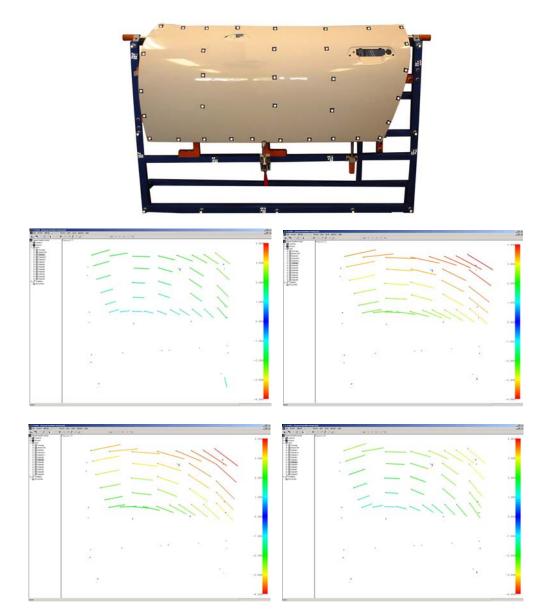
# Automated Repeatability Module (ARM) Release Notes



September 2002

# Automated Repeatability Module (ARM) Release Notes

ntroduction	4
mplementation	4
Step 1: Object Targeting	5
Step 2: Baseline Measurement	6
Step 3: Setting the Track Points	7
Step 4: Create a Template Project	
Step 5: Repeatability Data Collection	10
Step 6: Repeatability Reduction	10
Step 7: Repeatability Results	12
Step 8: Repeatability Output Files	14
Step 9: Additional Functions	16
Appendix	18

## Introduction

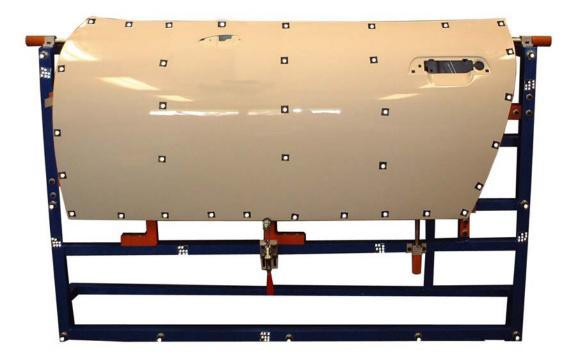
The following document describes the new Automated Repeatability Module (ARM) available in the latest V-STARS release. (Version 4.3) For more information on the new features found in V-STARS Version 4.3 please refer to the V-STARS 4.3 Release Notes.

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.

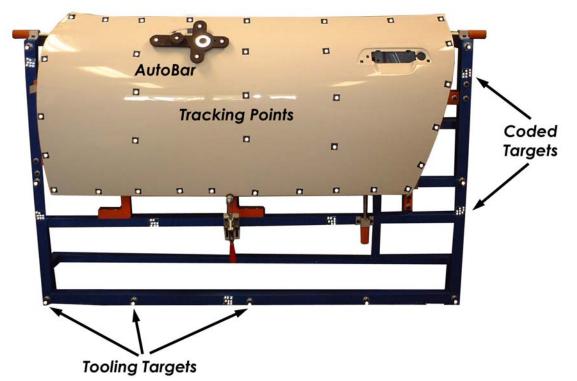


The measurement consisted of one baseline measurement and 11 measurements (trials) where the door was removed and then replaced.

### 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**

ŧ.

- 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.

