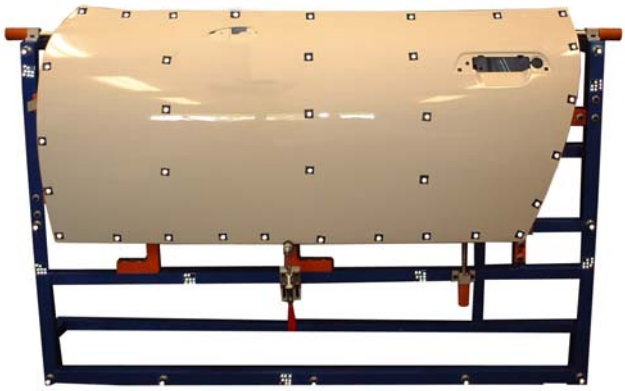
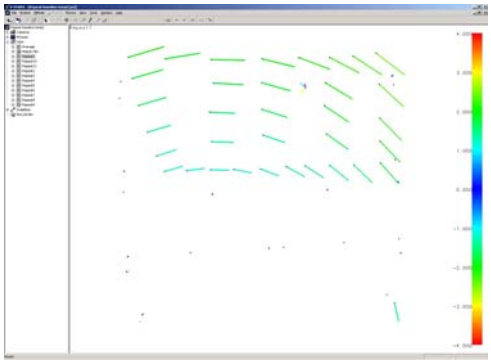
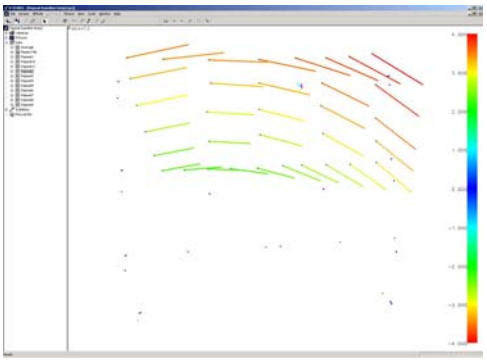
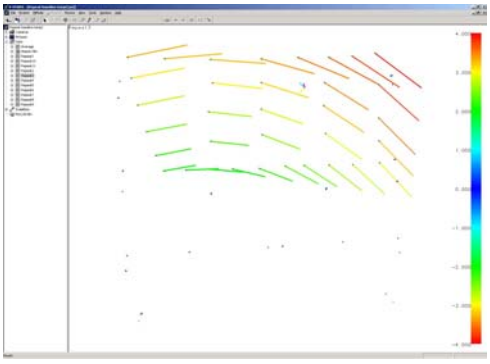
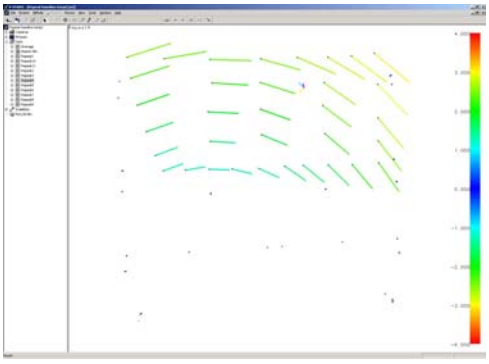
Automated Repeatability Module (ARM) Release Notes











September 2002

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Introduction

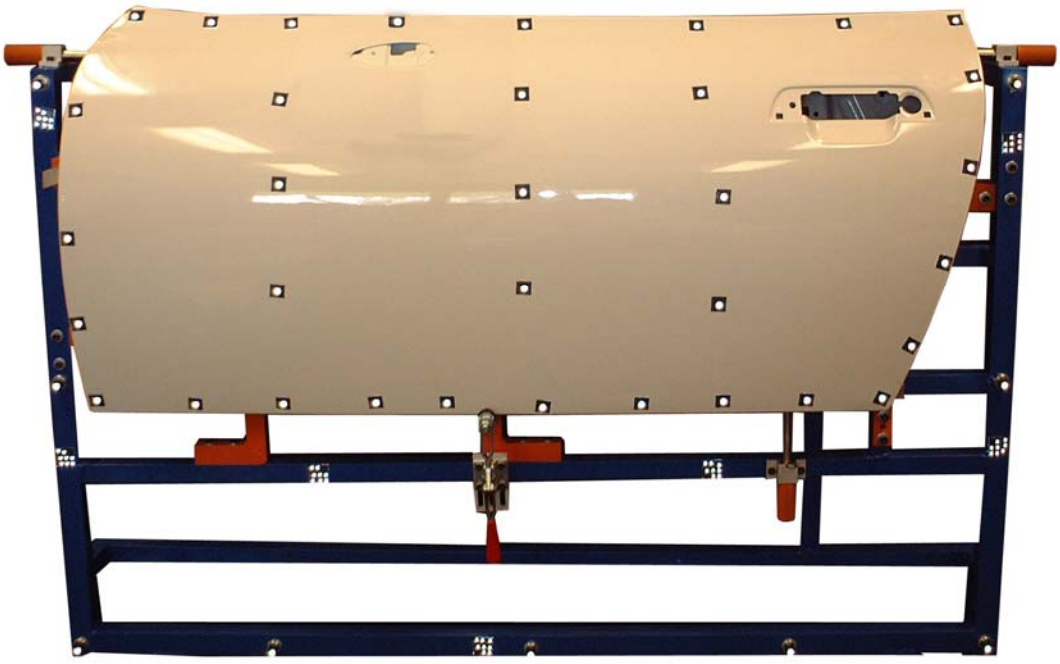
The following document describes the new Automated Repeatability Module (ARM) available in the latest V-STARS release. (Version 4.3) For more information on the new features found in V-STARS Version 4.3 please refer to the V-STARS 4.3 Release Notes.

ARM is a fast, easy and automated way to complete Repeatability Studies. ARM will do the following:

- Automatically split the images from each trial into separate jobs.
- Scan, measure, and reduce each trial to produce a 3D file.
- Transform the file against the selected Baseline file.
- Organize the output from each trial into a series of summary Excel spreadsheets.

Implementation

To simplify the explanation of how ARM works and is used, a mock measurement was conducted. The mock measurement is a repeatability study concerned with the loading and unloading of a door into a holding fixture. The fixture and door used are shown below.

