

# V-STARS Measurement Report

## Introduction:


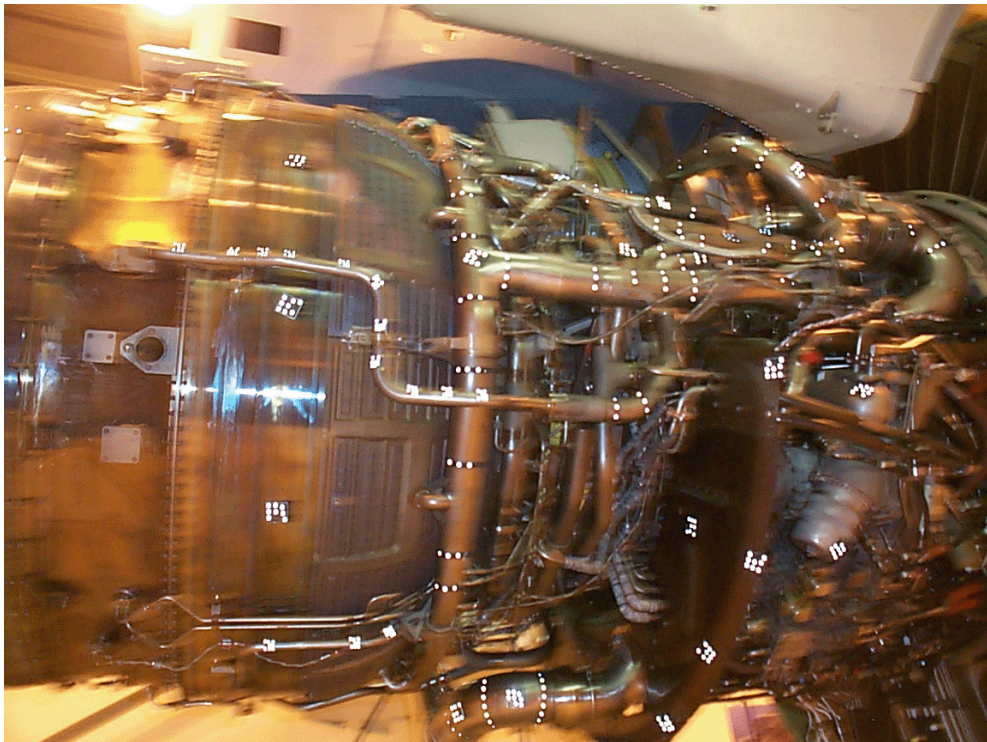
Object	Description	Requirements	Equipment
Aircraft Engine		<ol style="list-style-type: none"><li data-bbox="932 506 1326 569">1. Trace the location of various pipes.</li><li data-bbox="932 575 1326 638">2. Measure surface points on rear section.</li></ol>	V-STARS/S

TABLE 1 – Measurement Summary

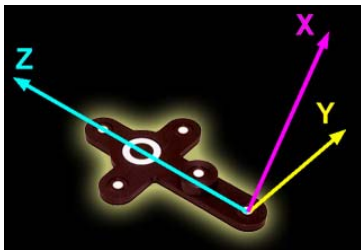
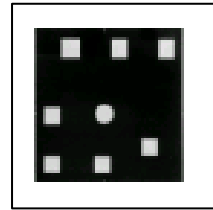


## Measurement Procedure:

## Targeting:

In order to meet the measurement objectives outlined earlier it was necessary to target the engine. 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 there were no bushed holes to measure. Strip tape was placed on each of the pipes that required measurement. Tape was also placed on a rear tail surface.

To automate the measurement process it was necessary to add "coded" targets to the engine. 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 engine. Special adapter targets that use coded targets for identification were also used to help measure a 1.25" section of pipe.



