Geodetic Services

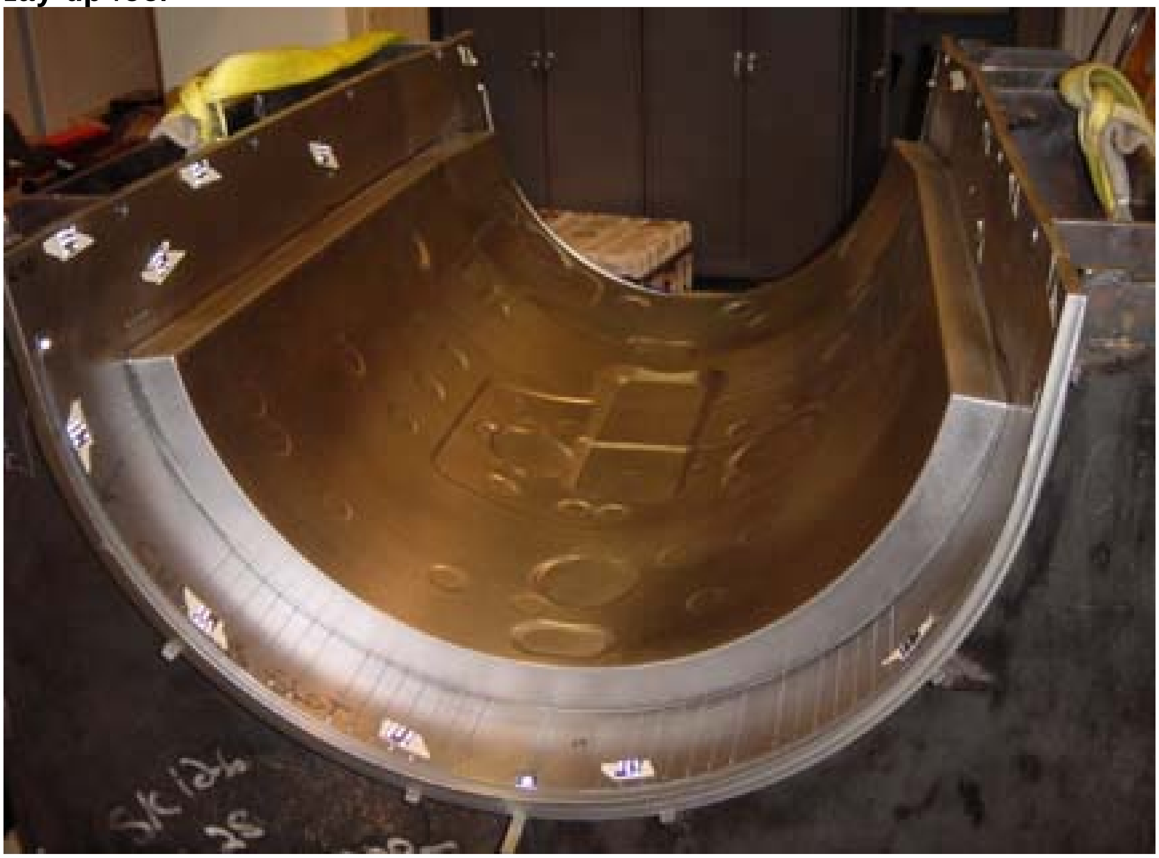
Edison ESI
V-STARS Demonstration

EXECUTIVE SUMMARY

Turbine Measurement

- The turbine was measured in less than two hours from start to finish. Analysis was completed in an additional hour.
- Coordinate data accuracy was typically better than 0.0011” in XYZ.
- System is portable and can be used to complete off site inspection and verification of large components.
- System is capable of working in environments with unstable floors.
- System is flexible enough to work in environments with challenging lines of sight.
- System can be used both indoors and outdoors.

Lay-up Tool



- The lay-up tool was measured in less than 90 minutes from start to finish.
- More than 5500 points collected.
- Coordinate data accuracy was typically better than 0.0006” in XYZ.

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Introduction

The following report is a summary of the V-STARS work carried out at the Edison ESI facility in Westminster, CA

Two measurements were undertaken using the V-STARS metrology system.

The first measurement involved the determination of the key dimensions on a large turbine. This turbine is shown on the front cover.

In second measurement the surface of an aircraft lay up tool was determined using the PRO-SPOT target projection system.

The objectives of the measurements are outline below in the requirements section. More details on each of the measurements is located in the results report.

