Geodetic Systems

V-STARS S8 Demonstration
Measurement Report

April 2006

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Object Measured

One object was measured as part of the V-STARS demonstration. The object was a block with a cylindrical center section. A photo of the object is shown on the cover of this report.

The primary objective of the measurement was to determine the geometric relationship between three key planes and the centerline of the central cylinder.

Equipment Used

1. V-STARS S8 INCA3 Camera
2. Scale Bars
3. AutoBar
4. Coded targets
5. Single dot targets to define key planes
6. Strip tape to define cylinder

Measurement Objectives

1. Demonstrate INCA3 camera use
2. Determine location of key planes
3. Determine central cylinder and centerline
4. Compute geometric relationship between planes and centerline.

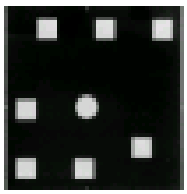
Targeting

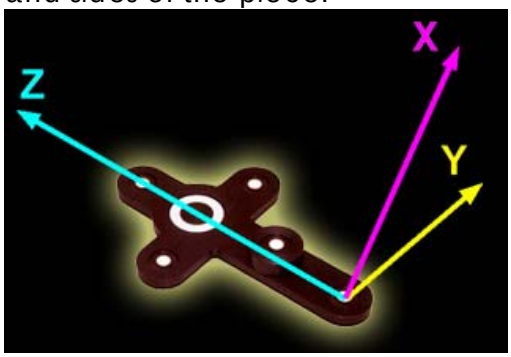
1. AutoBar for initial coordinate system
2. Reference coded targets to tie photography together
3. Two scale bars
4. Strip tape to measure surface of cylinder
5. Single dot targets to define planes

In order to meet the measurement objectives outlined earlier it was necessary to target the object. In general, targets are placed on points or surfaces that are of interest. For surfaces, strips of retro-reflective tape of variable pitch and dot size are commonly used. They are relatively cheap, disposable and easy to apply.

To coordinate tooling datums such as bushed holes or button datums, tooling targets are used. These come in a variety of shank and dot sizes. They are also available in variable orientations. For this measurement single dot targets were used to define the key planes. The cylinder was measured with strip tape.

To automate the measurement process it was necessary to add "coded" targets to the jig. 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 codes were placed on the front, back and sides of the piece.





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 Target 1 at the bottom of the AutoBar. The positive Z-axis goes through Target 3 at the top of the bar. The positive X-axis is up out of the AutoBar. The diagram on the left shows both the AutoBar and its coordinate system

