

Report on demonstration of V-STARS for Northrop Grumman- Stuart, FL

Introduction:

The following report is a summary of the V-STARS work carried out at the Northrop Grumman facility in Stuart, FL. As part of the demonstration one object was measured. The object measured was a 777 flap tool.

The primary objectives of the measurement were to determine the location of alignment points on the jig and to also check a number of other features and points.



This report summarizes the results of the measurements while also providing information on how V-STARS was used to meet the measurement requirements.

Primary Measurement Requirements:

- Measure alignment points
- Align to aircraft coordinate system
- Check the location of slots, contour boards, station values and other features.

Documentation:

The following documentation is included in this report.

- A report outlining methodology and results.
- XYZ data for the measured component.



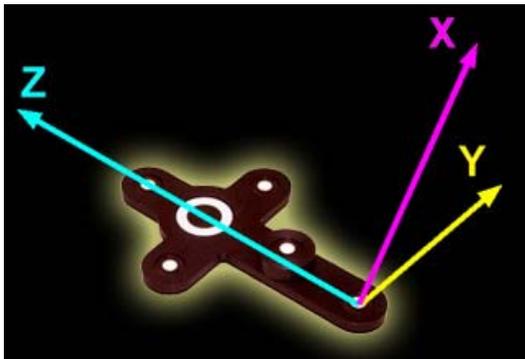
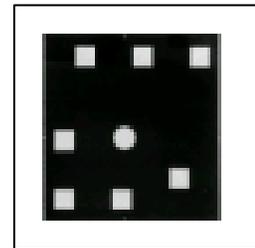
Measurement Procedure:

Targeting.

In order to meet the measurement objectives outlined earlier it was necessary to target the jig. 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, tooling targets are used. These come in a variety of shank and dot sizes. They are also available in variable orientations. For this measurement adapter sleeves were used to adapt the targets from the standard 0.250" to the 0.325" and 0.500" hole sizes.

Due to the variability of the features measured it was necessary to improvise on some of the targeting. For example, where no target was available at the correct offset a local plane was created and the point vectored to the correct offset. For a genuine period inspection program it would be advisable to have a collection of special targeting to meet the measurement objectives.

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 along the length of the front and rear faces 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

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 matchbox 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. 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. As this was only a demonstration no scale distance was used in this measurement.

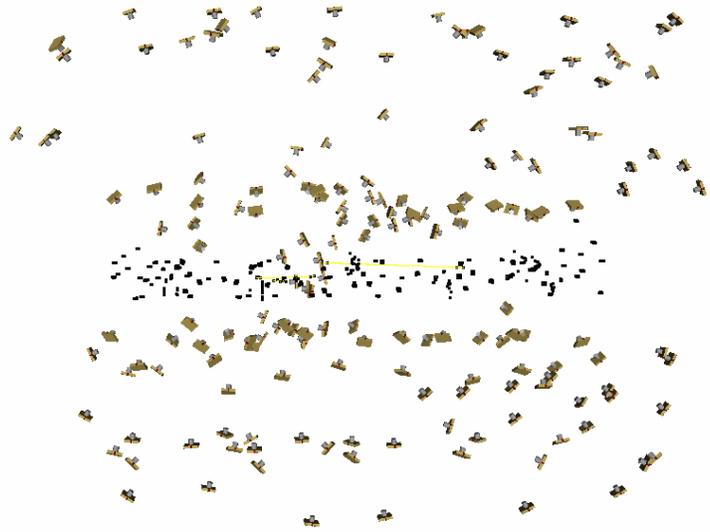


Photography

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. Due to the absence of the correct targeting and the need to measure points on both sides of the jig it was necessary to dramatically increase the number of images taken.

A total of 175 photographs were taken of the jig. The number of photos taken depends on the complexity of the measurement and accuracy requirements. With planning and correct targeting this number could probably be reduced to 100 photographs.

The photography for the jig was completed in approximately 20 minutes. Camera station locations for the measurement are shown in the adjacent diagram.