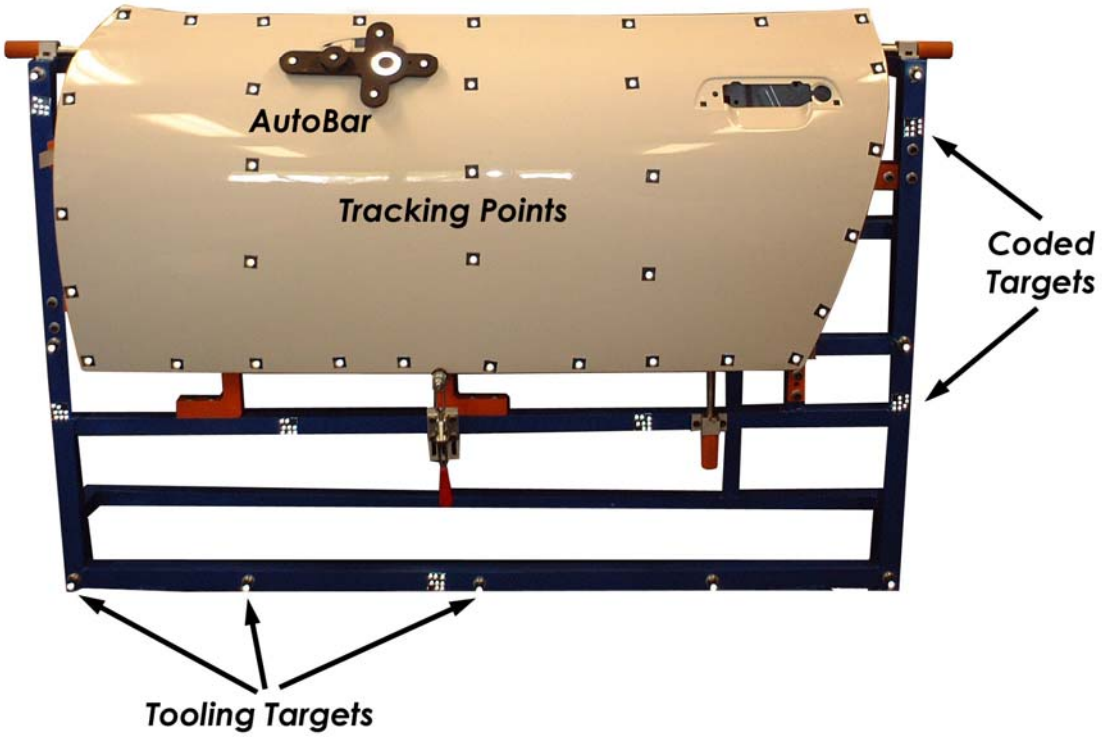


The measurement consisted of one baseline measurement and 11 measurements (trials) where the door was removed and then replaced.

Step 1: Object Targeting

The following targeting was used.

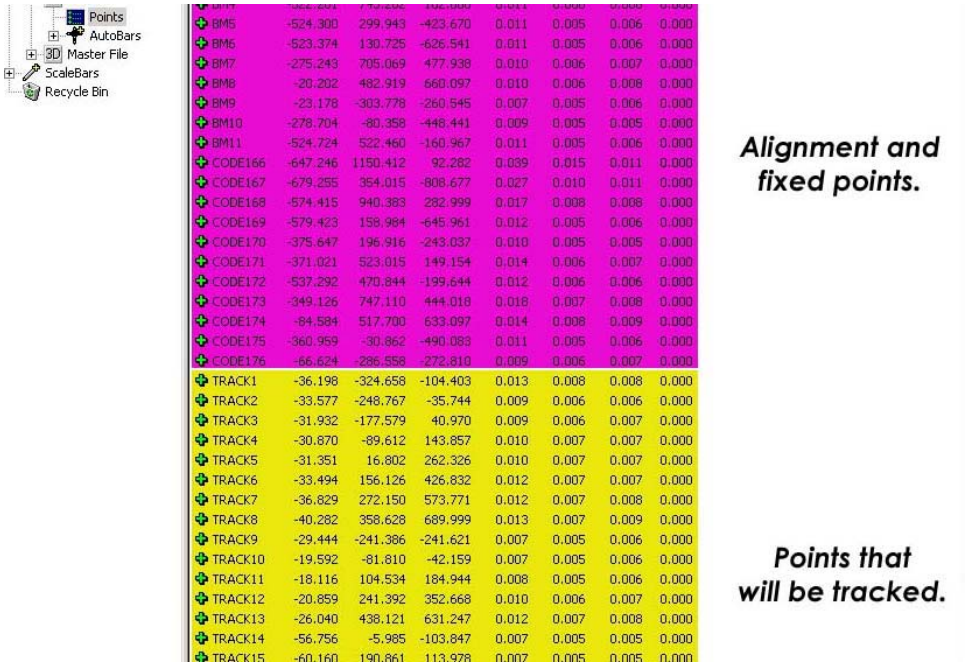
- Tooling targets on the fixture to transform data into car coordinate system.
- Coded targets to automate the measurement.
- Points on the door that need to be tracked.
- AutoBar for initial coordinate system.
- Scale bars to scale the measurement.



Note that in this case no Coded Targets were placed on the door itself. This is because the door will be moved in and out of the fixture and we would like our Codes to be fixed. In some cases it will be impossible to avoid placing codes on the object. In these instances the Coded Targets should be treated as approximates ("APPROX"). We will talk more about this later.

Step 2: Baseline Measurement

- Shoot the object as you would normally. Take care to ensure that every point has a good selection of rays to it.
- Rename the "TARGET" points on the object to something that will easily signify that it is a tracking point. In this example we used the word "TRACK". Rename the tooling points to their designated tooling name (TB1, TB2, etc.)
- Align the object using the tooling points into the object coordinate system.



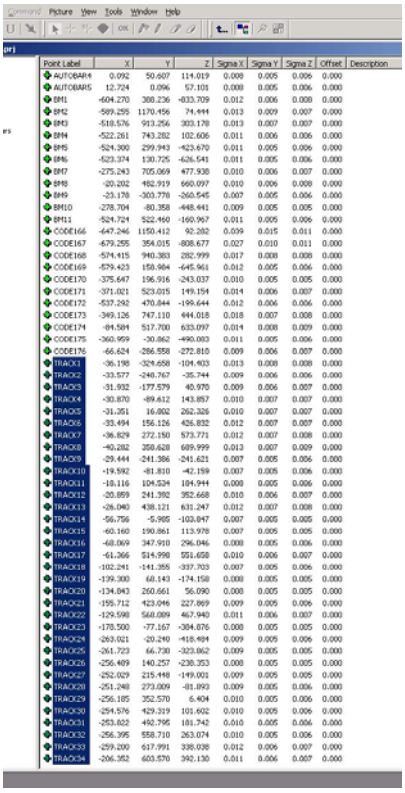
Step 3: Setting the Track Points

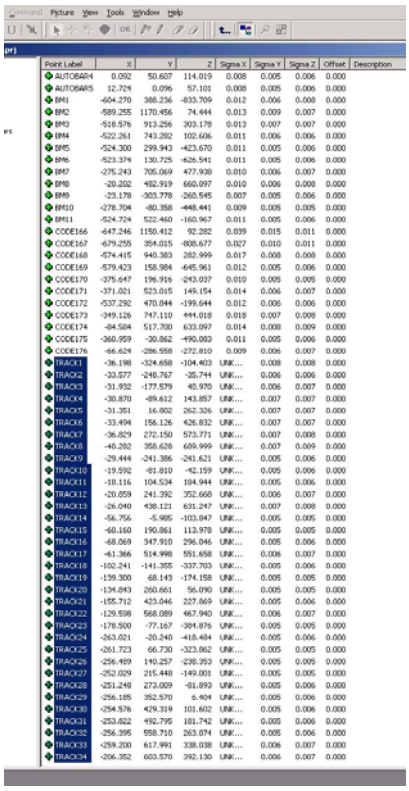
- Rename the current bundle file to something that easily identifies it as the Baseline file. In this example we used "*Master File.3D*".

- View the points listing and select all the points that will be tracked.

- Click on the "*Sigma X*" tab and select the "*U*" icon. The word "*UNKNOWN*" should appear in the text box.

