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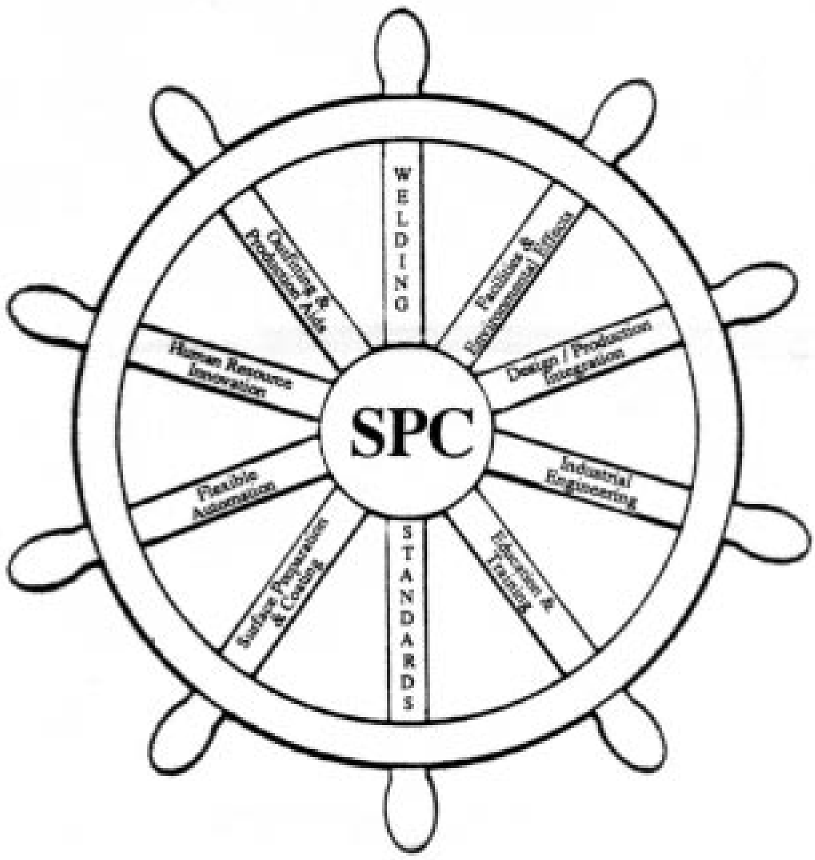

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Photogrammetry, Shipcheck of USS Constellation (cv64) Arresting Gear Engines 7B-2

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ABSTRACT

Arresting gear engines are large heavy pieces of machinery which are costly to replace because of expensive repairs and modifications to existing decks. These costs can be avoided and the units installed in a more timely efficient manner if the photogrammetric process is used. This article outlines the methods and techniques for using photogrammetry as a planning tool. It also demonstrates the practicality of collecting dimensional data from existing ship structures and foundations and using this data directly in the manufacturing phase of the equipment.

BACKGROUND

As part of the Aircraft Carrier Service Life Extension Program (SLEP), the arresting gear engines which are part of the system used to absorb the energy from landing aircraft are replaced with modern updated versions. This work is accomplished under Ship Alteration (S/A) 6790. In the past, arresting gear engines were maneuvered into position several times during fit-up. Because these units weigh over **31750** kg (70,000 pounds) each, this is a difficult process. The precedent for using photogrammetry to locate arresting gear engine bolt holes was set when successfully used on the USS KITTY HAWK (CV-**63).** On the CV-63 photogrammetric data from both the deck and the arresting gear engines were compared so that the arresting gear engines could be positioned to avoid extra handling. It was an outgrowth of this previous success that encouraged a more integrated approach when using photogrammetry on the USS CONSTELLATION (cv-64). Investigations during the advanced planning revealed that the existing engine base and the new engine base were nearly identical. It was then determined that if the existing bolt hole pattern of each engine could be used as a template for the soon to be manufactured engines, then expensive and time consuming deck repairs could be avoided.

PAST REPAIRS

On the older aircraft carriers, the gallery decks are made of special treated steel (STS) plating, usually about 19 mm **(3/4** of an inch) thick. Older STS plate is very brittle making it extremely difficult to accomplish weld repairs. For example, on the USS INDEPENDENCE **(CV62),** it was necessary to make extensive deck plating replacement because of cracks created by repair welding.