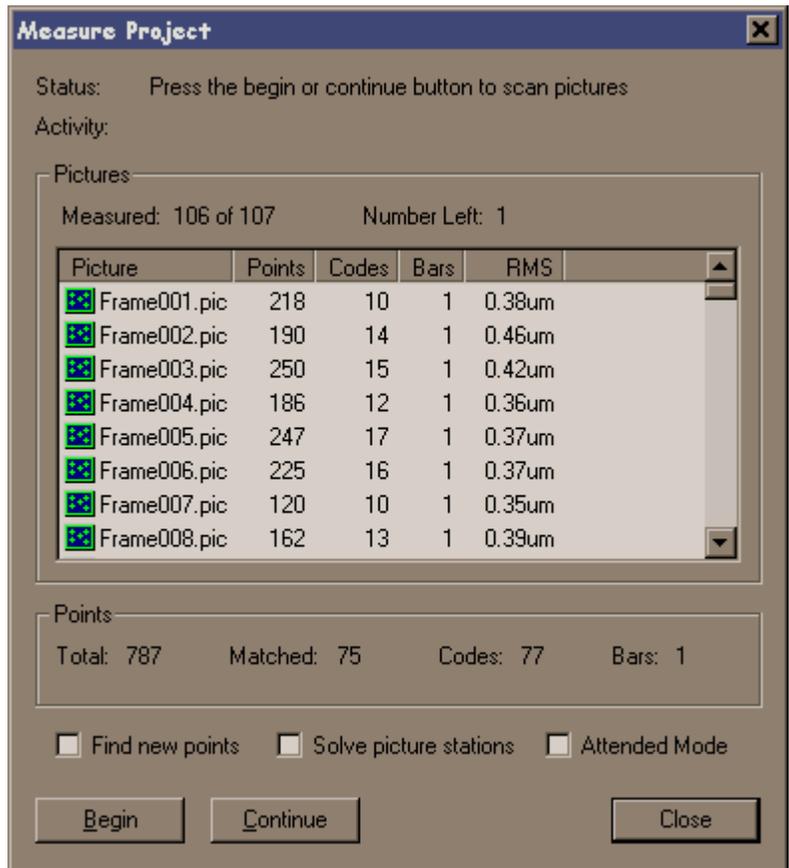


Processing

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.

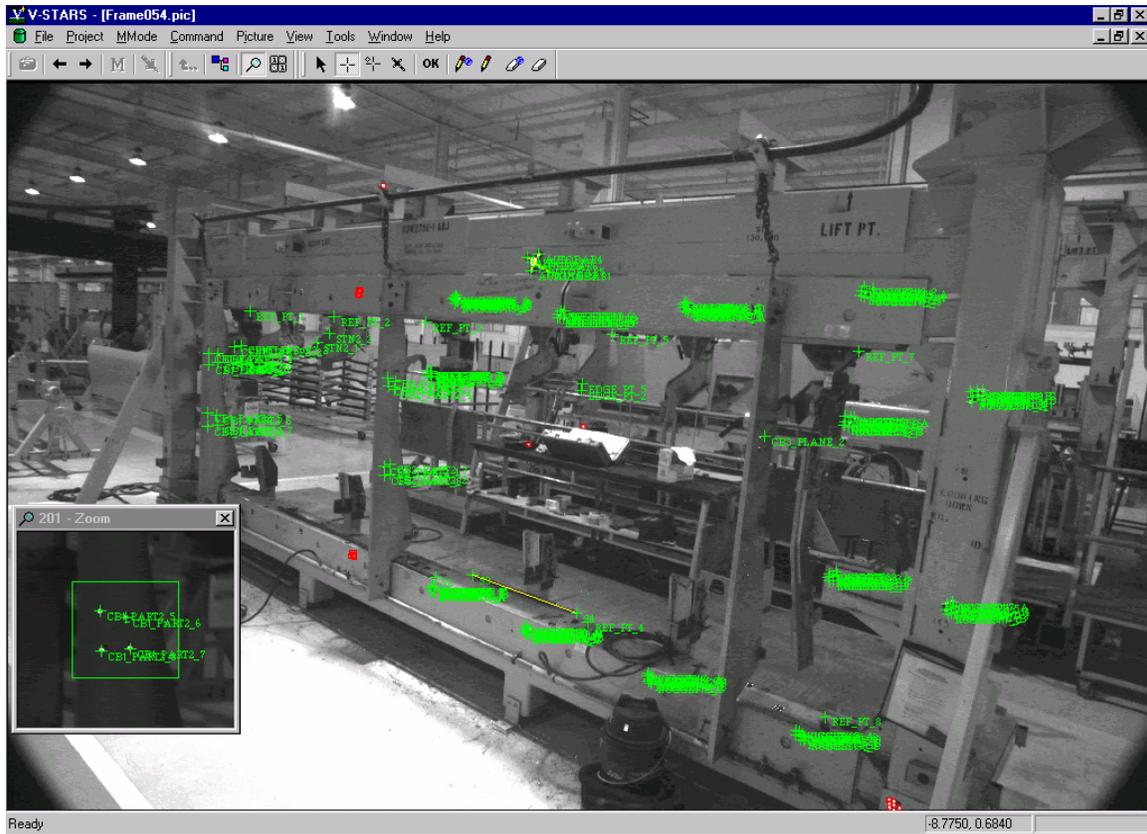
Almost all of the measurement process is automated. The images are processed and the coordinates extracted by the "AutoMeasure" command. A typical AutoMeasure dialog box is shown on the right. The AutoMeasure command will open each of the images, determine the camera location, find new target points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

Seen below is an image taken as part of the jig 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. One of these targets is 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.

