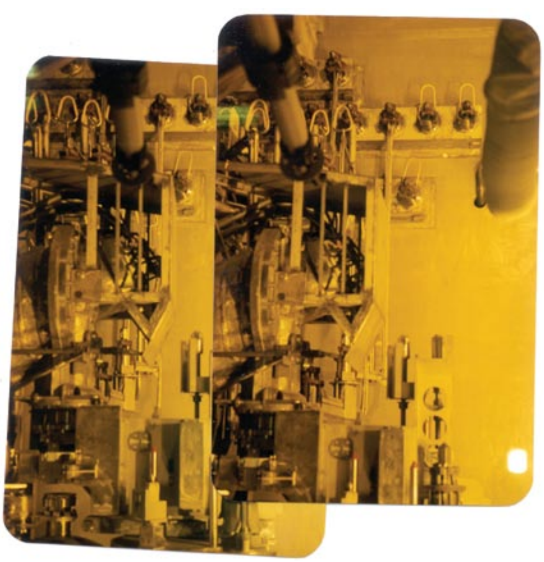
Terrestrial photogrammetry used to be the preferred method used for recording structures for architectural preservation, but LiDAR is supplanting the camera in many applications because of the relative ease of use. The level of precision necessary determines the choice of system used. The LiDAR subcommittee of the Photogrammetric Applications Division of ASPRS is currently working on standards and specifications for the industry, both aerial and terrestrial. Calibration techniques and specifications have already been addressed for digital cameras for mapping applications as well as for remote sensing. Stay tuned to this column for the latest news from the ASPRS on developments in photogrammetry, LiDAR, and direct georeferencing. Furthermore, consider joining ASPRS! Check us out at *www.ASPRS.org.* The 5th edition of the *Manual of Photogrammetry* is now available for sale by the Society, and ASPRS members receive a substantial discount. Student members get even greater discounts! The Manual is a superb addition for any surveyor's collection of reference books.



Tank explosion stereopair



Tank explosion plan and profile in ink



Nuclear weapon waste vitrification stereopair

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