	TUCK RUT	V TUREUE	1021000	citor 1	0.000	0,000	01000	
SM5	-524,300	299,943	-423,670	0.011	0.005	0.006	0.000	
BM6	-523.374	130.725	-626.541	0.011	0.005	0.006	0.000	
BM7	-275.243	705.069	477.930		0.006	0.007	0.000	
🗢 BMB	-20.202	482.919	660.097		0.006	0.008	0.000	
🔁 BM9	-23.178	-303.778	-260 545	0.007	0.005	0.006	0.000	
BM10	-278.704	-80.358	-448.441	0.009	0.005	0.005	0.000	
BM11	-524.724	522.460	-160,967	0.011		0.006	0.000	Alignment and
CODE166	-647.246	1150,412	92.282	0.039	0.015	0,011	0.000	-
CODE167	-679,255	354.015	-808.677	0.027		0,011	0.000	fixed points.
CODE168	-574.415	940.383	282.999			0.008	0.000	
CODE169	-579.423	158,984	-645.961	0.012	0.005	0.006	0.000	
CODE170	-375.647	196.916	-243.037		0.005	0.005	0.000	
CODE171	-371.021		149.154	0,014	0.006	8.007	0.000	
CODE172	-537,292	470.844	-199,644	0.012	0.006	0.006	0.000	
CODE173	-349,126	747,110	444.018	0.018	0.007	0.008	0.000	
CODE174	-84,584	517.700	633.097	8.014	0.008	0.009	0.000	
CODE175	-360.959	-30.862	-490.083	0.011	0.005	0.006	0.000	
CODE176	-66,624	-286.558	-272.810	0.009	0.006	0.007	0.000	
TRACK1	-36,198	-324.658	-104.403	0.013	0.008	0.008	0.000	
TRACK2	-33.577	-248.767	-35.744	0.009	0.006	0.006	0.000	
TRACK3	-31,932	-177,579	40.970	0.009	0.006	0.007	0.000	
TRACK4	-30.870	-89.612	143.857	0.010	0.007	0.007	0.000	
TRACK5	-31.351	16.802	262.326	0.010	0.007	0.007	0.000	
TRACK6	-33,494	156.126	426,832	0.012	0.007	0.007	0.000	
TRACK7	-36.829	272.150	573.771	0.012	0.007	0.008	0.000	
TRACK8	-40.282	358,628	689,999	0.013	0.007	0.009	0.000	
TRACK9	-29,444	-241.386	-241.621	0,007	0.005	0.006	0,000	
TRACK10	-19.592	-81.810	-42.159	0.007	0.005	0.006	0.000	Points that
TRACK11	-18,116	104.534	184.944	0.008	0.005	0.006	0.000	will be tracked
TRACK12	-20.859	241.392	352.668	0.010	0.006	0.007	0.000	will be iracked
TRACK13	-26.040	438.121	631.247	0.012	0.007	0.008	0.000	
TRACK14	-56,756	-5.985	-103.847	0.007	0.005	0.005	0.000	
TRACK15	-60,160	190.861	113,978	0.007	0.005	0.005	0.000	

### **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.

	F	Α	(TU
+   x   =	4	v	172

 Press the "=" icon to accept the change.



