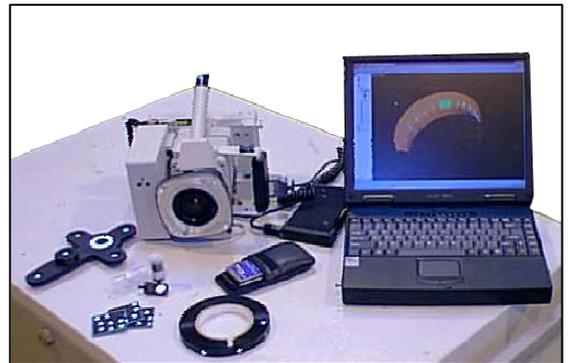




## Report on demonstration of V-STARS for GKN Westland Aerospace Structures – Isle of Wight

### Introduction:

The following report is a summary of the V-STARS work carried out at the GKN Westland facility on the Isle of Wight. As part of the demonstration two measurements were undertaken. The first object measured was a Boeing Bullnose mould. The second measurement was a group of three small Boeing lay up moulds.



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

### Primary Measurement Requirements:

#### *Object 1 – Bullnose mould*

- Compute XYZ location of strip target points on surface.
- Measure edge of part and trim scribe lines
- Measure random surface points using hand-held probe.
- Import IGES model of mould
- Align component using five reference holes and tooling datums
- Compute deviations from surface points to IGES model



#### *Object 2 – Small moulds ( x 3)*

- Compute XYZ location of strip target points on surface of each mould. (These strips are visible in the image shown on the left)

Documentation:

The following documentation is included in this report.

- A report outlining methodology and results.
- The results of coordinate determination for each object
- Output of deviations from IGES model for Object 1
- Background information on the V-STARS system (Also refer to Appendix 1)
- A list of users and contact names

Itinerary:

The itinerary undertaken was as follows: -

*Monday 2<sup>nd</sup> November*

Afternoon	Equipment check out
Afternoon	Initial Measurement of object 1

*Tuesday 3<sup>rd</sup> November*

Morning	Measurement to IGES model
Morning	Demonstration Preparation
Afternoon	Measurement of object 2
Afternoon	Demonstration of Single and Multiple camera system

*Wednesday 4<sup>th</sup> November*

Morning	Measurement of object 2
Morning	Demonstration of Single and Multiple camera system

Measurement Procedure:

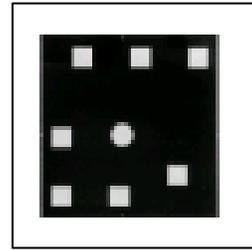
### ***Targeting.***

In order to meet the measurement objectives outlined earlier it was necessary to target each of 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. 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.

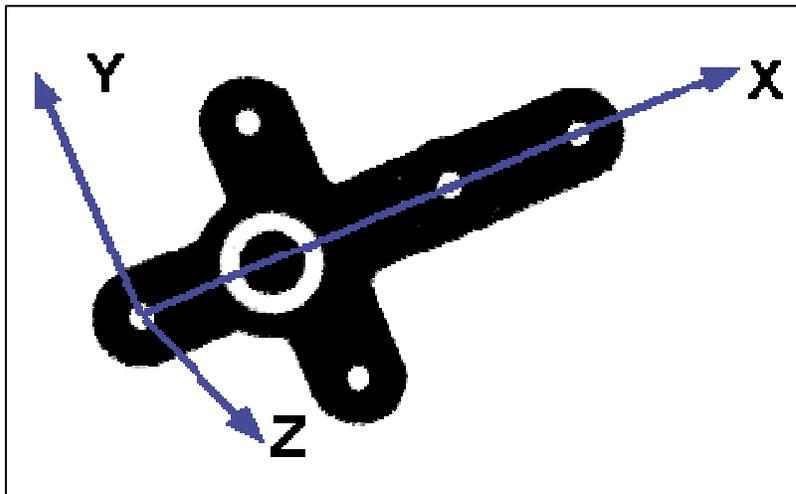
In the case of the Bullnose mould, strips of targets were placed at intervals along the curved section. Between two intervals, additional strips were also added to demonstrate how the increase the density of points measurement.

The targeting strategy for the second measurement was almost identical to the first. Once again additional strips were added to increase the point data on one of the small moulds. There were no datums available for targeting.