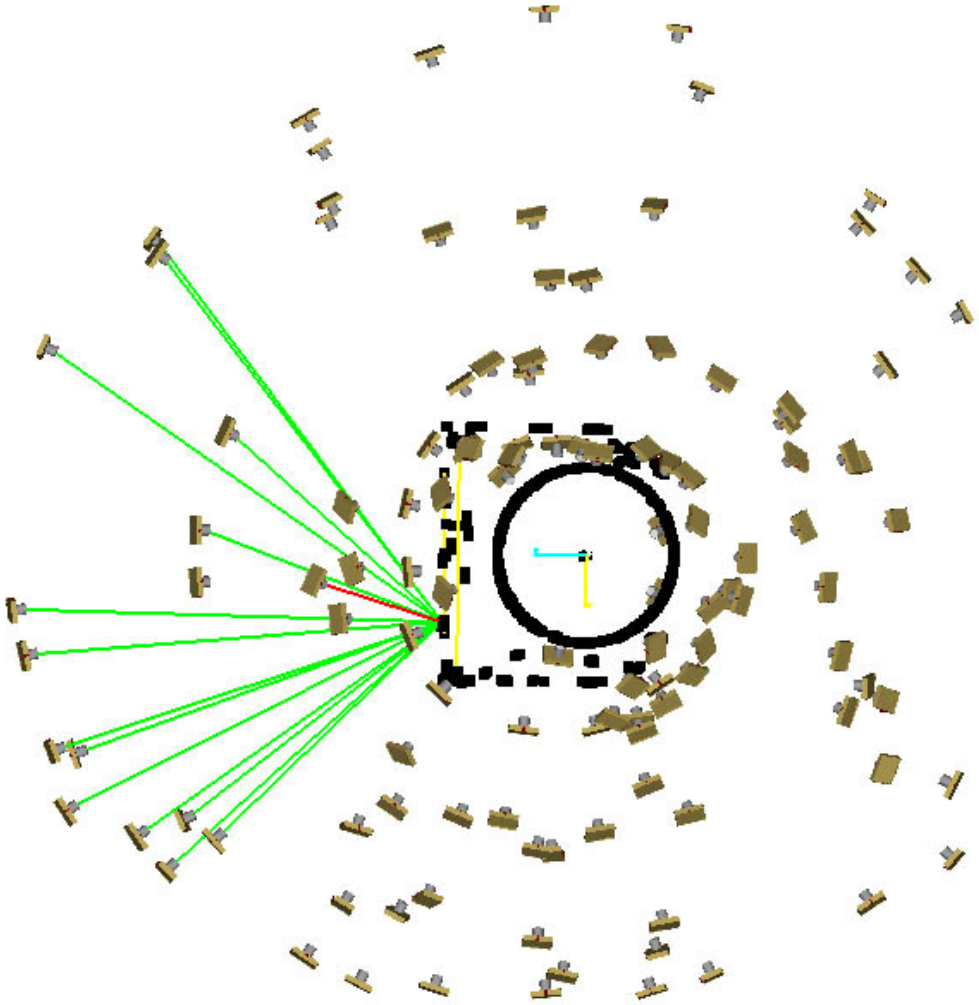
To scale a photogrammetric measurement, there must be at least one known distance. Normally this distance comes from a calibrated coded graphite scale bar or invar scale bar (Refer to adjacent image). Typically multiple scales are used for redundancy. Two scale bars were used to complete this measurement.

Some of the key targeting features of the measurement are shown in the image below:

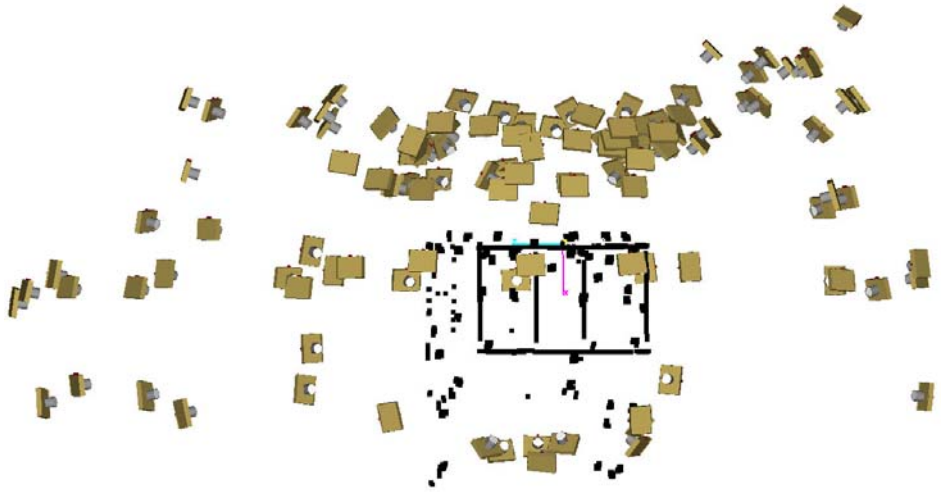
Photography

The photography is carried out once the object targeting is completed. 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 measurement, generally photos are taken both close to the ground and from an elevated position. The number of photos taken depends on the complexity of the measurement and accuracy requirements.

The diagrams below illustrate the geometry used to create the point cloud for the object.



