V-STARS E3X and S6 Demonstration
Measurement Report for

Doosan Heavy Industries & Construction Co., Ltd.

South Korea

June 2004

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Object Measured

One object was measured as part of the V-STARS demonstration. The object was a large ship block (13.6L x 2.8W x 1.6H). The block is shown on the cover of this report.

The primary objective of this measurement was to determine some of the key dimensional information of the block.

Of key importance in this measurement was the time to complete the measurement and the accuracy.

The block was measured once with the E3X system and once with the INCA2 S6 system. Due to a hardware problem with the INCA2 the second measurement of the block had to be completed on the following day.

Equipment Used

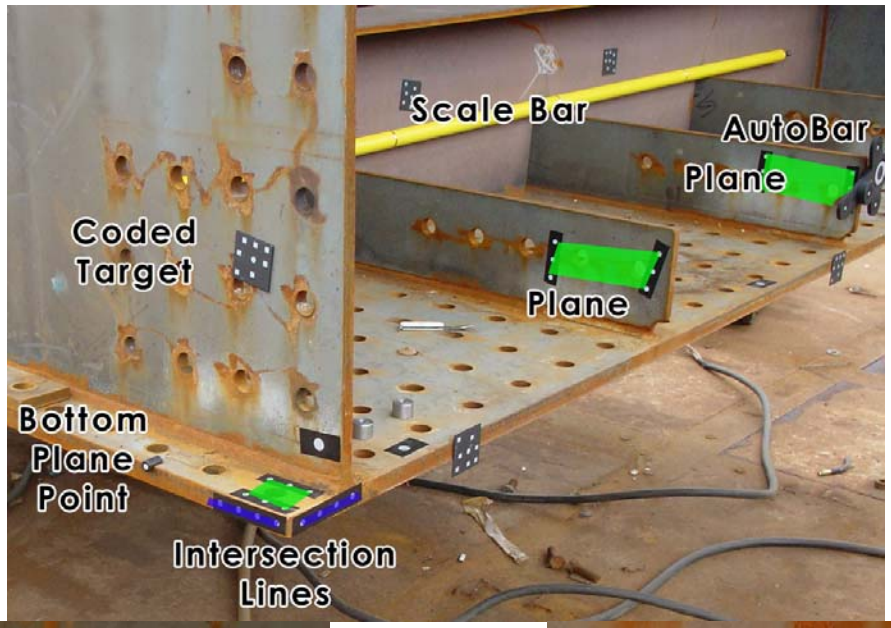
1. V-STARS S6 Camera System (INCA3 S8 system shown in image below)
2. V-STARS E3X Camera System
3. Scale Bars
4. AutoBar.
5. Various Targets

Block Measurement Objectives

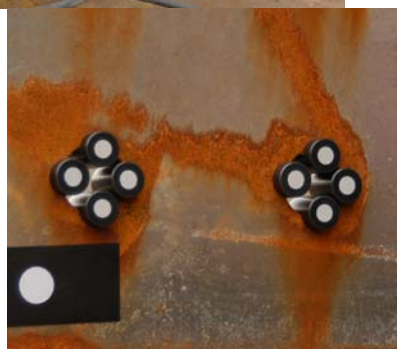
1. Demonstrate camera use and object targeting
2. Determine location of key corners
3. Determine the location of key bolt holes
4. Compute best-fit planes for block sides
5. Compute distances outlined on customer check sheet
6. Complete various analysis tasks

Block Targeting

1. AutoBar for initial coordinate system
2. Reference coded targets to tie photography together
3. Edge targets for bolt holes
4. Adapters for bolt holes (not used due to incorrect hole size)
5. Edge targets for key planes
6. Single dot targets for key planes
7. Two scale bars