		PI C	10	t "C	の間			U   '	<b>4</b> ] 14 字 写	• ОК	111	10	t	2 記		
	_		_	_				pri								
Point Label	X	Y		Signa X				cription	Point Label	×	Y		Signa X			
AUTOBAR4 AUTOBAR5	0.092	50.607 0.096	114.019 57.101	0.008	0.005	0.006	0.000		AUTOBAR4	0.092	50.607	114.019	0.008	0.005	0.006	0.000
BMI	-604.270	308.236	-833 709	0.012	0.006	0.000	0.000		AUTOBAR5	12.724	0.096	57.101	0.008	0.005	0.006	0.000
6842	-589.255	1170.456	74.444	0.012	0.009	0.0007	0.000		I DP41	-604.270	300.236	-833.709	0.012	0.006	0.008	0.000
Q (P1)	-518.576	913.256	303.178	0.013	0.007	0.007	0.000		C EM2	-589.255	1170.456	74.444	0.013	0.009	0.007	0.000
Q 5014	-522.261	743.282	102.606	0.011	0.006	0.006	0.000	#S	EP43	-518.576	913.256 743.282	303.178	0.013	0.007	0.007	0.000
0 6915	-524.300	299.943	-423.670	0.011	0.005	0.006	0.000		Q 1014	-522.261 -524.300	299.943	102.606	0.011	0.005	0.006	0.000
Q 1016	-523.374	130.725	-626.541	0.011	0.005	0.006	0.000		C 5745	-523.374	130.725	+626.541	0.011	0.005	0.006	0.000
C E017	-275.243	705.069	477.938	0.010	0.006	0.007	0.000		Q [[M2	-275.243	705.069	477,930	0.010	0.006	0.007	0.000
Q 5113	-20.202	462.919	660.097	0.010	0.006	0.008	0.000		C 1010	-20.202	402.919	660.097	0.010	0.006	0.000	0.000
6643	-23.178	-303.778	-260.545	0.007	0.005	0.006	0.000		C EMO	-23.178	-303.778	-260.545	0.007	0.005	0.006	0.000
SM10	-278.704	-80.358	-448.441	0.009	0.005	0.005	0.000		O 67410	-278.704	-80.358	-648,641	0.009	0.005	0.005	0.000
EP111	-524.724	522.460	-160.967	0.011	0.005	0.006	0.000		4 DP111	-524.724	522.460	-160.967	0.011	0.005	0.006	0.000
CODE166	-647.246	1150.412	92.282	0.039	0.015	0.011	0.000		CODE166	-647.246	1150.412	92.282	0.039	0.015	0.011	0.000
CODE167	-679.255	354.015	-808.677	0.027	0.010	0.011	0.000		CODE167	-679.255	354.015	-808.677	0.027	0.010	0.011	0.000
CODE168	-574.415	940.383	282.999	0.017	0.008	0.008	0.000		CODE160	-574.415	940.383	282.999	0.017	0.008	0.000	0.000
CODE169	-579.423	150.904	-645.961	0.012	0.005	0.006	0.000		CODE169	-579.423	158.984	-645.961	0.012	0.005	0.006	0.000
CODE170	-375.647	196.916	-243.037	0.010	0.005	0.005	0.000		CODE170	-375.647	196.916	-243.037	0.010	0.005	0.005	0.000
CODE171	-371.021	523.015	149.154	0.014	0.006	0.007	0.000		CODE171	-371.021	523.015	149.154	0.014	0.006	0.007	0.000
CODE172	-537.292	470.044	-199.644 444.018	0.012	0.006	0.006	0.000		CODE172	-537.292	470.844	-199.644	0.012	0.006	0.005	0.000
CODE173	-349.126	517,700	994.018 633.097	0.018	0.007	0.008	0.000		CODE173	-349.126	747.110	444.018	0.018	0.007	0.008	0.000
CODE174	-360.959	-30.862	-490.083	0.014	0.005	0.009	0.000		CODE174	-04.504	\$17.700	633.097	0.014	0.008	0.009	0.000
CODE175	-360.959	-30.062	-272.810	0.009	0.005	0.005	0.000		CODE175	-360.959	-30.062	-490.000	0.011	0.005	0.006	0.000
TRACKI	-36,198	-200.550	-104.403	0.013	0.008	0.008	0.000		CODE176	-66.624	-286.558	-272.810	0.009	0.006	0.007	0.000
TRACK2	-33.577	-240.767	-35.744	0.009	0.006	0.000	0.000			-36.198	-324.658	-104.403	UNK	0.008	0.008	0.000
TRACK3	-31.932	-177.579	40.970	0.009	0.006	0.007	0.000		TRACK2 TRACK3	-33.577	-240.767	-35.744 40.920	UNK	0.006	0.005	0.000
TRACK4	-30,870	-89.612	143.857	0.010	0.007	0.007	0.000		TRACK4	-30.870	-89.612	143.857	UPAK	0.007	0.007	0.000
TRACKS	-31.351	16.002	262.326	0.010	0.007	0.007	0.000		TRACKS	-31.351	16.002	262.326	UNK	0.007	0.007	0.000