Network - Top View

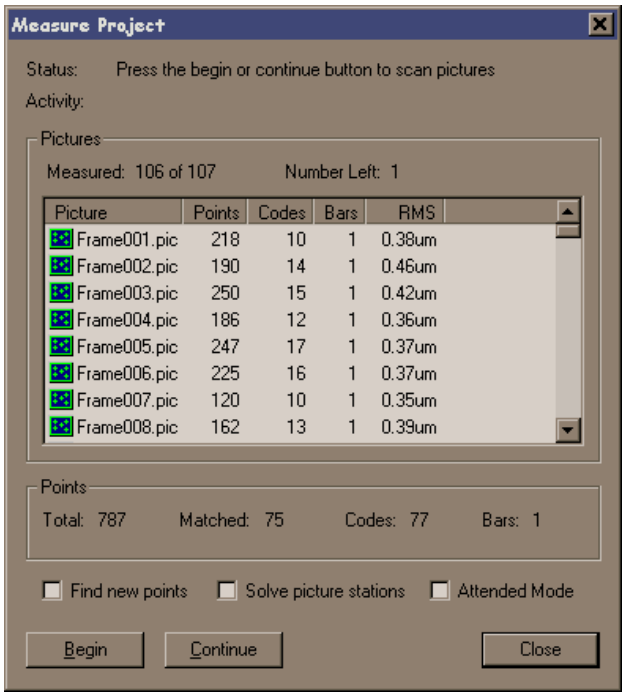


Network - Side View

Processing

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

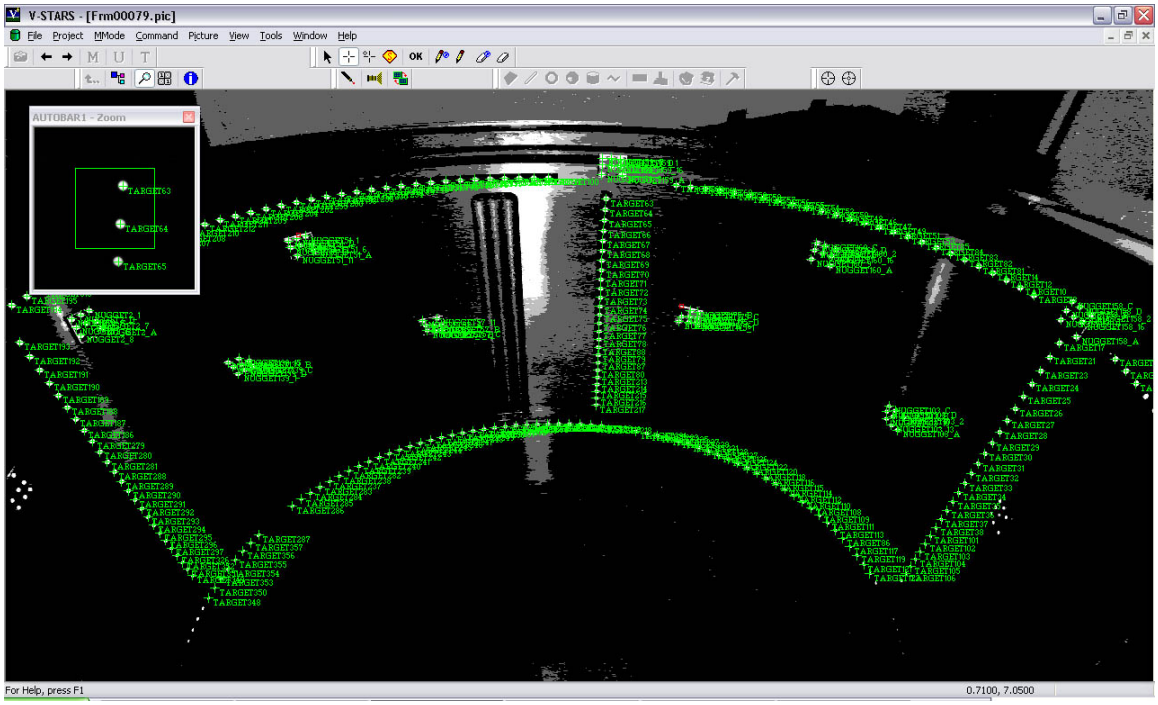
Almost all of the measurement process is automated. The images are processed and the coordinates extracted by the "AutoMeasure" command. A typical AutoMeasure dialog box is shown on the right. The AutoMeasure command will open each of the images, determine the camera location, find new target points 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.

