



## V-STARS S8 Demonstration Measurement Report



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## Object Measured

One measurement was completed as part of the V-STARS demonstration. The measurement involved the alignment of a white metal bush cylinder and the starboard kort nozzle to the centerline of the engine shaft. Part of the measurement area is shown on the cover of this report.

The primary objective was to determine the center of the cylinder and nozzle relative to the centerline of the engine shaft.

## Equipment Used

1. V-STARS S8 Camera System
2. Scale Bars
3. Retro-reflective targets
4. Retro-reflective strip tape



## Measurement Objectives

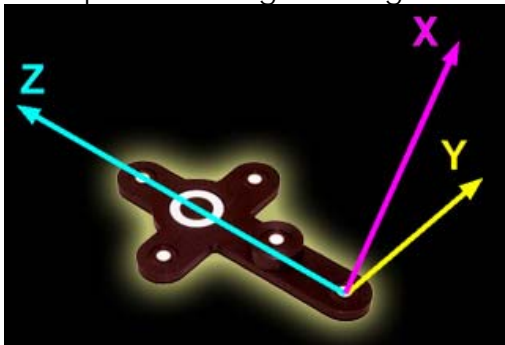
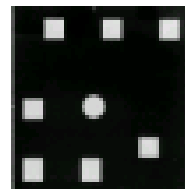
1. Demonstrate camera use and object targeting
2. Measure location of piano wire centerline
3. Measure white metal and determine center
4. Measure white metal cylinder end planes
5. Determine nozzle circle and center point
6. Calculate deviations of center points to centerline

## Measurement Targeting

1. AutoBar for initial coordinate system
2. Coded targets to tie photography together
3. Two scale bars
4. Strip tape targets on the white metal bush
5. Single dot targets with cross hair on the piano wire
6. Single dot targets on the inside of the nozzle on the scribed center
7. Single dot targets on the white metal bush planes

In order to meet the measurement objectives outlined earlier it was necessary to target the area. 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. The remaining key planes and lines were measured using single dot targets with a cross hair or single dot targets.

To automate the measurement process it was necessary to add "coded" targets to the block and the area surrounding it. 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 along the length of the front of the jig.



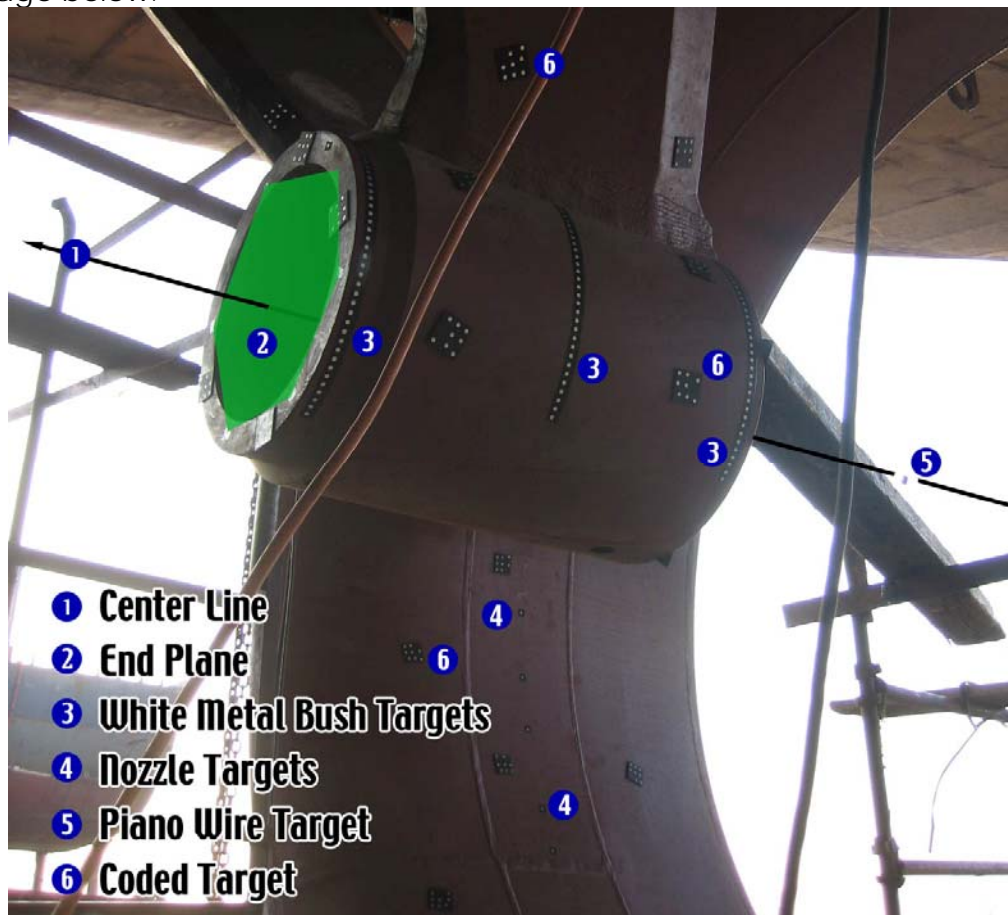
The initial coordinates system and scale is determined via the AutoBar. The AutoBar used by the V-STARS system is a fixture with five targets arranged in the form of a cross. The target's known coordinates are used by the AutoMatch procedure to determine the camera's orientation relative to the AutoBar. 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 elements of the measurement are shown in the image below.