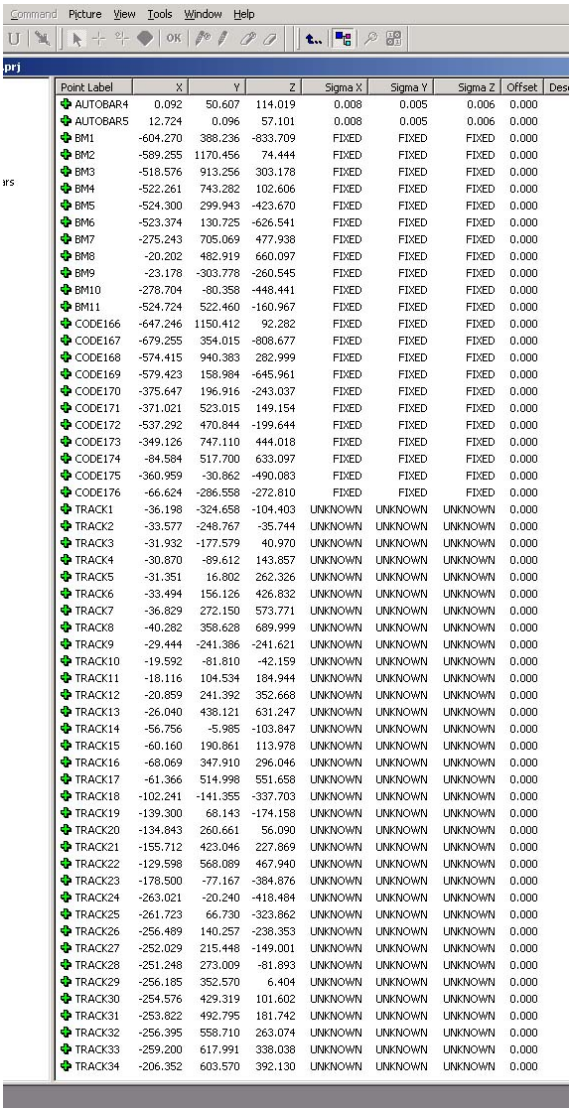
- Press the "=" icon to accept the change.





- Repeat this process for the "*Sigma Y*" and "*Sigma Z*" columns.

- Select the points that are stable and that are going to be used as "*FIXED*" points. Set their sigma X, Y, and Z values as "*FIXED*" using the same procedure.

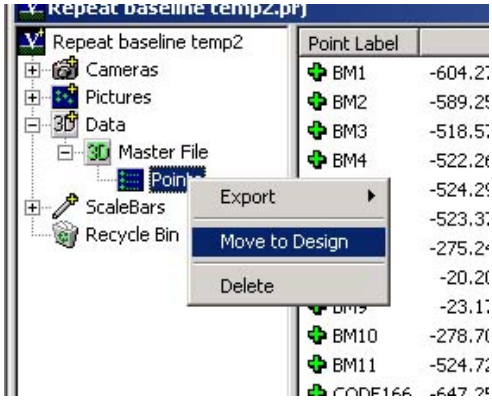


Point Label	X	Y	Z	Sigma X	Sigma Y	Sigma Z	Offset	Des
AUTOBAR4	0.092	50.607	114.019	0.008	0.005	0.006	0.000	
AUTOBAR5	12.724	0.096	57.101	0.008	0.005	0.006	0.000	
BM1	-604.270	388.236	-833.709	FIXED	FIXED	FIXED	0.000	
BM2	-589.255	1170.456	74.444	FIXED	FIXED	FIXED	0.000	
BM3	-518.576	913.256	303.178	FIXED	FIXED	FIXED	0.000	
BM4	-522.261	743.282	102.606	FIXED	FIXED	FIXED	0.000	
BM5	-524.300	299.943	-423.670	FIXED	FIXED	FIXED	0.000	
BM6	-523.374	130.725	-626.541	FIXED	FIXED	FIXED	0.000	
BM7	-275.243	705.069	477.938	FIXED	FIXED	FIXED	0.000	
BM8	-20.202	482.919	660.097	FIXED	FIXED	FIXED	0.000	
BM9	-23.178	-303.778	-260.545	FIXED	FIXED	FIXED	0.000	
BM10	-278.704	-80.358	-448.441	FIXED	FIXED	FIXED	0.000	
BM11	-524.724	522.460	-160.967	FIXED	FIXED	FIXED	0.000	
CODE166	-647.246	1150.412	92.282	FIXED	FIXED	FIXED	0.000	
CODE167	-679.255	354.015	-808.677	FIXED	FIXED	FIXED	0.000	
CODE168	-574.415	940.383	282.999	FIXED	FIXED	FIXED	0.000	
CODE169	-579.423	158.984	-645.961	FIXED	FIXED	FIXED	0.000	
CODE170	-375.647	196.916	-243.037	FIXED	FIXED	FIXED	0.000	
CODE171	-371.021	523.015	149.154	FIXED	FIXED	FIXED	0.000	
CODE172	-537.292	470.844	-199.644	FIXED	FIXED	FIXED	0.000	
CODE173	-349.126	747.110	444.018	FIXED	FIXED	FIXED	0.000	
CODE174	-84.584	517.700	633.097	FIXED	FIXED	FIXED	0.000	
CODE175	-360.959	-30.862	-490.083	FIXED	FIXED	FIXED	0.000	
CODE176	-66.624	-286.558	-272.810	FIXED	FIXED	FIXED	0.000	
TRACK1	-36.198	-324.658	-104.403	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK2	-33.577	-248.767	-35.744	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK3	-31.932	-177.579	40.970	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK4	-30.870	-89.612	143.857	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK5	-31.351	16.802	262.326	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK6	-33.494	156.126	426.832	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK7	-36.829	272.150	573.771	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK8	-40.282	358.628	689.999	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK9	-29.444	-241.386	-241.621	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK10	-19.592	-81.810	-42.159	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK11	-18.116	104.534	184.944	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK12	-20.859	241.392	352.668	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK13	-26.040	438.121	631.247	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK14	-56.756	-5.985	-103.847	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK15	-60.160	190.861	113.978	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK16	-68.069	347.910	296.046	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK17	-61.366	514.998	551.658	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK18	-102.241	-141.355	-337.703	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK19	-139.300	68.143	-174.158	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK20	-134.843	260.661	56.090	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK21	-155.712	423.046	227.869	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK22	-129.598	568.089	467.940	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK23	-178.500	-77.167	-384.876	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK24	-263.021	-20.240	-418.484	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK25	-261.723	66.730	-323.862	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK26	-256.489	140.257	-238.353	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK27	-252.029	215.448	-149.001	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK28	-251.248	273.009	-81.893	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK29	-256.185	352.570	6.404	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK30	-254.576	429.319	101.602	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK31	-253.822	492.795	181.742	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK32	-256.395	558.710	263.074	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK33	-259.200	617.991	338.038	UNKNOWN	UNKNOWN	UNKNOWN	0.000	
TRACK34	-206.352	603.570	392.130	UNKNOWN	UNKNOWN	UNKNOWN	0.000	

If there are Coded Targets on the object, make the sigmas of these points "*APPROX*". These point will not be used to compute the final transformation. They will only be used as approximate values and then discarded for the final calculation.

- Delete any other points in the file that are not needed (AutoBar, Scale, etc.).