The AutoMeasure routine will assign random labels to the points it finds. These labels start with the key word "Target" followed by a number. If specific labeling is required the random labels can be easily changed to labels defined by the user. This is possible in both the picture view and the graphical 3D view. For this particular project it was not necessary to re-label the points.

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

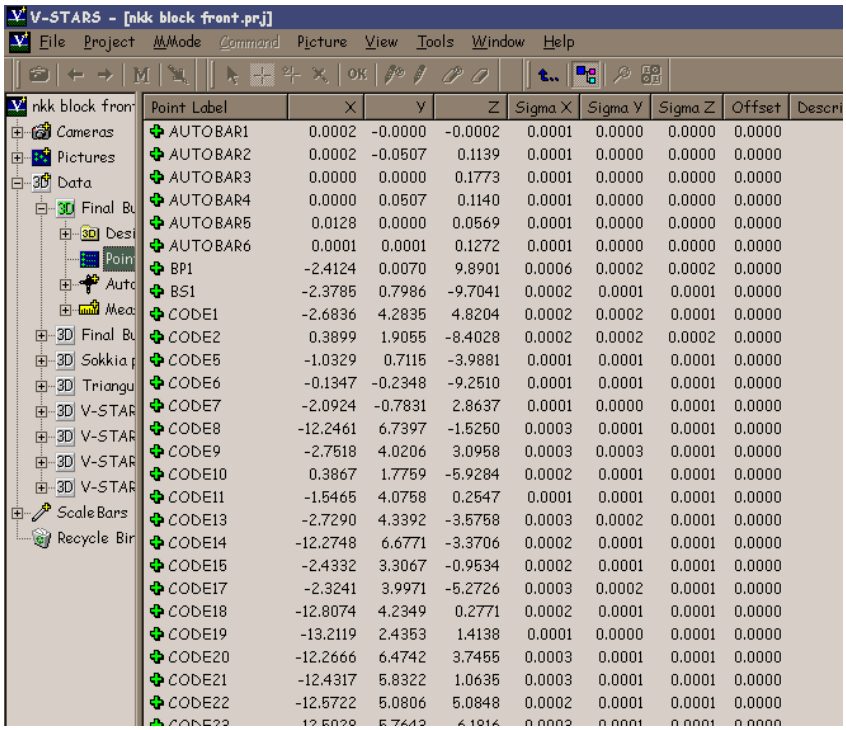


The green crosses represent points that have been located in this particular image. Note that the image appears a little dark and difficult to see. This is intentional as the best photogrammetric measurements are made on images that have dark backgrounds and bright targets. Some of these targets are shown in the zoom window in the corner. If the scale bar is visible then a yellow line will be drawn between the two end points.

Measurement Statistics

No. of photos	120
No. of points	1021
Accuracy RMS X,Y,Z X 0.012mm Y 0.010mm Z 0.012mm	
Scale Agreement = 0.015mm	

A typical point listing is shown below.



