LARGE COMPONENT DEFORMATION STUDIES USING VIDEOGRAMMETRY

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1. INTRODUCTION

Fermilab has the responsibility for developing certain components for the Large Hadron Collider (LHC), to be commissioned at CERN in 2005. As part of the development process, a referencing strategy must be created such that the position of internal active components may be known relative to external targeting. One question to be answered is the issue of dimensional stability of a part that will be transported over long distances; another is whether the external framework is coherent.

This paper reviews the efforts of the designers of the component and the Lab's Alignment & Metrology Group to understand the behavior of a moderately large part, in this case a pie-shaped CSC chamber of dimensions 2x3x0.3m, as it is positioned in various orientations relative to gravity.

A CSC chamber is a sandwich of seven panels loosely held together by a set of bolts and "precisely" positioned with respect to each other by two tight tolerance alignment pins. The purpose of this photogrammetric measurement was to assess the existence of possible relative movement of one panel with respect to another when the chamber is lifted in the vertical position and rotated to some of the positions a chamber will assume in the final detector configuration.

All measurements were made using a Geodetic Services, Inc. INCA 6.3 camera with an 18mm Nikon lens (Fig. 1) and were processed using GSI's V-STARS 4.1 software.

Figure 1 - GSI INCA 6.3 camera

It should be noted that this paper is being presented for its metrological value, and should not be considered a rigorous examination of the dynamics of the part; the latter conclusions are best left to the designer of the part.

2. OBJECTIVES

The designers of the chamber wished to determine if the seven panels performed as a coherent unit as the chamber was placed in various orientations, simulating operating and servicing conditions. Additionally, a measure of the reliability of the internal-external referencing was desired. Nine epochs were planned to identify the performance characteristics of the chamber:

1. Horizontal, fully supported (Baseline 1) (Fig. 2);
2. A second horizontal, fully supported measurement, to determine the internal precision of the measurement process (Baseline 2);
3. After transportation across the lab, suspended from a crane, large end up (12 o’clock);
4. Suspended by a crane, one side up (3 o’clock);
5. Suspended by a crane, small end up (6 o’clock);
6. Suspended in a service fixture, supported at the center of each end, lying flat (0°);
7. Suspended in a service fixture, supported at the center of each end, lying vertically (90°);
8. Horizontally, fully supported, as in 1. above (Post run 1);
9. A second horizontal, fully supported measurement, to determine the internal precision of the measurements, as in 2. above (Post run 2).