TRACK6	-33.494	156.126	426.832	0.012	0.007	0.007	0.000		TRACKS	-33,494	156.126	426,832	UNK	0.007	0.007	0.000
TRACK7	-36.829	272.150	573.771	0.012	0.007	0.008	0.000		TRACK7	-36.829	272.150	573,771	LP#	0.007	0.008	0.000
TRACKD	-40.282	350.620	609.999	0.013	0.007	0.009	0.000		TRACK0	-40.202	350.620	609.999	UNK	0.007	0.009	0.000
TRACK9	-29.444	-241.386	-241.621	0.007	0.005	0.006	0.000		TRACK9	-29.444	-241.386	-241.621	UNK	0.005	0.006	0.000
TRACK10	-19.592	-81.810	-42.159	0.007	0.005	0.006	0.000		TRACK10	-19.592	-81.810	-42.159	URK	0.005	0.006	0.000
TRACK11	-10.116	104.534	104.944	0,000	0.005	0.006	0.000		TRACK11	-10.116	104.534	104.944	UNK	0.005	0.006	0.000
TRACK12	-20.859	241.392	352.668	0.010	0.006	0.007	0.000		TRACK12	-20.859	241.392	352.668	UNK	0.006	0.007	0.000
TRACK13	-26.040	438.121	631.247	0.012	0.007	0.008	0.000		TRACK13	-26.040	438.121	631.247	UNK	0.007	0.008	0.000
TRACK14	-56.756	-5.905	-103.047	0.007	0.005	0.005	0.000		TRACK14	-56.756	-5.905	-103.847	UNK	0.005	0.005	0.000
TRACK15	-60.160	190.861	113.978	0.007	0.005	0.005	0.000		TRACKIS	-60.160	190.061	113.970	UNK	0.005	0.005	0.000
TRACK16 TRACK17	-68.069	347.910	296.046	0.008	0.005	0.006	0.000		TRACK16	-68.069	347.910	296.046	UNK	0.005	0.005	0.000
TRACK17 TRACK18	-61.366	-141.355	-337.703	0.010	0.005	0.007	0.000		TRACK17 TRACK18	-61.366 -102.241	514.998	551.658	UNK	0.006	0.007	0.000
TRACK19	-139.300	60.143	-174.158	0.007	0.005	0.005	0.000		<ul> <li>TRACKIE</li> <li>TRACKIE</li> </ul>	-102.241	-141.355 68.143	-337.703	UNK	0.005	0.005	0.000
TRACK19	-134.043	260.661	-1/4.198	0.008	0.005	0.005	0.000		<ul> <li>TRACK19</li> <li>TRACK20</li> </ul>	-139.300	68.143	-174.158 56.090	UNK	0.005	0.005	0.000
TRACK21	-155.712	423.046	227.869	0.009	0.005	0.005	0.000		TRACK21	-155.712	423.046	227.069	UNK	0.005	0.005	0.000
TRACK22	-129.598	568.089	467.940	0.011	0.006	0.007	0.000		TRACK22	-129,598	568.089	467.940	UNK	0.006	0.007	0.000
TRACK23	-178,500	-77.167	-304.076	0.008	0.005	0.005	0.000		O TRACK23	-178.500	-77.167	-384.876	UNK	0.005	0.005	0.000
TRACK24	-263.021	-20.240	-418.484	0.009	0.005	0.006	0.000		TRACK24	-263.021	-20.240	-410.404	UNK	0.005	0.006	0.000
TRACK25	-261.723	66.730	-323.862	0.009	0.005	0.005	0.000		TRACK25	-261.723	66.730	-323.062	UNK	0.005	0.005	0.000
TRACK26	-256.409	140.257	-238.353	0.008	0.005	0.005	0.000		TRACK26	-256.489	140.257	-238.353	UNK	0.005	0.005	0.000
TRACK27	-252.029	215.448	-149.001	0.009	0.005	0.005	0.000		TRACK27	-252.029	215.440	-149.001	UR#(	0.005	0.005	0.000
TRACK20	-251.240	273.009	-01.093	0.009	0.005	0.006	0.000		TRACK20	-251.240	273.009	-01.090	UNK	0.005	0.006	0.000
TRACK29	-256.185	352.570	6.404	0.010	0.005	0.006	0.000		TRACK29	256.185	352.570	6.404	UNK	0.005	0.006	0.000
TRACK30	-254.576	429.319	101.602	0.010	0.005	0.006	0.000		TRACK30	-254.576	429.319	101.602	UR#(	0.005	0.006	0.000
TRACK31	-253.022	492.795	101.742	0.010	0.005	0.006	0.000		TRACK31	-253.822	492.795	101.742	UNK	0.005	0.005	0.000
TRACK32	-256.395	558.710	263.074	0.010	0.005	0.006	0.000		TRACK82	-256.395	558.710	263.074	UNK	0.005	0.006	0.000
TRACK33	-259.200	617.991	338.038	0.012	0.006	0.007	0.000		TRACK33	-259.200	617.991	338.038	UNK	0.006	0.007	0.000
TRACK34	-206.352	603.570	392.130	0.011	0.006	0.007	0.000		TRACK04	-206.352	603.570	392.130	UNK	0.006	0.007	0.000

