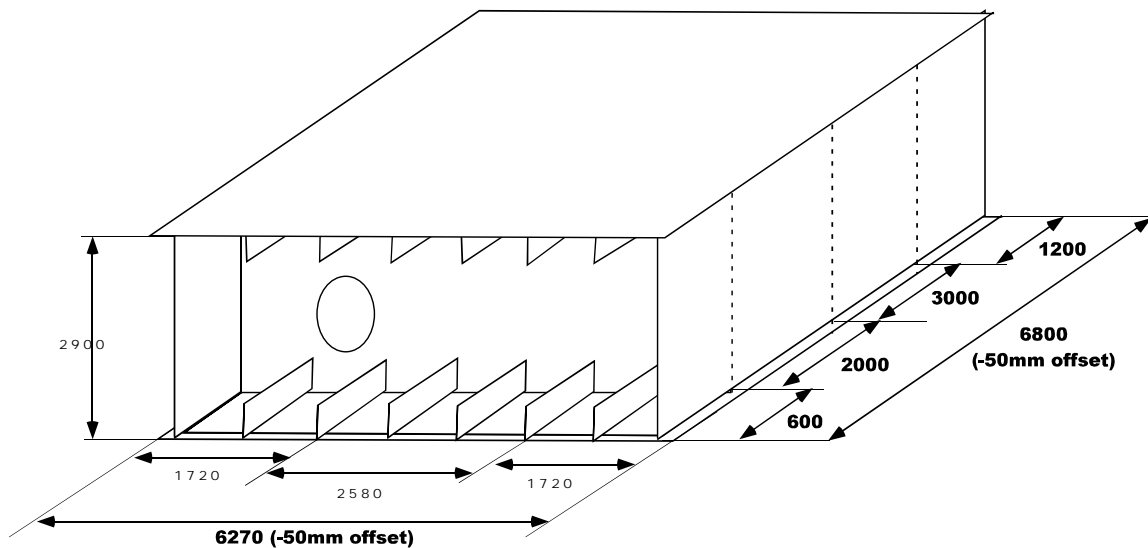


Report of Ship Block Test Measurements

Introduction:

The following is a summary of the videogrammetry work carried out at the XXX Shipyard facility in XXXXX on behalf of the XXXXXX. One object was measured as part of an evaluation study involving a number of different 3D measurement system manufacturers. The object in question is a large ship block (SR237) with approximate dimensions of (6.2 x 6.8 x 2.9m).



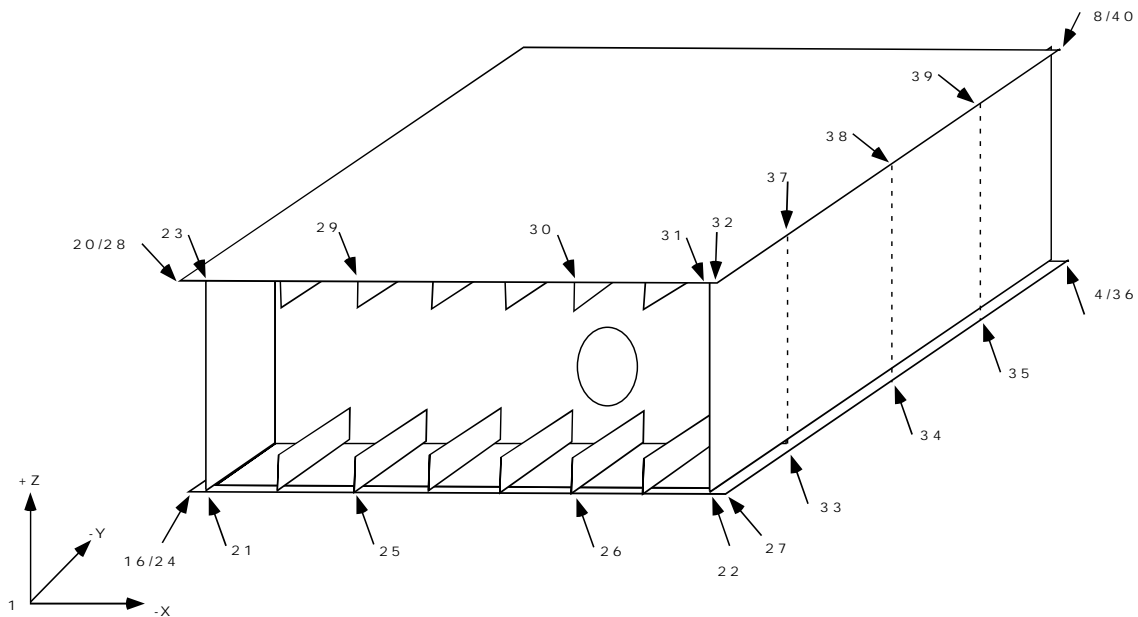
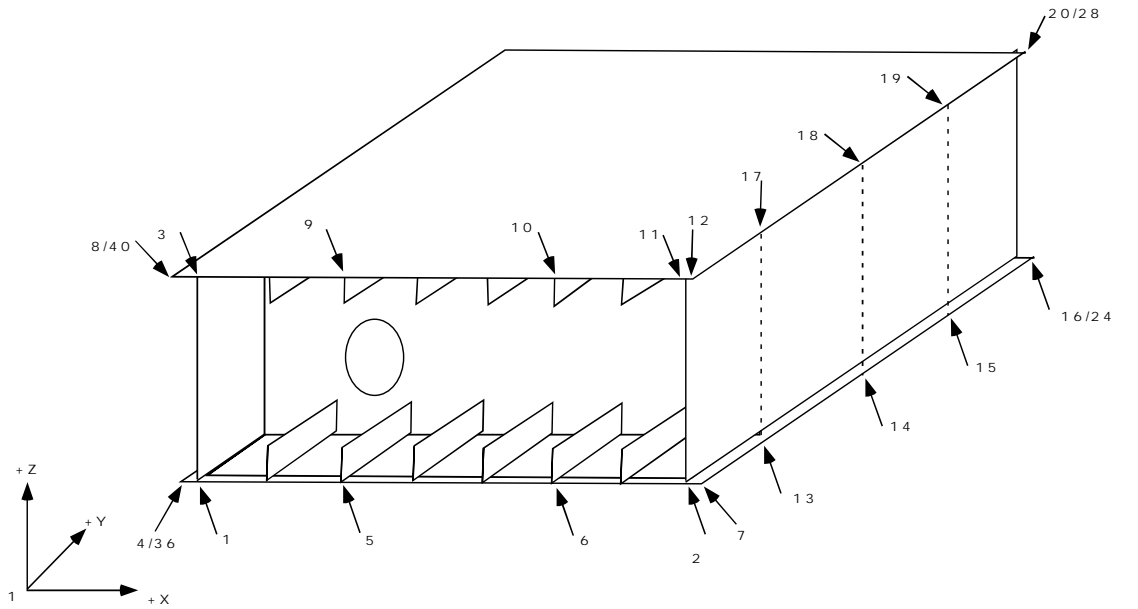
#All the dimensions shown are in mm.

#There is a 25mm offset between the edge of the block and the edge scribe lines.

Using the dimensional information supplied in the plans a “theoretical” file was created. This file contains the XYZ coordinates for each of the 36 points.