To automate the measurement process it was necessary to add "coded" targets to the objects being measured. 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 in quasi-random order on each of the objects.



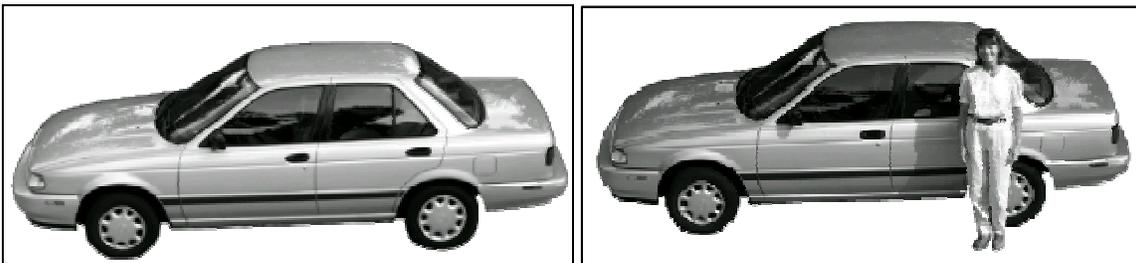
The initial coordinates system and scale is determined via the AutoBar. The AutoBar used by the V-STARS system is a fixture with five targets arranged in the form of a cross.



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

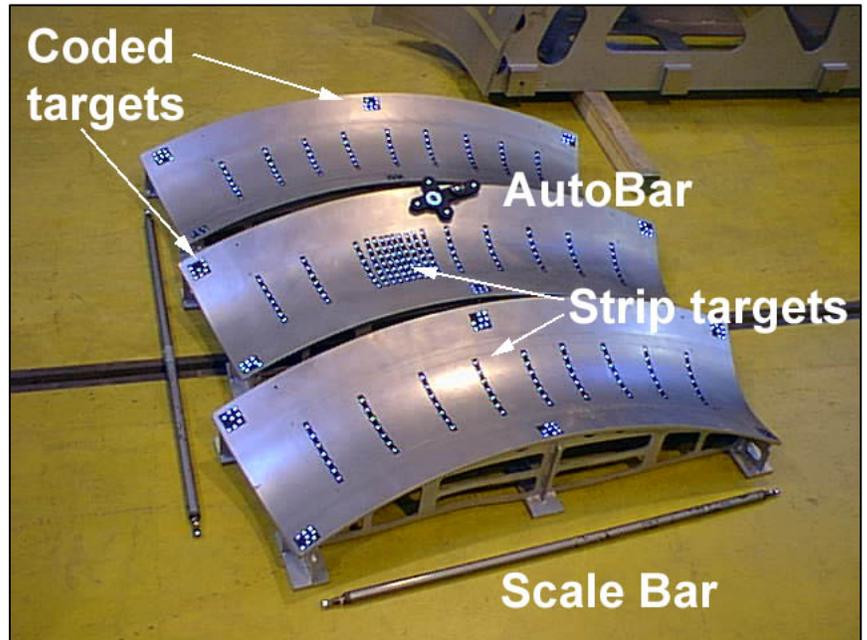
Y-axis goes through Target 3 at the top of the bar. The positive Z-axis is up out of the AutoBar. The diagram on the left shows both the AutoBar and its coordinate system

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 match box 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. Two scale distances was used in each measurement. These distances came from two calibrated scale bars. Typically multiple scales are used for redundancy.

The image on the right of object 2 shows the distribution and location of the AutoBar, coded targets, strip targets and scale bars.

