K. Jeyapalan
Department of Civil Engineering
Iowa State University
Ames, IA 50011

Photogrammetry in Recording the Historic Ship Niantic

Close-Range Photogrammetry was used to photograph and map the remains of the ship's hull *in situ.*

In April 1978, in the process of excavating the foundation piers for a new high-rise in downtown San Francisco, the skeletal remains of a ship were uncovered (see Figure 1).

The discovery was promptly reported to the National Trust for Historic Preservation. The Maritime Museum, which is a subsidiary of the National Trust, researched existing maps (Figure 2) and concluded that the remains were that of the gold rush ship, the *Niantic*.

Abstract: *In April 1978, while excavating the site for a high-rise in the banking district of San Francisco, the remains of a "gold rush" ship, the* Niantic, *were discovered. The cost of removal and preservation of the hulk was estimated to be $600,000. Meanwhile, construction work on the high-rise was also halted, costing the construction company about $15,000 per day. Under the circumstances, photogrammetric methods were successfully employed to photograph and map the remains. Vertical photographs were taken using a pair of Wild P32 cameras attached to a 4 ft bar carried in a bucket hoisted on a Fireman's Ladder at a height of 45 ft above ground level. From the photographs thus taken, a plan was drawn at a scale of 1 in. = 5 ft with 0.25 m contours using a Wild A9 Stereoplotter.*

The *Niantic* was a New England whaler believed to have carried 300 passengers and crew to California. It arrived on a foggy morning in July 1849 and, like many other gold rush ships, was abandoned. It was eventually hauled up on land a full six blocks from the current waterfront. She then served as a hotel and storehouse (see Figure 3) until a fire in 1851 destroyed her down to the level protected by the landfill. In the 19th Century, three buildings were constructed in succession on top of the *Niantic* remains, the last one after the earthquake and fire of 1906.

An attempt was made to excavate and save the remains, but this proved to be costly. The firm engaged in the work of constructing the high-rise was losing many work days awaiting the decision of the National Trust. Under these circumstances, it was decided to use some other quick method of recording the historic skeletal ship. A photogrammetric technique was the obvious choice. The National Trust contacted Mr. Bill Robinson,

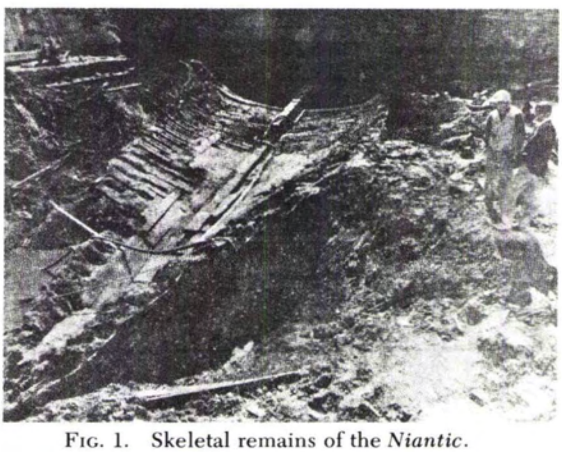

Fig. 1. Skeletal remains of the *Niantic*.

Photogrammetric Engineering and Remote Sensing,
Vol. 46, No. 12, December 1980, pp. 1531-1536.

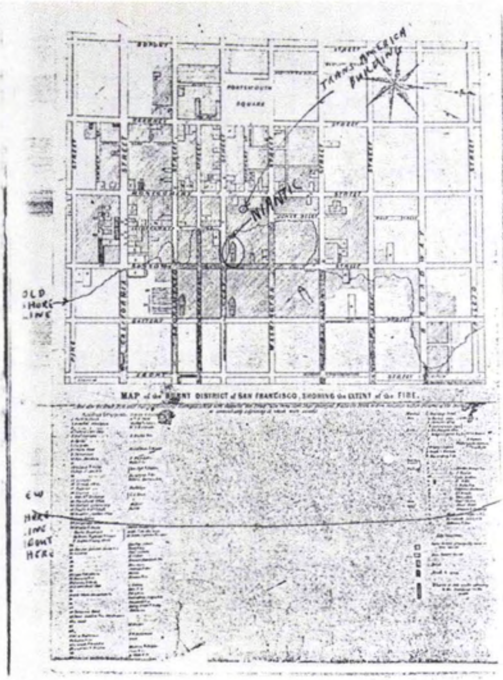

FIG. 2. Location of the *Niantic*.

