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Applications of Photogrammetry in Shipbuilding

Dimensioning of a midship section, development of piping drawings from a design model, survey of a section of a large cylinder, and a check on the shape of a ship's cross section are described.

Introduction

Early in 1975 our firm ("JFK") was selected to conduct a 14-month program to assess the potential usefulness of photogrammetry within the U.S. Shipbuilding Industry. As one of many investigations growing out of the National Shipbuilding Research Program, the project was cost shared by the U.S. Maritime Administration and Todd Shipyards Corporation. Todd assumed responsibility for execution of the project and selected the photogrammetric firm to work under the technical direction of their R&D Program Manager, Mr. L. D. Chirillo. The basic guiding principles in performing the entire project were to assess the usefulness of photogrammetry from a practical point of view but, above all, with emphasis upon the potential for increased productivity within our shipbuilding industry.

Of primary interest to photogrammetrists are several demonstration photogrammetric surveys which were conducted for this project.* Each of these is summarized in this article.

Abstract: *In conjunction with the National Shipbuilding Research Program, the potential for applying photogrammetry within the U.S. shipbuilding industry has been assessed. Several actual applications of photogrammetry were undertaken for demonstration purposes. These included dimensioning of a midship section, development of piping drawings from a design model, survey of a section of a large cylinder, and a check on the shape of a ship's cross section bounded by highly curved shell plating. Photogrammetric procedures and key results are summarized for each of these demonstrations.*

Demonstrated Applications

Measurement of a Midship Section

In order to increase the payload of existing ships it has become commonplace to cut a ship in half (fore and aft sections), insert a midship section, and then weld the three units together. The midship section is almost always constructed in advance of cutting the "mother" ship. Although the shipbuilder exercises quality controls to reasonably assure that the midship section will be dimensionally equivalent to the mother ship, the midship section is a large three-dimensional body which is difficult to survey as such by using conventional shipyard procedures. Of particular concern is whether the two ex-

* For complete details, see *Photogrammetry in Shipbuilding*, report of the National Shipbuilding Research Program, sponsored by the U. S. Maritime Administration in cooperation with Todd Shipyards Corporation. Available through the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Document No. PB-262-130A/S

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posed cross sections of the midship are parallel to each other and perpendicular to the centerline. If they are not, the joined ship will not be straight and may develop serious steering and power loss problems.

Whereas it was desirable to demonstrate a photogrammetric survey of a midship section, this work also served to illustrate how photogrammetry can be used to dimension mating faces of very large ships built in halves.‡ In either case, as in most large steel dimensioning tasks within shipbuilding, the accuracy requirements are such that all points must be located within 1/16 inch (one standard deviation) in each of the three cardinal directions.

About 100 targets were attached to the midship section at points of particular interest to the shipbuilder. Typically, these locations were intersections of main longitudinal girders with the decks and decks with the shell plating. The targets were attached by small but very strong magnets. Several additional targets were attached (pressure sensitive adhesive) to the main deck; distances measured by steel tape between these served to scale the photogrammetric model.

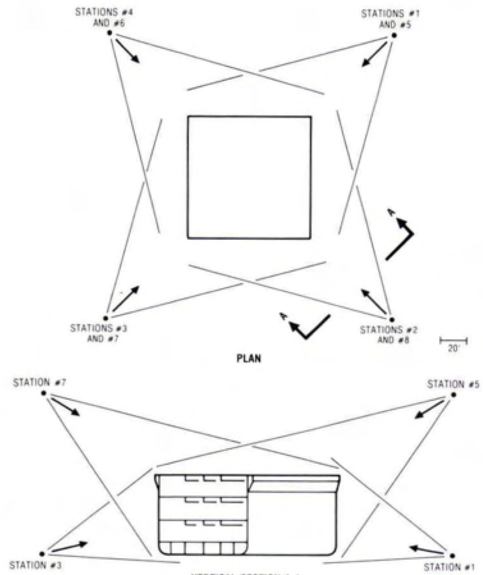

FIG. 1. Camera locations for survey of midship section. A single camera was moved between camera stations. Overhead pictures were taken from a personnel carrier slung from the boom of a crane.