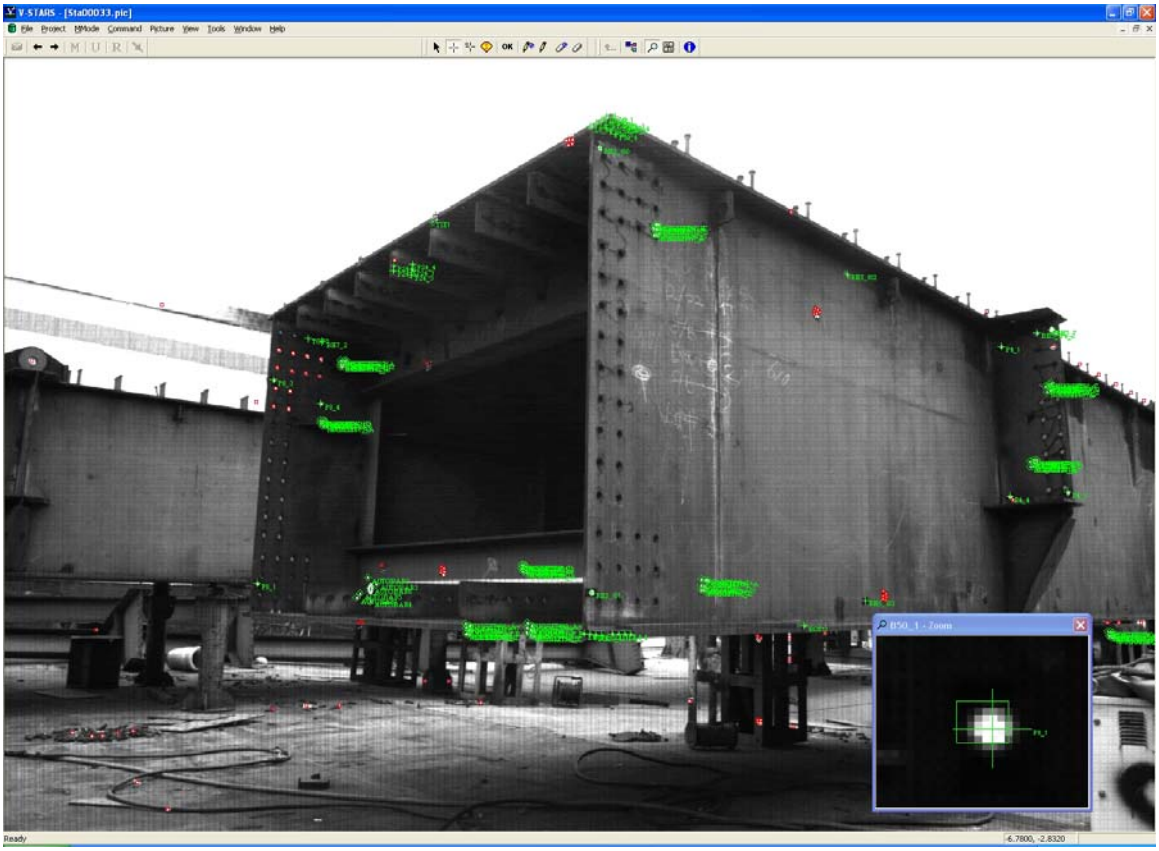
Bolt hole adapter



Bolt hole edge targets

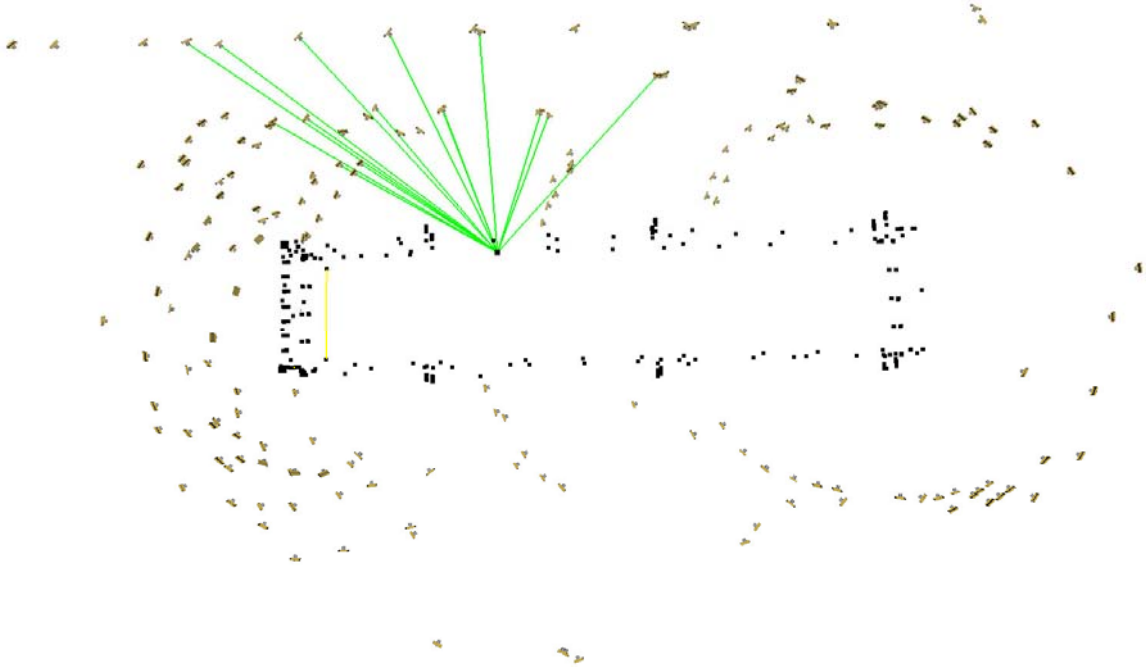
Measurement Statistics

E3X		**INCA2**	
No. of photos	180	No. of photos	175
No. of points	1357	No. of points	1546
Accuracy RMS X,Y,Z X 0.15mm Y 0.07mm Z 0.12mm		Accuracy RMS X,Y,Z X 0.04mm Y 0.03mm Z 0.05mm	
Scale Agreement = 0.12mm		Scale Agreement = 0.05mm	