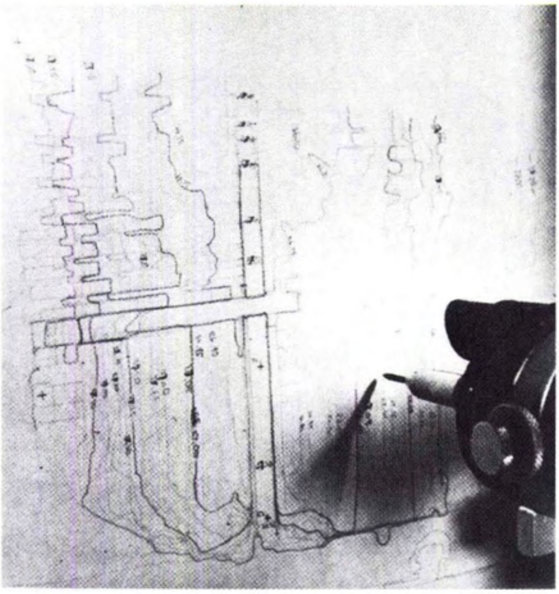

FIG. 4. Photogrammetric plotting.

President of Towell, Inc., who communicated with Mr. M. Quarteroli and the author. A team consisting of Mr. Robinson, Mr. Quarteroli, and the author traveled to San Francisco, established ground control, and photographed the remains of the *Niantic* for photogrammetric plotting (Figure 4). The photographs were taken under the direction of the author by Mr. Quarteroli and a fireman hoisted on a fireman's ladder (Figure 5). A pair of Wild P32 cameras attached to a 4-foot bar was used to take the photographs (see Figure 6). Plotting on a scale of one inch to 5 feet (1:60) with 0.25 m contours, was done using a Wild A9. A cross section was also done for every 5 feet along the stern. These specifications were determined by the author in consultation with Mr. Harry Baker, a naval architect and curator of the Maritime Museum at the Massachusetts Institute of Technology. Under the direction of the author, Mr. D. Haller used a Wild A9 to do the plotting.

FIG. 3. Niantic Hotel.

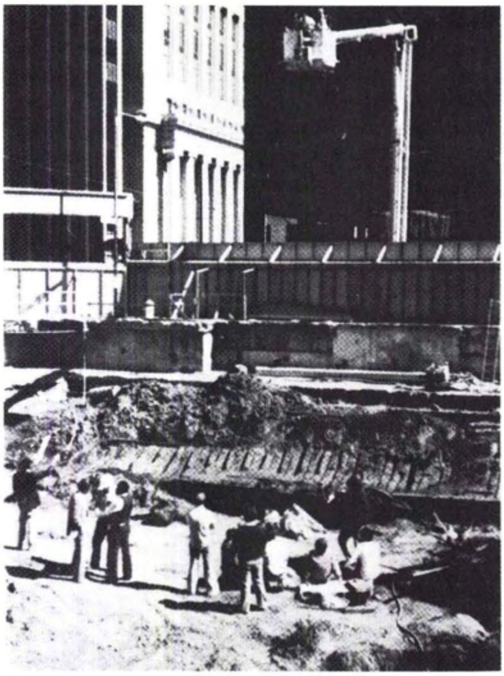

FIG. 5. Photographing the *Niantic*.

FIG. 6. Wild P32 terrestrial camera.