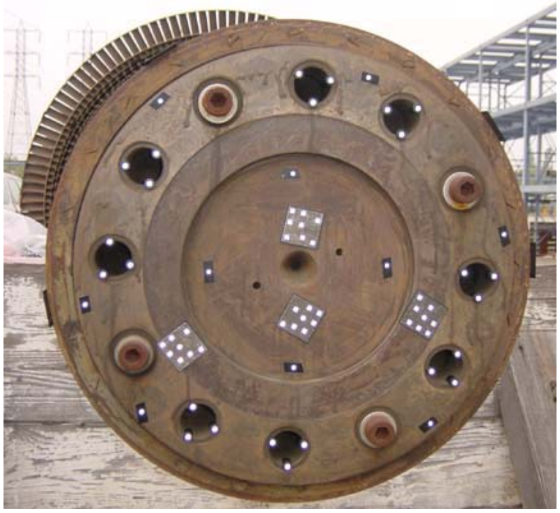
Equipment Used

1. V-STARS S6 INCA Camera System
2. PRO-SPOT Target Projector
3. 5,600 point projection slide.

V-STARS with INCA camera and accessories. PRO-SPOT is shown on the left.

Requirements

Turbine Measurement

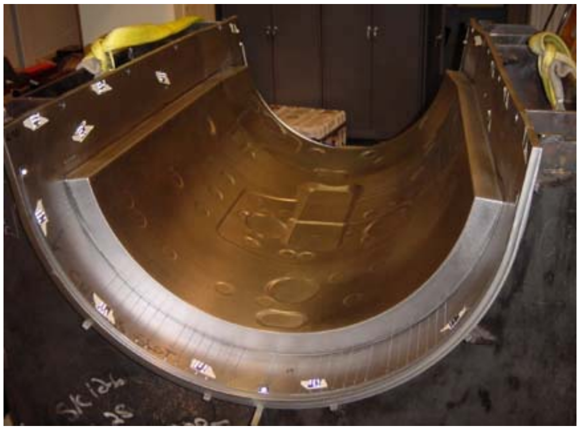


Turbine Measured

1. Demonstrate camera use and object targeting.
2. Compute center points along turbine.
3. Compute key circles on end face.
4. Compute key planes.
5. Compute length.

Lay-up tool Measurement

1. Demonstrate PRO-SPOT target projector use.
2. Determine surface point locations
3. Align to defined coordinate system.
4. Transfer measured data to CATIA

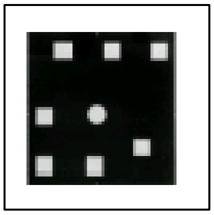


Lay-up Tool Measured.

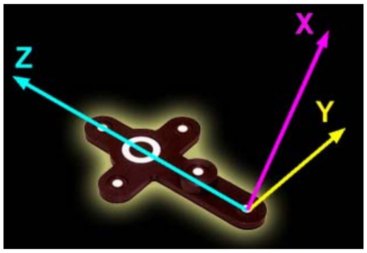
Measurement Procedure

Targeting

In order to meet the measurement objectives outlined earlier it was necessary to target the objects. 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. For the lay-up measurement, the targets were generated using the PRO-SPOT target projection system. 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.



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

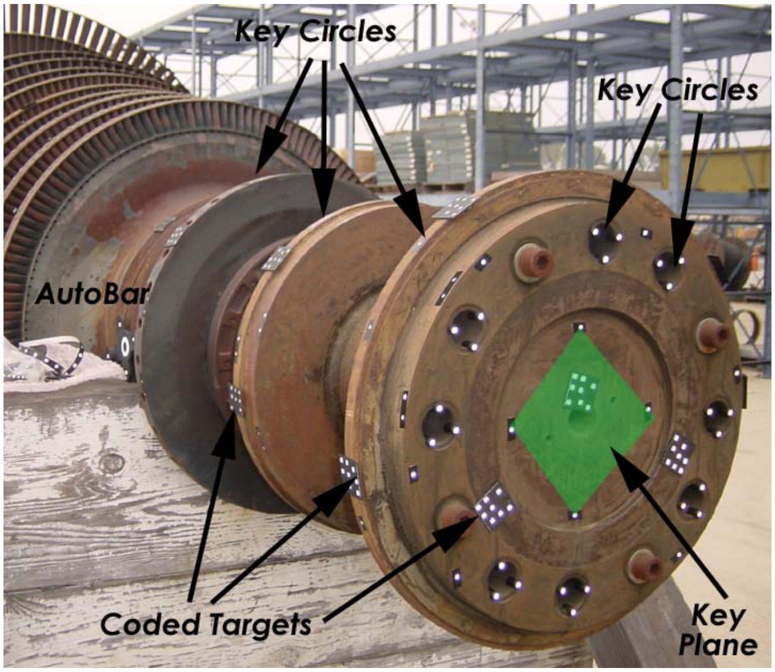


The initial coordinates system and approximate scale is determined via the AutoBar. The AutoBar used by the V-STARS system is a fixture with five targets arranged in the form of a cross. The target's known coordinates are used by the resection procedure to determine the camera's orientation relative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