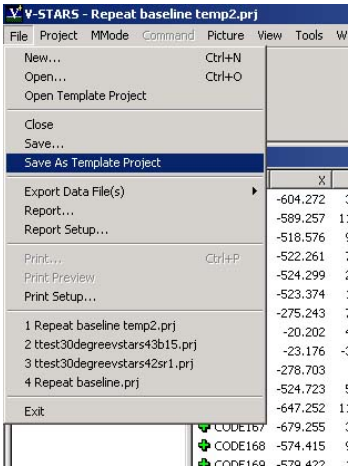
- Right click on the points icon in the "Master File.3d" and select "Move to Design".



- Once you have done this, delete any 3D files you don't need.

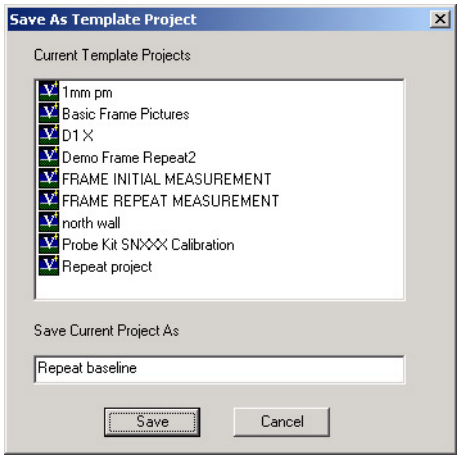
Step 4: Create a Template Project

The last step before commencing the Repeatability Study is to save the project as a Template Project.



- Select the "*Save as Template Project*" option from the "*File*" menu. This will save the current project and all the files into the template directory.

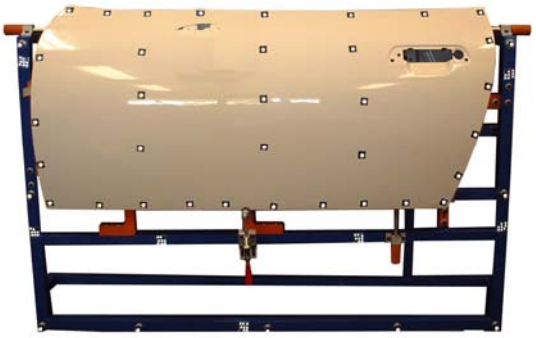
- Select or enter a name and press "*Save*" to create the template. Note that previous Template Projects can be over-written if you select them from the list.



You are now ready to complete the Repeatability Study.

Step 5: Repeatability Data Collection

In the example we are using we removed and replaced the door a total of 11 times.



After each time the door was removed and replaced we collected a total of six images. The number of images you collect will depend on the complexity of the object. It is not essential to collect the same number of images for each cycle, but we recommend it, as it will help you achieve results with similar accuracy estimates for each Bundle.

Note: There is no need to roll the camera in the cycles as the calibrated camera from the baseline measurement will be used.

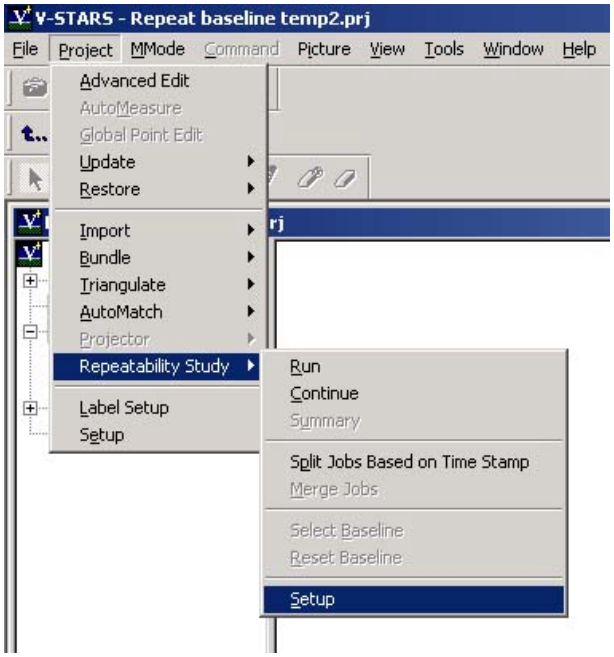
The images can be stored in the one Job folder or in Multiple Jobs. If you store all the images in the same *JOB* folder, V-STARS will separate the images into their individual cycles using the image time stamp. In this case it is important that the images you collect for a cycle are not separated by too much time. For example, if you need to stop halfway through a measurement cycle to change a battery we recommend deleting the images taken for that cycle and starting afresh. The time interval V-STARS uses to separate JOBS can be changed in the Repeatability Setup dialog. The general rule of thumb we recommend is to separate cycles by about 60 seconds or more.

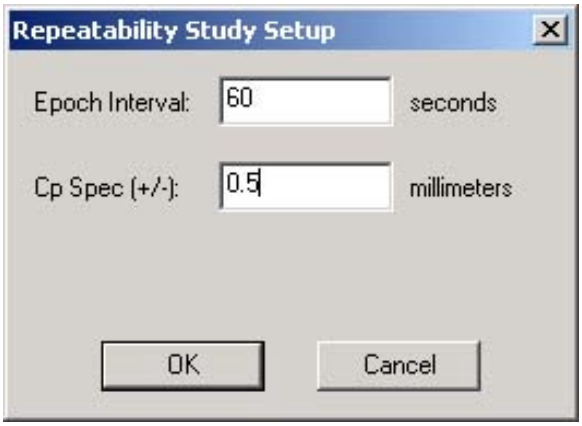
Step 6: Repeatability Reduction

- Launch V-STARS and select "*Open Template Project*" from the *File* menu. Select the Repeatability Project you created and select an appropriate name.

- Right click on the pictures icon and set the image path to the job that contains the Repeatability images.

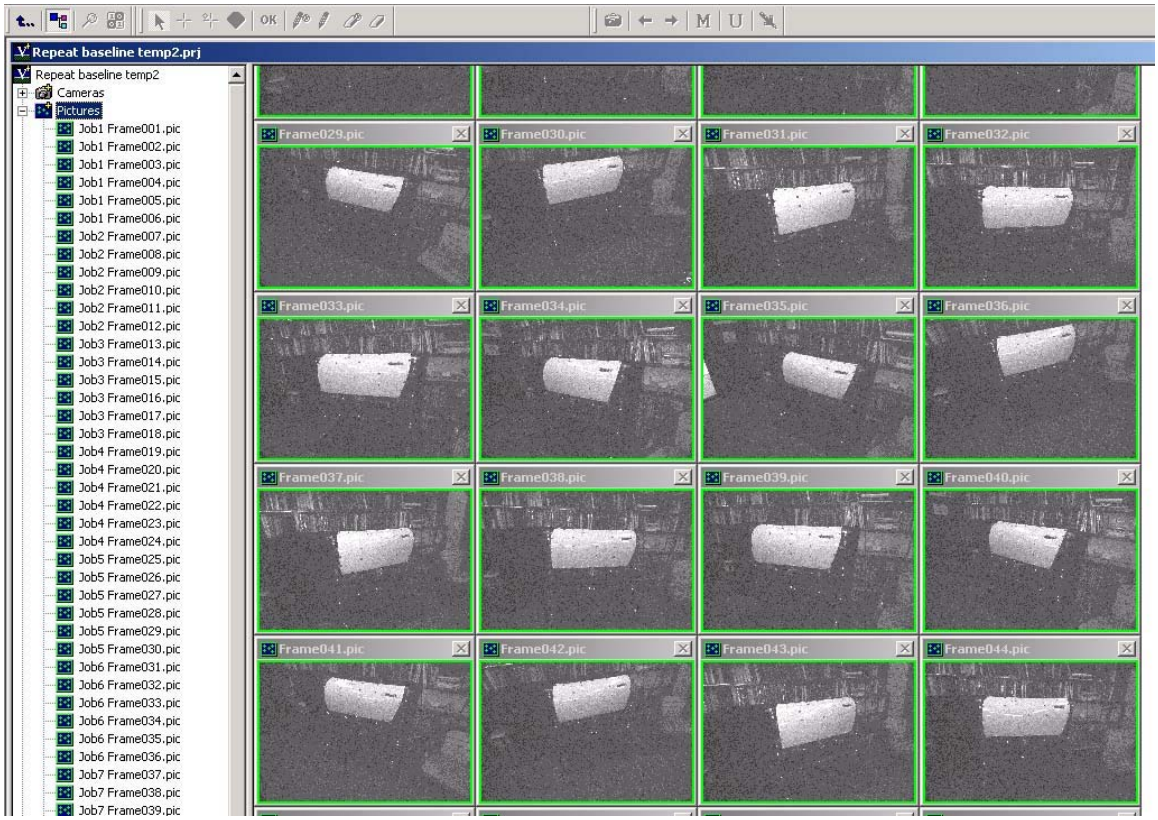
- Go to "*Project – Repeatability Study*" and select "*Setup*". Enter an appropriate time interval and Cp Spec number. (Refer to the Appendix for more information on Cp and Cpk)