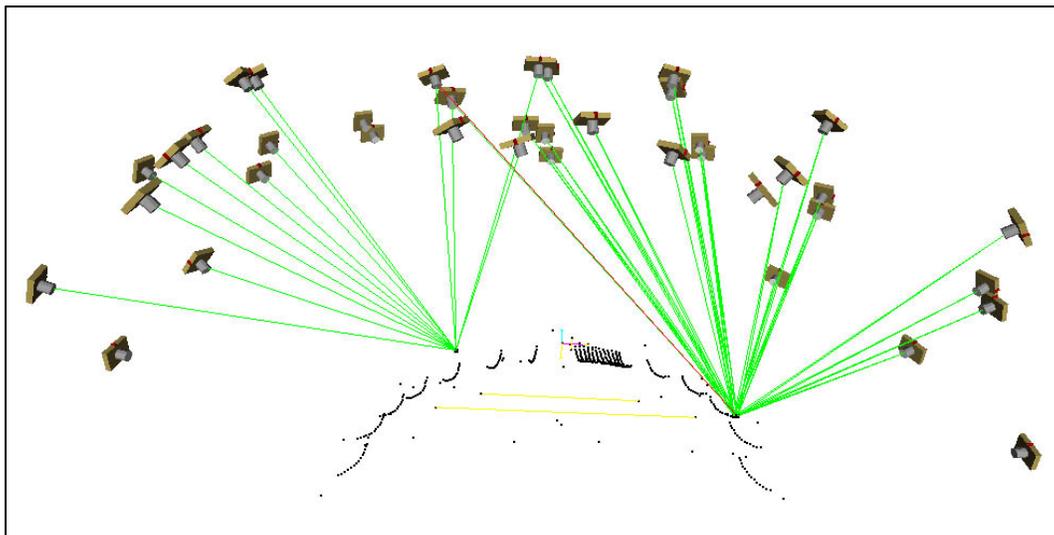


### ***Photography***

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.

### ***Object 1 – Bullnose mould***

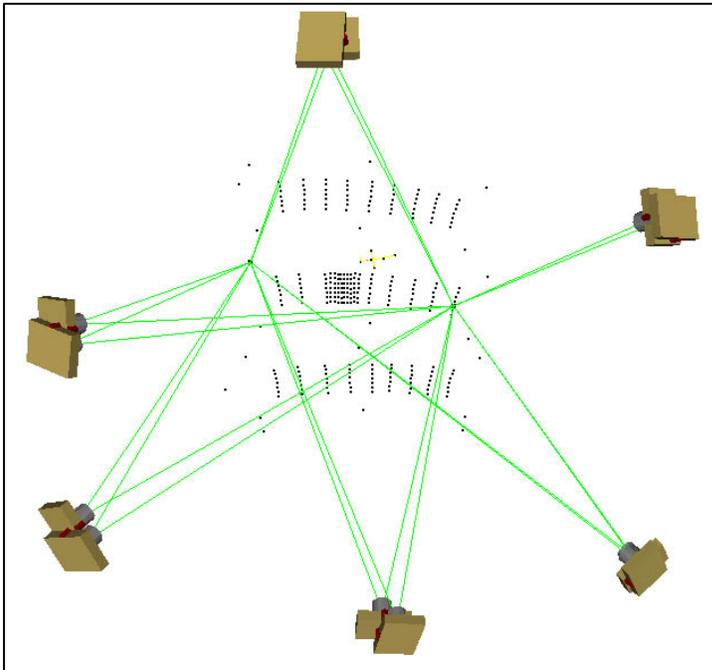
The photography for the mould was completed in approximately 5 minutes. The camera station locations for the measurement are shown in the diagram below. Also shown are some sample intersection angles to points of interest.



A total of 40 photographs were taken of the mould. The number of photos taken depends on the complexity of the measurement and accuracy requirements. In this case perhaps 30 photos would have sufficed.

**Object 2 – Small moulds**

The photography for the three small moulds was completed in less than 3 minutes. The camera station locations for the measurement are shown in the diagram below.



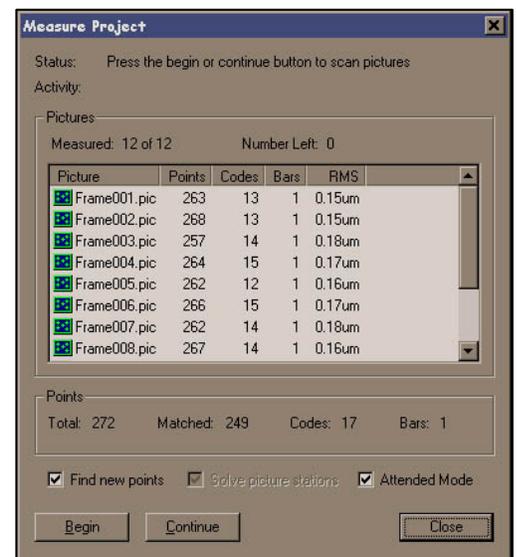
Once again some sample intersection angles to points of interest are also shown. Also shown is an image of the data collection.