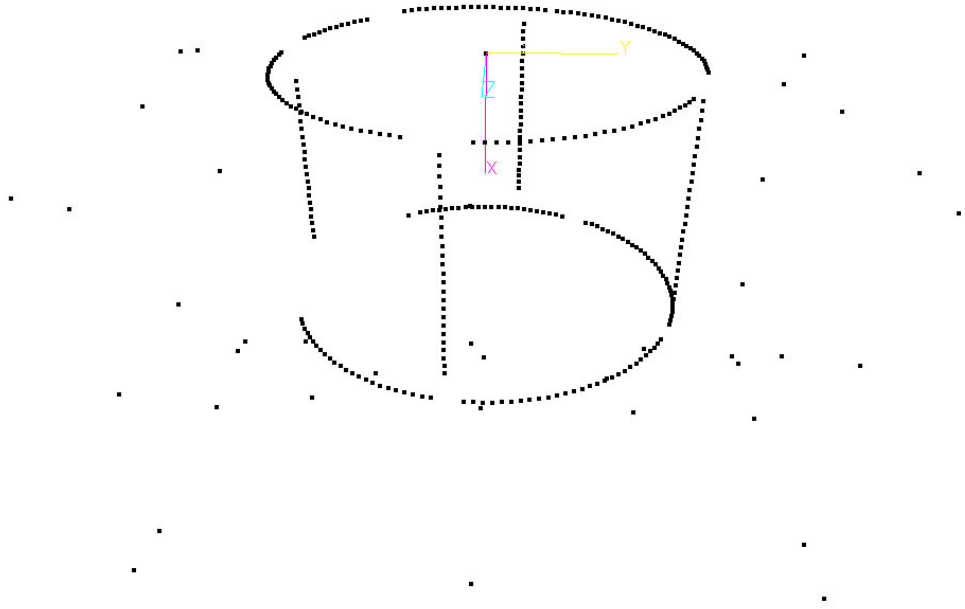
Point Label	X	Y	Z	Sigma X	Sigma Y	Sigma Z	Offset	Descri
AUTOBAR1	0.0002	-0.0000	-0.0002	0.0001	0.0000	0.0000	0.0000	
AUTOBAR2	0.0002	-0.0507	0.1139	0.0001	0.0000	0.0000	0.0000	
AUTOBAR3	0.0000	0.0000	0.1773	0.0001	0.0000	0.0000	0.0000	
AUTOBAR4	0.0000	0.0507	0.1140	0.0001	0.0000	0.0000	0.0000	
AUTOBAR5	0.0128	0.0000	0.0569	0.0001	0.0000	0.0000	0.0000	
AUTOBAR6	0.0001	0.0001	0.1272	0.0001	0.0000	0.0000	0.0000	
BP1	-2.4124	0.0070	9.8901	0.0006	0.0002	0.0002	0.0000	
BS1	-2.3785	0.7986	-9.7041	0.0002	0.0001	0.0001	0.0000	
CODE1	-2.6836	4.2835	4.8204	0.0002	0.0002	0.0001	0.0000	
CODE2	0.3899	1.9055	-8.4028	0.0002	0.0002	0.0002	0.0000	
CODE5	-1.0329	0.7115	-3.9881	0.0001	0.0001	0.0001	0.0000	
CODE6	-0.1347	-0.2348	-9.2510	0.0001	0.0001	0.0001	0.0000	
CODE7	-2.0924	-0.7831	2.8637	0.0001	0.0000	0.0001	0.0000	
CODE8	-12.2461	6.7397	-1.5250	0.0003	0.0001	0.0001	0.0000	
CODE9	-2.7518	4.0206	3.0958	0.0003	0.0003	0.0001	0.0000	
CODE10	0.3867	1.7759	-5.9284	0.0002	0.0001	0.0001	0.0000	
CODE11	-1.5465	4.0758	0.2547	0.0001	0.0001	0.0001	0.0000	
CODE13	-2.7290	4.3392	-3.5758	0.0003	0.0002	0.0001	0.0000	
CODE14	-12.2748	6.6771	-3.3706	0.0002	0.0001	0.0001	0.0000	
CODE15	-2.4332	3.3067	-0.9534	0.0002	0.0001	0.0001	0.0000	
CODE17	-2.3241	3.9971	-5.2726	0.0003	0.0002	0.0001	0.0000	
CODE18	-12.8074	4.2349	0.2771	0.0002	0.0001	0.0001	0.0000	
CODE19	-13.2119	2.4353	1.4138	0.0001	0.0000	0.0001	0.0000	
CODE20	-12.2666	6.4742	3.7455	0.0003	0.0001	0.0001	0.0000	
CODE21	-12.4317	5.8322	1.0635	0.0003	0.0001	0.0001	0.0000	
CODE22	-12.5722	5.0806	5.0848	0.0002	0.0001	0.0001	0.0000	

Alignment

No alignment was necessary for this measurement.