PHOTOGRAPHY

The skeletal remains of the ship were found below the ground surface surrounded by tall buildings. The best view for photogrammetric plotting is the aerial view. Horizontal photography gives a large Z-range and oblique photography gives a large tilt.

Two precision cameras, each a Wild P32 with a 64-mm focal length and a 90-mm by 60-mm format, were available. The recommended *B/H* ratio for good stereoscopic plotting is between 1:4 and 1:20. The fireman's ladder could be stretched 45 feet horizontally and 45 feet vertically. Since the horizontal distance from the ship to the adjoining road was about 45 feet, the maximum possible height of the ladder was 45 feet. Therefore, the maximum base length that could have been used was about 10 feet. As mentioned before, the cameras were attached to a 4-foot bar. This was a satisfactory choice since it gave a *B/H* ratio of about 1:10 (see Figure 7). In order to avoid the shadows from adjoining tall buildings, the photographs were taken about 3:30 p.m. on Wednesday, 10 May, when the sun was nearly overhead. Also, in order to ensure maximum coverage, the larger edge of the camera format, which is 90 mm, was made to face the lateral section (*Y* axis) and three stereo pairs were taken along the longitudinal section (*X* axis). The cameraman held the bar to which the cameras were attached over a premarked position and, with the help of a fireman, triggered the cameras almost simultaneously. The fireman and the cameraman were carried in the bucket. The fire truck was moved and the bucket adjusted to position for each exposure under the direction of the ground crew.

Figure 8 shows a composite stereo pair formed by mosaicking adjoining photographs.

GROUND CONTROL

The accuracy of the final plotting depends on the accuracy of the ground control. In this case, since the distances are within 100 feet, a transit and a 100-foot tape were used for horizontal control. An automatic level with a staff was used for vertical control.

A base line, ABC, of about 30 feet was established along the top of the foundation. An Azimuth marker was placed on the wall in line with the base line. Three lines were set at right angles to the base line and stakes and/or nails were driven in at about every 15 feet along these lines. The horizontal distances from the base line to the nail head were then measured by the "plumbing" method. Specially designed targets were then nailed on top of the stakes.

The elevations were established by the usual "leveling" procedure. The city benchmark served as a reference point. Using the distances and ele-

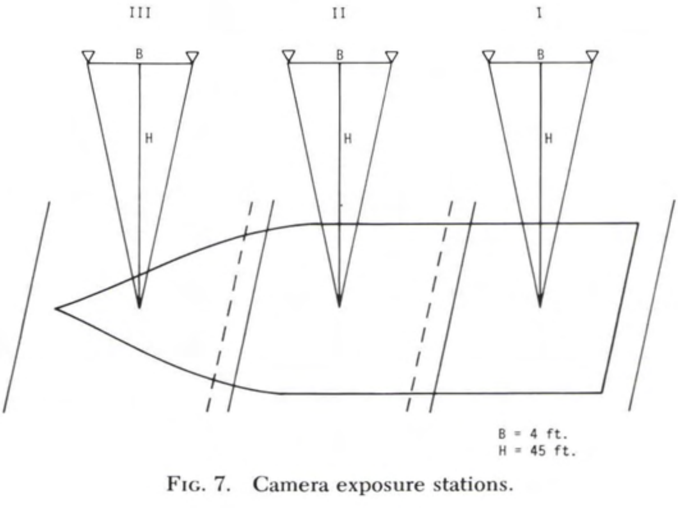

FIG. 7. Camera exposure stations.