- Once you have set up the interval and Cp Spec value select "*Run*" from the "*Repeatability Study*" menu.

The first thing V-STARS will do is split the images into their individual cycle. If you have any reason to suspect that the jobs won't be split correctly select the "*Split Jobs Based on Time Stamp*" option and verify that there are the correct number of cycles.



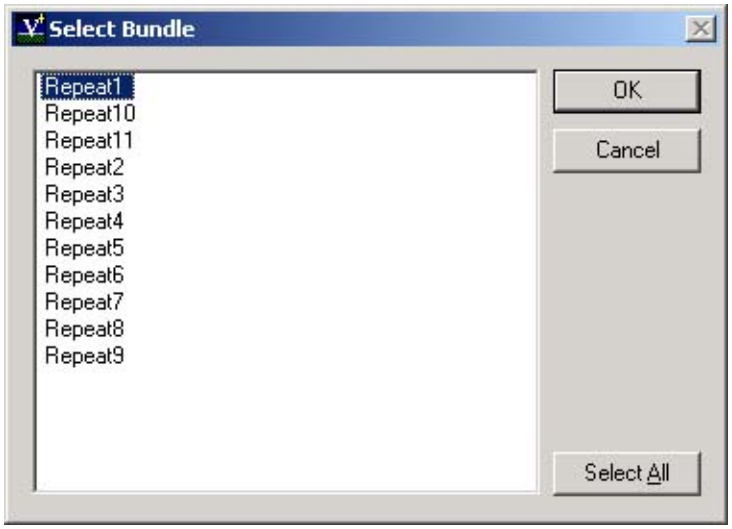
Once the images have been split V-STARS will measure each of them and then run a series of individual bundles.

Step 7: Repeatability Results

Once the Repeatability reduction process has been completed a number of new 3D files will be created in the project.

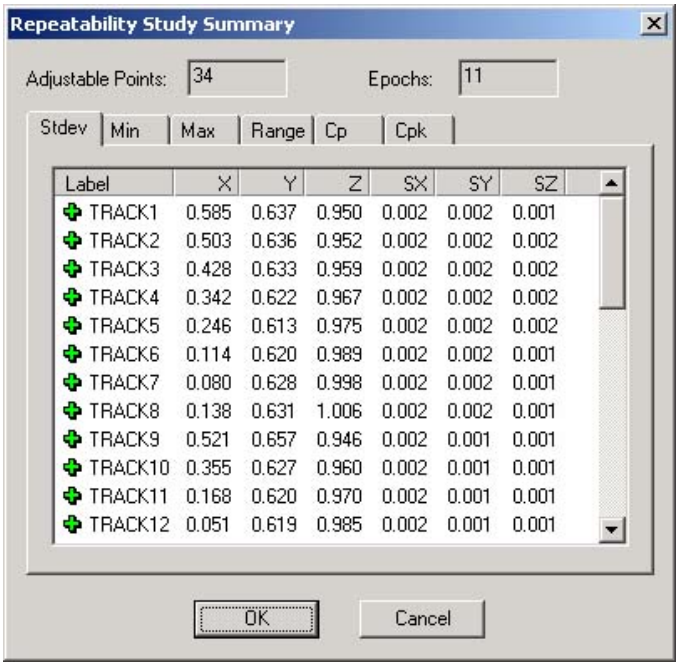
There will be a new Repeat file for each of the cycles. These are named *Repeat1.3D, Repeat2.3D* etc. Each of these files has been aligned to the Master Baseline file that was selected. Click on the individual 3D files and select "*Alignment*" "*Residuals – Standard*" to view the results of the transformation.

The individual bundle summary can also be viewed by selecting it from the Bundle Summary (*Project – Bundle – Summary*).



ARM will also create an average file. The "*average.3D*" file is, as the name suggests, an average of all the points for all the epochs. It has also been aligned to the Master File.

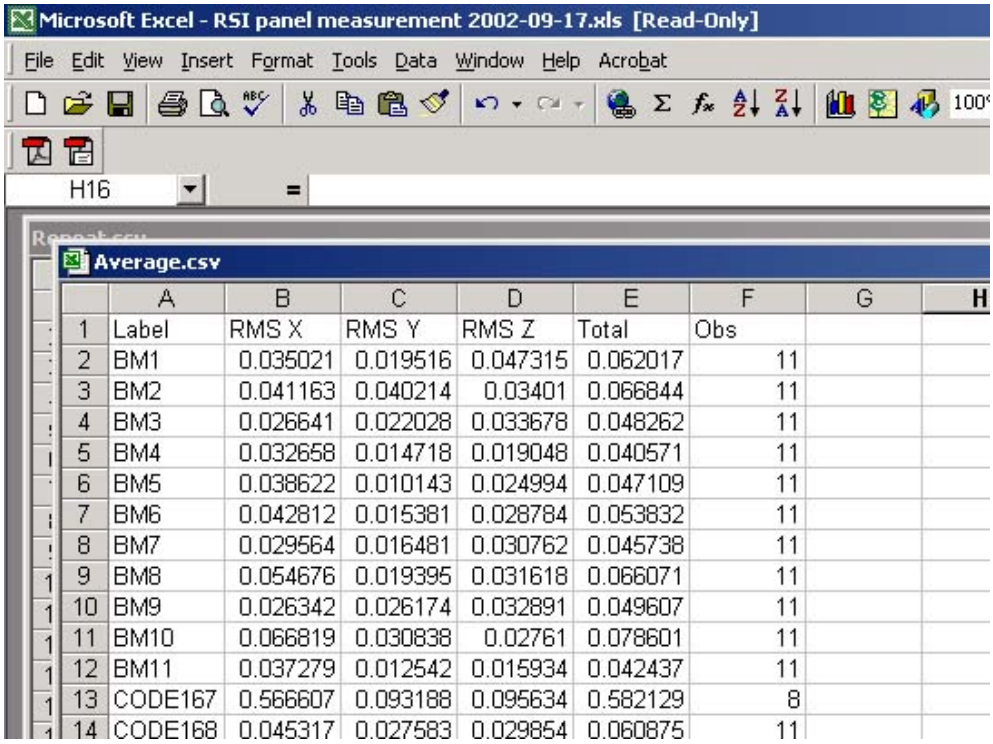
The results of the repeatability can be viewed in the *Repeatability Summary Dialog*. The summary will tell you the number of adjustable points, number of epochs (cycles), standard deviations of the point coordinates, min and max point coordinate values, range as well as the Cp and Cpk tolerance value results. (Refer to the Appendix for more information on Cp and Cpk)



Step 8: Repeatability Output Files.