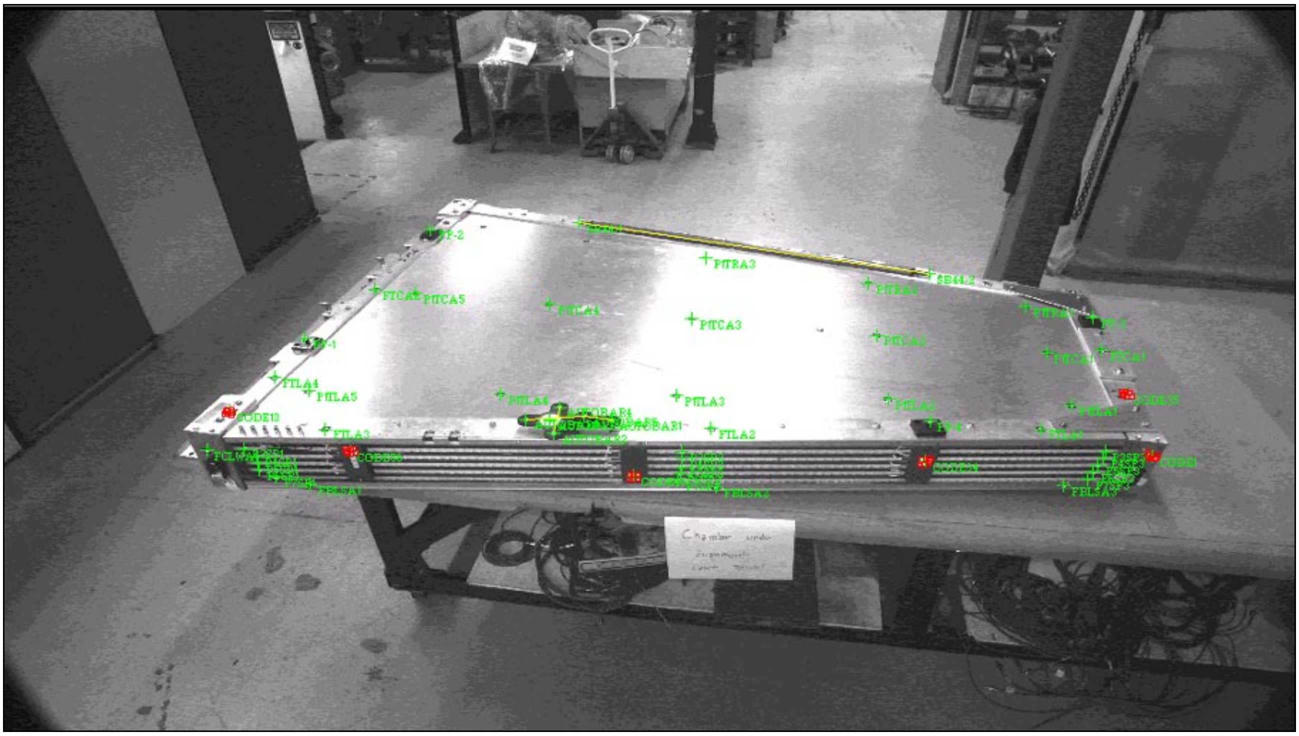

Figure 2 - Chamber on surface table

The mission specification called for targeting the top panel, one side and both ends of the seven panels (Fig. 2, 3 & 4), and the components of the external framework. The mission began with 126 targets; however, not all were visible during all epochs because of lifting fixture interference. The number of images acquired for each epoch varied from 45 to 57, according to the number of visible targets (Fig. 5).

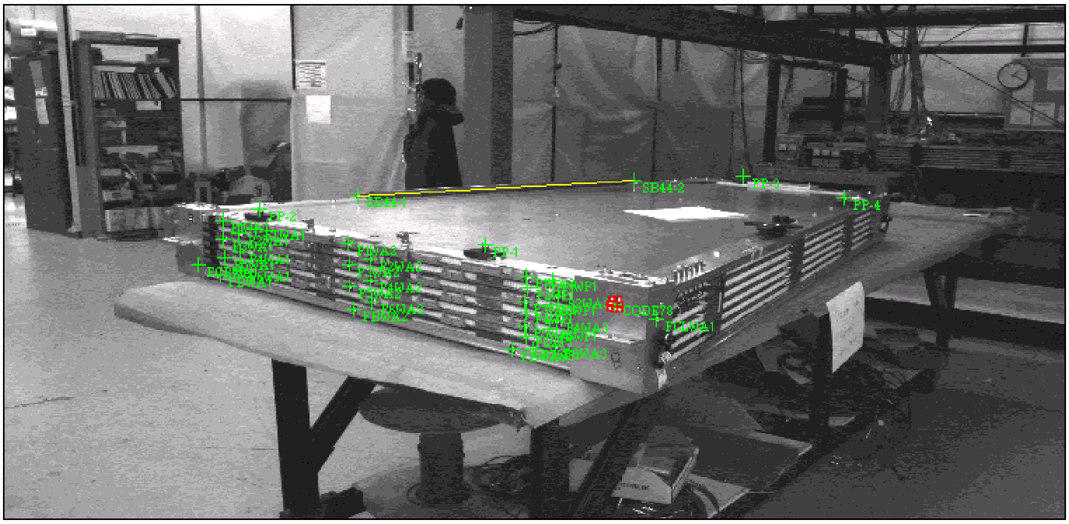

Figure 3 - Large end targets

A variety of targets were used, including 6mm adhesive, coded adhesive, ¼" pin, and 1/8" pin targets. The 1/8" pin targets were hot glued into the ends of the hex-board panels. A 44" Invar scale bar was used throughout.