A total of 12 photographs were taken of the small lay up mould.

**Processing**

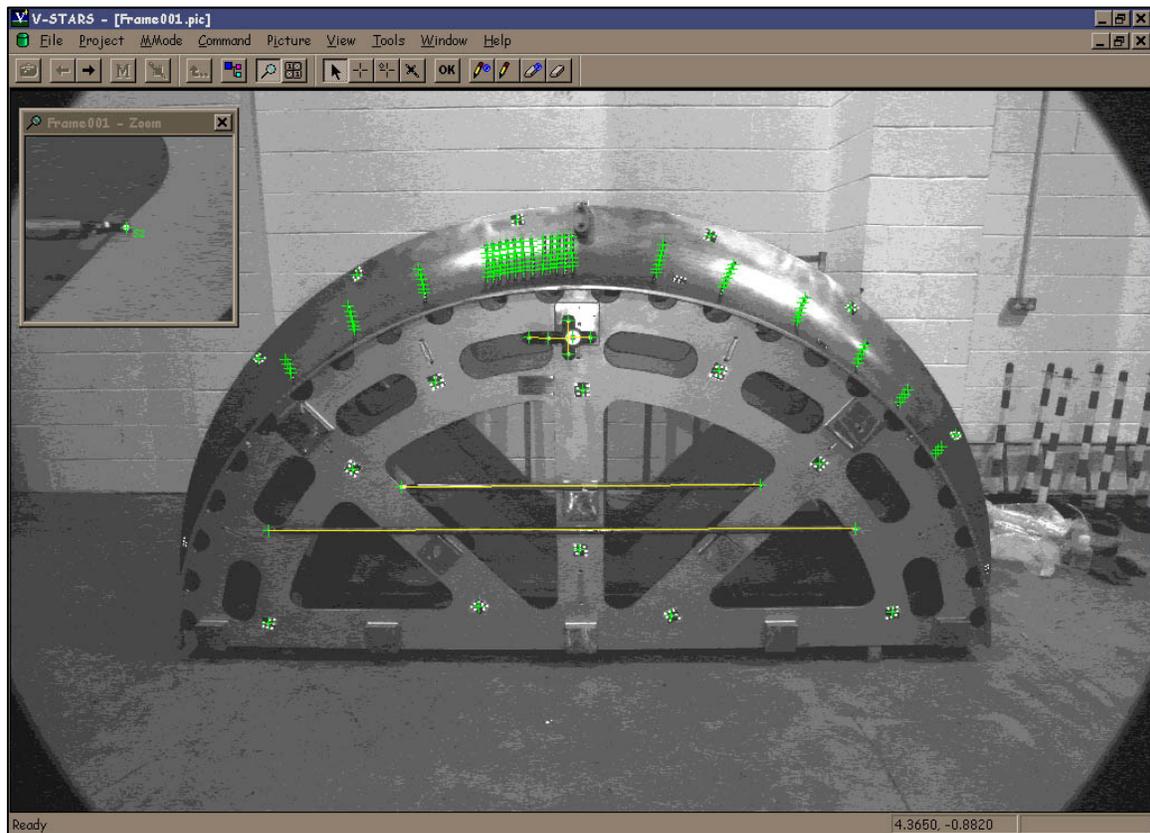
Once the photography has been completed the images are transferred to the system laptop. The images are stored on a PCMCIA hard drive and V-STARs accesses these images directly from the drive.

Almost all of the measurement process is automated. The images are processed and the coordinates extracted by the “AutoMeasure” command. The 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.