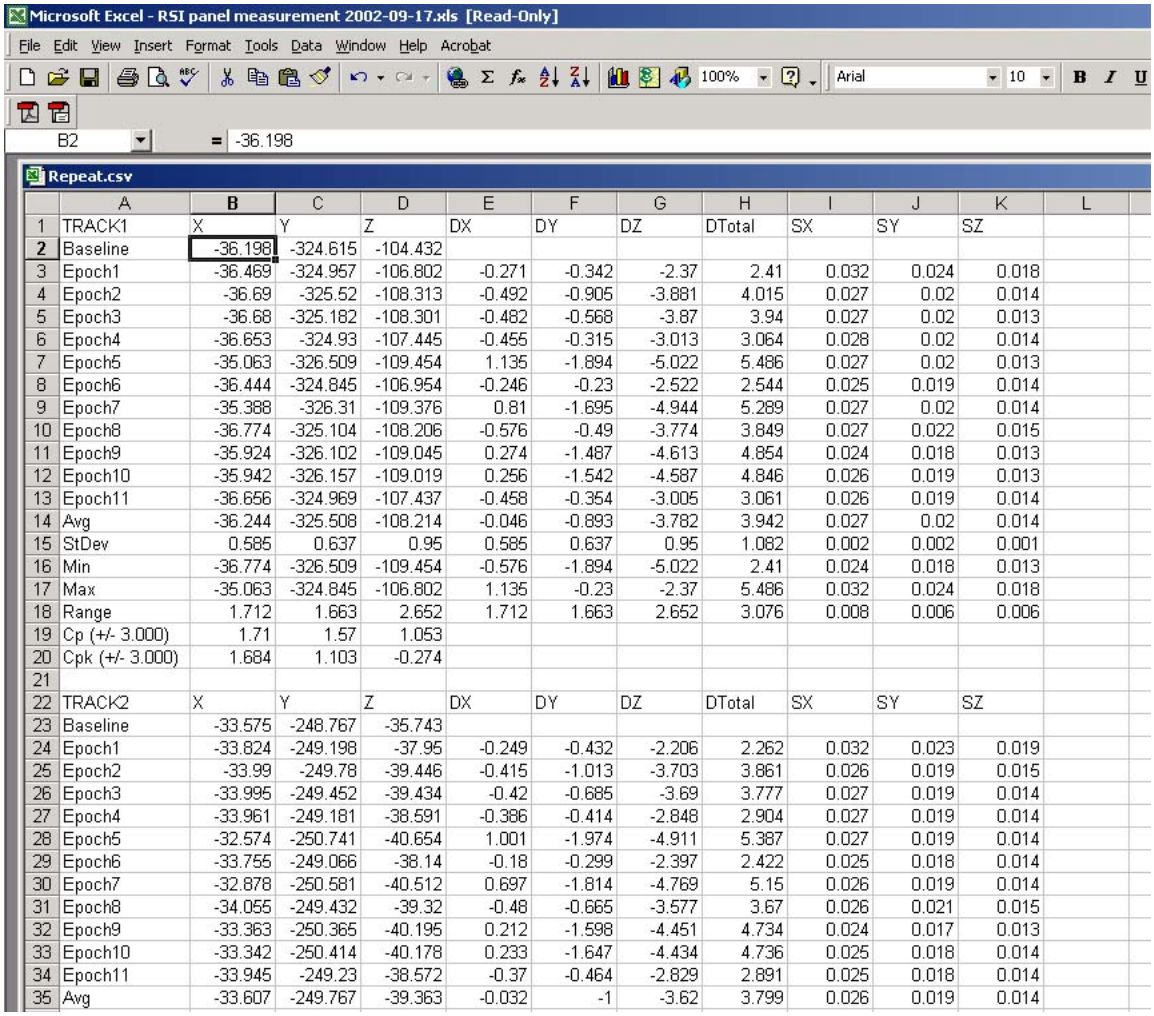
V-STARS will create three output files at the end of the Repeatability reduction. These are called "*Average.cvs*", "*Repeat.cvs*" and "*Report.cvs*". These are compatible with Microsoft Excel.

The "Average.cvs" file contains the RMS of the deviations for each of the points in the X, Y, Z, and Total direction. It also contains the number of observations for each point.



	A	B	C	D	E	F	G	H
1	Label	RMS X	RMS Y	RMS Z	Total	Obs		
2	BM1	0.035021	0.019516	0.047315	0.062017	11		
3	BM2	0.041163	0.040214	0.03401	0.066844	11		
4	BM3	0.026641	0.022028	0.033678	0.048262	11		
5	BM4	0.032658	0.014718	0.019048	0.040571	11		
6	BM5	0.038622	0.010143	0.024994	0.047109	11		
7	BM6	0.042812	0.015381	0.028784	0.053832	11		
8	BM7	0.029564	0.016481	0.030762	0.045738	11		
9	BM8	0.054676	0.019395	0.031618	0.066071	11		
10	BM9	0.026342	0.026174	0.032891	0.049607	11		
11	BM10	0.066819	0.030838	0.02761	0.078601	11		
12	BM11	0.037279	0.012542	0.015934	0.042437	11		
13	CODE167	0.566607	0.093188	0.095634	0.582129	8		
14	CODE168	0.045317	0.027583	0.029854	0.060875	11		

The "*Repeat.cvs*" file contains information about each tracking point organized by each cycle. It also contains the results of the Cp and Cpk tolerance tests.



Microsoft Excel - RSI panel measurement 2002-09-17.xls [Read-Only]