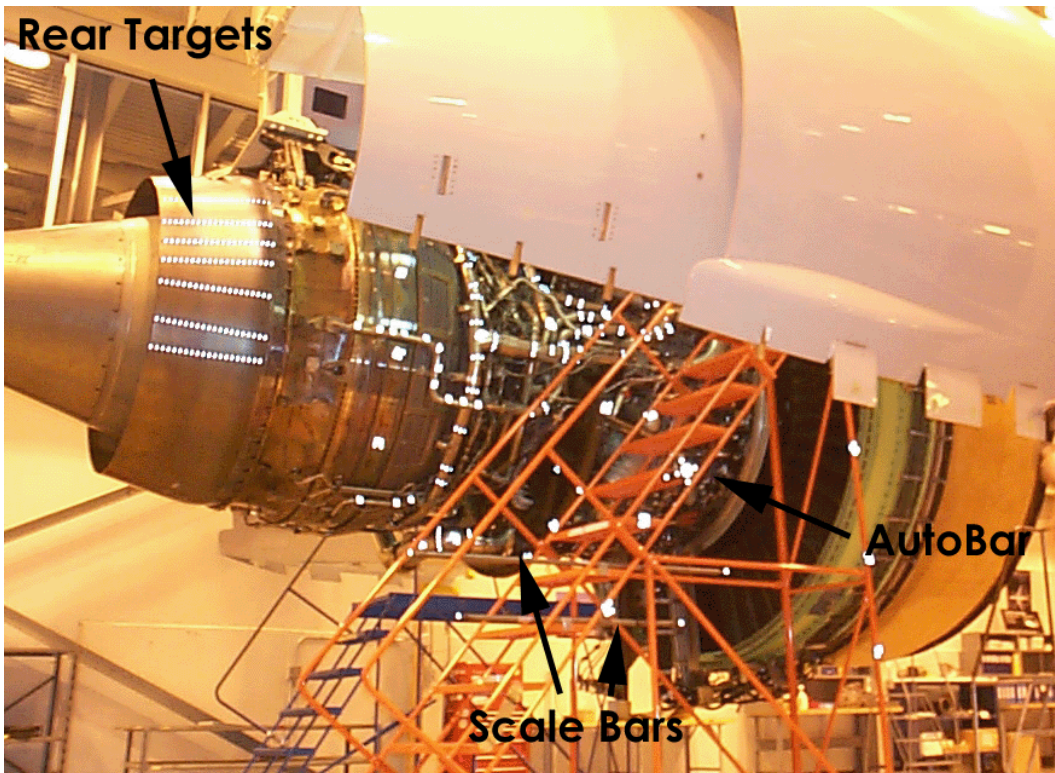
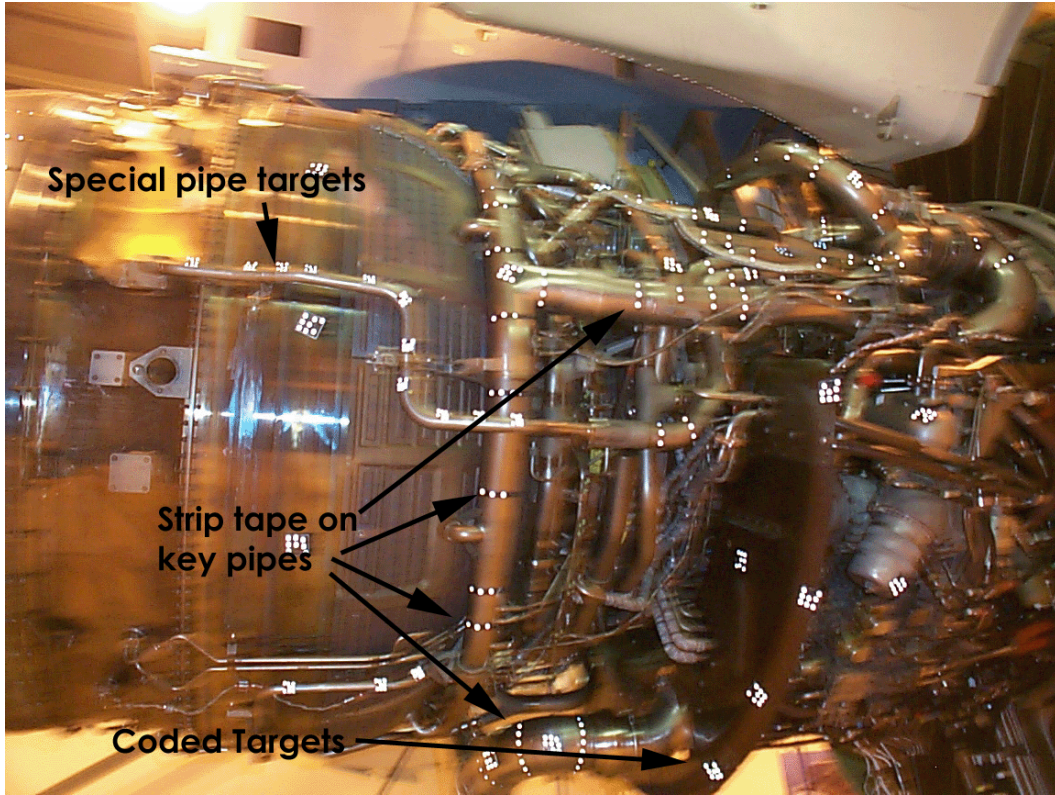
The initial coordinates system and scale is determined via the AutoBar. The AutoBar used by the V-STARS system is a fixture with five targets arranged in the form of a cross. The target's known coordinates are used by the AutoMatch procedure to determine the camera's orientation relative to the AutoBar.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