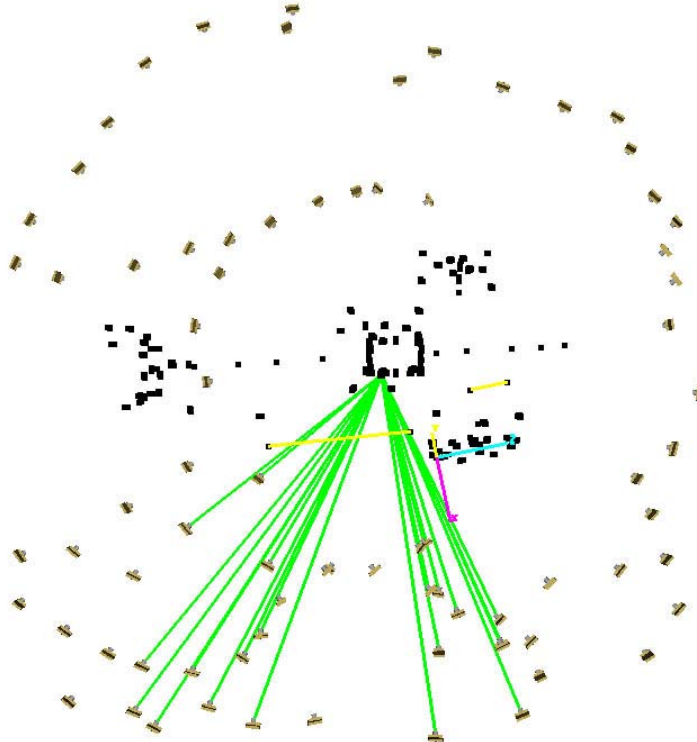




## Photography

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 diagram below illustrates the typical geometry used to create a point cloud.

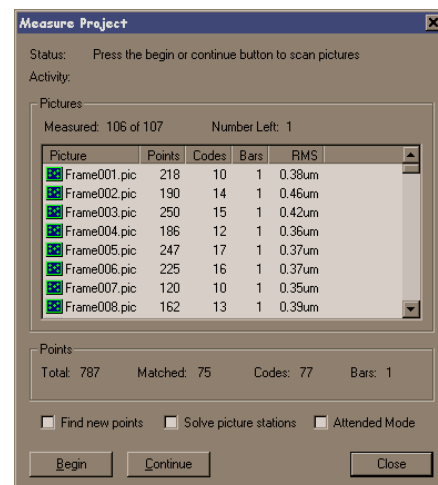


## Processing

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 necessary to re-label the points so that analysis could be simplified.

Seen below is a typical measurement image.