‡ An analytic fit-up prediction of a tanker built in halves was successfully completed in early 1977.

Figure 1 illustrates the photographic scheme. All exposures were secured with JFK's Wild P31 which was moved from one camera station to the next. Overhead photographs were taken from a personnel carrier slung from the boom of a "cat" crane. Figure 2 illustrates a typical photograph taken from the ground.

All eight exposures were measured on a Kern MK2 monocomparator* and the resulting measurements were processed through the JFK-developed CRABS† software package. Upon convergence of the 8-station solution, the rms of the photographic measurement residuals was 2.2 micrometers and the typical accuracy of a triangulated target was 0.03 inch (standard deviation) in each of the three cardinal directions.

Once the photogrammetric solution was completed, a variety of dimensional analyses were performed for the shipbuilder. These involved calculations of distances, best-fitting planes, best-fitting planes perpendicular to other determined planes, translation of planes parallel to themselves, best-fitting circles to turns of the bilges, and comparing as-built dimensions to design data. All of these analyses were designed to provide a complete three dimensional "picture" of the midship as-built.

PIPING DRAWINGS FROM A SCALE MODEL

In the design of distributive systems, especially within engine rooms, a scale model is often constructed to assure that interferences do not occur. One school of thought holds that design should take place at the model and, once completed, the model is the design. This concept is in contrast to the more conventional approach wherein the design takes place on paper first and if a model is built at all it is usually done only as a final test for interferences.

With the design modeling concept it is necessary to transfer the design inherent in the model to paper for dissemination to all personnel requiring details of the design. In order to illustrate how photogrammetry can accomplish this quite readily (as opposed to manual measurement of the model) a sample drawing was prepared on the Wild A10**

* Mensuration was performed by Analytic Photo Control, Inc., of Indian Harbour Beach, Florida.

† CRABS is the acronoym for Close Range Analytical Bundle Solution which is a totally rigorous weighted least-squares simultaneous solution with error propagation.

** Stereo plotter work was performed by Henderson Aerial Surveys, Inc., of Columbus, Ohio.

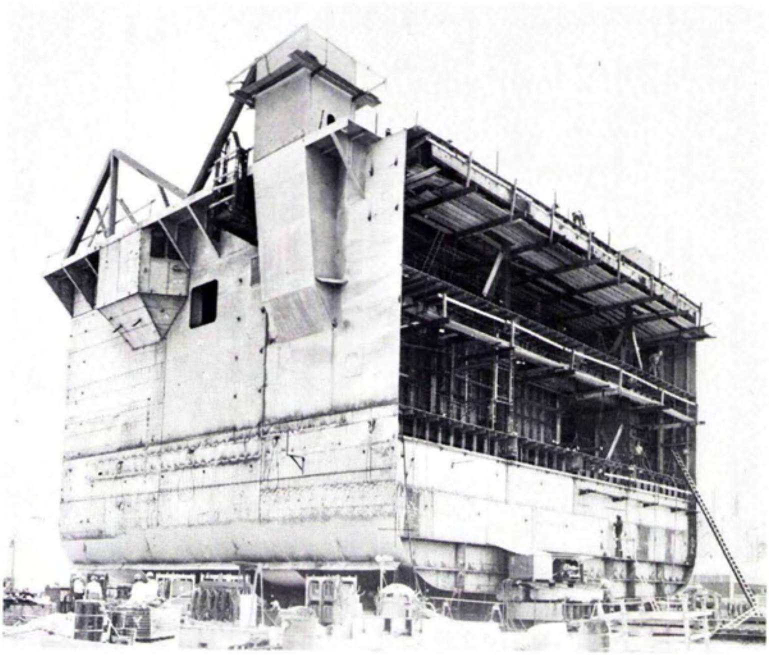

FIG. 2. Typical photograph of the midship section taken from the ground.

from a series of stereo pairs taken with the Wild P31 camera of a portion of a 3/4″ = 1′ model of an engine room. Figure 3 is typical of the photographs used to compile the piping drawing shown in Figure 4. It should be noted that the final product is a dimensioned drawing; i.e., locations of the pipe centerlines are indicated by distances from overhead decks and bulkheads.