Primary Requirement:

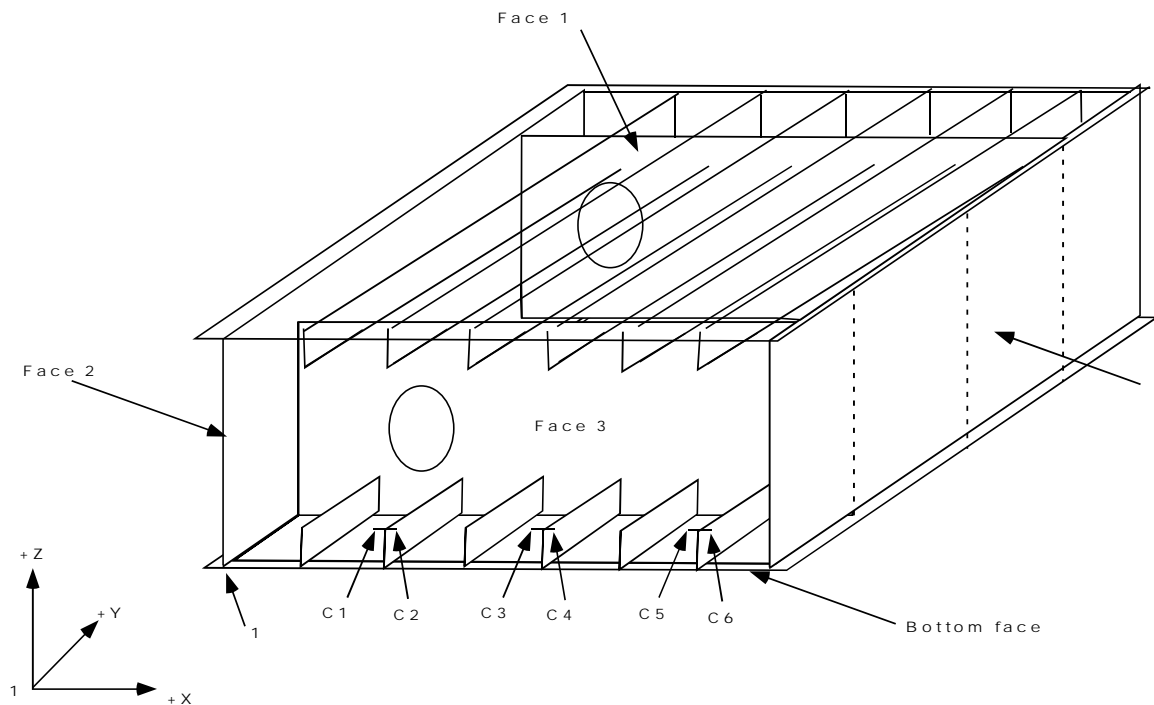
- To determine the XYZ location of 36 points at nominated locations on block SR237. These locations are signalled by the intersection of scribe lines. The numbering diagrams are shown below.



Additional Information:

To take advantage of the fact that videogrammetry can measure additional data with very little additional effort the following information was also collected: -

- Six corner points on transverse beams. (Refer to diagram below)
- Plane information on key surfaces. (Refer to diagram below)
- Distances between lower transverse beams
- Plane fit between ends of transverse beams.
- Lengths of transverse beams.



Documentation:

The following documentation is included in this report.

- A report outlining methodology and results.
- The XYZ coordinates of the 36 determined points.
- The XYZ coordinates of the 6 corners on the transverse beams
- Results of the least squares fit between V-STARs data, Sokkia data and nominal information from supplied plans of the ship block.
- Analysis of plane information gathered.
- Dimensional information on the transverse beams.
- Background information on the V-STARs system

Itinerary:

The itinerary undertaken was as follows: -

Sunday 13th September

| | |
|---------|---|
| 12:20pm | Introduction to measurement. |
| 12:45pm | Overview of V-Stars System |
| 1:00pm | Measurement of ship block (Targeting, photography and processing) |
| 2:00pm | Point re-labeling, target removal and initial discussion |
| 3:00pm | Measurement discussion |
| 3:45pm | Close of discussion. |

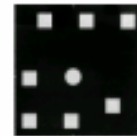
Measurement Procedure:

Targeting.

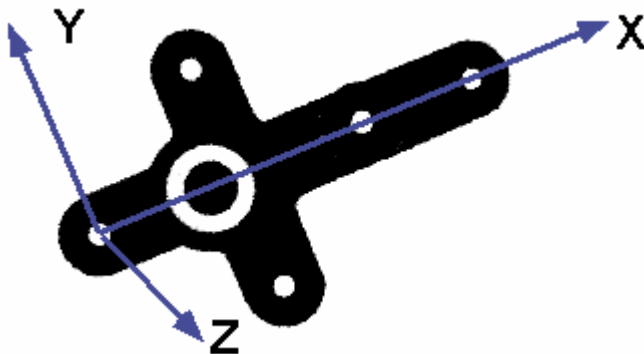
The key objective of this test measurement was to determine the coordinates of 36 scribe intersection points on the block. To complete this objective it was necessary to place offset targets on the points of interest. The targets used had an offset of 15.5mm.

In order to collect the additional information outlined earlier in the *Additional Information* section it was also necessary to target these points. Both offset targets and normal stick on dots were used to target these points.

To automate the process it was necessary to add "coded" targets to the block. These targets are automatically detected and help the software determine the location and orientation of the camera at the time the photo was taken. They also help tie the entire object into a uniform coordinate system.



The initial coordinates system and scale is determined via the AutoBar. The AutoBar used by the V-STARS system is a fixture with five targets arranged in the form of a cross. The target's known coordinates are used by the AutoMatch procedure to determine the camera's orientation relative to the AutoBar. The AutoBar is securely attached on or near the measured object, preferably in a highly visible location. The AutoBar's default coordinate system has its origin at target1 at the bottom of the AutoBar. The positive Y axis goes through point 3 at the top of the bar. The positive Z axis is up out of the AutoBar.



Photogrammetric measurements are initially dimensionless. An example of this is shown below. The picture of the first car could be a picture of a full-size car or of a match box model; there is no way to tell. However, if we know the size of something that is also in the picture, we can now say something about the size of the car.

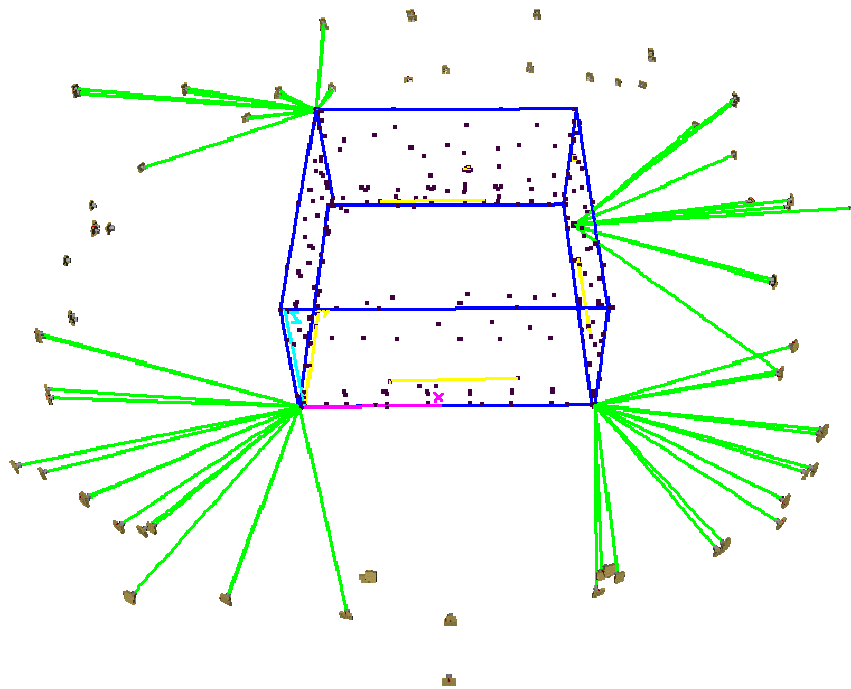


To scale a photogrammetric measurement, there must be at least one known distance. Four scale distances were used in the block measurement.

Photography

Once the object targeting was completed the object was photographed. Put simply, the aim of the photography is to record each of the targeted points in as many images as possible from as wide a range of angles as possible.

To improve the accuracy of the survey photos were taken both close to the ground and from a stepladder. The photography was completed in approximately 15 minutes. The camera station locations are shown in the diagram below. Also shown are some sample intersection angles to points of interest.