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

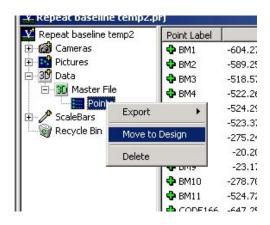
• Select the points that are stable and that are going to be used as "FIXED" points. Set their sigma X, Y, and Z values as "FIXED" using the same procedure.

194	► + º+	• ок	101	#p 17 07	t 📲	0		
~	K I I		P P C		····   [0   /	- <b>M</b> J		_
_	eiet Label	v	Y	7	Ciamo V	Ciamo V	Ciamo 7	Offset
	oint Label	X 0.092	50.607	Z 114.019	Sigma X 0.008	Sigma Y 0.005	Sigma Z 0.006	0.000
	AUTOBARS	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
4	BM3	-518.576	913.256	303.178	FIXED	FIXED	FIXED	0.000
	BM4	-522.261	743.282	102.606	FIXED	FIXED	FIXED	0.000
4	BM5	-524.300	299.943	-423.670	FIXED	FIXED	FIXED	0.000
4	BM6	-523.374	130.725	-626.541	FIXED	FIXED	FIXED	0.000
4	BM7	-275.243	705.069	477.938	FIXED	FIXED	FIXED	0.000
4	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 FIXED	0.000
	CODE176 TRACK1	-66.624 -36.198	-286.558 -324.658	-272.810 -104.403	UNKNOWN	FIXED UNKNOWN	UNKNOWN	0.000
	TRACKI TRACK2				UNKNOWN		UNKNOWN	0.000
	TRACK2	-33.577 -31.932	-248.767 -177.579	-35.744 40.970	UNKNOWN	UNKNOWN UNKNOWN	UNKNOWN	0.000
	TRACKS	-30.870	-89.612	143.857	UNKNOWN	UNKNOWN	UNKNOWN	0.000
	TRACKT	-31.351	16.802	262.326	LINKNOWN	UNKNOWN	LINKNOWN	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
4	TRACK13	-26.040	438.121	631.247	UNKNOWN	UNKNOWN	UNKNOWN	0.000
4	TRACK14	-56.756	-5.985	-103.847	UNKNOWN	UNKNOWN	UNKNOWN	0.000
4	TRACK15	-60.160	190.861	113.978	UNKNOWN	UNKNOWN	UNKNOWN	0.000
4	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
4	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	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			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".



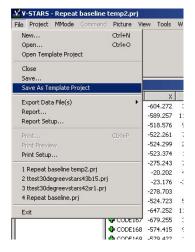
• Once you have done this, delete any 3D files you don't need.

#### **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.

Y 1mm pm			
Basic Frame Picture	s		
2 D1X 2 D	12		
Demo Frame Repea FRAME INITIAL ME		FNT	
FRAME REPEAT M			
north wall			
Probe Kit SNXXX Ca	alibration		
Repeat project			
ve Current Project As			
epeat baseline			



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)