Each of the four arresting gear engines are held down by 266 bolts. These are **22.23** mm **(7/8** inch) bolts in a clearance hole of **23.81** mm **(15/16** of an inch). heck repairs, in the past, have included plug welding the existing bolt holes after the existing engines had been removed. These plug welds were then required to pass non-destructive testing. Then, the new engine was lowered into the space (gallery deck) from the flight deck above, and used as a template to determine the location of the new holes to be drilled.

The new engine was then removed and stowed on the flight deck where efforts to preserve and maintain it had to be accomplished. Once the new engine was removed, the drilling of new bolt holes could begin. The next step required the sizing and installation of the foundation pads to the gallery deck. Once installed they had to also be drilled and machined to allow a level plane for the engine to rest. The number of steps in this process leave the door open to allow many errors, as well as schedule delays to enter into the process.

PLANNING

The design and construction of the new engines are accomplished at the Naval Air Engineering Center (NAEC). After erection, they are sent to installing activities such as the Philadelphia Naval Shipyard. After meetings held with NAEC engineering and production personnel, they agreed to support the shipyard's effort by drilling the new engines to specifications to be provided by the shipyard. Concurrence by NAEC was received **31** August 1988.

The new arresting gear engines were scheduled to begin erection in September 1989. This meant that any useful information would be required by NAEC prior to that date. This required the data to be retrieved prior to the ship's arrival at the shipyard and therefore, prior to the removal of the existing engines from the ship. Photogrammetry became the method of choice for recovering this data based on accuracy requirements and ease of data extraction.

Pre-planning, as with most photogrammetric applications, was a significant part of the project. First, the ship's availability was considered and its home port of North Island, San Diego, Ca. was chosen by the shipyard to perform the photogrammetric survey. A June 1989 time frame was proposed, and ultimately accepted. To deal with the technical issues, the shipyard required the photogrammetric contractor to perform a feasibility study to determine not only the best photogrammetric approach but also to identify any technical issues that would have to be addressed prior to the photogrammetric survey team's arrival in San Diego. The method of photogrammetry (convergent or stereo) and requirements of said method needed to be determined. Because individual point coordinates were needed for bolt hole centers the convergent method of photogrammetry was ideal. The existing bolts extend through the gallery deck and are visible from the hanger bay. The overhead clearance of 7.62 m (25 feet) provides ample distance to provide good camera angles.

The basic photographic plan was the same for each of the four engines. Two athwartship rows of photographs each were to be taken from a 4.57 ❑ (15 foot) high rolling platform with the camera approximately 3.05 m (10 feet) below the gallery deck. To aid photographic viewing of the bolts, because of obstructing transverse stiffeners, both rows of photos were offset forward or aft of the engine above. Locations of photo stations within a row were pre-planned to avoid excessive obstruction by longitudinal stiffeners. As a result, each photograph was oblique rather than "straight on" insofar as viewing angle was concerned.

To assure strong inter-connectivity amongest all photos, a series of self adhesive stick-on targets were attached at pre-planned nominal locations along the stiffeners and extemporaneously at strategic locations on the underside of the gallery deck in the vicinity of bolt groups. Both types of target locations also served to allow tying in of auxiliary close up photos taken as needed in particularly obstructed situations; i.e. where a bolt(s) could not be seen by two or more photos from the main scheme of pre-planned camera stations. Finally, to assure that the laboratory-assembled series of photos spanning some 15.24 m (50 feet) would not be subject to scaling or "bending" errors, several very accurate 6 foot steel rules were clamped into the overhead, end-to-end, and aligned parallel to an adjacent taunt piano wire. Actually, small gaged gaps were left between the ends of the scales. These gaps were added into the calculation of known locations of targets previously placed on the scales.

The development of a suitable target for the bolt hole centers took on much more of a research and development effort. Since the engines existed, hence the mounting bolts existed, it was decided the center of existing bolts would be used to represent the center of the existing bolt holes. Ideas ranging from a threaded "nut like" target that could be screwed on to a magnetic type that could be stuck on were investigated. Since a majority of the bolts were installed from the hanger bay side of the 03 level (only the bolt head showing), and the need for an accurate depiction of the bolt's centers were paramount, the following idea was developed.

A three pronged fixture (target placement device) which fit over the hexagonal bolt head was used. In the center of the fixture was a "syringe" type device that allowed for a small white dot to be placed in the center of the bolt head. In order to be able to identify the bullseye, it was necessary to have the ship's force pre-paint all the bolt heads flat black.