In performing this demonstration it was recognized that the direct graphical product of analog photogrammetry was merely

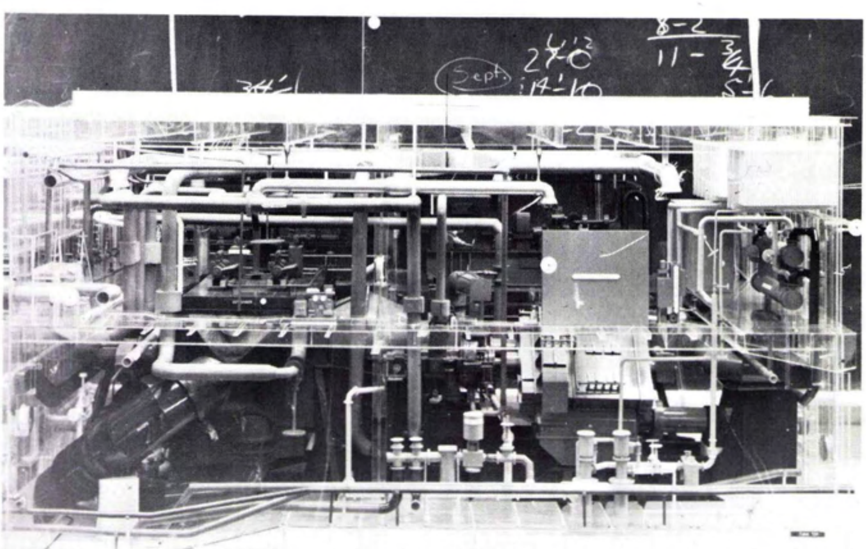

FIG. 3. Portion of a photograph of the machinery space model showing the extent of the model mapped.

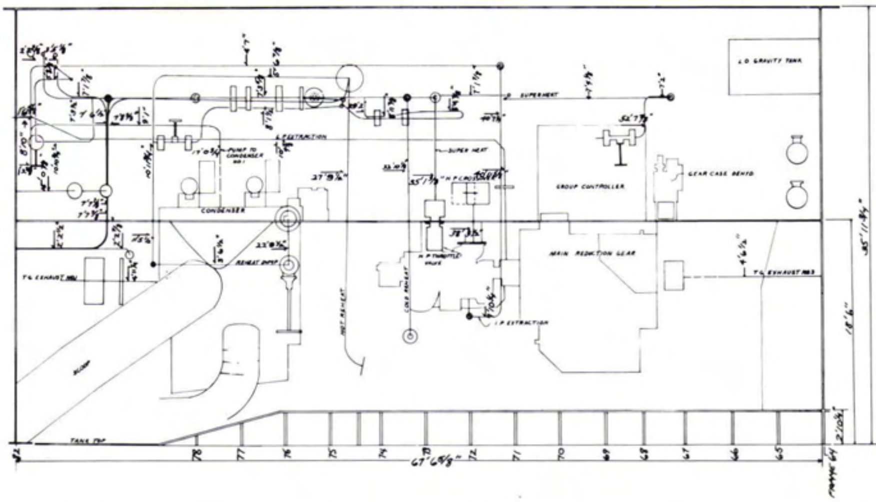

FIG. 4. Elevation drawing of the steam systems in a portion of the machinery space model. The drawing is reproduced from the original compilation manuscript and not redrafted for aesthetic value. Compilation scale was ⅜″ = 1′. Note that locations of centerlines of pipes are dimensioned.

touching upon the full potential of photogrammetry as an aid to design modeling. Should a model be prepared with an eye toward photogrammetric dimensioning (the model photographed was not), a digital representation would be most desirable so that pipe subassemblies, arrangements of individual piping systems, composites of several systems, and even isometrics could be plotted by computer drafting at any scale and at any time.