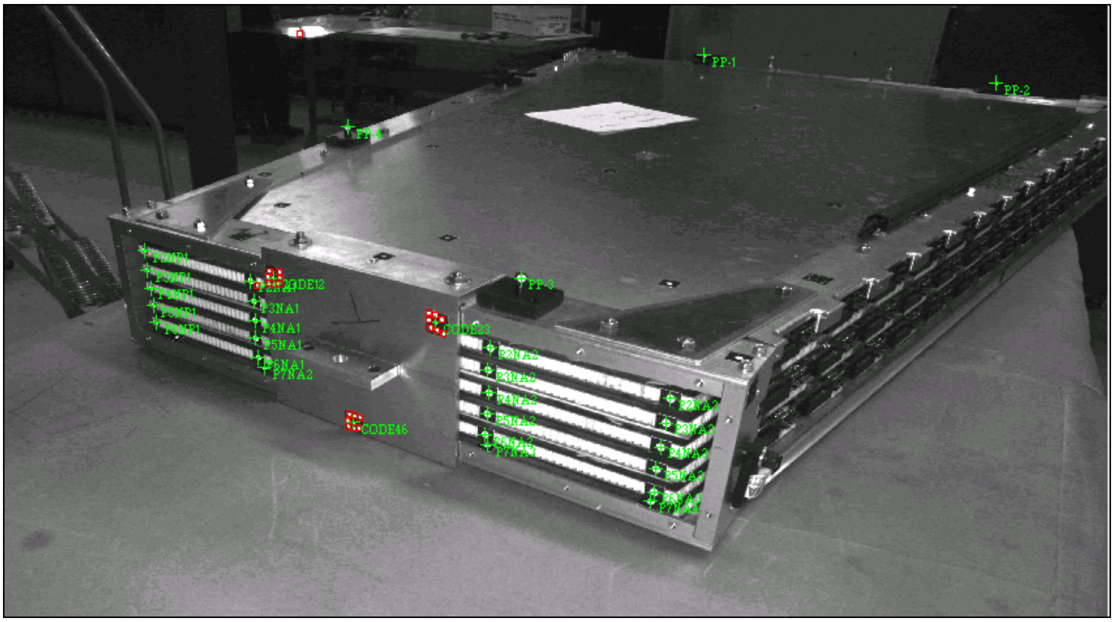

Figure 4 - Small end targets

Measurements took place over a period of four days, constrained mainly by the availability of crane coverage and rigging time.

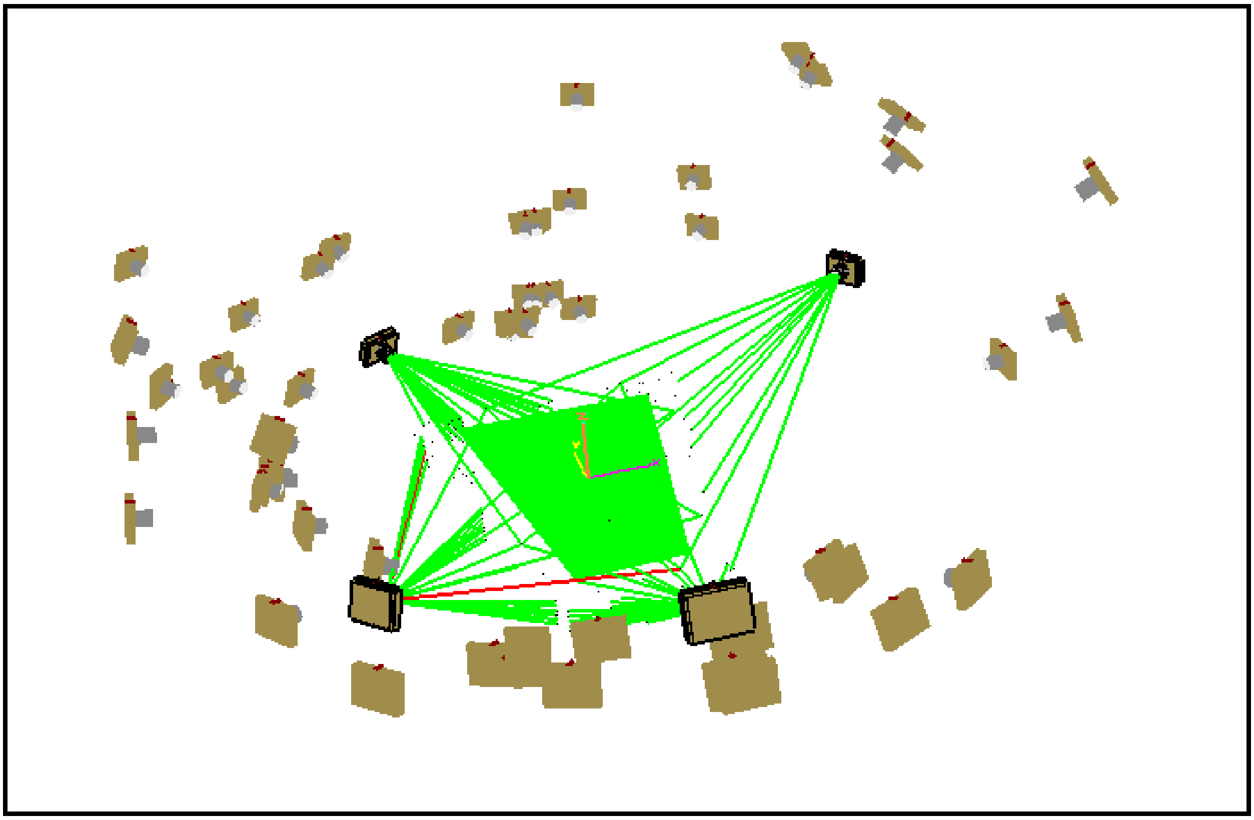

Figure 5 - Baseline 1 epoch camera stations

3. FINDINGS

The fifteen targets on the top surface of the panel defined the part reference frame. Each subsequent epoch was best-fit to these points. Figures 6 thru 14 show the residual vectors of each successive epoch, relative to Baseline 1. Figure 6 shows that the initial confirmation observations, with respect to Baseline 1, indicate a consistency better than 0.2mm. Indeed, an examination of the vector components would lead one to believe a small thermal expansion of the part took place; a reasonable conclusion since Baseline 1 was measured on the afternoon of Day 1, while Baseline 2 was measured early the following morning.