The numbering sequence for all targets was developed in two phases. The first was a four digit system which gave each bolt on all four engines a unique number. The second was a five digit system which gave a unique number to each tie-in target used. This simple, yet unique, numbering sequence allowed an excess of 250 photographs to be taken without the possibility of disorder.

With the pre-planning completed, the actual retrieval of data from the work site began. The production work sequence allowed for this data collection to be completed over a two week time frame (**13** - 27 June 1989). Essentially, the first week was spent in preparation and the second in the actual photography segment. Site preparation included :

(1) installation of the tie-in targets;
(2) preparation of bolt heads to accept bullseye installation;
(3) installation of bullseye on bolt head ;
(4) installation of scales;
(5) numbering of all tie-in and bolt head targets;

The photography segment included:

(1) laying out and identifing camera stations;
(2) installation of the camera on a rolling staging assembly;
(3) taking of all photographs;
(4) preparation of darkroom;
(5) development of photos;
(6) intense review of all negatives;

The main scheme photos of each engine were taken with a WILD P31 photogrammetric camera employing glass plates as the negative recording medium (see Figure(l)). All photos were carefully reviewed near the job-site so as to ascertain which bolts were not captured on two or more photos. Numerous instances so identified owing to stiffeners, cables and lighting fixtures were then resolved by taking very close-in shots with a semi-metric Rolleiflex 6006 camera (Figure 2) employing 70mm Kodak Plus-X Estar-base film. Figures 3 and 4 are typical photos from the two cameras.