Results:

The following is a summary of the measurement statistics from the measurement of the jig

No of photos		175
No of points		790
No of scales		4
Scale Agreement		0.0018"
RMS(") X,Y,Z	X	0.0007
	Y	0.0006
	Z	0.0006

A typical point listing is shown below.

Point Label	X	Y	Z	Sigma X	Sigma Y	Sigma Z	Offset	Descr
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	
CODE23	12.5028	5.7412	6.1816	0.0003	0.0001	0.0001	0.0000	

This point data can be analyzed within the V-STARS' Solids module, easily exported to almost any CAD platform or other analysis program. For this particular project, the analysis was completed in SOLIDS.

Computing the point-to-point distance is as simple as highlighting the two points and pressing "d". The result appears on the screen and is also written to a report file.

Calculation of the Best-fit plane is also very simple. The plane points are highlighted and the "P" key is pressed. The plane dialog is shown in the adjacent images.

Plane Parameters

Name:

A: -0.0008
 B: -0.0039
 C: 1.0000
 D: 16.3405

Rejection Limit: 0.0040
 Final RMS: 0.0011
 Points Accepted: 8
 Points Rejected: 0

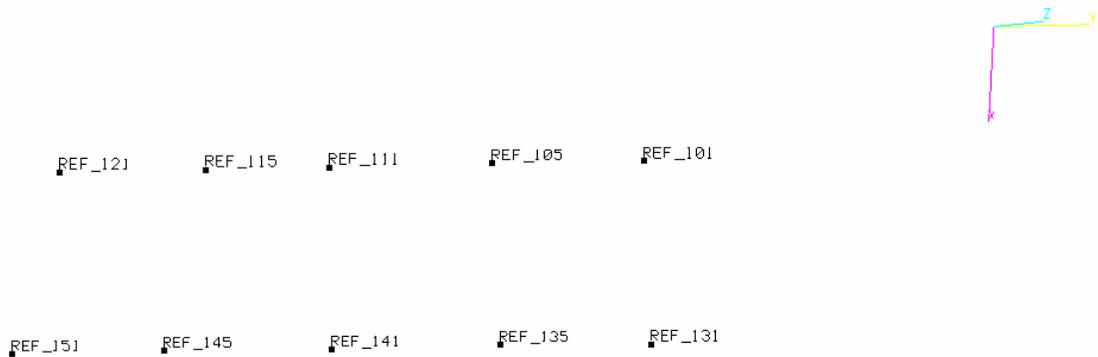
Create Template Offset:

Label	Residuals
CODE118	0.0017
NUGGET118_1	0.0004
NUGGET118_9	0.0001
NUGGET118_14	0.0011

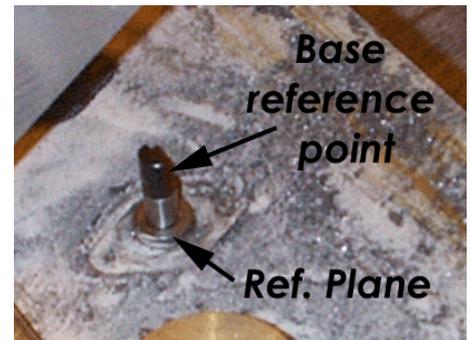
OK Cancel

Alignment:

A total of ten points were used to transfer the data from the arbitrary AutoBar coordinate system to that of the aircraft coordinate system. These are shown in the image below:



Prior to completing this transformation it was necessary to compute the equivalent point in the V-STARS data. As mentioned earlier this was due to the correct targets not being available at the time of the survey. For the reference points located at the top of the tool it was a matter of creating a vector point to the correct offset. For the reference points at the base of the tool it was necessary to create a reference plane and then vector a point to the 0.5" offset.



The results of the alignment are shown below.