	STARS	- Repeat	baseline t	emp2.pr	rj			
Eile	Project	Mode	⊆ommand	Picture	⊻iew	Tools	<u>W</u> indow	Help
6		nced Edit						
	States.	Measure						
<b>t</b>	Globa Upda	al Point Edi be			-			
k	Resto		17	00				
V					-			
_¥* _¥* ⊕…	<u>I</u> mpor <u>B</u> undl							
+	77,00,000	gulate						
	- <u>1</u> 96203	Match						
Ē	Proje	2+0+0-5000 per	÷.					
	Repe	atability S	tudy 🔸	Run				
	Label	Setup						
1	S <u>e</u> tup	5	_	Symmary				-
				Split Jobs		on Time	e Stamp	
				Merge Jo	DS			-
				Select <u>B</u> a				
				<u>R</u> eset Ba	seline			-
				<u>S</u> etup				
			Т					12
n	anast	abilitu	Study 9	Telana.				x
R	epeac	ability	Scuuy	secup			-	
	_				_			
	Epoch	Interva	l: 60			seco	onds	
	Co Soe	ec (+/-):	0.5			millin	neters	
	ch oh		1 - · · · ·				ICCOIS.	
	3				-		1	
	2		IK		Car	ncel	-	
	1						- 58	

• 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.

t   📲   🔎 🕮     k + 박 ◆	OK 10 1 0 0		M   U   🛰	
Repeat baseline temp2.prj				
Repeat baseline temp2     Gameras     Figure Pictures				
30b1 Frame001.pic           30b1 Frame002.pic           30b1 Frame003.pic           30b1 Frame003.pic           30b1 Frame005.pic           30b1 Frame006.pic           30b1 Frame006.pic           30b1 Frame007.pic           30b2 Frame007.pic           30b2 Frame006.pic           30b2 Frame006.pic	Frame029.pic	Frame030.pic X	Franco3Lpic X	Frane032.pic
30b2 Frame010.pic           30b2 Frame011.pic           30b2 Frame012.pic           30b3 Frame013.pic           30b3 Frame014.pic           30b3 Frame015.pic           30b3 Frame015.pic           30b3 Frame016.pic           30b3 Frame017.pic           30b3 Frame017.pic           30b3 Frame017.pic           30b3 Frame017.pic           30b3 Frame017.pic           30b3 Frame017.pic	Frame035.pic	Frame034.pic	Franc035 pic	Frame035.pic 🗶
3064 Frame020.pic           3064 Frame021.pic           3054 Frame022.pic           3054 Frame023.pic           3054 Frame023.pic           3055 Frame025.pic           3055 Frame026.pic           3055 Frame027.pic           3055 Frame027.pic           3055 Frame026.pic           3055 Frame027.pic           3055 Frame027.pic           3055 Frame028.pic	Frame037.pic	Frame038.pic	Frame039.pic	Frane040.pic
3005 Frame030.pic     3065 Frame033.pic     3066 Frame033.pic     3066 Frame033.pic     3066 Frame033.pic     3066 Frame033.pic     3066 Frame035.pic     3066 Frame036.pic     3066 Frame036.pic     3067 Frame036.pic     3067 Frame038.pic     3067 Frame039.pic     3067 Frame039.pic	Frame041.pic	Frame042.pic	Frame043.pic	Frane044.pic

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*).

Repeat1	OK
Repeat10 Repeat11	1 deste de
Repeat2	Cancel
Repeat3	
Repeat4	
Repeat5	
Repeat6	
Repeat7	
Repeat8	
Repeat9	

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)

dev Min	Max	Range	Cp	Cpk	1		
		Y	z		• ~~!	SZ	
Label TRACK1	X			SX 0.002	SY	0.001	-
TRACK1	0.585	0.637	0.950		0.002		
	0.503		0.952	0.002		0.002	
	0.428	0.633	0.959	0.002	0.002	0.002	
	0.342	0.622	0.967	0.002	0.002	0.002	_
TRACK5	0.246	0.613	0.975	0.002	0.002	0.002	
TRACK6	0.114	0.620	0.989	0.002	0.002	0.001	
TRACK7	0.080	0.628	0.998	0.002	0.002	0.001	
🗣 TRACK8	0.138	0.631	1.006	0.002	0.002	0.001	
TRACK9	0.521	0.657	0.946	0.002	0.001	0.001	
TRACK10	0.355	0.627	0.960	0.002	0.001	0.001	
TRACK11	0.168	0.620	0.970	0.002	0.001	0.001	
TRACK12	0.051	0.619	0.985	0.002	0.001	0.001	-