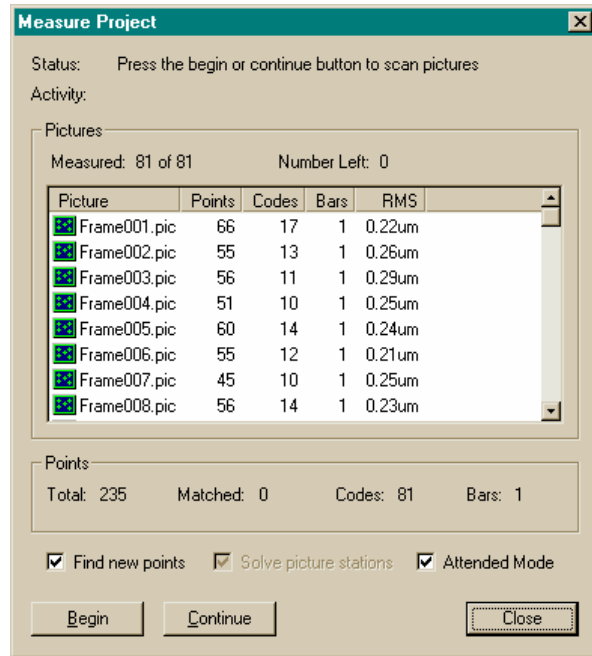


Approximately 80 photographs were taken. With planning this number can be reduced to approximately 40-60 depending on the measurement requirements.

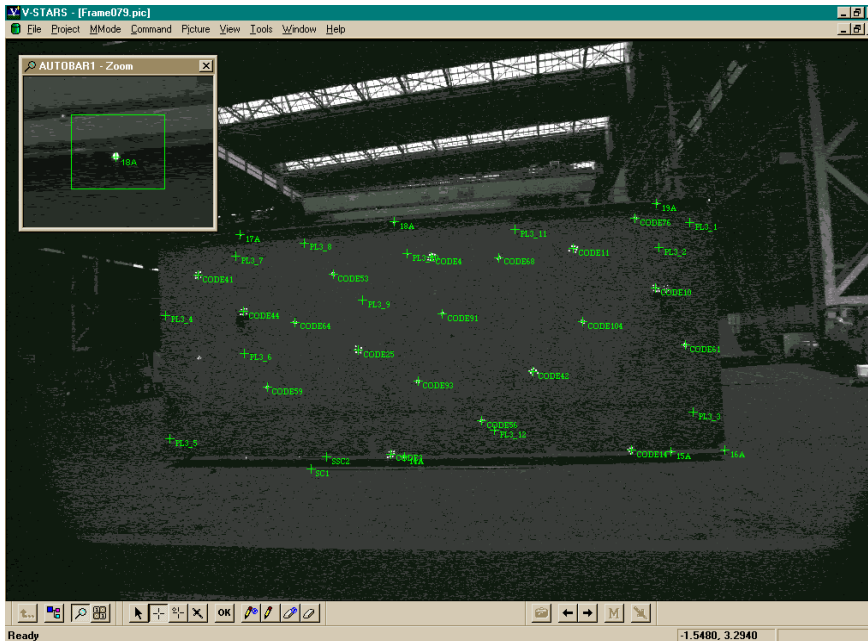
Processing

Once the photography was completed the images were transferred to the system laptop. The images are stored on a PCMCIA hard drive and V-STARS accesses these images directly from the drive.

Almost all of the measurement process is automated. The images are processed and the coordinates extracted by the "AutoMeasure" command. The AutoMeasure dialog box is shown on the right. The AutoMeasure command will open each of the images, determine the camera location, find new target points and finally adjust all the measurements in the "Bundle Adjustment". At the conclusion the user is left with the XYZ coordinates for all the target points in the network. The AutoMeasure procedure is very powerful as it allows the user to continue working while it processes the data. It also means that relatively unskilled workers can be used to process the data.



Seen below is an image taken as part of the ship block measurement.



The green text represents points that have been located in this particular image. Note that the image appears very dark and difficult to see. This is intentional as the best photogrammetric measurements are made on images that have dark backgrounds and bright targets. One of these targets is shown in the zoom window in the top left-hand corner.

Finally, the points can be listed. A typical point listing is shown below.

| Point Label | X | Y | Z | Sigma X | Sigma Y | Sigma Z | Offset | Description |
|-------------|----------|----------|----------|---------|---------|---------|--------|-------------|
| AUTOBAR2 | 3524.682 | 6195.547 | 1428.861 | 0.030 | 0.049 | 0.023 | 0.000 | |
| AUTOBAR3 | 3589.883 | 6197.177 | 1477.552 | 0.030 | 0.049 | 0.023 | 0.000 | |
| AUTOBAR4 | 3528.047 | 6196.112 | 1530.330 | 0.030 | 0.047 | 0.023 | 0.000 | |
| AUTOBAR5 | 3469.115 | 6207.352 | 1481.443 | 0.029 | 0.046 | 0.022 | 0.000 | |
| AUTOBAR6 | 3539.062 | 6196.136 | 1479.362 | 0.031 | 0.062 | 0.026 | 0.000 | |
| CODE1 | 2609.603 | 6293.420 | 1247.436 | 0.038 | 0.057 | 0.026 | 0.000 | |
| CODE2 | 6100.599 | 356.049 | -31.603 | 0.055 | 0.050 | 0.039 | 0.000 | |
| CODE3 | 6062.734 | 3011.476 | -33.794 | 0.064 | 0.038 | 0.033 | 0.000 | |
| CODE4 | 6047.898 | 3595.059 | 2347.634 | 0.067 | 0.039 | 0.030 | 0.000 | |
| CODE5 | 2103.673 | 6642.001 | -9.284 | 0.036 | 0.055 | 0.028 | 0.000 | |
| CODE6 | 5498.733 | 24.825 | -22.585 | 0.038 | 0.048 | 0.032 | 0.000 | |
| CODE7 | 21.836 | 3270.797 | 1548.500 | 0.064 | 0.036 | 0.025 | 0.000 | |
| CODE8 | -40.381 | 6226.860 | 1884.840 | 0.043 | 0.054 | 0.030 | 0.000 | |
| CODE9 | 3728.802 | 21.869 | 6.347 | 0.037 | 0.052 | 0.028 | 0.000 | |
| CODE10 | 6117.231 | 6116.006 | 1810.926 | 0.084 | 0.058 | 0.037 | 0.000 | |
| CODE11 | 6047.307 | 5249.134 | 2335.661 | 0.071 | 0.040 | 0.032 | 0.000 | |
| CODE12 | 2826.833 | 1049.729 | 1363.890 | 0.046 | 0.070 | 0.028 | 0.000 | |
| CODE13 | 30.721 | 693.396 | 2357.973 | 0.056 | 0.037 | 0.030 | 0.000 | |
| CODE14 | 6072.327 | 5756.822 | -48.387 | 0.048 | 0.043 | 0.032 | 0.000 | |
| CODE15 | -48.876 | 6112.853 | 1861.597 | 0.076 | 0.051 | 0.034 | 0.000 | |
| CODE16 | 1488.718 | 13.401 | 16.069 | 0.035 | 0.048 | 0.027 | 0.000 | |
| CODE17 | 3934.685 | 1043.411 | 1447.088 | 0.065 | 0.086 | 0.031 | 0.000 | |
| CODE18 | 4793.210 | 1162.673 | 2001.171 | 0.036 | 0.068 | 0.030 | 0.000 | |
| CODE19 | 1291.419 | 6186.719 | 2495.097 | 0.037 | 0.108 | 0.038 | 0.000 | |
| CODE20 | 4304.167 | 6286.084 | 1479.330 | 0.034 | 0.057 | 0.025 | 0.000 | |
| CODE21 | -54.004 | 360.405 | 38.184 | 0.047 | 0.046 | 0.033 | 0.000 | |
| CODE22 | 3.105 | 5431.769 | 173.950 | 0.070 | 0.040 | 0.034 | 0.000 | |
| CODE23 | 6127.105 | 6794.600 | 744.657 | 0.040 | 0.047 | 0.031 | 0.000 | |
| CODE24 | 4732.773 | 6185.035 | 2199.596 | 0.034 | 0.070 | 0.031 | 0.000 | |
| CODE25 | 6036.162 | 2662.363 | 1259.006 | 0.056 | 0.036 | 0.025 | 0.000 | |
| CODE26 | 1373.121 | 1160.180 | 1896.731 | 0.033 | 0.059 | 0.027 | 0.000 | |
| CODE27 | 6100.417 | 6233.463 | 1796.199 | 0.050 | 0.049 | 0.031 | 0.000 | |
| CODE28 | -26.347 | 2960.016 | 18.692 | 0.063 | 0.035 | 0.031 | 0.000 | |
| CODE29 | 223.797 | 6851.677 | -4.171 | 0.040 | 0.070 | 0.035 | 0.000 | |
| CODE30 | 6105.332 | 1111.604 | 1811.811 | 0.060 | 0.057 | 0.028 | 0.000 | |
| CODE31 | 4846.966 | 6735.351 | -43.906 | 0.036 | 0.056 | 0.031 | 0.000 | |
| CODE32 | 27.607 | 4972.430 | 2390.286 | 0.061 | 0.038 | 0.028 | 0.000 | |