This demonstration was not maximized for accuracy. A comparison of 20 distances determined by photogrammetry to the corresponding design distances* revealed an average difference of 1-⅛ inch at the scale of the ship. This includes photogrammetric error and error in the model itself. In true design modeling, however, the model is the design and only the photogrammetric error is of consequence. Nonetheless, it is felt that the photogrammetric error in this particular demonstration is about twice that which would be acceptable to shipbuilders. But, with the model built to suit, there is little doubt that photogrammetry can supply the necessary data with sufficient accuracy.

MEASUREMENT OF A SECTION OF CYLINDER

One series of liquid natural gas (LNG) tankers under construction within the U.S. utilizes 120-foot diameter spherical tanks for containment of the cargo. Attached to the equator of each tank is a full section of a cylinder which hangs from the equator in the fashion of an apron. A similar section of cyl-

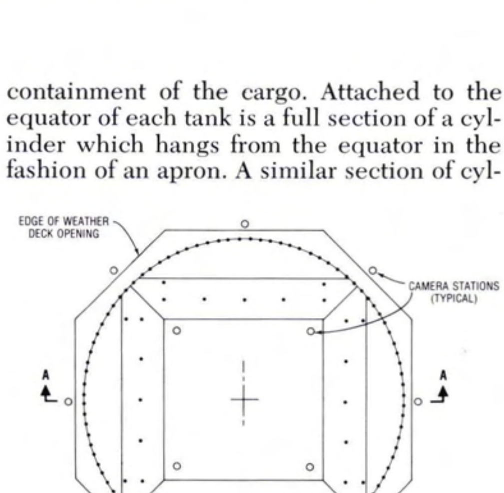

FIG. 5. Target and camera locations for the survey of a section of a cylinder within the hold for a spherical LNG tank. Dots indicate locations of targets. At each camera station the camera is pointed across the hold with the axis depressed or elevated depending upon whether the camera is on the weather deck or within the hold. A single camera was moved between camera stations.

* This particular model was first designed on paper.