File Edit View Insert Format Tools Data Window Help Acrobat

B2 = -36.198

Repeat.csv

	A	B	C	D	E	F	G	H	I	J	K	L
1	TRACK1	X	Y	Z	DX	DY	DZ	DTotal	SX	SY	SZ	
2	Baseline	-36.198	-324.615	-104.432								
3	Epoch1	-36.469	-324.957	-106.802	-0.271	-0.342	-2.37	2.41	0.032	0.024	0.018	
4	Epoch2	-36.69	-325.52	-108.313	-0.492	-0.905	-3.881	4.015	0.027	0.02	0.014	
5	Epoch3	-36.68	-325.182	-108.301	-0.482	-0.568	-3.87	3.94	0.027	0.02	0.013	
6	Epoch4	-36.653	-324.93	-107.445	-0.455	-0.315	-3.013	3.064	0.028	0.02	0.014	
7	Epoch5	-35.063	-326.509	-109.454	1.135	-1.894	-5.022	5.486	0.027	0.02	0.013	
8	Epoch6	-36.444	-324.845	-106.954	-0.246	-0.23	-2.522	2.544	0.025	0.019	0.014	
9	Epoch7	-35.388	-326.31	-109.376	0.81	-1.695	-4.944	5.289	0.027	0.02	0.014	
10	Epoch8	-36.774	-325.104	-108.206	-0.576	-0.49	-3.774	3.849	0.027	0.022	0.015	
11	Epoch9	-35.924	-326.102	-109.045	0.274	-1.487	-4.613	4.854	0.024	0.018	0.013	
12	Epoch10	-35.942	-326.157	-109.019	0.256	-1.542	-4.587	4.846	0.026	0.019	0.013	
13	Epoch11	-36.656	-324.969	-107.437	-0.458	-0.354	-3.005	3.061	0.026	0.019	0.014	
14	Avg	-36.244	-325.508	-108.214	-0.046	-0.893	-3.782	3.942	0.027	0.02	0.014	
15	StDev	0.585	0.637	0.95	0.585	0.637	0.95	1.082	0.002	0.002	0.001	
16	Min	-36.774	-326.509	-109.454	-0.576	-1.894	-5.022	2.41	0.024	0.018	0.013	
17	Max	-35.063	-324.845	-106.802	1.135	-0.23	-2.37	5.486	0.032	0.024	0.018	
18	Range	1.712	1.663	2.652	1.712	1.663	2.652	3.076	0.008	0.006	0.006	
19	Cp (+/- 3.000)	1.71	1.57	1.053								
20	Cpk (+/- 3.000)	1.684	1.103	-0.274								
21												
22	TRACK2	X	Y	Z	DX	DY	DZ	DTotal	SX	SY	SZ	
23	Baseline	-33.575	-248.767	-35.743								
24	Epoch1	-33.824	-249.198	-37.95	-0.249	-0.432	-2.206	2.262	0.032	0.023	0.019	
25	Epoch2	-33.99	-249.78	-39.446	-0.415	-1.013	-3.703	3.861	0.026	0.019	0.015	
26	Epoch3	-33.995	-249.452	-39.434	-0.42	-0.685	-3.69	3.777	0.027	0.019	0.014	
27	Epoch4	-33.961	-249.181	-38.591	-0.386	-0.414	-2.848	2.904	0.027	0.019	0.014	
28	Epoch5	-32.574	-250.741	-40.654	1.001	-1.974	-4.911	5.387	0.027	0.019	0.014	
29	Epoch6	-33.755	-249.066	-38.14	-0.18	-0.299	-2.397	2.422	0.025	0.018	0.014	
30	Epoch7	-32.878	-250.581	-40.512	0.697	-1.814	-4.769	5.15	0.026	0.019	0.014	
31	Epoch8	-34.055	-249.432	-39.32	-0.48	-0.665	-3.577	3.67	0.026	0.021	0.015	
32	Epoch9	-33.363	-250.365	-40.195	0.212	-1.598	-4.451	4.734	0.024	0.017	0.013	
33	Epoch10	-33.342	-250.414	-40.178	0.233	-1.647	-4.434	4.736	0.025	0.018	0.014	
34	Epoch11	-33.945	-249.23	-38.572	-0.37	-0.464	-2.829	2.891	0.025	0.018	0.014	
35	Avg	-33.607	-249.767	-39.363	-0.032	-1	-3.62	3.799	0.026	0.019	0.014	

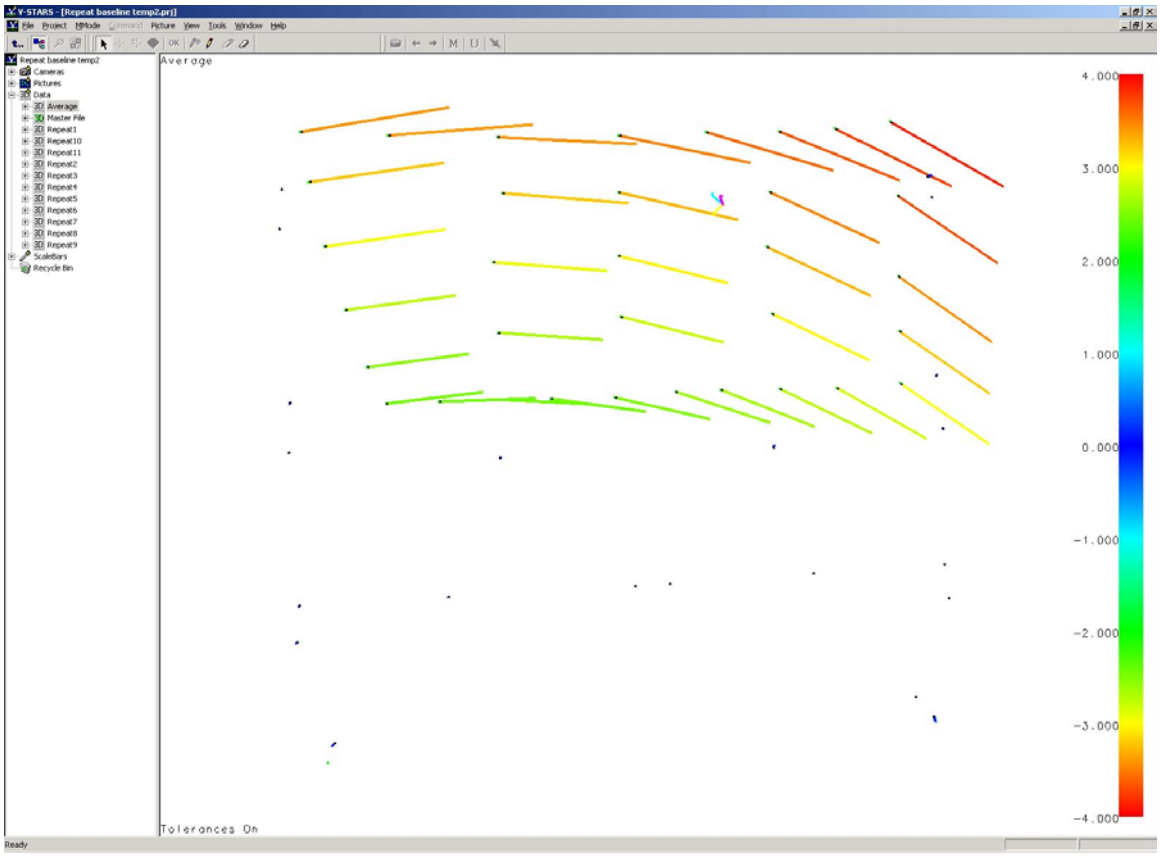
The "*Report.cvs*" file is a summary version of the "*Repeat.CVS*" file. It contains no individual epoch values for the coordinates.