Primary Results:

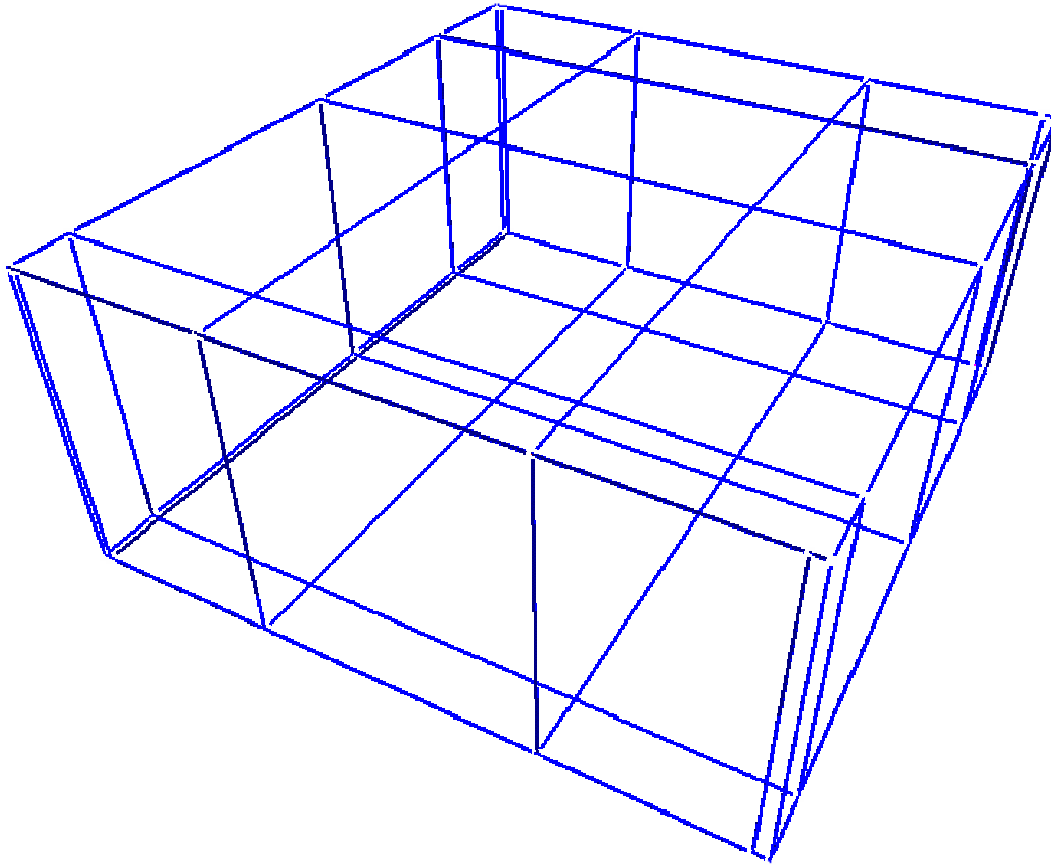
The following is a summary of the measurement statistics from the measurements.

| | | | |
|-----------------|------|---|------|
| No of photos | 81 | | |
| No of points | 235 | | |
| No of scales | 4 | | |
| Scale Agreement | 0.06 | | |
| RMS(mm) X,Y,Z | | X | 0.04 |
| | | Y | 0.05 |
| | | Z | 0.03 |

A full listing of V-STARS coordinates can be found in Appendix 1

A full listing of Design coordinates can also be found in Appendix 1

Based on the coordinates determined by V-STARS and the Sokkia system the distances between points were computed. These distances were compared to the design distances. The differences between the three data sets were also computed. The blue lines shown below indicate computed distances.



The distance results are shown in the table below.

| Start Point | End Point | Distances(mm) | | | Difference | | |
|-------------|-----------|---------------|---------|--------|------------------|-----------------|------------------|
| | | Design | V-STARS | Sokkia | Design - V-STARS | Design - Sokkia | V-STARS - Sokkia |
| 20 | 23 | 75.0 | 70.4 | 72.4 | 4.6 | 2.6 | -2.0 |
| 11 | 12 | 75.0 | 72.2 | 72.7 | 2.8 | 2.3 | -0.4 |
| 16 | 21 | 75.0 | 72.5 | 74.4 | 2.5 | 0.6 | -1.9 |
| 2 | 7 | 75.0 | 73.5 | 73.5 | 1.5 | 1.5 | 0.1 |
| 3 | 8 | 125.0 | 123.6 | 125.7 | 1.4 | -0.7 | -2.1 |
| 22 | 27 | 125.0 | 124.4 | 123.6 | 0.6 | 1.4 | 0.8 |
| 1 | 4 | 125.0 | 124.5 | 125.2 | 0.5 | -0.2 | -0.7 |
| 31 | 32 | 125.0 | 125.3 | 124.1 | -0.3 | 0.9 | 1.2 |
| 20 | 19 | 575.0 | 571.0 | 570.4 | 4.0 | 4.6 | 0.6 |
| 16 | 15 | 575.0 | 573.2 | 573.9 | 1.8 | 1.1 | -0.7 |
| 27 | 33 | 575.0 | 574.6 | 573.3 | 0.4 | 1.7 | 1.3 |
| 32 | 37 | 575.0 | 575.1 | 575.2 | -0.1 | -0.2 | -0.1 |
| 13 | 7 | 1175.0 | 1172.5 | 1172.1 | 2.5 | 2.9 | 0.4 |
| 35 | 4 | 1175.0 | 1172.8 | 1174.3 | 2.2 | 0.7 | -1.5 |
| 39 | 8 | 1175.0 | 1173.6 | 1175.1 | 1.4 | -0.1 | -1.5 |
| 17 | 12 | 1175.0 | 1200.8 | NA | -25.8 | NA | NA |
| 11 | 10 | 1720.0 | 1719.5 | 1720.9 | 0.5 | -0.9 | -1.4 |
| 2 | 6 | 1720.0 | 1720.0 | 1721.3 | 0.0 | -1.3 | -1.3 |
| 22 | 26 | 1720.0 | 1720.8 | 1721.8 | -0.8 | -1.8 | -0.9 |
| 21 | 25 | 1720.0 | 1720.9 | 1719.6 | -0.9 | 0.4 | 1.3 |
| 30 | 31 | 1720.0 | 1721.2 | 1720.8 | -1.2 | -0.8 | 0.4 |
| 23 | 29 | 1720.0 | 1721.2 | 1721.3 | -1.2 | -1.3 | -0.1 |
| 5 | 1 | 1720.0 | 1721.3 | 1721.4 | -1.3 | -1.4 | -0.1 |
| 9 | 3 | 1720.0 | 1722.1 | 1720.0 | -2.1 | 0.0 | 2.1 |
| 18 | 17 | 2000.0 | 1973.3 | NA | 26.7 | NA | NA |
| 38 | 39 | 2000.0 | 1999.8 | 1999.8 | 0.2 | 0.2 | 0.1 |
| 34 | 35 | 2000.0 | 2000.6 | 1999.7 | -0.6 | 0.3 | 0.9 |
| 14 | 13 | 2000.0 | 2001.0 | 2000.4 | -1.0 | -0.4 | 0.5 |
| 30 | 29 | 2580.0 | 2580.6 | 2580.6 | -0.6 | -0.6 | 0.0 |
| 25 | 26 | 2580.0 | 2581.7 | 2582.4 | -1.7 | -2.4 | -0.7 |
| 9 | 10 | 2580.0 | 2581.8 | 2581.5 | -1.8 | -1.5 | 0.2 |
| 5 | 6 | 2580.0 | 2582.5 | 2581.7 | -2.5 | -1.7 | 0.8 |
| 35 | 39 | 2900.0 | 2892.7 | 2892.8 | 7.3 | 7.2 | -0.1 |
| 27 | 32 | 2900.0 | 2894.2 | 2893.9 | 5.8 | 6.1 | 0.2 |
| 33 | 37 | 2900.0 | 2894.2 | 2893.6 | 5.8 | 6.4 | 0.7 |
| 4 | 8 | 2900.0 | 2894.7 | 2894.3 | 5.3 | 5.7 | 0.4 |
| 34 | 38 | 2900.0 | 2895.0 | 2895.3 | 5.0 | 4.7 | -0.3 |
| 15 | 19 | 2900.0 | 2895.0 | 2894.9 | 5.0 | 5.1 | 0.2 |
| 13 | 17 | 2900.0 | 2895.7 | NA | 4.3 | NA | NA |
| 14 | 18 | 2900.0 | 2896.2 | 2895.9 | 3.8 | 4.1 | 0.3 |
| 16 | 20 | 2900.0 | 2897.5 | 2897.8 | 2.5 | 2.2 | -0.3 |
| 7 | 12 | 2900.0 | 2898.1 | 2897.7 | 1.9 | 2.3 | 0.4 |
| 22 | 31 | 2900.0 | 2898.3 | 2897.2 | 1.7 | 2.8 | 1.1 |
| 1 | 3 | 2900.0 | 2898.5 | 2898.3 | 1.5 | 1.7 | 0.2 |
| 21 | 23 | 2900.0 | 2898.7 | 2899.2 | 1.3 | 0.8 | -0.4 |