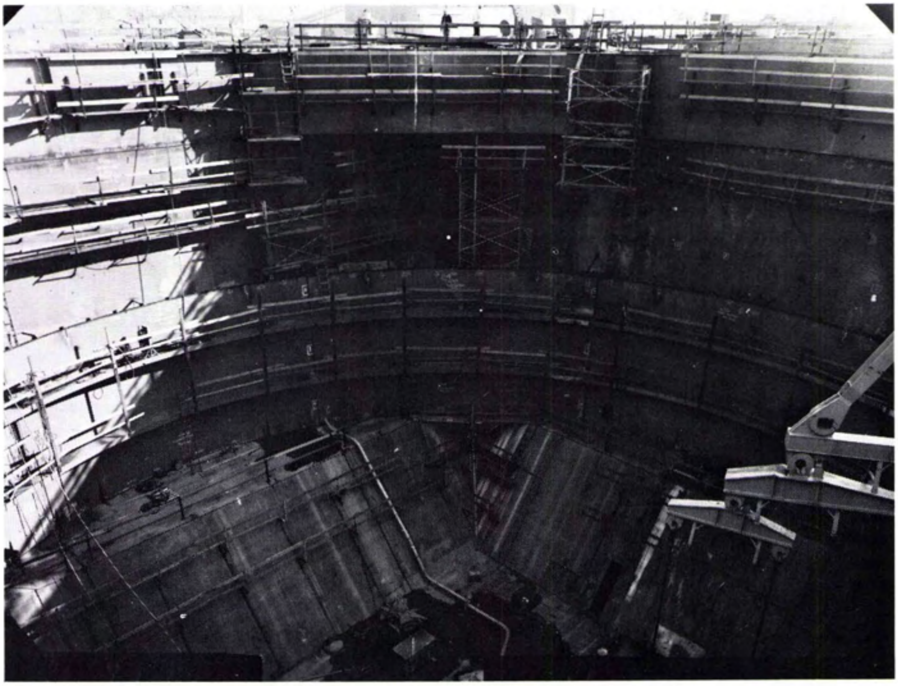

FIG. 6. A typical photograph looking into the hold from the weather deck. The section of cylinder is seen as an arc across the center of the photograph.

inder is constructed within each hold of the ships which transport the spheres. When a sphere is lowered into a hold, the two sections of cylinder mate so as to support the tank in the same manner as a slightly oversized ball set on top of an open coffee can.

Because the shipbuilder desired detailed information regarding the as-built configuration of the first-constructed cylinder within the first ship of the series, a photogrammetric solution was devised. Targets were placed about the top edge of the cylinder and at other locations of interest to the shipbuilder. Twelve photographs were taken with the P31 from the locations illustrated in Figure 5. Figure 6 is a typical photograph. Each plate was measured on the MK2 and the resulting measurements were processed through CRABS. An rms of 1.7 micrometers was achieved for the photographic measurement residuals and the typical resultant accuracy of a triangulated target location was 0.04 inch (one standard deviation) in each of the three cardinal directions. Taped distances between selected pairs of targets were used to scale the solution.

A number of different analyses were performed for the shipbuilder. The most interesting of these was a determination of the planarity (i.e., deviation from a best-fit plane) of the top edge of the cylinder and the "out of roundness" of the top edge. The latter was determined by a best-fit circle calculation, the results of which are presented in Figure 7.

SURVEY OF A SHIP'S CROSS SECTION

This particular demonstration involved an LNG tanker which was to receive its bow

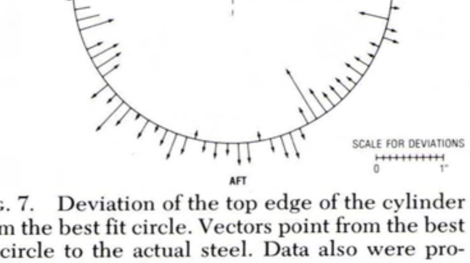

FIG. 7. Deviation of the top edge of the cylinder from the best fit circle. Vectors point from the best fit circle to the actual steel. Data also were provided in tabular form.

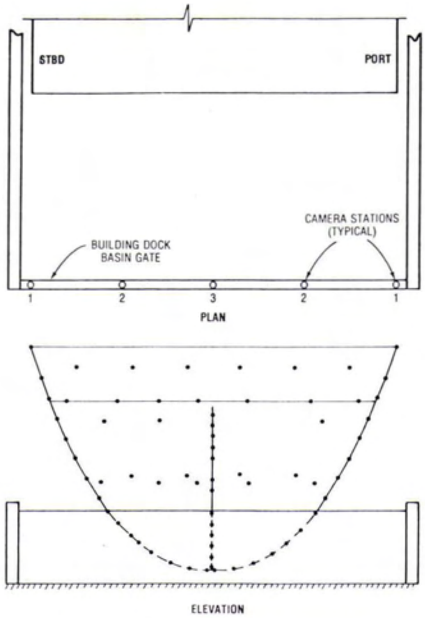

FIG. 8. Target and camera locations for the survey of a ship's cross section. Dots indicate locations of targets. Targets interior to the shell and not on the centerline served mainly as passpoints. A single camera was moved between camera stations. Numbers below the camera stations indicate the number of exposures taken; each exposure viewed somewhat different portions of the ship's cross section.