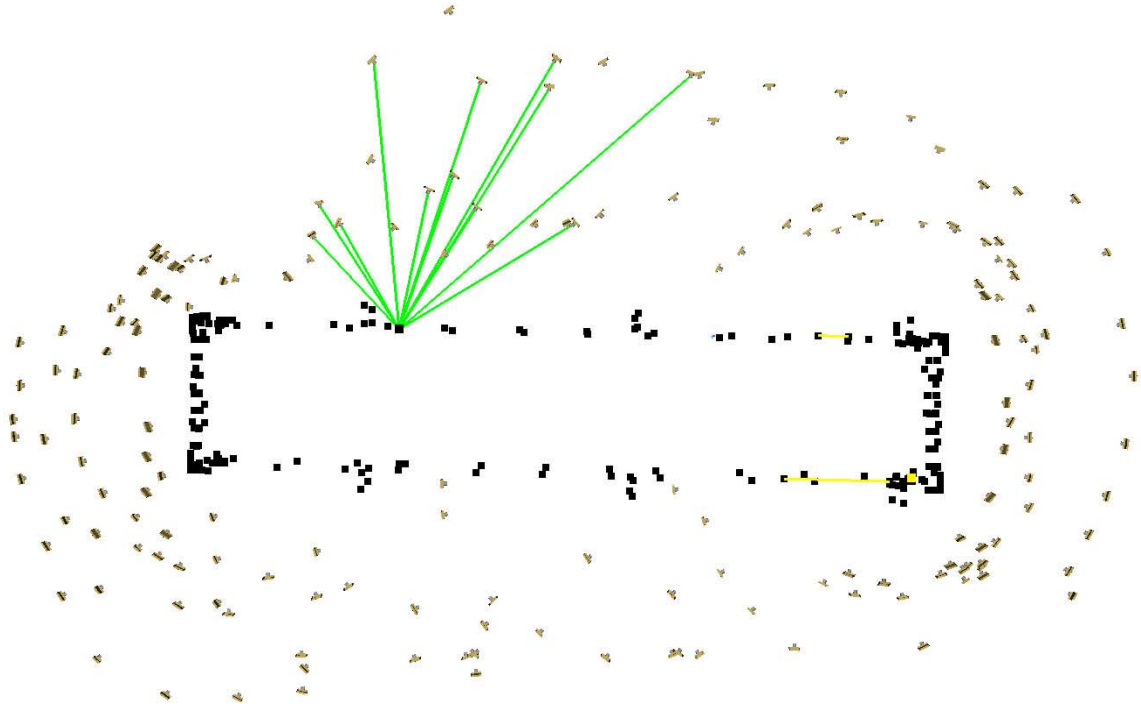


Typical V-STARS measurement image

The diagram below illustrates the geometry used to create the point cloud for each network.



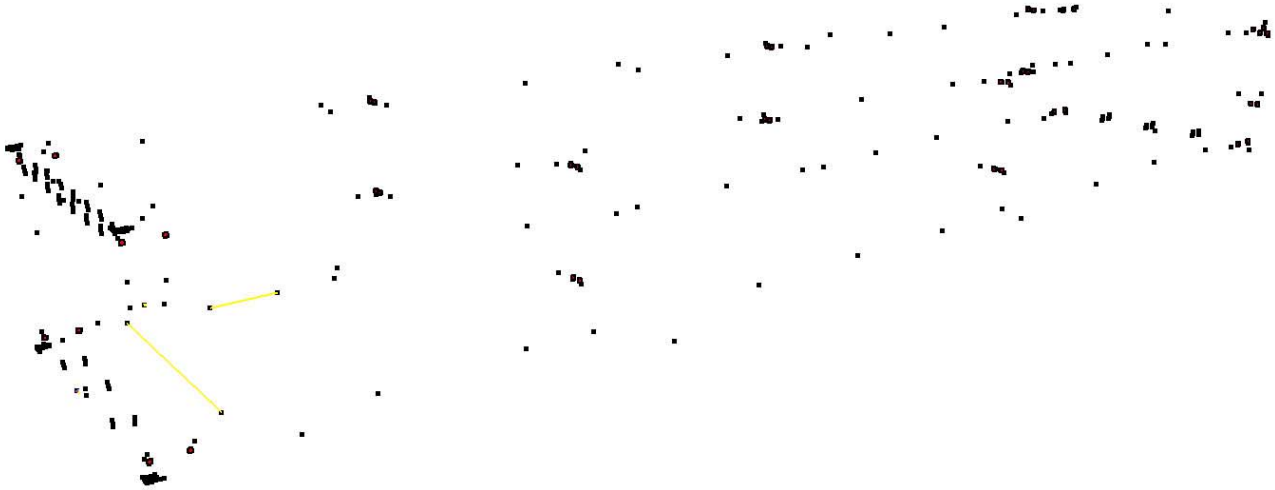
E3X Network - Top View



INCA2 Network - Top View

Point Cloud

The final point cloud from the E3X network is shown below. A similar point cloud was produced for the INCA2 measurement.