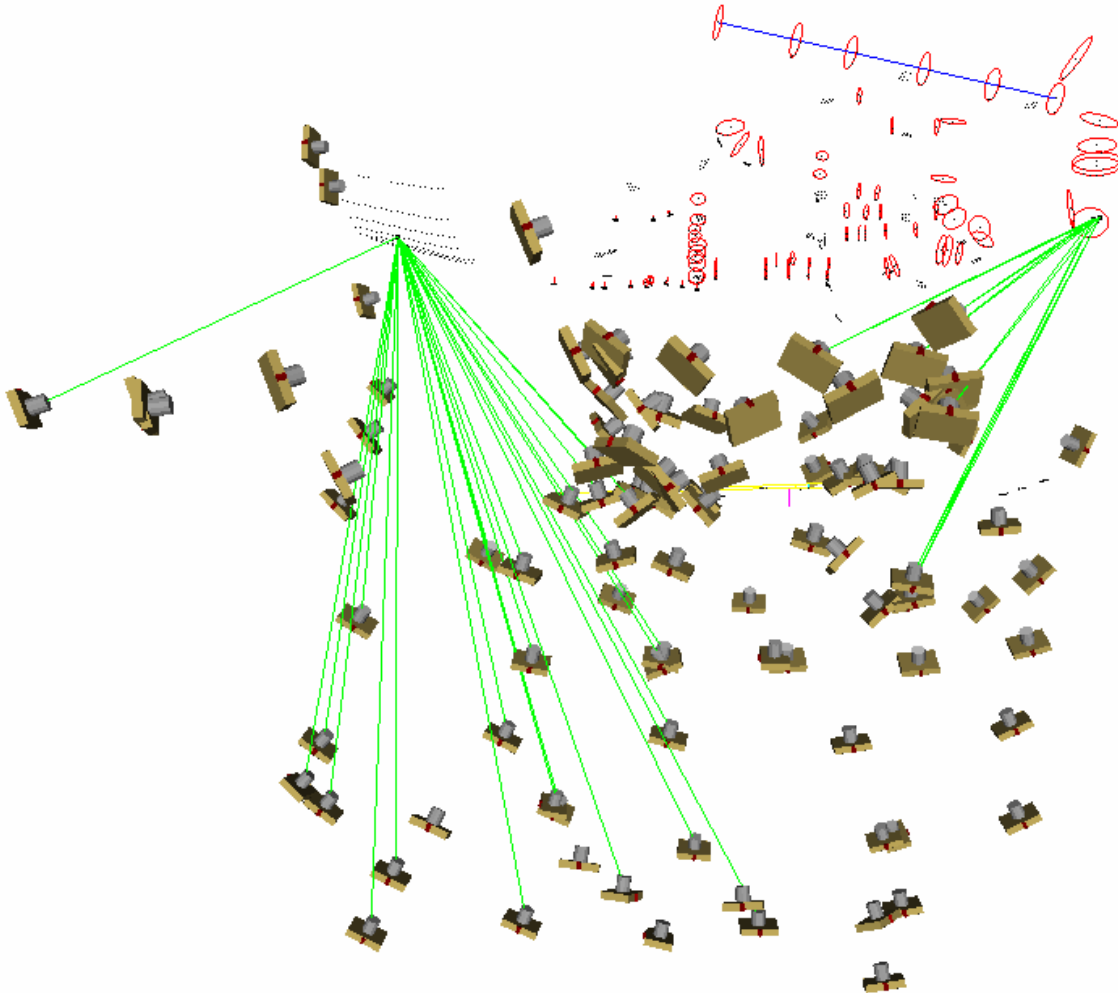
Some of the key targeting features are shown in the image below: -