Point Cloud

The measurement produced the following point cloud.

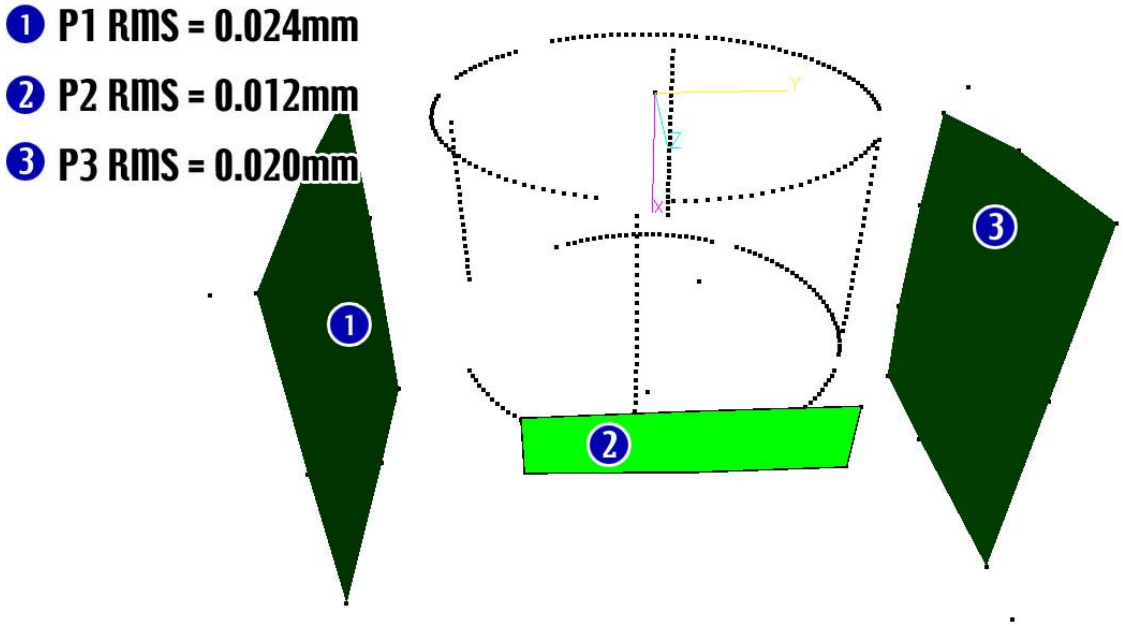


Analysis

The following analysis was completed

Planes

Three planes were created (P1, P2 and P3). These are shown in the image below.

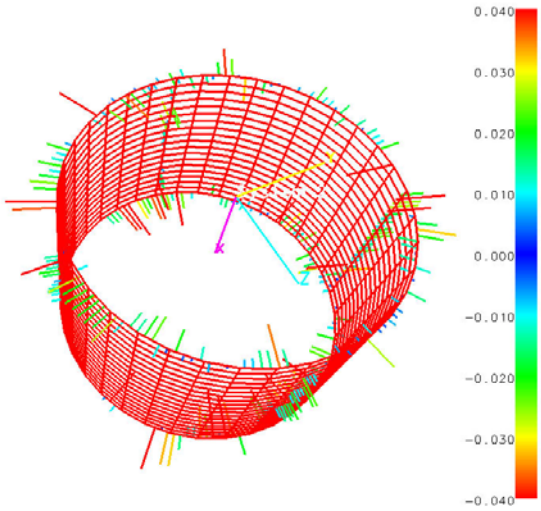


The respective angle between the three planes is tabulated below.