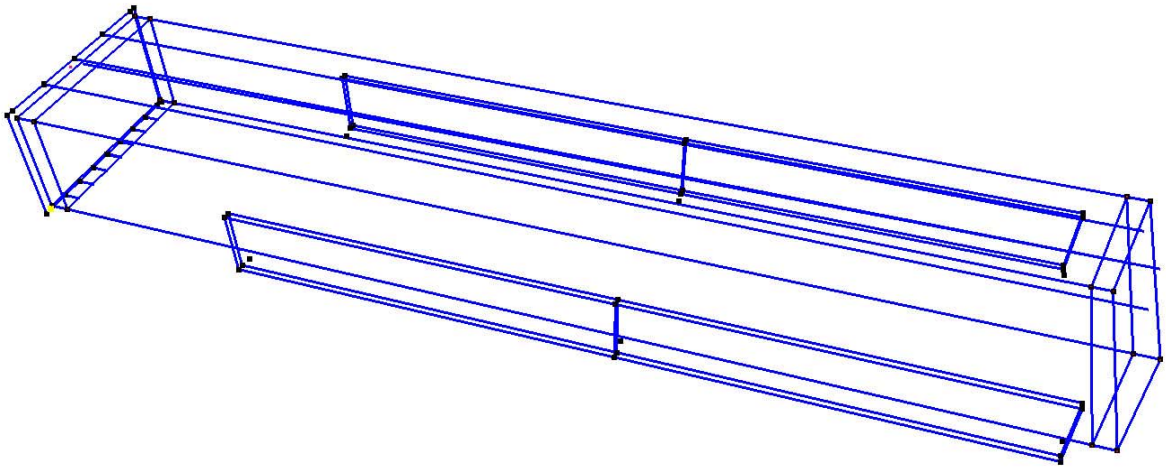


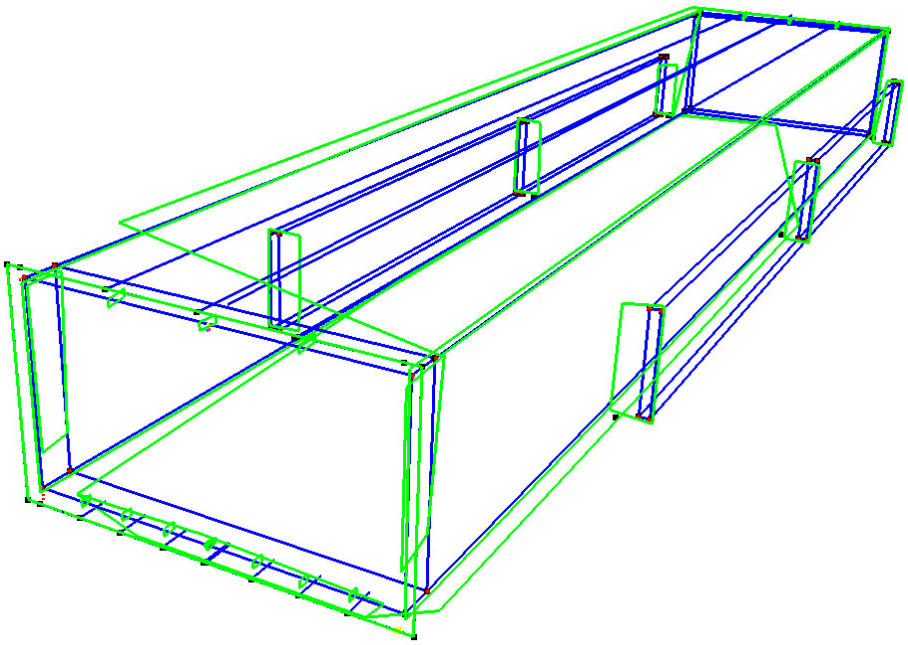
Alignment

No Alignment was necessary for this measurement. Typically the block would be aligned into the relevant design coordinate system.

Analysis

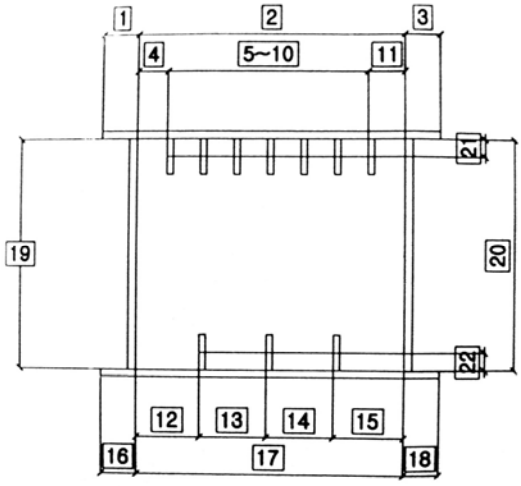
The data collected was used to compute the some of the key geometric characteristics of the block. Some of the key planes and lines computed are shown in the images below.