| Start Point | End Point | Distances(mm) | | | Difference | | |
|-------------|-----------|---------------|---------|----------------|------------------|-----------------|------------------|
| | | Design | V-STARS | Sokkia | Design - V-STARS | Design - Sokkia | V-STARS - Sokkia |
| 2 | 11 | 2900.0 | 2899.5 | 2898.9 | 0.5 | 1.1 | 0.7 |
| 26 | 30 | 2900.0 | 2904.3 | 2904.6 | -4.3 | -4.6 | -0.2 |
| 25 | 29 | 2900.0 | 2905.4 | 2905.8 | -5.4 | -5.8 | -0.4 |
| 6 | 10 | 2900.0 | 2905.5 | 2905.8 | -5.5 | -5.8 | -0.3 |
| 5 | 9 | 2900.0 | 2905.8 | 2906.1 | -5.8 | -6.1 | -0.4 |
| 33 | 34 | 3000.0 | 2999.5 | 3001.6 | 0.5 | -1.6 | -2.1 |
| 15 | 14 | 3000.0 | 2999.6 | 3000.2 | 0.4 | -0.2 | -0.7 |
| 37 | 38 | 3000.0 | 3001.3 | 3001.7 | -1.3 | -1.7 | -0.4 |
| 19 | 18 | 3000.0 | 3001.7 | 3001.7 | -1.7 | -1.7 | 0.0 |
| 37 | 19 | 6220.0 | 6217.6 | 6218.7 | 2.4 | 1.3 | -1.1 |
| 20 | 32 | 6220.0 | 6218.6 | 6219.1 | 1.4 | 0.9 | -0.4 |
| 8 | 12 | 6220.0 | 6219.2 | 6219.8 | 0.8 | 0.2 | -0.7 |
| 39 | 17 | 6220.0 | 6219.3 | NA | 0.7 | NA | NA |
| 38 | 18 | 6220.0 | 6219.6 | 6220.7 | 0.4 | -0.7 | -1.1 |
| 27 | 16 | 6220.0 | 6220.3 | 6221.8 | -0.3 | -1.8 | -1.4 |
| 33 | 15 | 6220.0 | 6220.3 | 6213.3 | -0.3 | 6.7 | 7.0 |
| 13 | 35 | 6220.0 | 6221.8 | 6222.1 | -1.8 | -2.1 | -0.3 |
| 7 | 4 | 6220.0 | 6221.8 | 6222.6 | -1.8 | -2.6 | -0.8 |
| 34 | 14 | 6220.0 | 6222.5 | 6222.7 | -2.5 | -2.7 | -0.2 |
| 29 | 10 | 6750.0 | 6746.0 | 6746.5 | 4.0 | 3.5 | -0.4 |
| 16 | 7 | 6750.0 | 6746.2 | 6746.6 | 3.8 | 3.4 | -0.4 |
| 30 | 9 | 6750.0 | 6746.6 | 6748.6 | 3.4 | 1.4 | -2.0 |
| 12 | 20 | 6750.0 | 6746.8 | 6746.5 | 3.2 | 3.5 | 0.4 |
| 25 | 6 | 6750.0 | 6747.0 | 6748.7 | 3.0 | 1.3 | -1.7 |
| 26 | 5 | 6750.0 | 6747.1 | 6748.4 | 2.9 | 1.6 | -1.3 |
| 4 | 27 | 6750.0 | 6747.5 | 6748.9 | 2.5 | 1.1 | -1.4 |
| 32 | 8 | 6750.0 | 6749.8 | 6751.7 | 0.2 | -1.7 | -1.9 |
| | | | | Average | 2.2 | 2.2 | 0.9 |
| | | | | Std Dev | 1.8 | 1.9 | 1.0 |

Notes:

The distance between 17-12 and 18-17 shows a discrepancy of 25mm. This indicates that the target was placed incorrectly or that the point 17 is incorrectly marked.

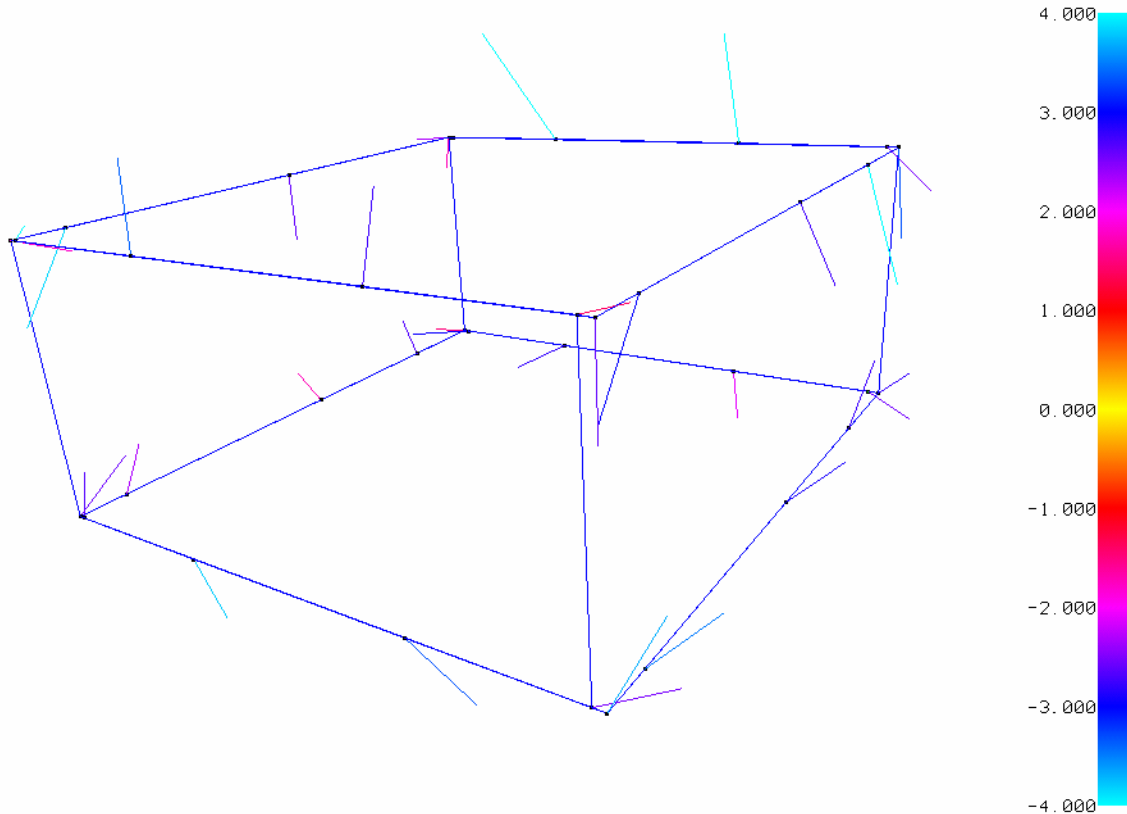
There is a high level of agreement between the V-STARS data and the Sokkia data. The average of the differences was 0.9mm. The other statistical information indicates that the V-STARS and Sokkia data agree to about the same degree with the Design data.