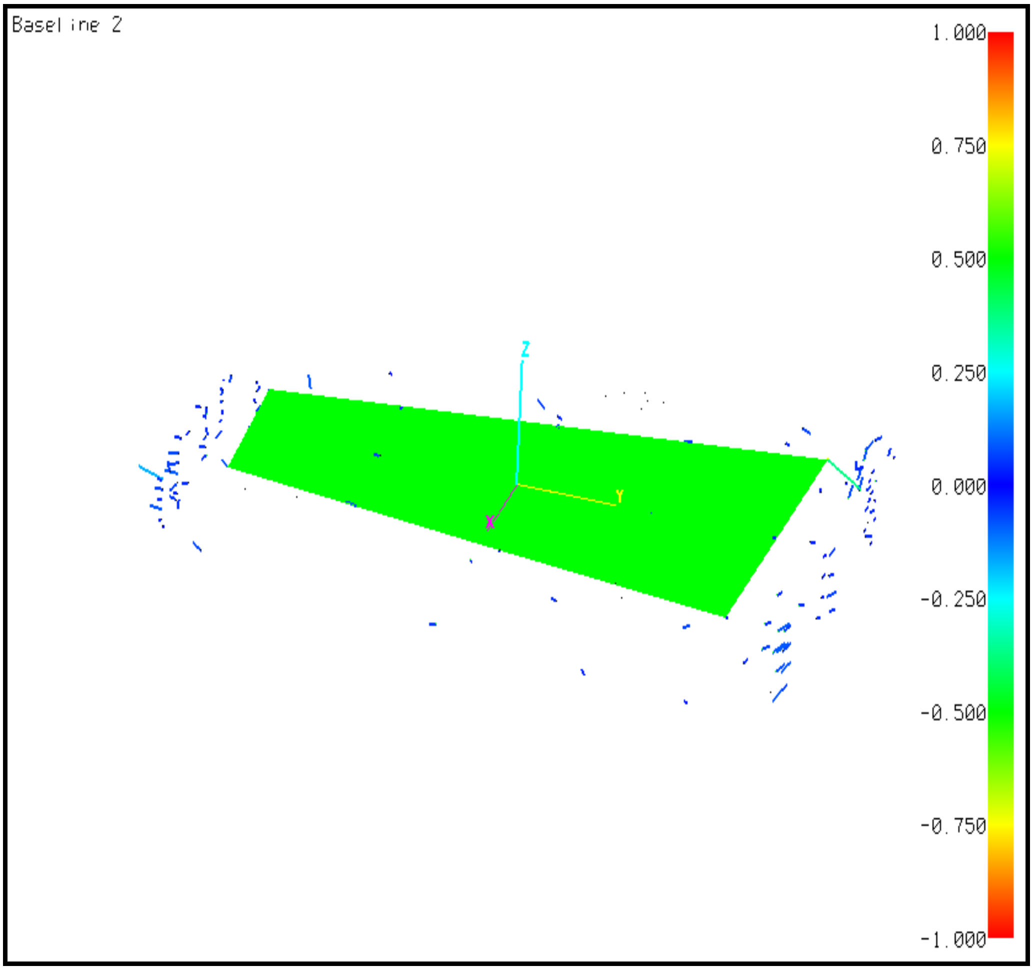

Figure 6 - Baseline 2 with Tolerance Bar in mm

The chamber was then transported by truck to an area with adequate vertical clearance in order to suspend the chamber in the desired orientations using an overhead crane. Figure 7 shows a distortion near the lifting points, which may be seen in Figure 3, near each edge of the chamber's large end. From Figures 7 thru 13, it is clear that one corner of the large end of the chamber was distorted, probably when it was taken in or out of the truck, or during the first lift. The two additional "flyers" are caused by poor geometry due to obstructions limiting the visibility of those points.

In Figure 8, the chamber was suspended using the near lifting point seen in Figure 3, and the lifting point seen at the center of the small end in Figure 4. Interestingly, this is the first evidence of the inelastic distortion mentioned above. In Figure 9, the chamber was suspended by the single lifting point at the small end.