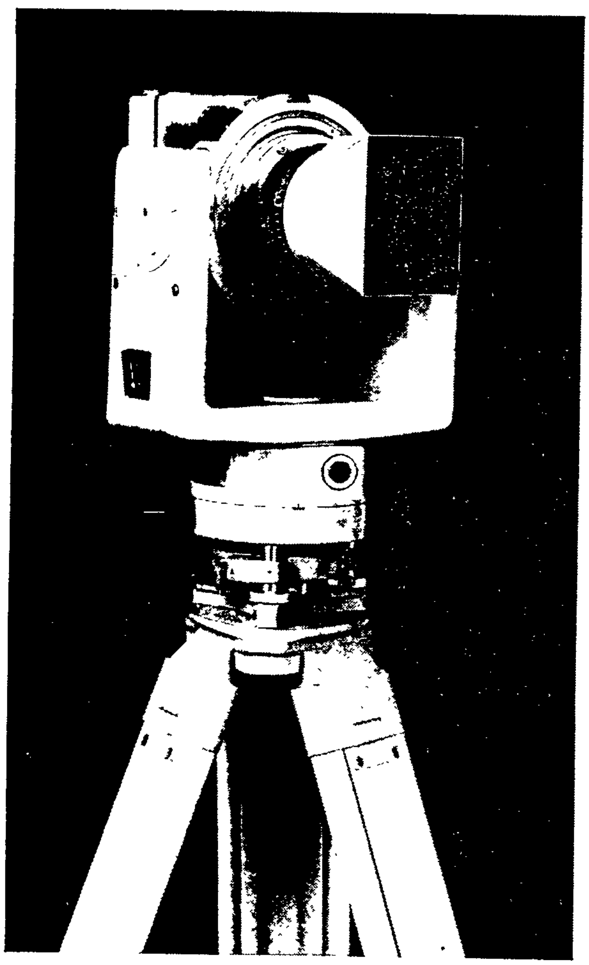

Fig. 1 Wild P31 photogrammetric camera

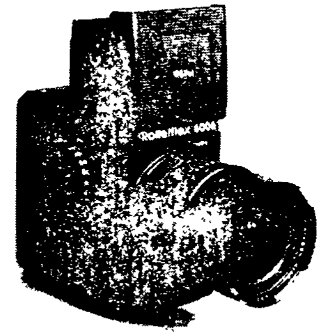

Fig. 2 Rolleiflex 6006 camera

Fig. 3 Typical photo from Wild P31 photogrammetric camera

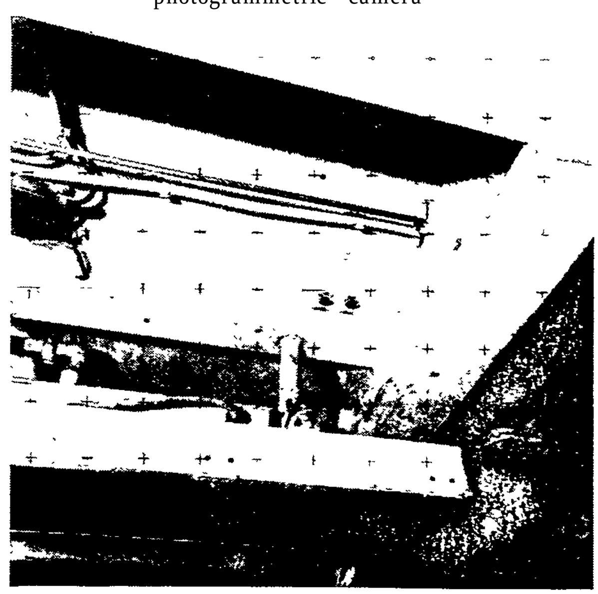

Fig. 4 Typical photo from Rolleiflex 6006 camera

RESULTS

In the time frame of July through August both the data reduction and data analysis were accomplished. The contractor reduced the data from the negatives and forwarded it to the shipyard in a pre-determined format. Data points which could not be captured, either by inability to set a target or take a photo, were identified. **10%** of the points were not captured photogrammetrically. The bulk of the non-captured points were not capable of being physically targetted. Coordinates for these points came from adjacent photogrammetric points and physical measurements taken on site.

With all points assigned a set of coordinates, an error analysis was performed to determine the total possible error between the actual center of the existing bolt hole and the identification of this location through photogrammetry.

In a worst case scenario the various possible errors would be from photogrammetry (.406 mm; .016 inch), placement of the bullseye (.787 mm; **031** inch), and actual location of existing bolt in the hole **(1.57 mm; .062** inch). It is therefore possible that the identified center of the existing hole by photogrammetry could be off by as much as 2.77 mm **(.109** inch). At the worst case. the accuracy-of locating the existing holes would allow for the installation of new bolts. However, when this theoretical error is added to the allowable drilling error (+ .787 mm; + .31 inch) of the new engine by NAEC there was a probability that some bolts would not fit.

In order to eliminate even this remote possibility, the shipyard entered into discussions with NAEC. Through technical precedence, analytical reasoning and prior knowledge of a potential problem, the shipyard was able to convince NAEC to enlarge the new bolt hole sizes from **23.81** mm **(15/16** inch) to 25.40 mm **(1** inch). This extra **1.57** mm **(1/16** inch) increased the probability that all bolts will fit.

Additional problems were that the existing engine which has six (6) rows of bolt holes (266 holes) while the new engine which only has four (4) rows of bolt holes (190 holes). With the accurate location of these additional 76 holes, the shipyard was able to convince NAEC to drill the extra holes in the engine. This will allow for all the existing bolt holes to be used and thus reduce expensive deck repairs.

Another phase of data analysis was to determine how many bolts would not fit if the new engine were drilled to the standard NAEC bolt hole drawing. An analysis to determine the acceptable limits of existing bolt hole locations verses standard drawing locations was completed. The results revealed that as many as 22% of the holes either in the deck or engine would require rework.

The final phase of this project was to develop drawings from the data and the delivery of these drawings to NAEC. There were eight drawings developed using the shipyard's computer aided design equipment, two drawings for each engine. One drawing showed existing bolt hole locations in the NAEC standard drawing format. The second was a recomputation of the data points (bolt hole locations) in order to simplify the drilling process at NAEC. The development of these drawings was completed for delivery to NAEC on 4 October **1989.**

CONCLUSION

The evolution of this project has run nearly 15 months from its inception in the summer of 1988 to the delivery of the drawings to NAEC 4 October 1989. Although the final conclusion will be sometime in the future (the installation of the new engines), some positive results can be noted at this time.

1. Data retrieval of complex nature can be accomplished at remote sites (i.e. outside PNSY).
2. Location of bolt holes can be found without disrupting existing conditions or ship's force routine.
3. Large quantities of data can be obtained and reduced in a relative short time frame.
4. The use of photogrammetry in this application can save an estimated 228 rework.
5. Concrete data obtained with photogrammetry convinced NAEC of the necessity to drill 25.40 mm **(1** inch) holes verses **23.81** mm **(15/16** inch) holes and to drill **266** holes verses **190** holes.
6. Data obtained prior to initiation of work at NAEC allowed correct holes to be pre-drilled in each engine in order to eliminate rework and schedule impacts during overhaul.

The success of this project has shown that photogrammetry can be employed to give not only accurate data but also data well in advance of a ship's arrival. This achieves a quality product while also allowing production worksites to open when necessary to balance production workloads.

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