Invar Scale Bar Kit

Some of the typical targeting features are shown in the image below: -



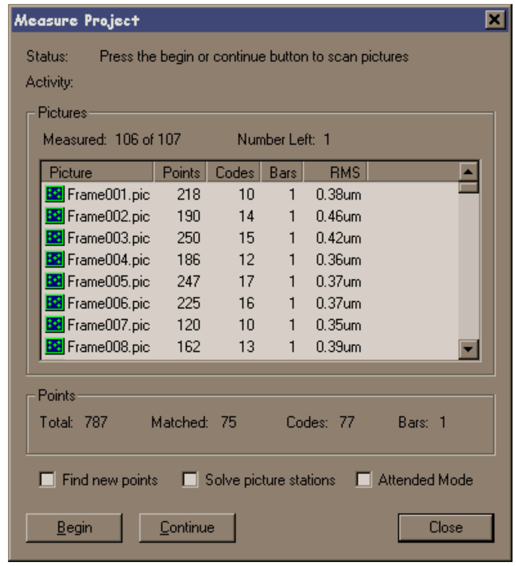
Photography

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. In most cases, the photography is very straightforward.

Processing

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

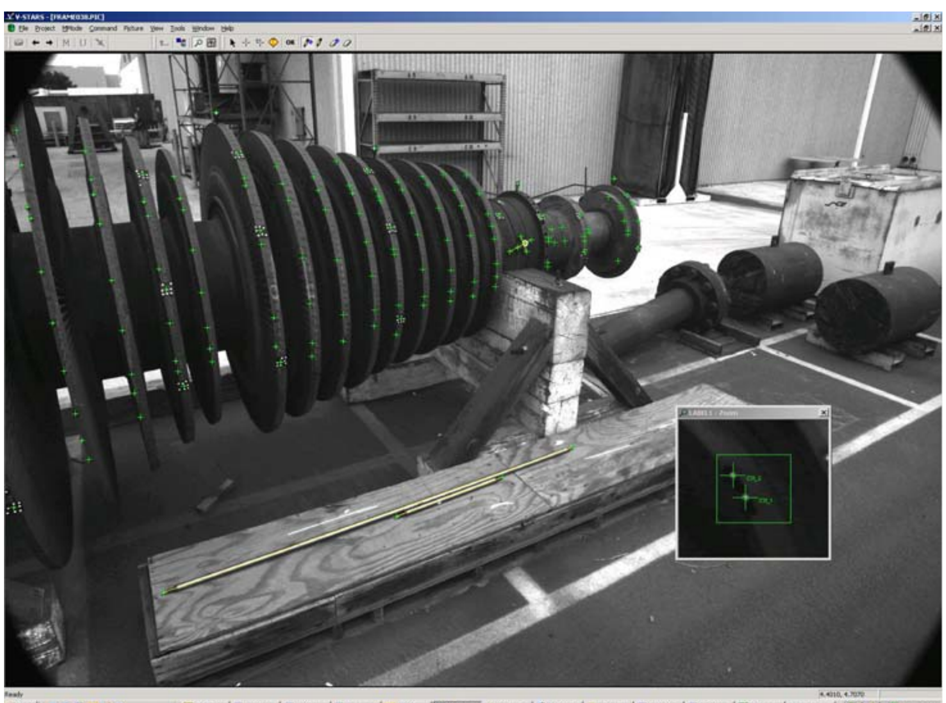
Almost all of the measurement process is automated. The images are processed and the coordinates extracted by the "AutoMeasure" command. A typical AutoMeasure dialog box is shown on the right. The AutoMeasure command will open each of the images, determine the camera location, find new target points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