Alignment Information				
Design Measured Residuals Transformation				
Label	DX	DY	DZ	Total
REF_115	0.0004	-0.0141	-0.0060	0.0153
REF_101	0.0018	0.0013	0.0041	0.0047
REF_105	-0.0014	-0.0041	-0.0018	0.0047
REF_111	-0.0000	0.0083	-0.0007	0.0083
REF_121	0.0010	-0.0068	-0.0017	0.0071
REF_131	0.0018	-0.0035	-0.0017	0.0043
REF_135	-0.0021	-0.0052	-0.0016	0.0058
REF_141	-0.0013	0.0044	0.0010	0.0047
REF_145	-0.0001	0.0016	0.0012	0.0020
REF_151	0.0003	0.0040	0.0012	0.0041

RMS of Residuals
X: 0.0013 Y: 0.0048 Z: 0.0019 Total: 0.0054

Save

OK Cancel Apply

The point REF_115 was rejected during the transformation. This is no doubt due to the high residual of the Y coordinate. The X and Z coordinates display very good agreement with the stamped data.

Feature	V-STARS			Nominal			Delta			Description
	X	Y	Z	X	Y	Z	X	Y	Z	
LE_2_X	53.449									Lead edge 2
LE_2_X	53.447									Lead edge 2
LE_2_Y		-175.980			-176.000		0.020			Lead edge 2
LE_2_Y		-175.959			-176.000		0.041			Lead edge 2
LE_2_Y		-175.976			-176.000		0.024			Lead edge 2
LE_2_Y		-175.947			-176.000		0.053			Lead edge 2
LE_2_Y		-175.966			-176.000		0.034			Lead edge 2
CB = -228		-227.998			-228.000		0.002			Con Board
CB = -228		-227.996			-228.000		0.004			Con Board
CB = -228		-227.998			-228.000		0.002			Con Board
CB = -228		-227.999			-228.000		0.001			Con Board
CB = -228		-228.001			-228.000		0.000			Con Board
CB = -228		-227.998			-228.000		0.002			Con Board
CB = -228		-228.000			-228.000		0.000			Con Board
CB = -228		-227.999			-228.000		0.001			Con Board
969		-229.997			-230.000		0.003			Point
221		-230.000			-230.000		0.000			Point
STN2_1		-277.917			-278.000		0.083			STN Point
STN2_2		-277.928			-278.000		0.072			STN Point
STN2_3		-277.891			-278.000		0.110			STN Point
STN2_4		-277.913			-278.000		0.087			STN Point
STN2_5		-277.924			-278.000		0.076			STN Point
CB = -329		-328.989			-329.000		0.011			Con Board
CB = -329		-328.997			-329.000		0.003			Con Board
CB = -329		-328.999			-329.000		0.001			Con Board
CB = -329		-328.996			-329.000		0.004			Con Board
CB = -329		-328.999			-329.000		0.001			Con Board
CB = -329		-328.997			-329.000		0.003			Con Board
CB = -329		-329.005			-329.000		-0.005			Con Board
CB = -329		-329.000			-329.000		0.000			Con Board
CB = -329		-329.000			-329.000		0.000			Con Board
CB = -329		-329.002			-329.000		-0.002			Con Board
CB = -329		-328.999			-329.000		0.001			Con Board
CB = -328		-327.998			-328.000		0.002			Con Board
CB = -328		-327.993			-328.000		0.007			Con Board
CB = -328		-327.997			-328.000		0.003			Con Board
CB = -328		-327.992			-328.000		0.008			Con Board
CB = -328		-327.994			-328.000		0.006			Con Board
CB = -328		-327.988			-328.000		0.012			Con Board
CB = -328		-327.988			-328.000		0.012			Con Board
CB = -328		-327.992			-328.000		0.008			Con Board

Feature	V-STARS			Nominal			Delta			Description
	X	Y	Z	X	Y	Z	X	Y	Z	
CB = -328	100.006	-328.231		100.000		0.006				CB Tool Point
CB = -328	100.825	-329.003			-329.000		-0.003			CB Tool Point
511		-340.984			-340.985		0.002			Point
525		-338.884			-338.520		-0.364			Point
523	53.704	-338.520	1.211	53.701	-338.520	1.200	0.003		0.011	Centerline

Concluding Remarks:

The measurement of this piece has demonstrated that V-STARS can be a very powerful measurement tool for objects such as jigs and other production tooling. The results of the measurement are very accurate and more importantly were produced quickly. With correct planning and targeting this data acquisition time could even be reduced further.

GSI would like to thank Northrop Grumman for welcoming us into their facility. We will be happy to discuss the results of this report or any other aspect of the technology presented.