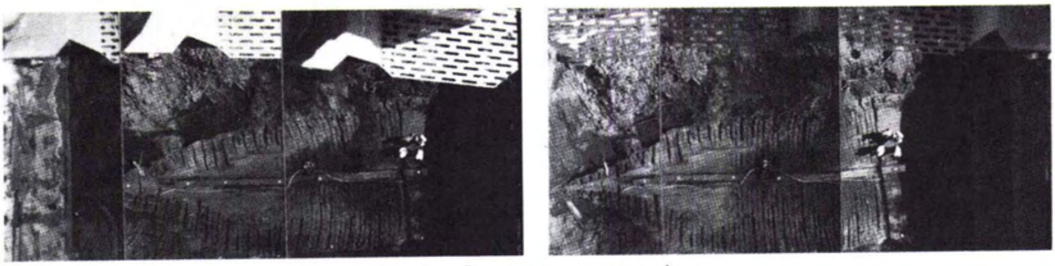

FIG. 8. Composite stereo pair.

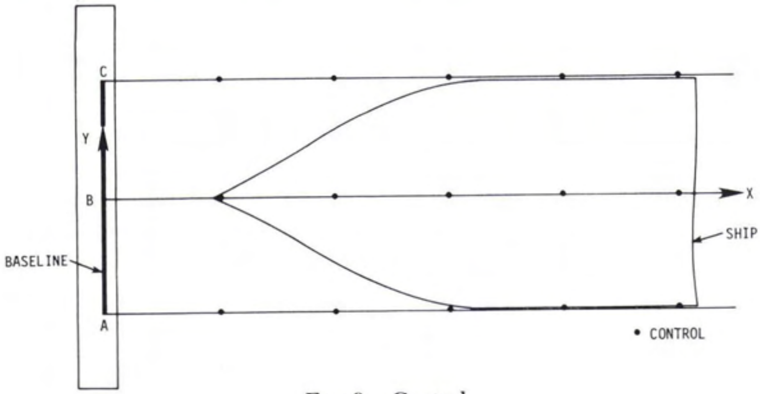

FIG. 9. Control.

vations, the three-dimensional X,Y,Z coordinates for the targets were computed with the Y axis along the base line and the X axis parallel to the stern or kessel of the ship (see Figure 9). The accuracy of the X,Y coordinates is expected to be better than ±0.1 foot and that of the elevation is expected to be better than ±0.05 foot or ±1.5 cm.

PLOTTING

A Wild A9 plotter with a focal-length range of 45 mm to 78 mm and a format size of 11 cm by 11 cm was used for plotting. The orientation of the model presented some difficulties. The imagery in half the film was obstructed by the bucket of the fireman's ladder and the cameras were unduly tilted due to the inability of the cameraman to hold the camera axis vertical. These problems were overcome by numerical relative and absolute orientation.

The model coordinates (MX,MY,MZ) obtained after relative and absolute orientation of the model were finally refined to form the ground coordinates (GX,GY,GZ) using the transformation equations:

$$GX = A \cdot MX + B \cdot MY + X_0$$

$$GY = -B \cdot MX + A \cdot MY + Y_0$$

$$GZ = C \cdot MX + D \cdot MY + Z_0 + (A^2 + B^2)^{1/2} \cdot MZ$$

The transformation parameters (A,B,C,D,X_0,Y_0,Z_0) were determined by least squares. Table 1 shows the results, indicating that a satisfactory orientation was performed. The transformation parameters were then used to transform the model coordinates of the longitude and cross section points (see Figure 10).

A detailed plan of the ship was plotted at a scale of 5 feet to one inch with 25-cm contours. Figure 11 shows the plan and Figure 10 shows the sections and cross sections.

TABLE 1. STANDARD ERROR

Model Number	Standard error, in X (ft)	Standard error, in Y (ft)	Standard error, in Z (ft)
1	± 0.014	± 0.046	± 0.014
2	± 0.052	± 0.153	± 0.043
3	± 0.063	± 0.037	± 0.024

CONCLUSION

Our experience in mapping the *Niantic* suggests that photogrammetric methods can be used successfully in mapping archaeological sites and archaeological restoration works. Photographing objects below the ground surface or in areas surrounded by tall buildings presents some problems. In the case of the *Niantic* the cameraman was lowered down in a fireman's bucket. Consequently, there was considerable obstruction of imagery and undue tilt of the camera. Both prob-