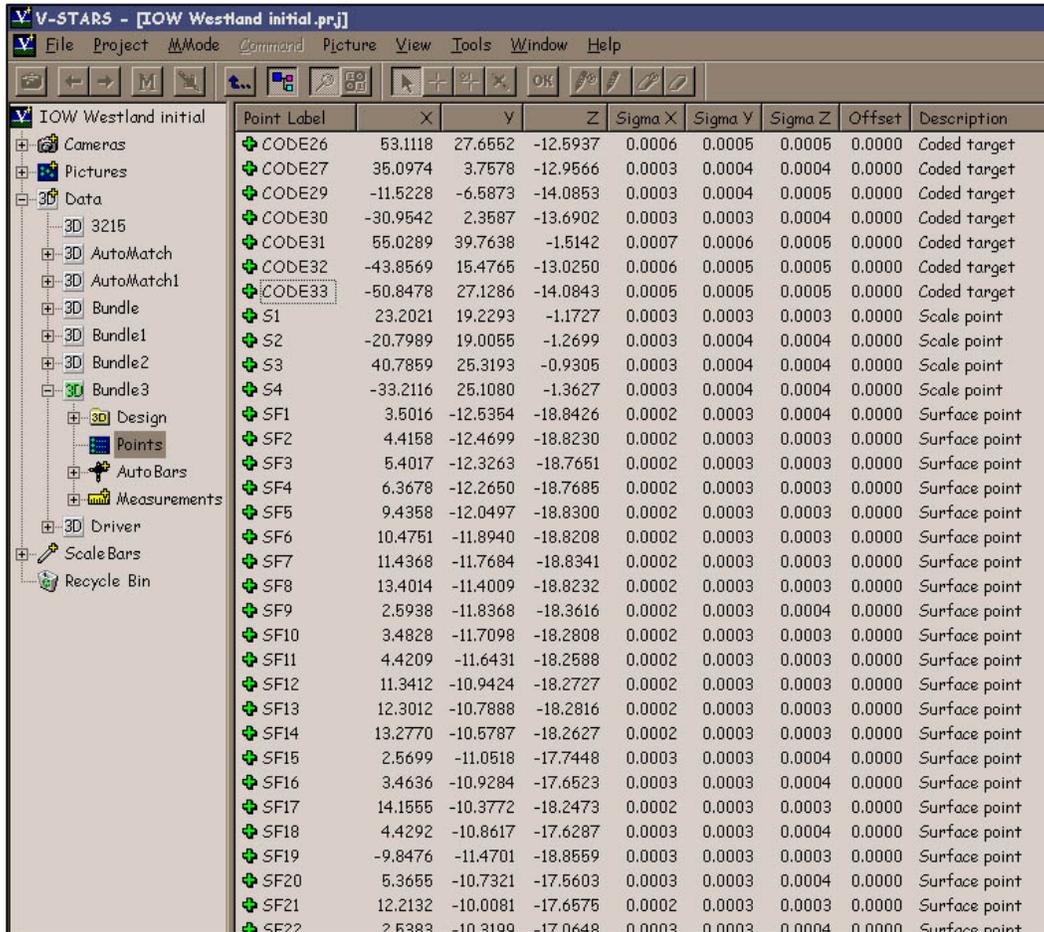
The AutoMeasure routine will assign random labels to the points it finds. These labels start with the key word "Target" followed by a number. If specific labelling is required the random labels can be easily changed to labels defined by the user. This is possible in both the picture view and the graphical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

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



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. The yellow lines represent the scale bars.

Finally, the points can be listed. A typical point listing is shown below.