Typical V-STARS measurement image

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

### Network

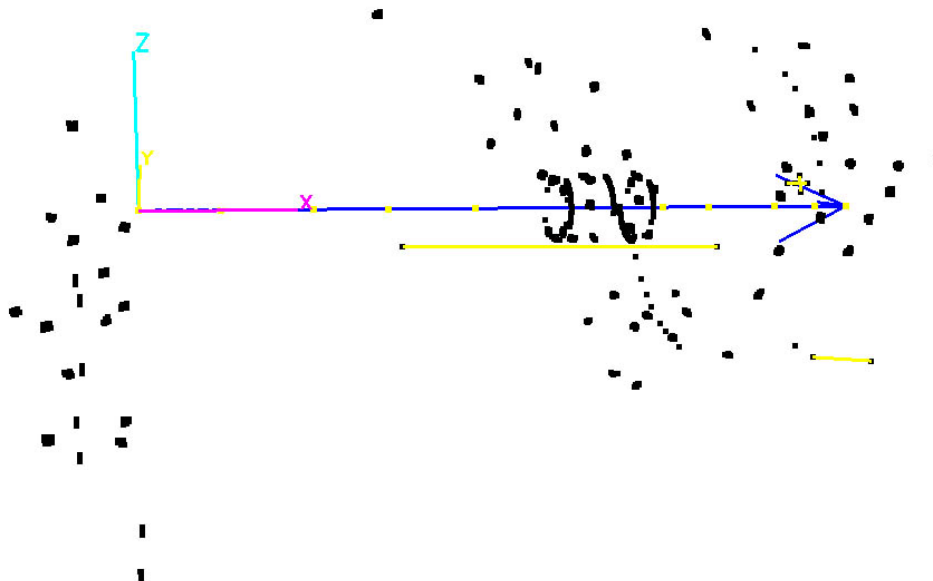
No. of photos	78		
No. of points	756		
Accuracy RMS X,Y,Z	X	0.063	
	Y	0.040	
	Z	0.047	
Scale Agreement		0.006mm	

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	0.0002	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	
CODE23	12.5028	5.7442	6.1816	0.0002	0.0001	0.0001	0.0000	

## Measurement Alignment

No alignment was necessary to complete the analysis. However in order to simplify the interpretation of the results a simple alignment was carried out. The origin of the axis was placed at one of the end points of the piano wire center line. An arbitrary point was selected as the clocking point. The alignment is shown in the image below.





## Measurement Analysis

The results of the analysis are shown below.

### Line

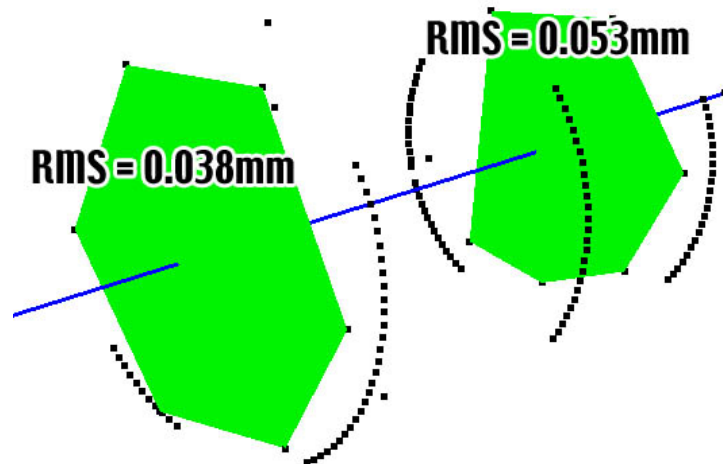
The points located on the piano wire were used to create the best-fit center line. The results of this are shown below.

Center Line RMS = **0.216mm**

Point Label	Proj X	Proj Y	Proj Z	Delta X	Delta Y	Delta Z	Total
+ CL1	5569.461	1.443	3.095	-0.000	0.148	0.039	0.153
+ CL2	5254.533	1.422	3.050	-0.000	0.370	0.178	0.411
+ CL3	4862.655	1.397	2.995	0.000	-0.286	-0.247	0.378
+ CL4	4251.325	1.356	2.908	0.000	-0.234	0.025	0.236
+ CL5	3836.957	1.329	2.850	0.000	-0.049	0.002	0.050
+ CL6	2293.233	1.227	2.631	0.000	-0.073	-0.049	0.088
+ CL7	1649.753	1.184	2.540	0.000	-0.089	0.025	0.092
+ CL8	1126.806	1.150	2.466	0.000	0.049	-0.069	0.084
+ CL9	515.243	1.109	2.379	-0.000	0.132	0.165	0.211
+ CL10	-0.000	1.075	2.306	0.000	0.032	-0.069	0.076