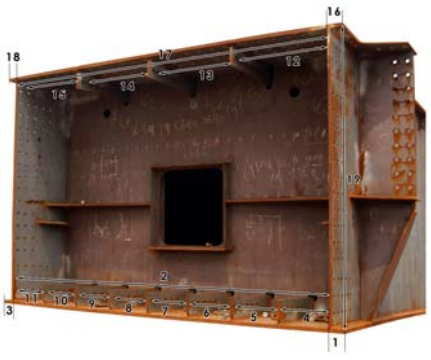




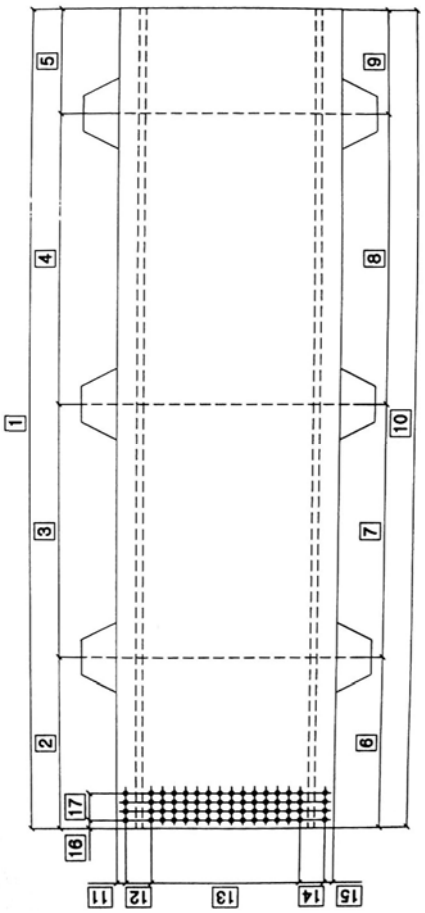
The check sheet supplied was used to verify some of the key distances. A "*" in the column signifies that no distance could be computed as that particular data was not collected. The results are summarized in the following tables.

	E3	INCA2	Difference
1	101.38	101.49	-0.11
2	2597.77	2598.45	-0.68
3	99.83	99.20	0.63
4	330.50	330.88	-0.38
5	324.74	324.59	0.15
6	324.98	325.21	-0.23
7	326.02	325.96	0.06
8	324.08	323.97	0.11
9	324.57	324.65	-0.08
10	326.89	327.07	-0.18
11	316.00	316.12	-0.12
12	655.75	*	
13	651.15	*	
14	648.06	*	
15	644.22	*	
16	100.25	*	
17	2599.16	*	
18	100.16	*	
19	1600.09	1599.75	0.34
20	1601.00	1600.84	0.16
21	*	*	
22	*	*	





	E3	INCA2	Difference
1	*	13750.71	
2	3120.07	3121.93	-1.86
3	5001.13	5001.73	-0.60
4	4997.88	5000.14	-2.26
5	*	632.62	
6	3116.88	3119.19	-2.31
7	4999.59	5000.71	-1.12
8	5000.49	5001.56	-1.07
9	*	*	
10	*	13752.00	
11	*	*	
12	*	*	
13	*	*	
14	*	*	
15	*	*	
16	*	*	
17	*	*	
18	49.62	*	
19	254.85	*	
20	50.05	49.71	0.34
21	255.19	*	
22	85.16	85.54	-0.38
23	1429.76	*	
24	85.19	*	