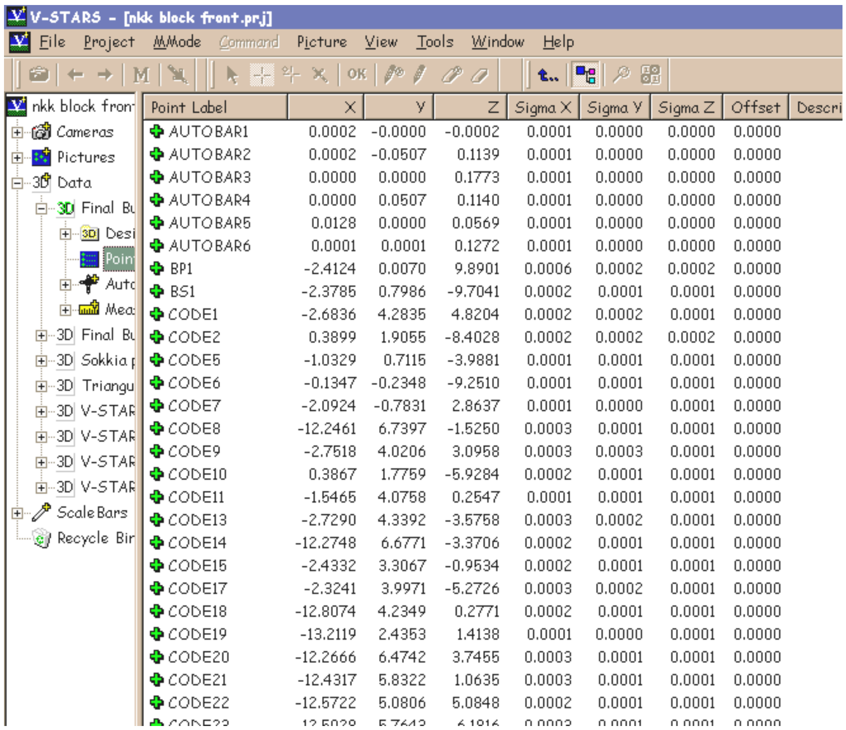
Typical AutoMeasure Dialog

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 most of the measurements undertaken the points were relabeled to simplify the analysis.

Seen below is a typical object measurement image. The image was taken from the Turbine measurement. Refer to the Results Report for more information.



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 ends.
At the conclusion of the AutoMeasure the 3D data is written to a file. A typical point listing from the 3D file 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	

This point data can be analyzed within the V-STARS' SOLIDS module, easily exported to almost any CAD platform or other analysis program.

Alignment

Typically one of the last tasks is alignment into the coordinate system of the object being measured. There are two basic types of alignment. The first is a simple Axis or 3-2-1 alignment. This alignment is based on three points – an origin, an axis point and a third point to define the plane in which the axis lies. The second type of alignment uses point correspondence from a known alignment (such as the CAD model) to transform the data into that coordinate system. This is a "best-fit" solution and is preferred as it involves greater redundancy.

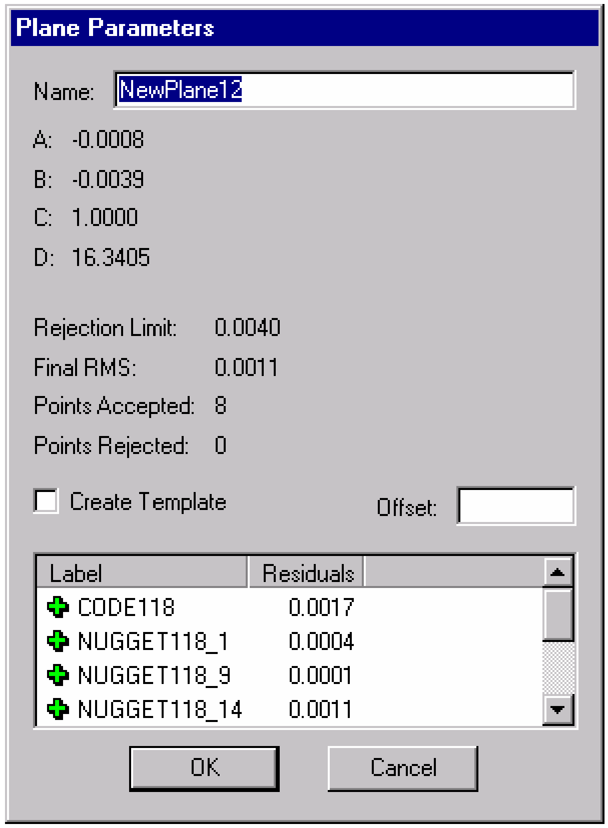
For both measurements an axis alignment was used to align the data.

Analysis

SOLIDS is the geometric analysis module of V-STARS. For example, consider a simple function like determining the distance between two points. 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 written to the 3D 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 image. The dialog gives you a few options and reports the results of the operation.

Similarly, best-fit lines, circles, cylinders, spheres, parabolas, etc. can also be calculated. SOLIDS also has the ability to measure between objects. For example, by selecting a point and a plane the normal distance can be computed. This makes SOLIDS a very useful analysis tool.



Typical Plane Dialog

Concluding Remarks

The measurements undertaken have shown that V-STARS with the INCA S6 system and PRO-SPOT projection system can be a very powerful measurement tool. The results of the measurement undertaken were very accurate and more importantly were produced quickly.

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