Point Label	X	Y	Z	Sigma X	Sigma Y	Sigma Z	Offset	Description
CODE26	53.1118	27.6552	-12.5937	0.0006	0.0005	0.0005	0.0000	Coded target
CODE27	35.0974	3.7578	-12.9566	0.0003	0.0004	0.0004	0.0000	Coded target
CODE29	-11.5228	-6.5873	-14.0853	0.0003	0.0004	0.0005	0.0000	Coded target
CODE30	-30.9542	2.3587	-13.6902	0.0003	0.0003	0.0004	0.0000	Coded target
CODE31	55.0289	39.7638	-1.5142	0.0007	0.0006	0.0005	0.0000	Coded target
CODE32	-43.8569	15.4765	-13.0250	0.0006	0.0005	0.0005	0.0000	Coded target
CODE33	-50.8478	27.1286	-14.0843	0.0005	0.0005	0.0005	0.0000	Coded target
S1	23.2021	19.2293	-1.1727	0.0003	0.0003	0.0003	0.0000	Scale point
S2	-20.7989	19.0055	-1.2699	0.0003	0.0004	0.0004	0.0000	Scale point
S3	40.7859	25.3193	-0.9305	0.0003	0.0004	0.0004	0.0000	Scale point
S4	-33.2116	25.1080	-1.3627	0.0003	0.0004	0.0004	0.0000	Scale point
SF1	3.5016	-12.5354	-18.8426	0.0002	0.0003	0.0004	0.0000	Surface point
SF2	4.4158	-12.4699	-18.8230	0.0002	0.0003	0.0003	0.0000	Surface point
SF3	5.4017	-12.3263	-18.7651	0.0002	0.0003	0.0003	0.0000	Surface point
SF4	6.3678	-12.2650	-18.7685	0.0002	0.0003	0.0003	0.0000	Surface point
SF5	9.4358	-12.0497	-18.8300	0.0002	0.0003	0.0003	0.0000	Surface point
SF6	10.4751	-11.8940	-18.8208	0.0002	0.0003	0.0003	0.0000	Surface point
SF7	11.4368	-11.7684	-18.8341	0.0002	0.0003	0.0003	0.0000	Surface point
SF8	13.4014	-11.4009	-18.8232	0.0002	0.0003	0.0003	0.0000	Surface point
SF9	2.5938	-11.8368	-18.3616	0.0002	0.0003	0.0004	0.0000	Surface point
SF10	3.4828	-11.7098	-18.2808	0.0002	0.0003	0.0003	0.0000	Surface point
SF11	4.4209	-11.6431	-18.2588	0.0002	0.0003	0.0003	0.0000	Surface point
SF12	11.3412	-10.9424	-18.2727	0.0002	0.0003	0.0003	0.0000	Surface point
SF13	12.3012	-10.7888	-18.2816	0.0002	0.0003	0.0003	0.0000	Surface point
SF14	13.2770	-10.5787	-18.2627	0.0002	0.0003	0.0003	0.0000	Surface point
SF15	2.5699	-11.0518	-17.7448	0.0003	0.0003	0.0004	0.0000	Surface point
SF16	3.4636	-10.9284	-17.6523	0.0003	0.0003	0.0004	0.0000	Surface point
SF17	14.1555	-10.3772	-18.2473	0.0002	0.0003	0.0003	0.0000	Surface point
SF18	4.4292	-10.8617	-17.6287	0.0003	0.0003	0.0004	0.0000	Surface point
SF19	-9.8476	-11.4701	-18.8559	0.0003	0.0003	0.0003	0.0000	Surface point
SF20	5.3655	-10.7321	-17.5603	0.0003	0.0003	0.0004	0.0000	Surface point
SF21	12.2132	-10.0081	-17.6575	0.0002	0.0003	0.0003	0.0000	Surface point
SF22	2.5383	-10.3199	-17.0648	0.0003	0.0003	0.0004	0.0000	Surface point

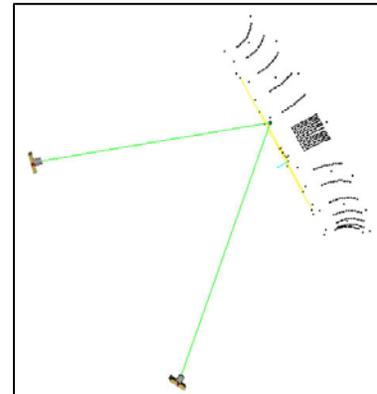
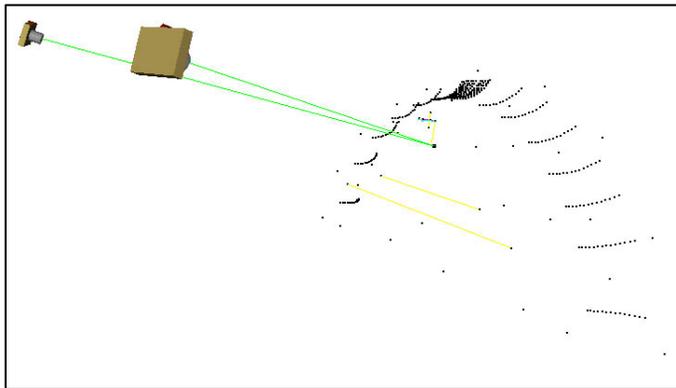
This point data can be analysed within the V-STARS' Solids module, easily exported to almost any CAD platform or other analysis program. This aspect of the Bullnose measurement was completed in less than 20 minutes. The measurement of the three small lay up tools was completed in less than 10 minutes.