#### 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.

	Mi	icros	oft Excel - F	RSI panel m	easuremen	t 2002-09-1	7.xls [Read	l-Only]		
E	<u>-</u> ile	Edit	<u>V</u> iew <u>I</u> nsei	rt F <u>o</u> rmat <u>1</u>	ools <u>D</u> ata	<u>W</u> indow <u>H</u> elp	o Acro <u>b</u> at			
[	3	<b>2</b>	8 8 3	K 💞 🐰 [	à 🛍 🝼	<b>N</b> + CI	- 🍓 Σ	f× Ž↓ Ž↓	11 🛐	🚯 100°
1	Ā	7					-			
1.4		H16	i <b>-</b>	=						
	94000	THE								
	Re	I A	verage.csv							
Ш	-		A	В	С	D	E	F	G	Н
Ш	H	1	Label	RMS X	RMS Y	RMS Z	Total	Obs		1
	F.	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		
	Hi	5	BM4	0.032658	0.014718	0.019048	0.040571	11		
	H	6	BM5	0.038622	0.010143	0.024994	0.047109	11		
		7	BM6	0.042812	0.015381	0.028784	0.053832	11		1
	E	8	BM7	0.029564	0.016481	0.030762	0.045738	11		
		9	BM8	0.054676	0.019395	0.031618	0.066071	11		
	H	10	BM9	0.026342	0.026174	0.032891	0.049607	11		
	Fil	11	BM10	0.066819	0.030838	0.02761	0.078601	11		
	Fil	12	BM11	0.037279	0.012542	0.015934	0.042437	11		
		13	CODE167	0.566607	0.093188	0.095634	0.582129	8		
	H	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.

Micr	rosoft Excel - RSI	panel meas	urement 20	Ю2-09-17.ж	ls [Read-O	nly]							
ile E	<u>i</u> dit ⊻iew Insert I	F <u>o</u> rmat <u>T</u> ools	; <u>D</u> ata <u>W</u> in	dow <u>H</u> elp <i>i</i>	Acro <u>b</u> at								
) 🖬	F 🖬 🎒 🖪 🗳	۶ 🔏 🖻	🛍 🝼 🔺	• €2 +	🍓 Σ f*		1 🛐 🚯	100% 👻 (	?) 🗸 🖌 Arial			BI	
0 12	2								14				-
	≝ B2 <b>▼</b>	= -36.1	98										
		30.1.	50										
R	epeat.csv												
	A	В	С	D	E	F	G	Н	L L	J	K	L	
		Х	γ	Z	DX	DY	DZ	DTotal	SX	SY	SZ		
	Baseline	-36.198	-324.615	-104.432					3		;		
	Epoch1	-36.469	-324.957	-106.802	-0.271	-0.342			0.032	0.024	0.018		_
	Epoch2	-36.69	-325.52	-108.313	-0.492	-0.905		4.015		0.02	0.014		
	Epoch3	-36.68	-325.182	-108.301	-0.482			3.94	0.027	0.02	0.013		
	Epoch4	-36.653	-324.93	-107.445	-0.455	-0.315			0.028	0.02	0.014		
	Epoch5	-35.063	-326.509	-109.454	1.135	-1.894				0.02	0.013		
	Epoch6	-36.444	-324.845	-106.954	-0.246	-0.23			0.025	0.019			
	Epoch7	-35.388	-326.31	-109.376		-1.695			0.027	0.02	0.014		
	Epoch8	-36.774	-325.104	-108.206	-0.576	-0.49			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							2		
21							-						
22	TRACK2	Х	γ	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		1
	Epoch2	-33.99	-249.78	-39.446					0.026	0.019			
	Epoch3	-33.995	-249.452	-39.434	-0.42				0.027	0.019			1
	Epoch4	-33.961	-249.181	-38.591	-0.386	-0.414			0.027	0.019	0.014		Ĩ
	Epoch5	-32.574	-250.741	-40.654	1.001	-1.974		5.387	0.027	0.019			1
	Epoch6	-33,755	-249.066	-38.14	-0.18	-0.299		2.422	0.025	0.018	0.014		1
	Epoch7	-32.878	-250.581	-40.512		-1.814				0.019	0.014		-
	Epoch8	-34.055	-249.432	-39.32		-0.665		3.67	0.026	0.021	0.015		1
	Epoch9	-33.363	-250.365	-40,195				4.734	0.024	0.017	0.013		
	Epoch10	-33.342	-250.414	-40.178			20.00000			0.018	0.014		Ť
	Epoch11	-33.945	-249.23	-38.572		-0.464			0.025	0.018			Ť
	Avg	-33.607	-249.767	-39.363	-0.032					0.019			+