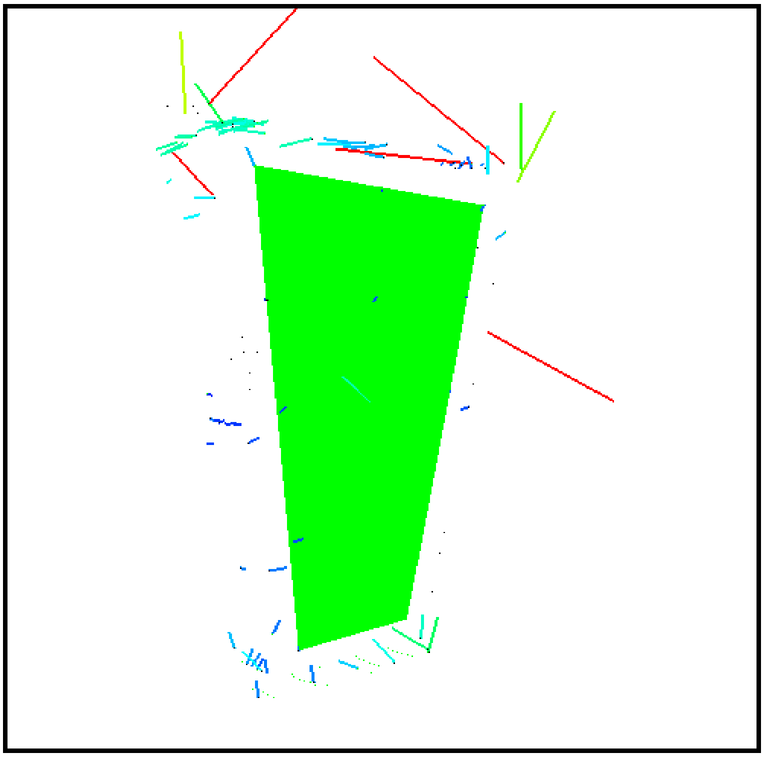

Figure 7 - 12 o'clock epoch

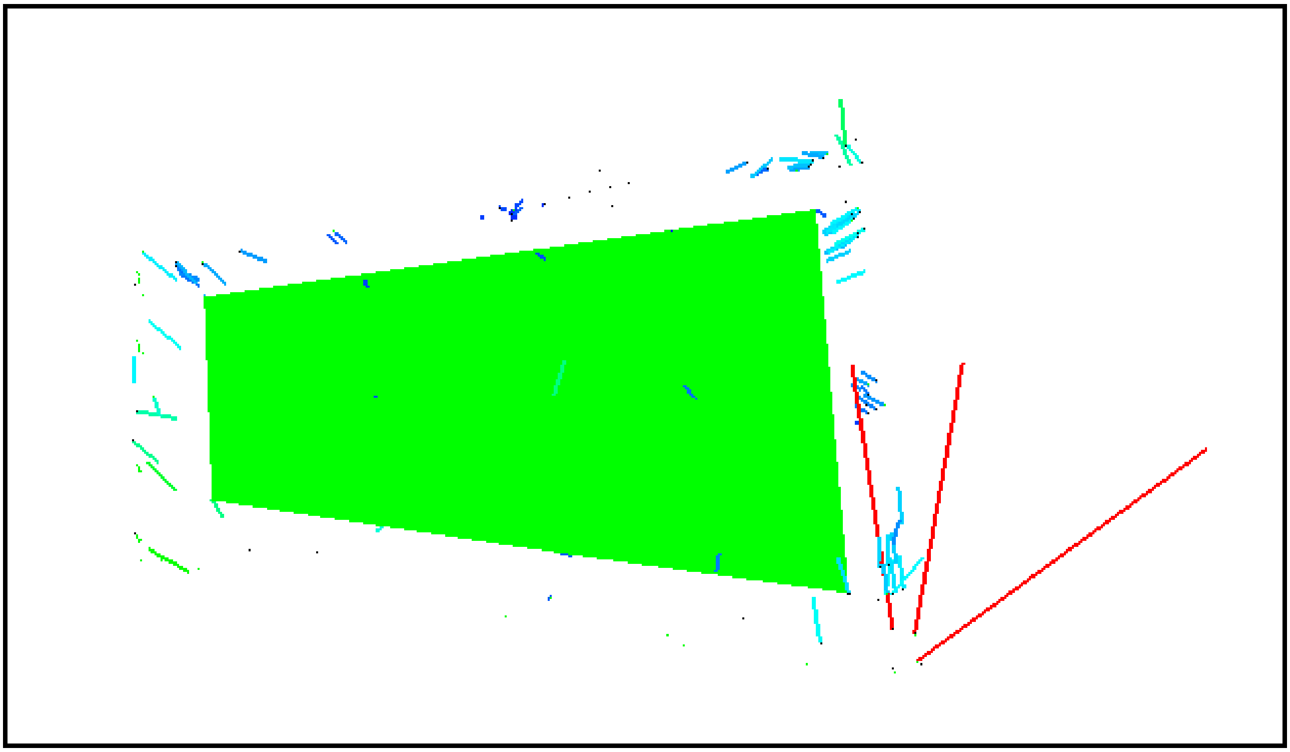

Figure 8 - 3 o'clock epoch

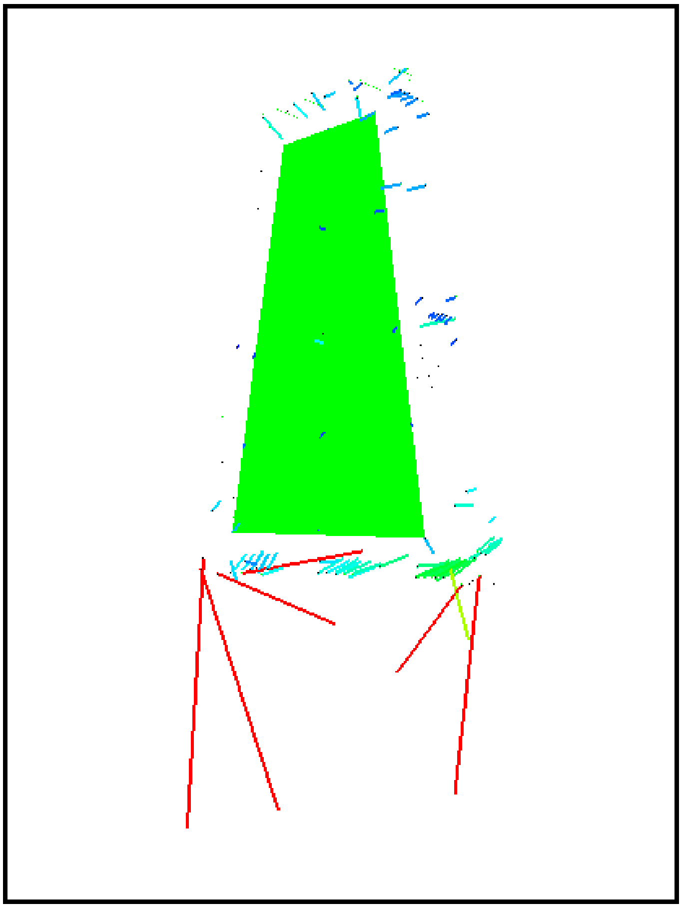

Figure 9 - 6 o'clock epoch

Figures 10 and 11 show the chamber when it is suspended in the service fixture. The fixture allows the chamber to be rotated about its long