It is also possible to fit the Design data and Sokkia data to the V-STARS data using a Least Squares transformation. The results of this transformation are shown below.

Fit of V-STARS data to Design Coordinates

| (mm) | X | Y | Z | Total |
|------|-----|-----|-----|-------|
| RMS | 1.6 | 1.2 | 2.6 | 3.0 |

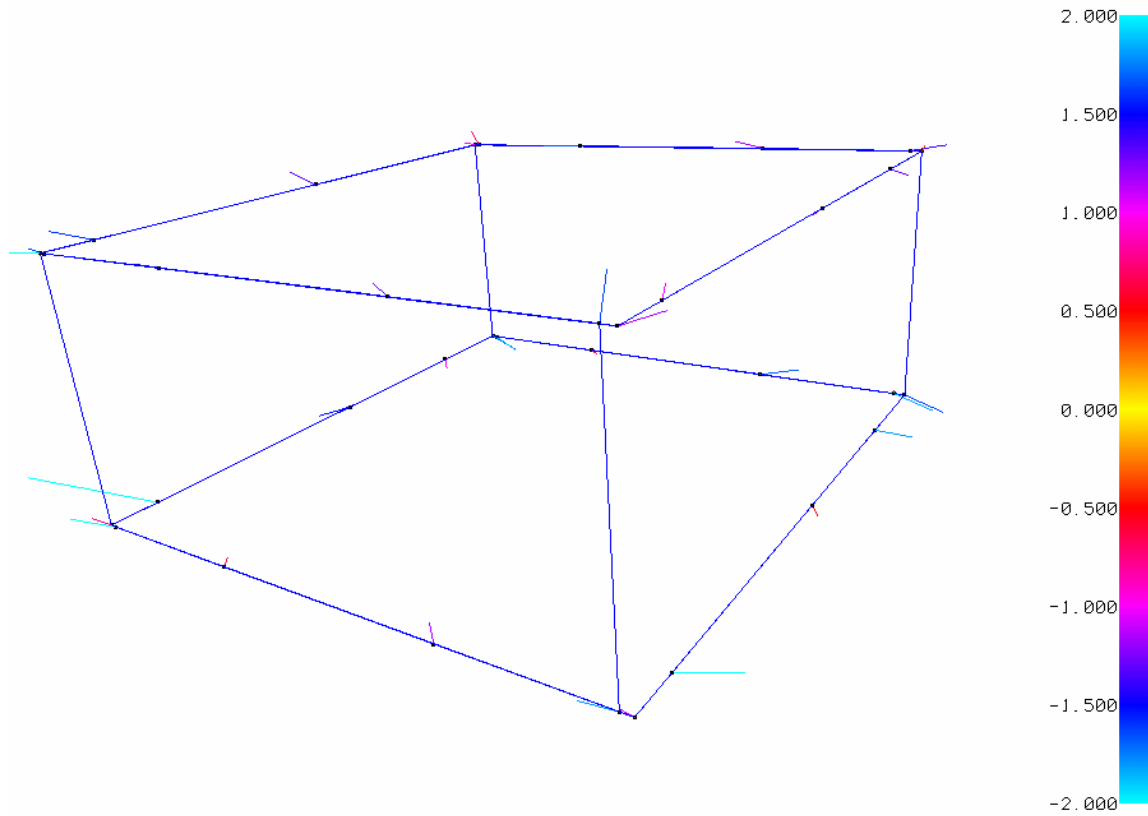
The full results of the transformation can be found in Appendix 2
The results are represented graphically below.



Fit of V-STARS data to Sokkia Coordinates

| (mm) | X | Y | Z | Total |
|------|-----|-----|-----|-------|
| RMS | 1.0 | 0.9 | 0.4 | 1.4 |

The full results of the transformation can be found in Appendix 2
The results are represented graphically below.



Once again the data indicates that the V-STARS and Sokkia data fit very well considering that the data was collected at different times, using different targets and in different temperatures.

Additional Results:

The following is a result summary for the additional measurement information collected.

Plane Data

A total of six planes were fit to the collected data. These are shown in the diagram at the start of this report. The six planes were named face1, face2, face3, face4, bottom face and top face respectively. The results of the plane fits are shown below.

| Face | Final RMS(mm) |
|-------------|---------------|
| Bottom Face | 1.8 |
| Face 1 | 1.1 |
| Face 2 | 1.3 |
| Face 3 | 0.8 |
| Face 4 | 1.8 |
| Top Face | 2.5 |

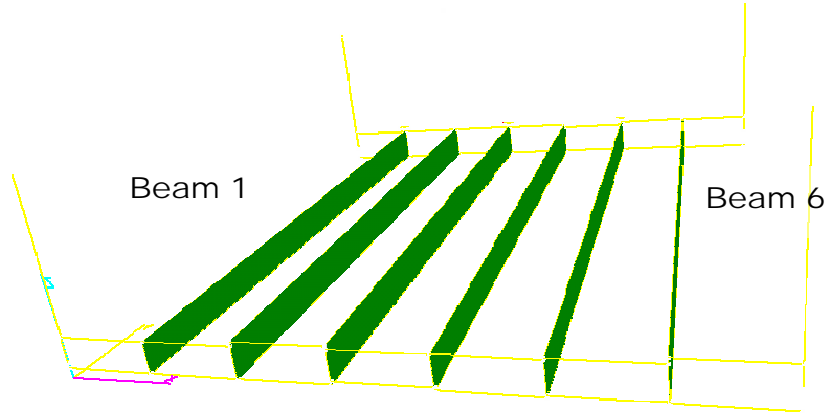
Using these planes it is possible to compute the perpendicularity and parallelism of the planes. These results are shown below.

| Face | Angle° |
|------------------|--------|
| Face 1 to Face 2 | 89.96 |
| Face 2 to Face 3 | 89.99 |
| Face 3 to Face 4 | 89.96 |
| Face 1 to Face 4 | 89.99 |
| Face 1 to Face 3 | 0.13 |
| Face 2 to Face 4 | 0.07 |
| Bottom to Top | 0.02 |
| Bottom to Face 1 | 89.97 |
| Bottom to Face 2 | 89.99 |
| Bottom to Face 3 | 89.85 |
| Bottom to Face 4 | 89.97 |
| Face 4 to Top | 89.95 |
| Face 3 to Top | 89.85 |
| Face 2 to Top | 89.99 |
| Face 1 to Top | 89.98 |