## 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. A total of 100 photographs were taken of the engine. The number of photos taken depends on the complexity of the measurement and accuracy requirements. In this case the photography was complicated by the difficult lines of sight.

The photography for the engine was completed in approximately five minutes. Camera station locations for the measurement are shown in the diagram below. Also shown is a sample intersection pattern for a point. Each of the green lines represents an observation to that point from the corresponding camera station.

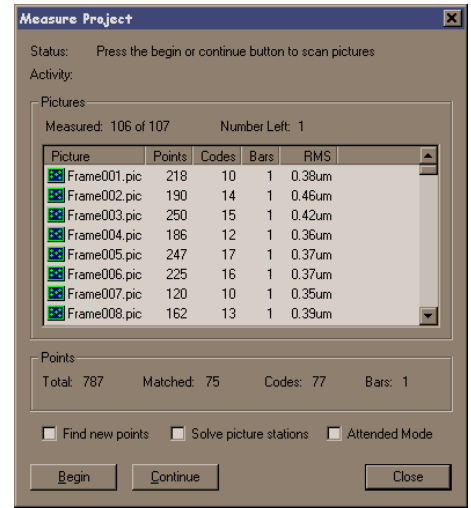


## Processing:

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 an image taken as part of the engine 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 engine.

No. of photos	100
No. of points	800
No. of scales	2
Scale Agreement	0.0002"
Accuracy RMS(") X,Y,Z	X      0.0007
	Y      0.0004
	Z      0.0004

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	
CODE23	12.5028	5.7413	6.1816	0.0003	0.0001	0.0001	0.0000	

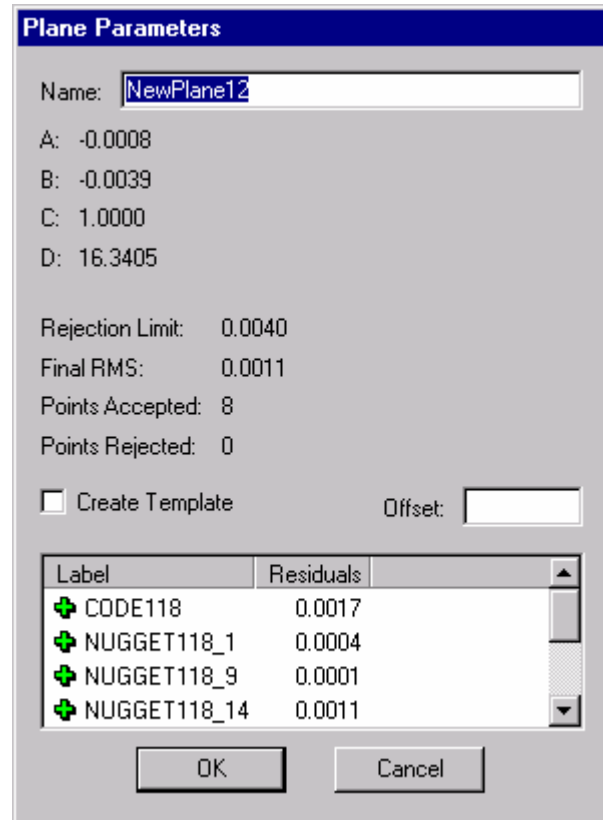
This point data can be analyzed within the V-STARS' SOLIDS module, easily exported to almost any CAD platform or other analysis program. For this particular project, the analysis was completed in SOLIDS.