axis, supported by pins attached to the ends. The vectors in Figure 10 indicate the external framework does not hold the panels rigidly, thereby allowing the reference frame to droop relative to the attachment points.

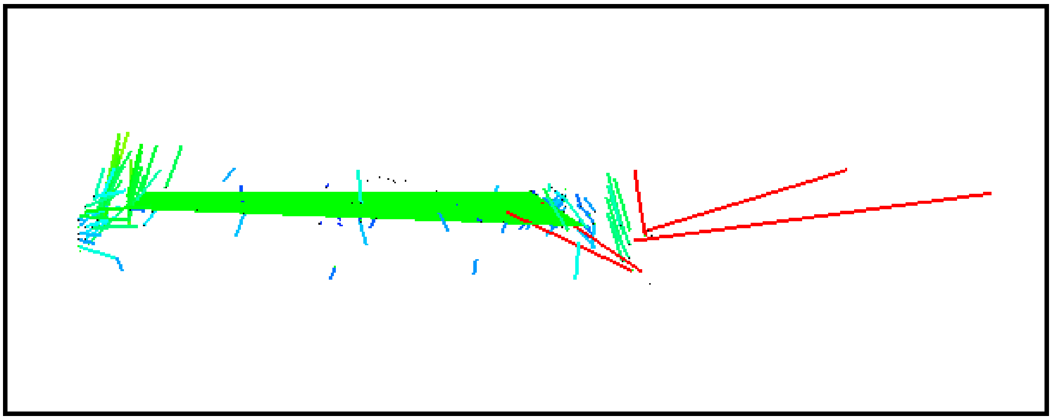

Figure 10 - 0° epoch

Figure 11 reveals the same problem but in the vertical direction.