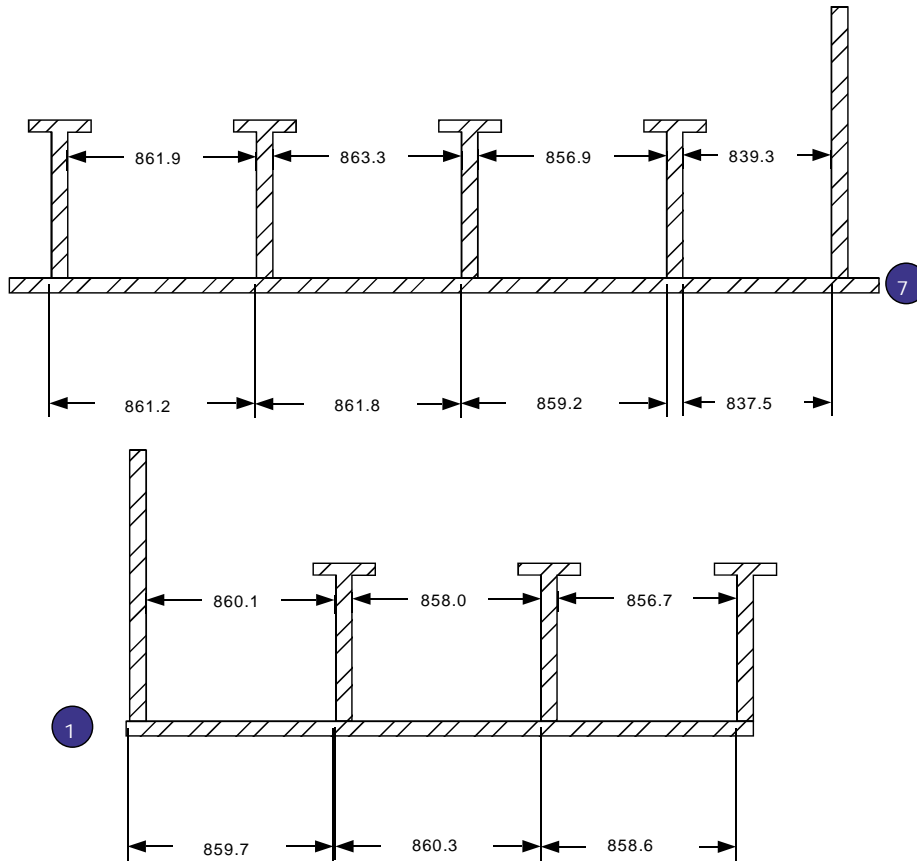
Transverse Data

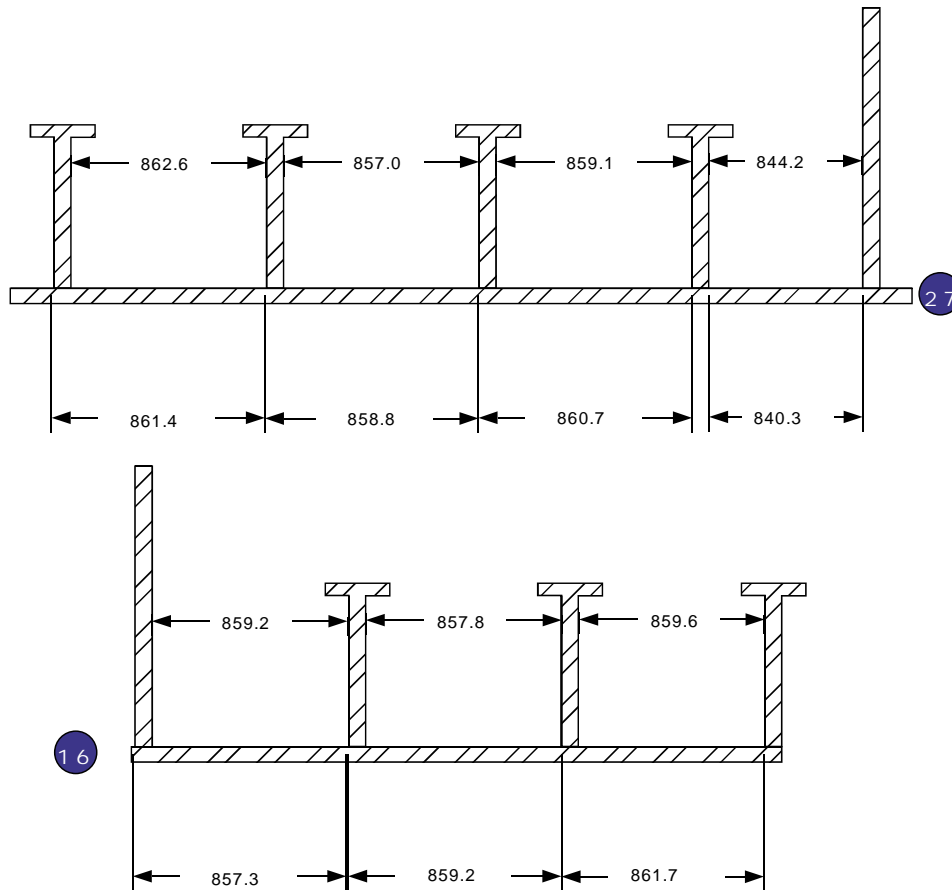
Various information was also collected on the transverse beams.

A diagram of the beams is shown below.



Distances were measured at a point near the top of the beam and at a point near the bottom of the beam. The diagram below shows these distances for both sides of the block.





The length of the beams was also computed. These are tabulated below: -

| Beam | Length (mm) |
|------|-------------|
| 1 | 6800.5 |
| 2 | 6800.6 |
| 3 | 6801.6 |
| 4 | 6802.2 |
| 5 | 6801.5 |
| 6 | 6801.4 |

Concluding Remarks

This ship block demonstration has clearly shown that videogrammetry is a very powerful measurement tool in the ship building industry. The results of the measurement are very accurate and more importantly were produced quickly. The time taken to complete the measurement can be significantly improved via the used of the correct targets and through adequate planning.

GSI and Leica would like to thank the XXX for welcoming us into their facility and the XXXX for the opportunity to present our system to them. We will be happy to discuss the results of this report or any other aspect of the technology presented.

Appendix 1 – Coordinate Data

V-STARS Coordinates (mm)