**Point Probing – M Mode.**

In order to meet the remaining measurement objectives outlined earlier for the Bullnose mould it was necessary to configure the system for use in M or Multi camera mode. In this mode two or more cameras are used to determine the location of a hand held probe. The use of these probes is typically called for when features that are cannot be readily targeted are required. These features might include edge points, holes or scribe lines. For this particular measurement both scribe lines and holes were required.



To work in M-Mode a coordinated reference frame is required. This reference frame is used to determine the location of the cameras after each flash. Fortunately no additional work is required to establish this reference as it was established during the initial single camera network. Once an image has been acquired the cameras are capable of determining their orientation relative to the object. This information is presented graphically so that the user can decide whether the positioning is suitable for the area of interest. Sample graphical information is shown below.



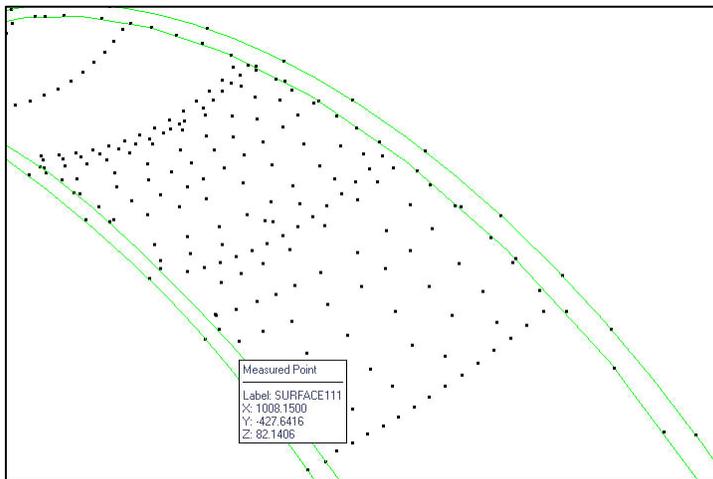
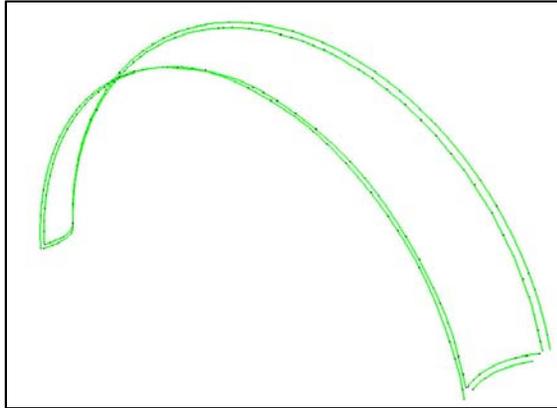
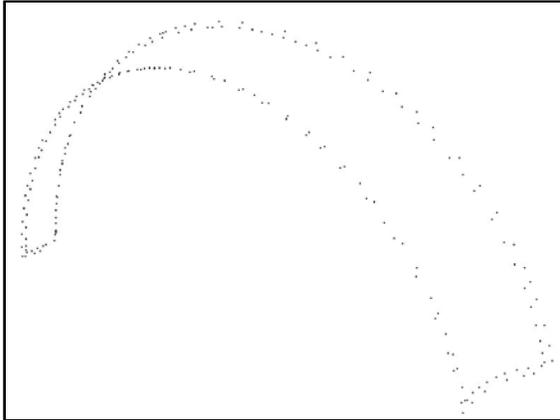
Measuring with the hand held probes is as simple as pointing the cameras roughly at the area of interest, placing the probe on the point of interest and pressing the hand held trigger. Each camera images the probe, determines the type of probe being used and sends this information to the system laptop. V-STARs then takes this data and computes the XYZ location of the probe tip.



Once all the points of interest are measured the cameras are simply moved to the next position. Camera re-orientation is carried out automatically. The cameras orientate themselves during each point measurement which means that the cameras or the object can be vibrating without any ill effect to the resulting point data.