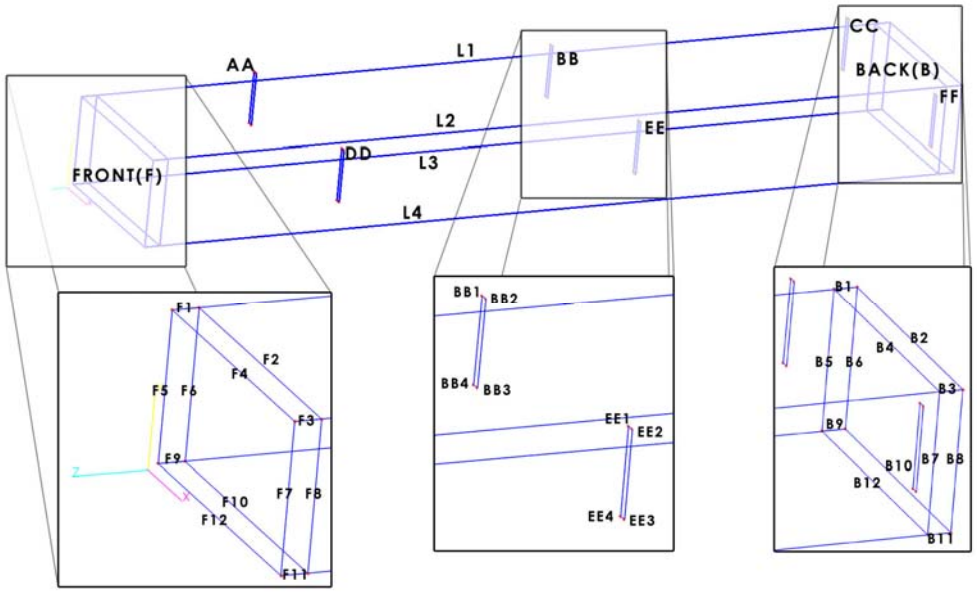


Note that no measurements were taken on the top bolt holes. Also note that only four corners were measured in the first survey and as a result the overall dimensions are missing.

Generally speaking most differences between surveys are quite small. Variability in the method used to create some of the key planes is responsible for some of the larger variations.

The bolt hole locations were used to compute some key distances. These are shown below. Note that in the second INCA2 measurement only four bolt holes were measured. As a result, there are only a minimum number of comparison distances.

The numbering scheme used and computed distances are shown below.

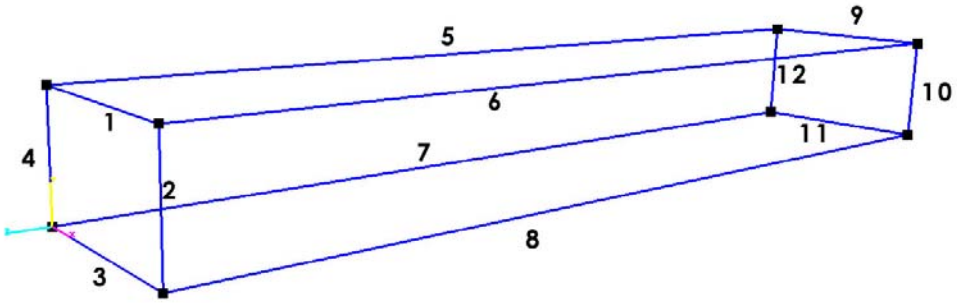


	Distance(mm)			Distance(mm)
F1	254.67		**B1**	256.38
F2	2631.99		**B2**	2631.53
F3	254.85		**B3**	55.59
F4	2632		**B4**	2631.55
F5	1430.07		**B5**	1432.1
F6	1430.29		**B6**	1428.85
F7	1429.76		**B7**	1428.92
F8	1429.49		**B8**	1429.28
F9	254.84		**B9**	256.15
F10	2629.72		**B10**	2629.27
F11	255.12		**B11**	254.64
F12	2629.73		**B12**	2629.28

Dist(mm)	1	2	3	4
AA	85.53	855.67	85.27	855.05
BB	84.40	854.89	84.71	856.30
CC	84.23	855.97	84.60	856.04
DD	84.63	855.30	84.69	855.28
EE	84.67	855.97	85.18	855.69
FF	83.92	855.86	84.04	855.00