Planes	Angle
P1 to P2	89.9922˚
P3 to P2	89.9922˚
P1 to P3	0.0173˚

Cylinder

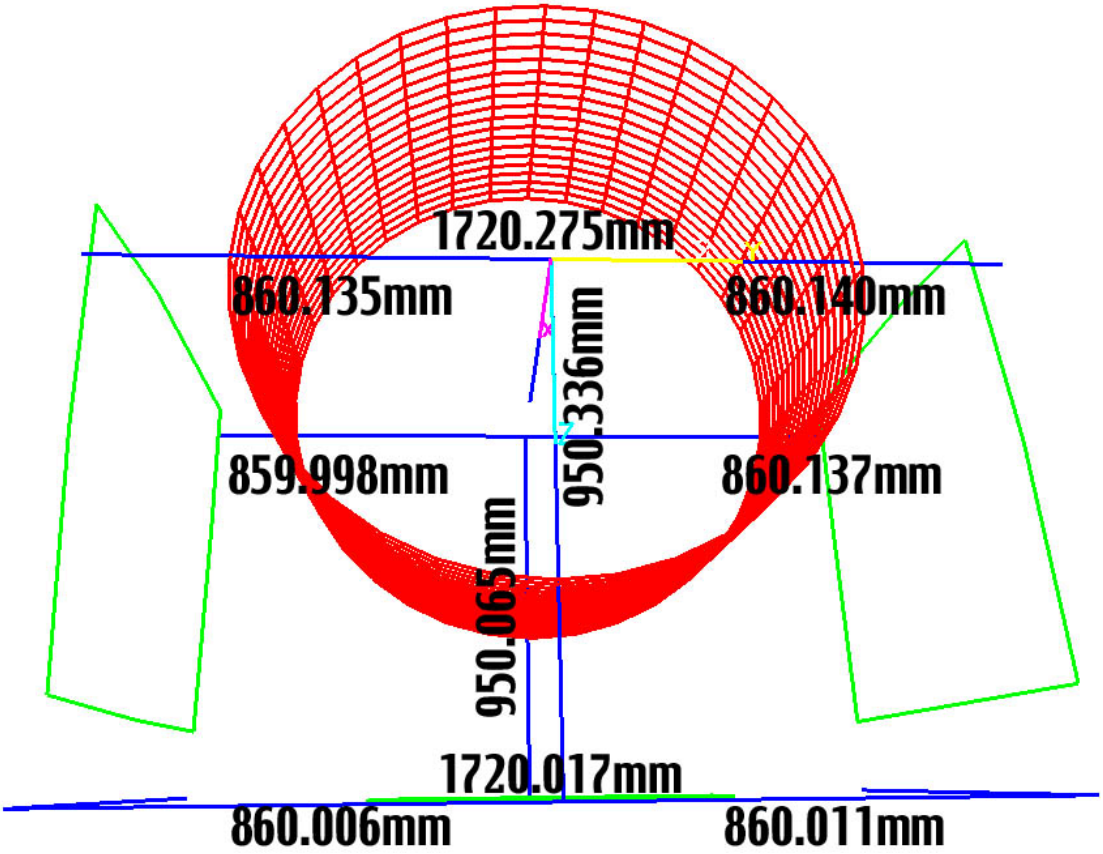
The strip point data in the middle of the piece was used to create the best-fit cylinder. The results of this cylinder are shown below.



RMS = 0.019mm
Radius = 597.381 + target thickness
= 597.381 + 0.145mm
= **597.536mm**
Diameter = 1195.072mm

Geometric Analysis

The centerline of the cylinder and the planes was used to compute some of the key dimensions. These are shown in the image below. The distances were computed at the top and at the bottom of the cylinder.



Geometric Comparison to CMM Data

The data collected was compared to the data collected from the CMM.

Measurement	CMM	V-STARS
Cylinder Diameter	1195.098mm	1195.072mm
950 Distance	950.284	950.201mm (ave of top and bottom distance)

Time Summary

Initial Investigation	1 minutes
Targeting	15 minutes
Photography	5 minutes
Processing	2 minutes
Analysis	10 minutes
Total	**33 minutes**

Concluding Remarks

The measurement undertaken has shown that V-STARS can be a very powerful measurement tool. The results of the measurement undertaken were very accurate and produced quickly.