Step 9: Additional Functions

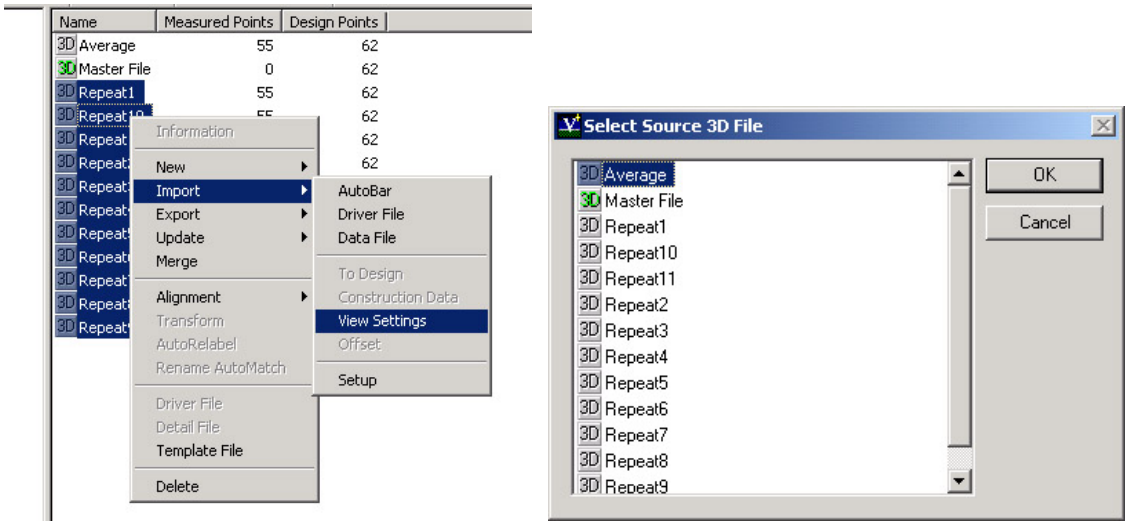
Select Baseline – This function allows you to select a new "Master Baseline" file. This is typically used when you want to compare all the repeat files against the "Average.3d" file or another 3D file. Changing the Baseline file will not change the output CSV files, but it will re-align all the Repeat files to the new Master file.

Reset Baseline – This function will reset the repeat files back to the Master file or whatever the current driver file is.

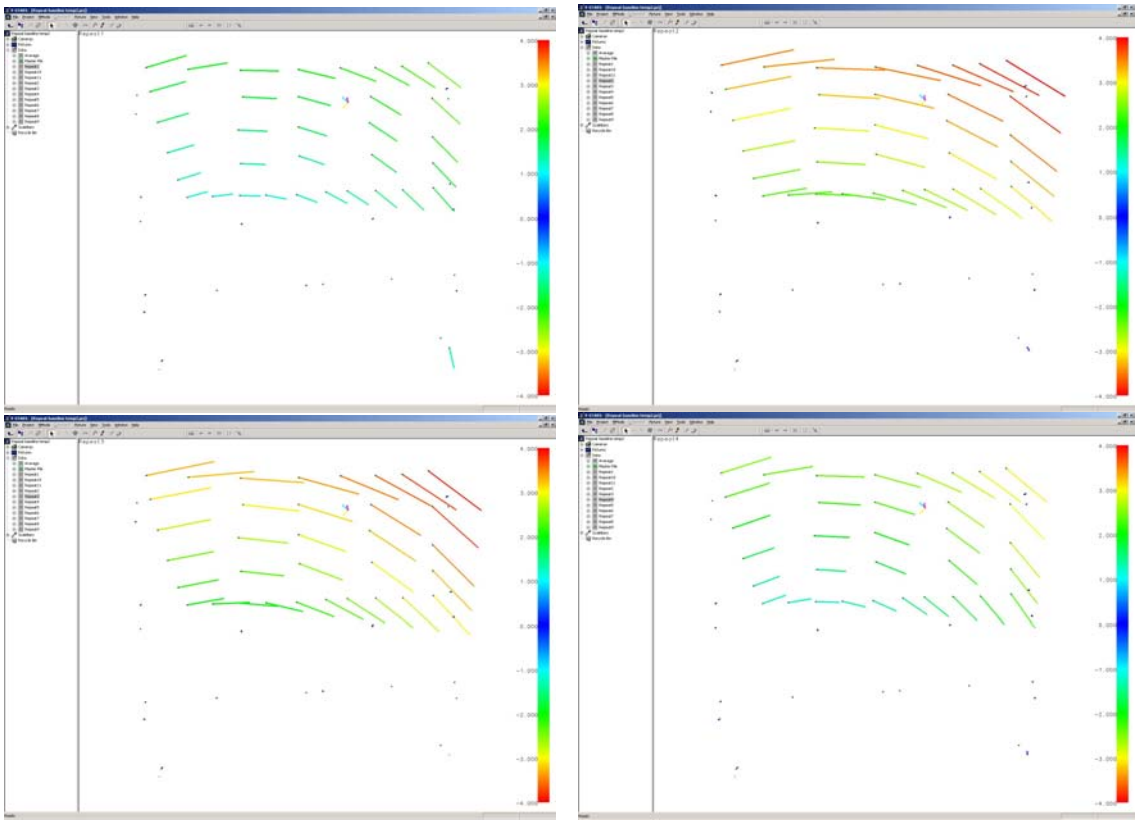
Import View Settings – Use this command (refer to 4.3 Release Notes) to give all your Repeat 3D files the same viewpoint and vectors view parameters as a master file. For example, take the Average.3D file and modify the parameter to illustrate the magnitude and direction of the vectors. The point size, line thickness, background color and tolerance bar can be set to best display these values. This is shown below:



To import the graphical view settings simply select the files you wish to import the settings to and then right click and select "*Import*" – "*View Settings*". Select the Source 3D file (the Average.3D file in this case) and then press *OK*.



After the view settings have been imported the Repeat Files appear as follows.



Appendix

Reproduced from http://www.qualitydigest.com/dec97/html/cpk.html

Process Capability: Minding Your Cpk's

The process potential index, or Cp, measures a process's potential capability, which is defined as the allowable spread over the actual spread. The allowable spread is the difference between the upper specification limit and the lower specification limit. The actual spread is determined from the process data collected and is calculated by multiplying six times the standard deviation, s. The standard deviation quantifies a process's variability. As the standard deviation increases in a process, the Cp decreases in value. As the standard deviation decreases (i.e., as the process becomes less variable), the Cp increases in value.
By convention, when a process has a Cp value less than 1.0, it is considered potentially incapable of meeting specification requirements. Conversely, when a process Cp is greater than or equal to 1.0, the process has the potential of being capable.

Ideally, the Cp should be as high as possible. The higher the Cp, the lower the variability with respect to the specification limits. In a process qualified as a Six Sigma process (i.e., one that allows plus or minus six standard deviations within the specifications limits), the Cp is greater than or equal to 2.0.
However, a high Cp value doesn't guarantee a production process falls within specification limits because the Cp value doesn't imply that the actual spread coincides with the allowable spread (i.e., the specification limits). This is why the Cp is called the process potential.

The process capability index, or Cpk, measures a process's ability to create product within specification limits. Cpk represents the difference between the actual process average and the closest specification limit over the standard deviation, times three.

By convention, when the Cpk is less than one, the process is referred to as incapable. When the Cpk is greater than or equal to one, the process is considered capable of producing a product within specification limits. In a Six Sigma process, the Cpk equals 2.0.

The Cpk is inversely proportional to the standard deviation, or variability, of a process. The higher the Cpk, the narrower the process distribution as compared with the specification limits, and the more uniform the product. As the standard deviation increases, the Cpk index decreases. At the same time, the potential to create product outside the specification limits increases.

Cpk can only have positive values. It will equal zero when the actual process average matches or falls outside one of the specification limits. The Cpk index can never be greater than the Cp, only equal to it. This happens when the actual process average falls in the middle of the specification limits.