Dist(mm)	E3	INCA2	Difference
L1	13648.05	*	*
L2	13650.81	*	*
L3	13649.44	13652.59	-3.15
L4	13650.42	13653.51	-3.09

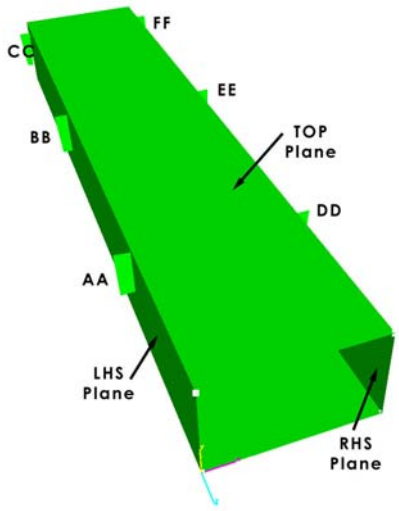
The corner distances are shown in the table below.



Dist(mm)	E3	INCA2	Difference
1	2798.97	2799.11	-0.14
2	1600.09	1600.54	-0.45
3	2799.58	2800.68	-1.10
4	1601.00	1599.75	1.25
5	*	13750.73	
6	*	13751.84	
7	*	13752.28	
8	*	13571.08	
9	*	2800.67	
10	*	1601.57	
11	*	2798.80	
12	*	1602.70	

The calculated plane to plane angles are shown below.

	E3		INCA2	
Angle °	**LHS Plane**	**RHS Plane**	**LHS Plane**	**RHS Plane**
AA	89.9557		89.9581	
BB	89.9751		89.9155	
CC	89.6591		89.5662	
DD		89.4673		89.5510
EE		89.7187		89.8615
FF		89.7616		89.8325
Top Plane	89.8847	89.9753	89.9541	89.9791



Time Summary

E3 Time

Initial Investigation	30 minutes
Targeting	60 minutes
Photography	30 minutes
Processing	120 minutes
Analysis	90 minutes
Total	**330 minutes**

INCA2 Time

Initial Investigation	10 minutes
Targeting	30 minutes
Photography	20 minutes
Processing	15 minutes
Analysis	15 minutes
Total	**90 minutes**

Future Measurements

With careful planning the time taken for future or ongoing measurements can be greatly reduced. It is envisaged that the measurement time can even be reduced to less than 60 minutes in most cases. The following are just a few examples of how the measurement time could be reduced.

Item	Effect	Estimated time saving
Neutral density filters	These filters cut out a great deal of ambient light and result in a much smaller image file size. This makes image file scanning and processing significantly faster.	Scanning will be 5-10 times faster
Dedicated measurement area.	The creation of a dedicated measurement area with permanent coded targets has a significant effect on targeting time and photography.	Approx. 15-30 minutes saved for targeting, more for processing.
Photographic procedure	The introduction of a photographic plan or procedure ensures that the time photographing the object is minimized, while maximizing the point accuracy.	Approx. 10 minutes.
Bolt hole adapters	Bolt hole adapters will allow rapid targeting of the bolt hole positions.	Adapter targeting in < 5 minutes
Special corner targets	Feature targets are special targets that allow features such as corners to be rapidly measured. They are processed automatically by V-STARS software. A time saving benefit is achieved both during the targeting and analysis stage.	Corner targeting in < 5 minutes. Analysis reduced to no time.

Item	Effect	Estimated time saving
Macro analysis functions	V-STARS incorporates "construction" objects which are powerful analysis macros. Construction objects allow repeated analysis tasks to be completed automatically.	Analysis tasks can be completed in minutes rather than hours
Template projects	Template project allow key project parameters to be set up the same way for each block measured.	Potential saving of 30-60 minutes

Concluding Remarks

The measurement undertaken has shown that V-STARS can be a very powerful measurement tool. The results of the measurement undertaken were very accurate. The results of the INCA2 importantly were produced quickly.

GSI would like to thank Doosan 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.