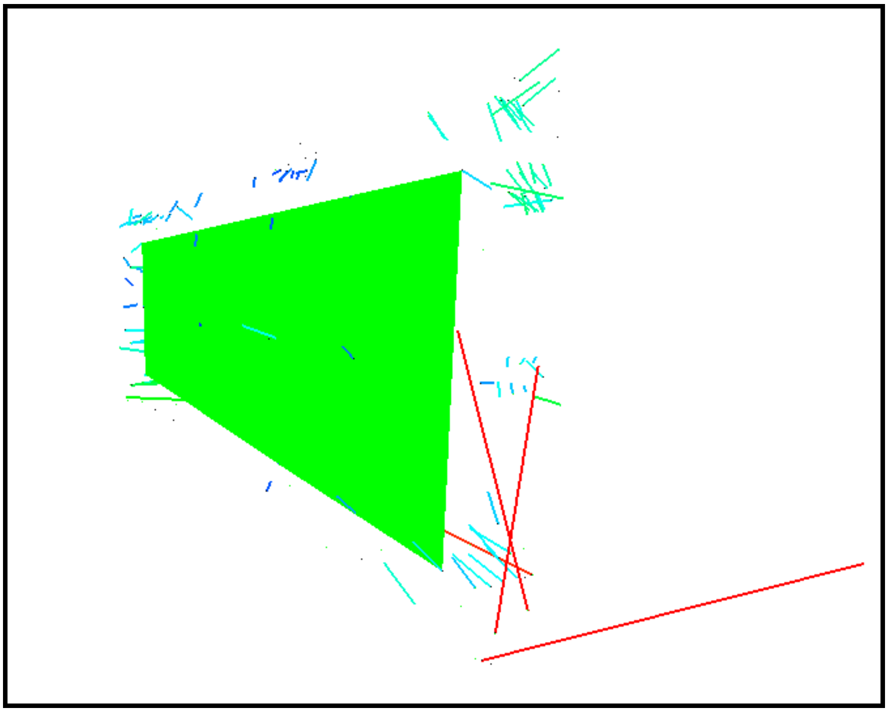

Figure 11 - 90° epoch

The post run measurements, Figures 12 and 13, were made on a surface table at the second facility. The work area was quite cramped, which gave a slightly poorer Plan Quality Factor. The Plan Quality Factor is a measure of the appropriateness of the number of exposure and the position and orientation of the camera stations. The effects of this can be seen in Figure 14, when compared to Figure 6. The distortion at the lifting point at the large end is still apparent, as is the likelihood that the small end external framework has not been replaced in the same location.