One of the stipulated requirements for the Bullnose mould measurement was the determination of the trim and edge of part scribe lines. These scribe lines were measured using a 3mm ball tip probe. Once this data was collected curves were created through the points. Images representing the scribe points and lines are shown below. A full listing of V-STARs coordinates for the scribe points can be found in "scribes.txt"

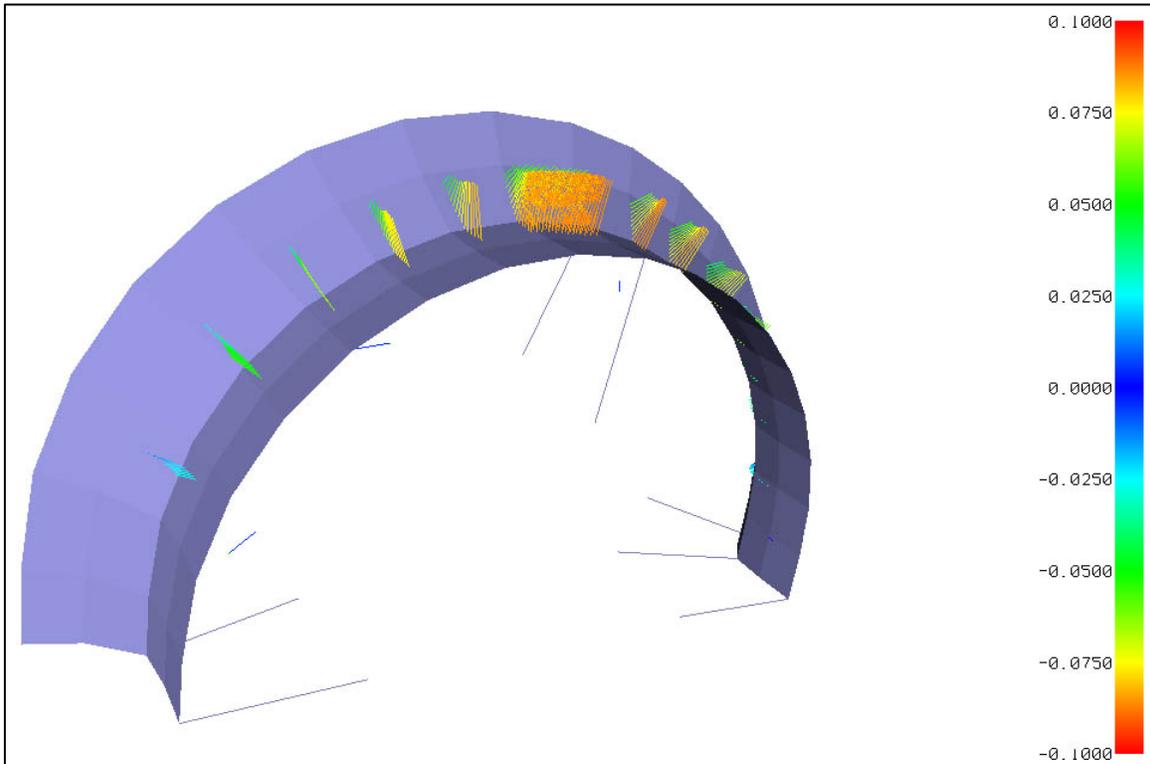


Another requirement was to pick up surface points off the mould using the hand held probe. These points are shown in the adjacent image. The probing was completed quasi-randomly. The use of a probe to establish surface points is naturally cheaper than the use of strip tape. However, it is more time consuming to do so. Probing is highly suited in areas where dense point data is required.

Another measurement requirement involved determining the deviation of surface points to the corresponding IGES model of the Bullnose mould. With the V-SURF module it is possible to import IGES models into the V-STARs graphical viewer and do point to surface comparisons. The IGES model is shown in the adjacent image. The comparison was completed using the surface target points determined in the initial network. These targets have an offset of 0.1mm or 0.004"



Surface deviations can be displayed in the form of a surface colour map. This helps the user identify problem areas visually.



Examination of the data reveals that there seems to be a datum shift. This shift may be inherent in the mould itself or perhaps a result of poor alignment. The results of this comparison can be found in "Deviations.txt".

Concluding Remarks:

The measurement of these objects has demonstrated that videogrammetry can be a very powerful measurement tool in the aerospace industry. The results of the measurement are very accurate and more importantly were produced quickly.

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