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 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 image. The dialog gives you a few options and also reports the results of the operation.

Similarly, best-fit lines, circles, spheres 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.

For this measurement only the best-fit circle option was used.



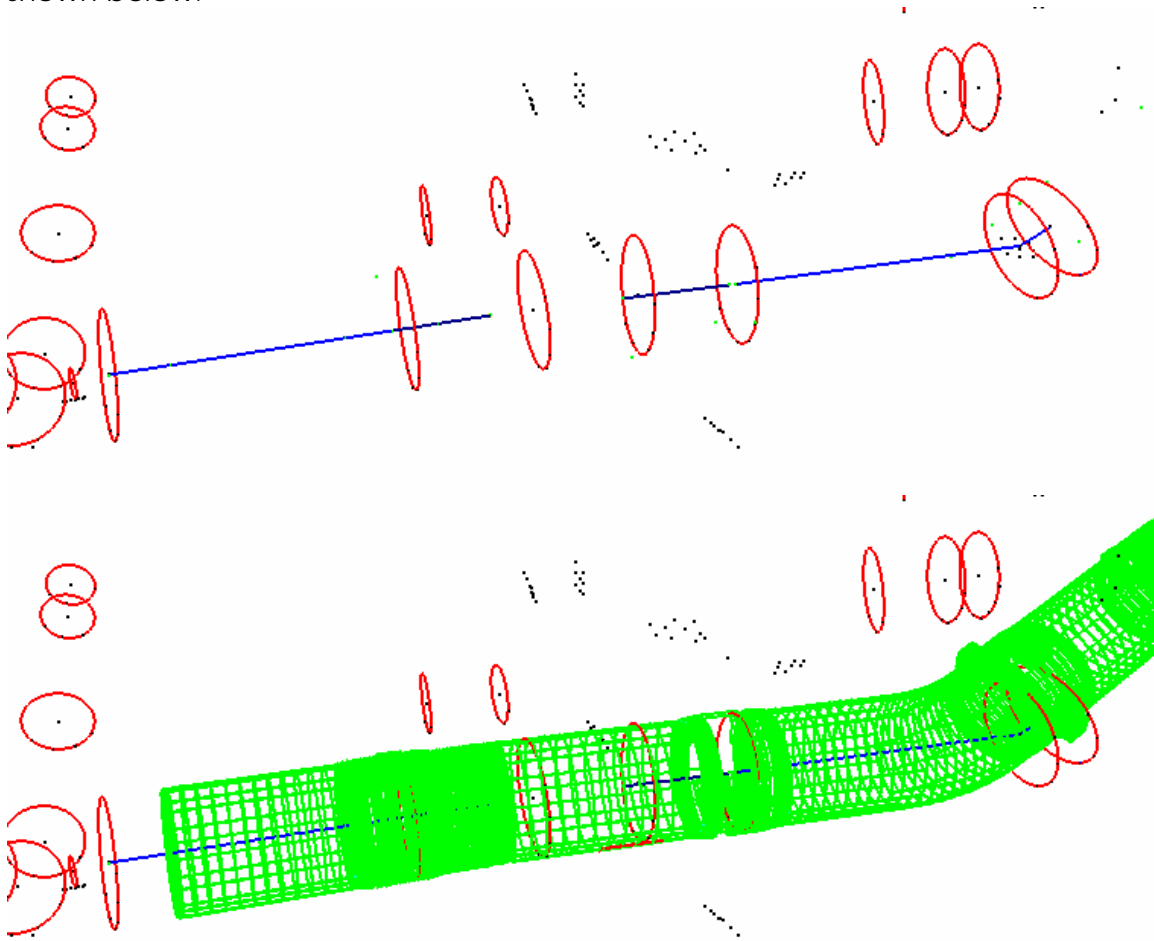
### Alignment:

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.