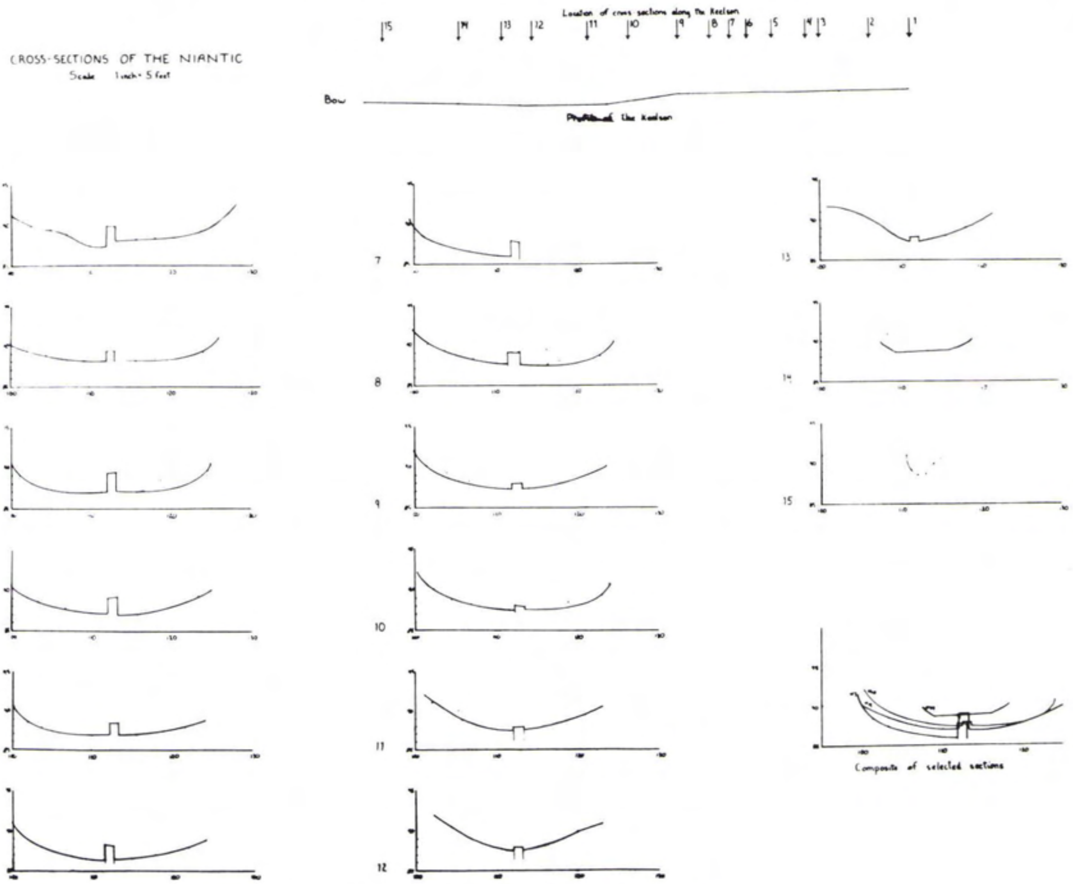

FIG. 10. Cross-sections of the *Niantic*.