| Point | Coordinate | | | Accuracy Estimate | | |
|----------------|------------|--------|--------|-------------------|-------------|-------------|
| | X | Y | Z | SX | SY | SZ |
| 1 | 4.1 | 2.9 | -9.0 | 0.04 | 0.05 | 0.03 |
| 2 | 6027.6 | 4.0 | -67.0 | 0.04 | 0.05 | 0.03 |
| 3 | 32.2 | 13.7 | 2889.3 | 0.04 | 0.06 | 0.04 |
| 4 | -120.4 | 3.0 | -5.9 | 0.04 | 0.04 | 0.03 |
| 5 | 1725.3 | 2.3 | -27.3 | 0.03 | 0.05 | 0.03 |
| 6 | 4307.7 | 2.9 | -51.6 | 0.03 | 0.05 | 0.03 |
| 7 | 6101.1 | 3.6 | -67.4 | 0.04 | 0.05 | 0.04 |
| 8 | -91.5 | 13.3 | 2888.6 | 0.05 | 0.05 | 0.04 |
| 9 | 1754.2 | 13.9 | 2878.2 | 0.03 | 0.05 | 0.03 |
| 10 | 4335.8 | 15.2 | 2853.8 | 0.04 | 0.06 | 0.03 |
| 11 | 6055.2 | 14.0 | 2832.4 | 0.04 | 0.06 | 0.04 |
| 12 | 6127.4 | 15.1 | 2830.6 | 0.06 | 0.07 | 0.04 |
| 13 | 6101.7 | 1176.0 | -71.2 | 0.05 | 0.04 | 0.03 |
| 14 | 6100.6 | 3177.0 | -79.1 | 0.06 | 0.04 | 0.03 |
| 15 | 6097.4 | 6176.5 | -89.7 | 0.05 | 0.04 | 0.04 |
| 16 | 6097.9 | 6749.7 | -92.4 | 0.05 | 0.05 | 0.04 |
| 17 | 6126.6 | 1215.9 | 2824.1 | 0.06 | 0.04 | 0.03 |
| 18 | 6126.6 | 3189.1 | 2817.0 | 0.06 | 0.04 | 0.03 |
| 19 | 6125.2 | 6190.8 | 2805.2 | 0.05 | 0.05 | 0.03 |
| 20 | 6125.0 | 6761.9 | 2804.9 | 0.05 | 0.05 | 0.04 |
| 21 | 6025.4 | 6750.1 | -92.7 | 0.04 | 0.05 | 0.04 |
| 22 | 2.2 | 6750.1 | -34.0 | 0.04 | 0.05 | 0.03 |
| 23 | 6054.6 | 6760.7 | 2805.9 | 0.05 | 0.05 | 0.04 |
| 25 | 4304.5 | 6749.8 | -80.1 | 0.03 | 0.05 | 0.03 |
| 26 | 1722.9 | 6749.3 | -54.6 | 0.03 | 0.05 | 0.03 |
| 27 | -122.1 | 6750.5 | -30.8 | 0.04 | 0.05 | 0.04 |
| 29 | 4333.5 | 6761.2 | 2825.1 | 0.03 | 0.05 | 0.03 |
| 30 | 1753.0 | 6760.4 | 2849.5 | 0.03 | 0.05 | 0.03 |
| 31 | 31.8 | 6760.5 | 2864.1 | 0.04 | 0.05 | 0.04 |
| 32 | -93.4 | 6763.1 | 2863.2 | 0.04 | 0.05 | 0.04 |
| 33 | -122.6 | 6175.9 | -29.2 | 0.05 | 0.05 | 0.03 |
| 34 | -121.6 | 3176.4 | -18.0 | 0.06 | 0.04 | 0.03 |
| 35 | -119.8 | 1175.8 | -9.5 | 0.05 | 0.04 | 0.03 |
| 37 | -92.1 | 6188.0 | 2864.9 | 0.04 | 0.05 | 0.04 |
| 38 | -92.7 | 3186.7 | 2876.9 | 0.06 | 0.04 | 0.03 |
| 39 | -92.4 | 1186.9 | 2883.0 | 0.05 | 0.04 | 0.03 |
| C1 | 4391.3 | 6777.0 | 499.3 | 0.04 | 0.05 | 0.03 |
| C2 | 4238.7 | 6776.5 | 503.2 | 0.04 | 0.05 | 0.03 |
| C3 | 2668.1 | 6775.1 | 517.1 | 0.04 | 0.05 | 0.03 |
| C4 | 2519.4 | 6774.2 | 520.1 | 0.04 | 0.05 | 0.02 |
| C5 | 952.7 | 6772.3 | 533.4 | 0.03 | 0.05 | 0.03 |
| C6 | 804.9 | 6771.9 | 536.2 | 0.04 | 0.05 | 0.03 |
| Average | | | | 0.04 | 0.05 | 0.03 |

| | | | | | | |
|------------|--|--|--|-------------|-------------|-------------|
| Max | | | | 0.06 | 0.07 | 0.04 |
|------------|--|--|--|-------------|-------------|-------------|

Design Coordinates (mm) (Derived from plans)

| Point | Coordinate | | |
|-------|------------|------|------|
| | X | Y | Z |
| 1 | 0 | 0 | 0 |
| 2 | 6020 | 0 | 0 |
| 3 | 0 | 0 | 2900 |
| 4 | -125 | 0 | 0 |
| 5 | 1720 | 0 | 0 |
| 6 | 4300 | 0 | 0 |
| 7 | 6095 | 0 | 0 |
| 8 | -125 | 0 | 2900 |
| 9 | 1720 | 0 | 2900 |
| 10 | 4300 | 0 | 2900 |
| 11 | 6020 | 0 | 2900 |
| 12 | 6095 | 0 | 2900 |
| 13 | 6095 | 1175 | 0 |
| 14 | 6095 | 3175 | 0 |
| 15 | 6095 | 6175 | 0 |
| 16 | 6095 | 6750 | 0 |
| 17 | 6095 | 1175 | 2900 |
| 18 | 6095 | 3175 | 2900 |
| 19 | 6095 | 6175 | 2900 |
| 20 | 6095 | 6750 | 2900 |
| 21 | 6095 | 6750 | 0 |
| 22 | 0 | 6750 | 0 |
| 23 | 6095 | 6750 | 2900 |
| 25 | 4300 | 6750 | 0 |
| 26 | 1720 | 6750 | 0 |
| 27 | -125 | 6750 | 0 |
| 29 | 4300 | 6750 | 2900 |
| 30 | 1720 | 6750 | 2900 |
| 31 | 0 | 6750 | 2900 |
| 32 | -125 | 6750 | 2900 |
| 33 | -125 | 6175 | 0 |
| 34 | -125 | 3175 | 0 |
| 35 | -125 | 1175 | 0 |
| 37 | -125 | 6175 | 2900 |
| 38 | -125 | 3175 | 2900 |
| 39 | -125 | 1175 | 2900 |

Appendix 2 – Transformation Results

V-STARS Coordinates v Design Data (mm) coordinate residuals

| Point | X | Y | Z | Total |
|--------------|-------------|-------------|-------------|--------------|
| 1 | -2.0 | 1.5 | -0.3 | 2.5 |
| 2 | 2.6 | 1.3 | -0.1 | 2.9 |
| 3 | -1.9 | 0.9 | -1.4 | 2.5 |
| 4 | -1.5 | 1.6 | 1.7 | 2.8 |
| 5 | -0.5 | 0.5 | -2.0 | 2.1 |
| 6 | 2.4 | 0.6 | -1.3 | 2.8 |
| 7 | 1.2 | 0.9 | 0.2 | 1.5 |
| 8 | -0.5 | 0.6 | -3.2 | 3.3 |
| 9 | 0.4 | 0.7 | 4.2 | 4.3 |
| 10 | 2.5 | 1.5 | 4.6 | 5.5 |
| 11 | 2.3 | -0.1 | -0.2 | 2.3 |
| 12 | -0.5 | 1.0 | -1.3 | 1.7 |
| 13 | 2.0 | -1.5 | 1.0 | 2.7 |
| 14 | 1.4 | -0.2 | 0.9 | 1.7 |
| 15 | -1.0 | -0.3 | 2.1 | 2.3 |
| 16 | -0.4 | -2.0 | 1.6 | 2.6 |
| 17 | -1.0 | 27.0 | -3.1 | 27.2 |
| 18 | -0.5 | 0.6 | -2.5 | 2.6 |
| 19 | -1.1 | 2.7 | -2.5 | 3.9 |
| 20 | -1.3 | -1.2 | -0.5 | 1.8 |
| 21 | 2.1 | -1.6 | 0.6 | 2.7 |
| 22 | -2.2 | -0.3 | 1.2 | 2.5 |
| 23 | 3.3 | -2.3 | -0.2 | 4.1 |
| 25 | 0.9 | -1.5 | -3.4 | 3.8 |
| 26 | -1.1 | -1.4 | -2.8 | 3.3 |
| 27 | -1.6 | 0.1 | 3.3 | 3.7 |
| 29 | 1.9 | -1.5 | 2.4 | 3.4 |
| 30 | 0.9 | -1.7 | 2.0 | 2.8 |
| 31 | -0.5 | -1.3 | 0.0 | 1.4 |
| 32 | -0.8 | 1.3 | -2.1 | 2.6 |
| 33 | -2.2 | 0.4 | 2.6 | 3.5 |
| 34 | -2.0 | 0.5 | 2.1 | 2.9 |
| 35 | -0.6 | -0.4 | 2.7 | 2.8 |
| 37 | 0.4 | 1.2 | -2.7 | 3.0 |
| 38 | -1.0 | -0.5 | -2.5 | 2.7 |
| 39 | -1.1 | -0.6 | -4.2 | 4.4 |

Data once again indicates that point 17 is in an incorrect position