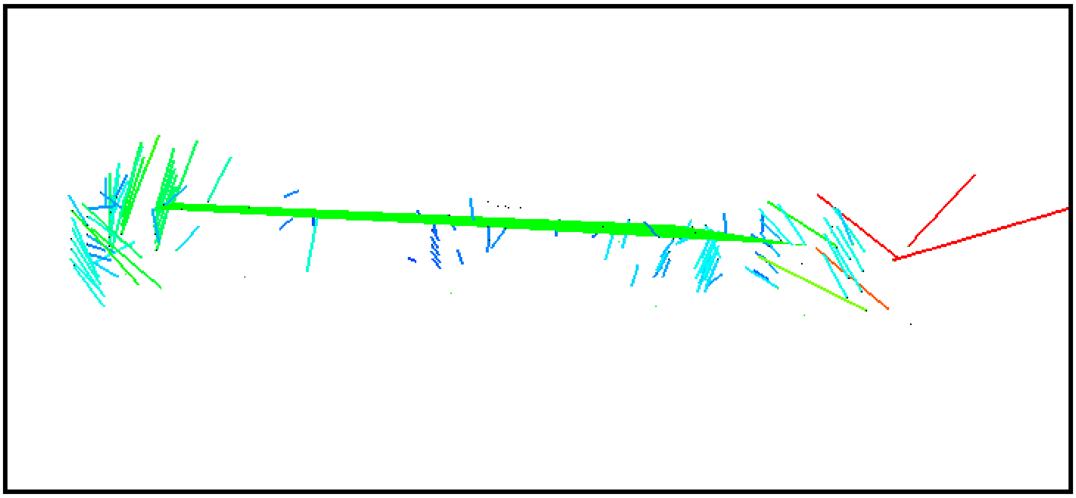

Figure 12 - Post run 1 epoch

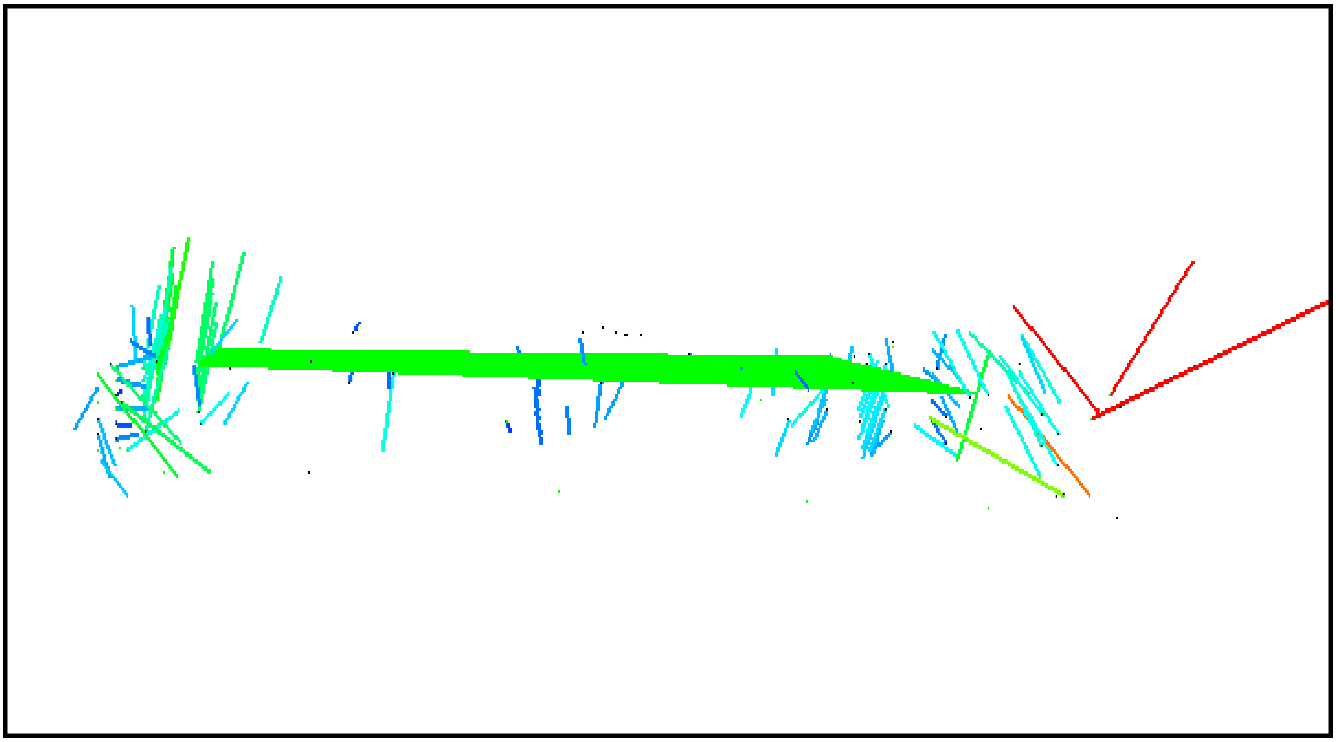

Figure 13 - Post run 2 epoch

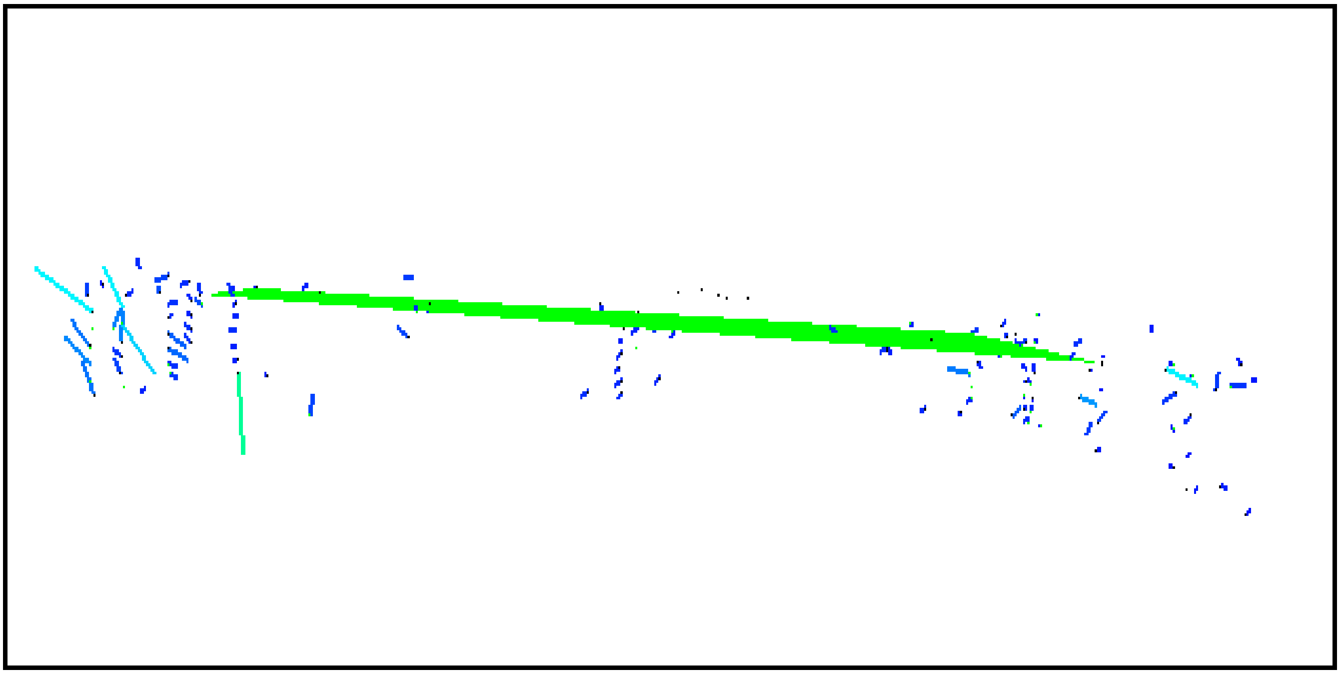

Figure 14 - Post run 1 - Post run 2 delta

4. CONCLUSIONS

Photogrammetry, more particularly digital videogrammetry, has shown that it can effectively service projects of this nature. When compared to optical tooling and laser tracker approaches, it is hard to imagine the full complement of difficulties videogrammetry allows one to avoid. Certainly the fact that neither the camera nor the part need to be stationary makes photogrammetry an obvious choice. Just the design, construction, and testing of a holding fixture that would keep the part stationary while a scale or retroreflector is placed at points of interest on the part, represents an enormous distinction. The fact that, once the targeting is complete, the entire measurement process requires no contact with the part represents an extremely valuable difference.

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