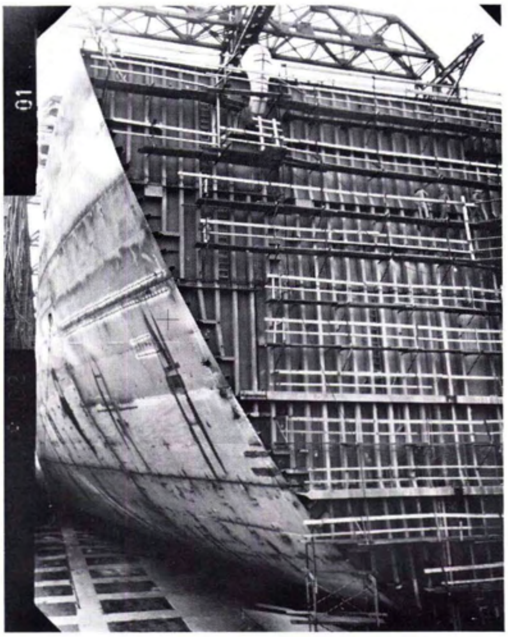

FIG. 9. Typical photograph for the survey of the ship's cross section.

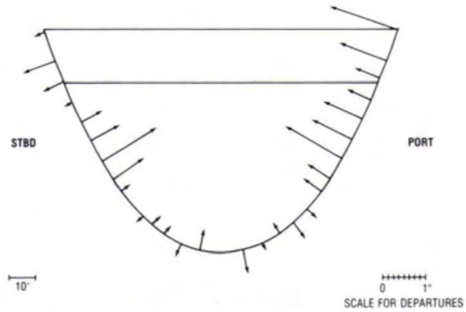

FIG. 10. Deviation of the shell plating of the ship's cross section from the design. Vectors point from the design surface to the actual steel. Data were also provided in tabular form.

section in two large pieces. The master butt where the join was to be made was bounded by shell plates having high degrees of curvature. To obtain a representative sample of the as-built configuration of the plating, targets were attached to the shell (in the plane of the cross section) as illustrated in Figure 8.

Due to physical restrictions of the job site, it was only possible to secure photographs from the walkway along the top of the gate to the ship's building basin (see Figure 8). Accordingly, nine slightly convergent and highly overlapping photographs were taken with the P31 from the locations indicated in Figure 8. Figure 9 is a typical photograph. The photographs were measured on the MK2 and the measurements were then processed through CRABS with a resultant rms of the photographic measurement residuals of 1.8 micrometers. The typical accuracy of a triangulated target was 0.03 inch (standard deviation) in the vertical plane and 0.08 inch to and from the observer. Finally, the as-built shape of the shell plating, as determined by photogrammetry, was compared to the original design in order to obtain the differences shown in Figure 10.

CONCLUDING REMARKS

Both fully analytical and analog photogrammetry can be used to the benefit of our shipbuilders. Applications for both methods were found scattered throughout the various phases of shipbuilding. Principal applications of fully analytical photogrammetry, however, lie in dimensioning large steel units with an eye toward predicting potential (and very costly) fit-up problems. Required photogrammetric tools and techniques are state-of-the-art, but it is necessary to abandon the concepts of stereo pairs and surveyed control in order to achieve sufficient accuracies and to produce results economically within an acceptable period of time.

Analog photogrammetry shows great potential for use in combination with design modeling of distributive systems. It may also be applied to the task of developing as-built piping drawings. For this latter application it is necessary to develop a simple, fast, and yet accurate solution which can be utilized within a shipbuilder's or naval architect's facility.

It is very clear that photogrammetry is merely a tool for developing basic data. Once the photogrammetric solution is achieved, it is usually necessary to perform additional analyses as was done for the applications just described. Thus, the photogrammetrist must be adept at performing such analyses for the shipbuilder in an uncompromising manner. Generally speaking, a fairly extensive inventory of "data manipulation" programs is needed in order to complement photogrammetric instrumentation and software.