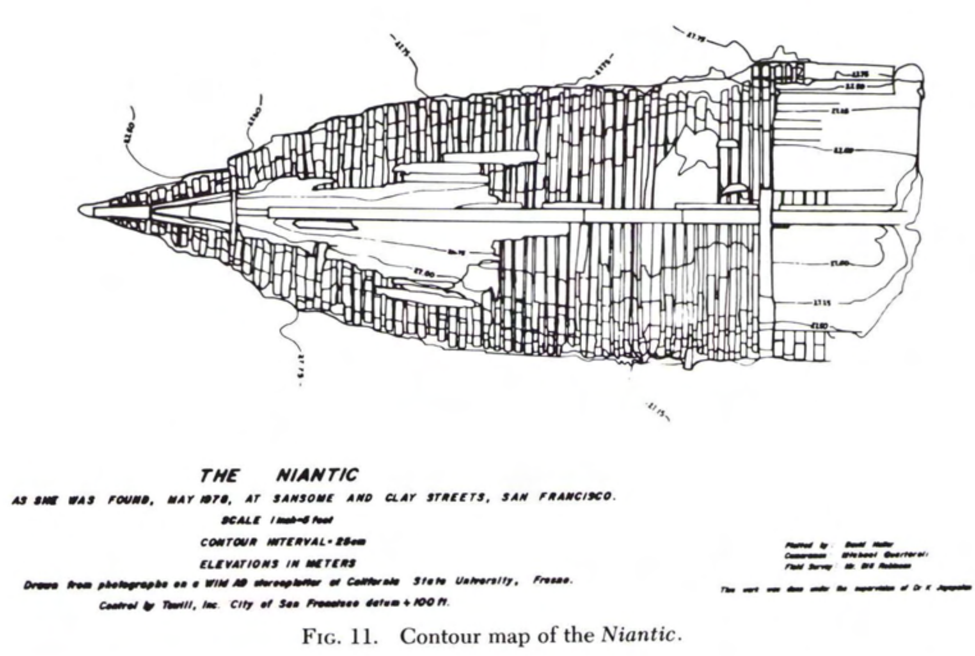

FIG. 11. Contour map of the *Niantic*.

lems may be overcome by devising a pulley system to lower and raise a bar to which a camera with an automatic exposure device is attached.

ACKNOWLEDGMENTS

I am indebted to Mr. Garland J. Gordon, Chief Interagency Archeological Services, San Francisco, and Captain Allendorfer, National Trust, Washington, D.C., for providing me with the opportunity to work on this project. Thanks are due to Messrs. Harry Baker, Curator, M.I.T., Mr. Bill Robinson, President of Towell, Inc., Mr. Mike Quarteroli, Associated Engineers and Planners, Manbeca, and Mr. Dave Haller of the Bureau of Land Management, Sacramento. Last, but not least, thanks are due to Mr. K. A. Atkinson, University College, London, for reviewing the paper and to the Engineering Research Institute of Iowa State University.

(Received 13 March 1980; accepted 28 June 1980)

New Sustaining Member

North West Survey Corporation International Ltd

17203-103 Avenue, Edmonton, Alberta T5S 1J4, Canada; (403) 483-8033

NORTH WEST SURVEY CORPORATION INTERNATIONAL is a Canadian company comprised of over one hundred dedicated professionals with many years of experience in providing photogrammetric services. North Wests expertise is offered on an international basis in the following disciplines:

Aerial Photography

We operate three air survey aircraft: a Cessna 402, a Cessna 320, and a Cessna Conquest Jet Prop Pressurized 441. The Conquest is equipped with two wild RC 10 cameras and has an altitude capability of 37,000 feet as well as a range of 2,500 miles.

Survey Control

A Pioneer in the utilization of inertial survey systems as well as doppler satellite positioning for control survey, North West has completed many large projects with these and conventional systems. Projects include pipe line surveys, control for large blocks of topographic mapping, and control surveys for the Canadian Government in Canada's Far North. Also available are various computer software programs for adjusting a wide variety of survey and photogrammetry data.

Photogrammetry

Along with conventional mapping, top quality orthophoto maps are produced through a complete inhouse operation which includes two wild PPO 8s. Digital mapping and quantity calculations are performed on our Wild A-10, Wild B 8, and Stereo Cartograph IV. All five stereo instruments are interfaced to our Eclipse 130 Date General computer. Aerial triangulation is performed semi-analytically and on line to the Eclipse computer.

For information on any of these services, contact North West Surveys International, 17203-103 Avenue, Edmonton, Alberta, Canada; (403) 483-8033; Telex 037-3039.