In this project the alignment was necessary to facilitate comparison to the CAD model. The CAD model supplied to aid the alignment is shown below:



For this project it was difficult to create an alignment. This was due to a lack of reference datums at the time of measurement. The intention was to create the alignment based on features. Due to the complexity of the engine, our lack of knowledge on the engine and the absence of engine point data, only an approximate alignment was carried out. Future measurements would benefit greatly through the inclusion of datum targets. The approximate alignment was completed using a bend in the pipe to help establish a correspondence point between the model and the acquired. Points along the centerline were then used to control the direction of the alignment. The alignment diagrams are shown below:

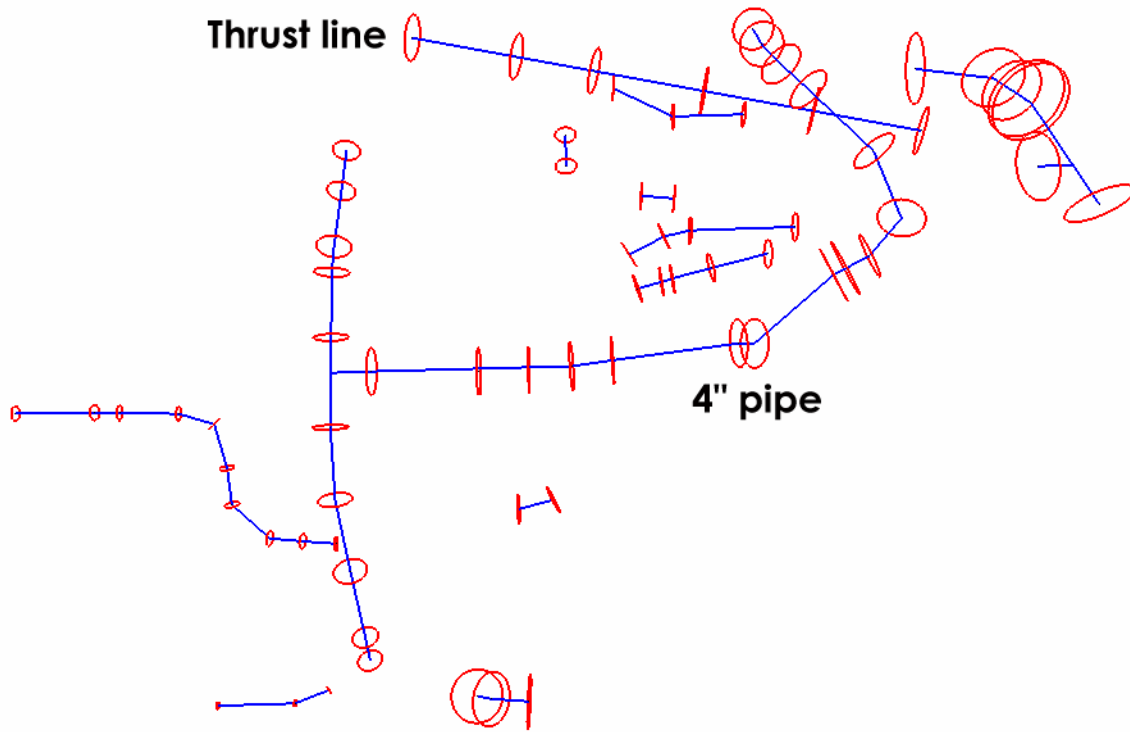


The diagrams above illustrate that the alignment should be translated to left. This is fairly obvious if you consider the circle sections on the right hand side of the diagram. The best approach would probably be a surface alignment.



**Analysis:**

The final point clouds and the derived circles are shown in the image below. For clarity, lines have been drawn between the circle centers to help define the pipe path.



**Time Summary:**

The following is an estimate of the time taken to complete the measurement.

Targeting	20 minutes
Photography	5 minutes
Processing	5 minutes
Analysis	30 minutes
<b>Total</b>	<b>60 minutes</b>