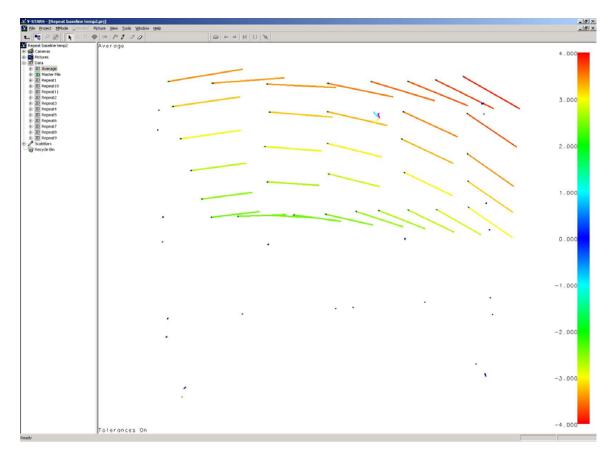
The "*Report.cvs*" file is a summary version of the "*Repeat.CVS*" file. It contains no individual epoch values for the coordinates.

#### **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.

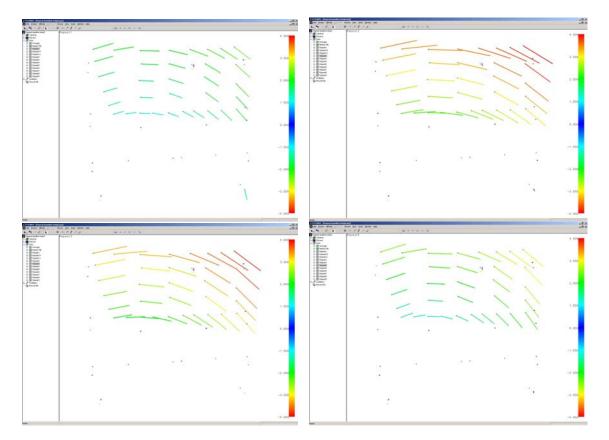
**Import View Settings** – Use this command (refer to 4.3 Release Notes) to give all your Repeat 3D files the same viewpoint and vectors view parameters as a master file. For example, take the Average.3D file and modify the parameter to illustrate the magnitude and direction of the vectors. The point 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.

Name	Measured Points	Desi	gn Points				
3D Average	55		62				
30 Master File	0		62				
3D Repeat1	55		62				
3D Repeat 10	To Course Marc		62		Vs	elect Source 3D File	X
3D Repeat	Information		62				
	New	- +	62		30	Average	ОК
3D Repeat:	Import	Þ	AutoBar			Master File	
3D Repeat	Export	•	Driver Fi	le	-	Repeat1	Cancel
	Update	•	Data File	•		Repeat10	
	Merge		To Desig	10:		Repeat11	
3D Repeat -	Alignment	+		ction Data		•	
3D Repeat: 3D Repeat	Transform		View Set			Repeat2	
ов кереас	AutoRelabel		Offset			Repeat3	
	Rename AutoMatch	n -				Repeat4	
			Setup			Repeat5	
	Driver File				30	Repeat6	
	Detail File				30	Repeat7	
	Template File				30	Repeat8	
	Delete				30	Repeat9	

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.