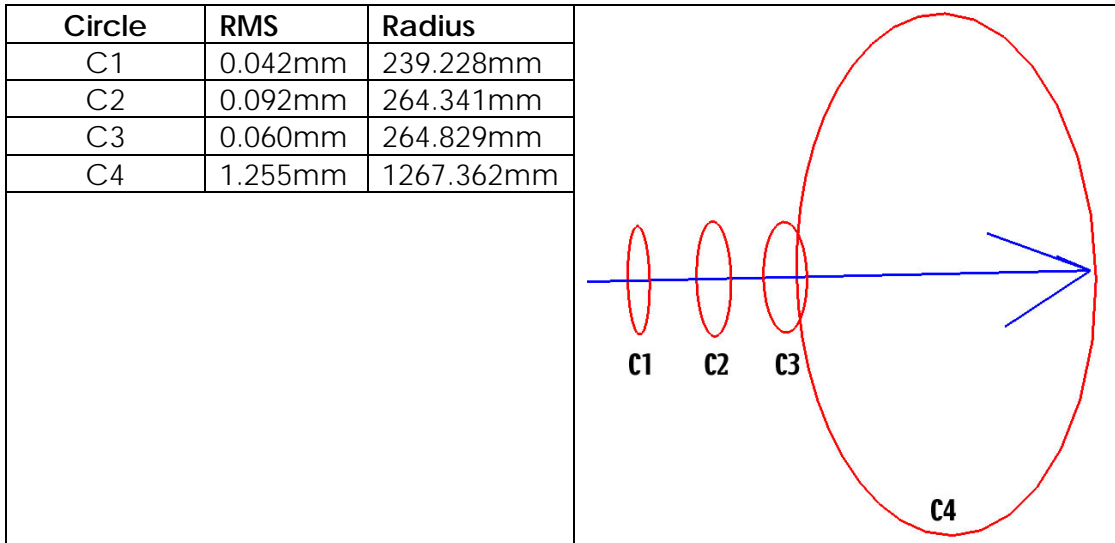
### Planes

The points located on each of the planes on the end of the white metal bush were used to create best-fit planes.



## Circles

Circles were generated through the three sets of points located on the white metal bush and the internal circle of the kort nozzle. The results of this are shown below.



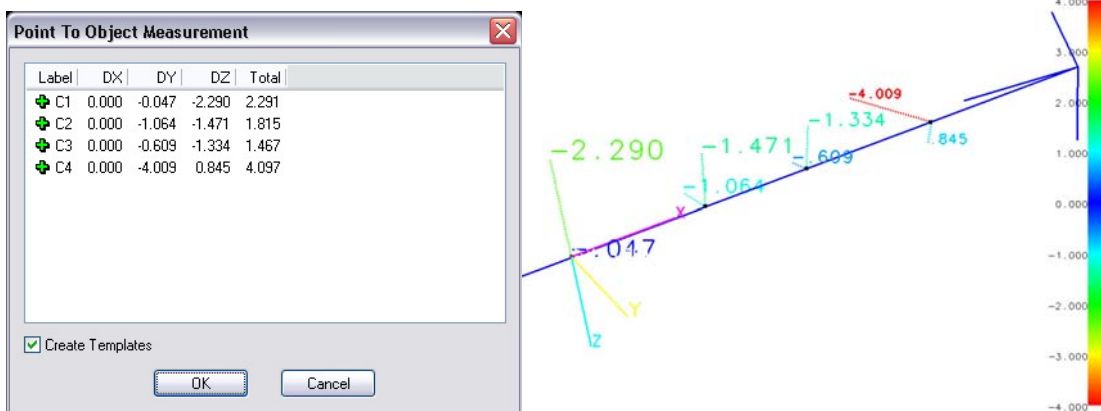
## Analysis

The data collected was used to create the necessary measurements. The results are shown below.

Center Line to White Metal Bush End Plane Angle = **89.9313°**

White Metal Bush Length = **701.058mm**

The deviations of the circle centers to the center line are shown below.



## Measurement Time Summary

<b>Measurement</b>	
Initial Investigation	10 minutes
Targeting	25 minutes
Photography	10 minutes
Processing	15 minute
<b>Total</b>	<b>60 minutes</b>

## Concluding Remarks

The measurement undertaken has shown that the V-STARS S8 system can be a very powerful measurement tool. The results of the measurement undertaken were very accurate and produced quickly.