Data Evaluation Environment- Necessity for Achieving the Goal of the Measurements

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The Goal

- To compare two different approaches to achieving the goal of the measurement: the “traditional software program” and the “software evaluation environment”
- To show through practical examples the advantages of using a “software evaluation environment”
  - Interactivity, simultaneity and the need for post-processing will be discussed
- Show how much the final result can be influenced by the software tools available in a “software evaluation environment”.
- To show that the “software evaluation environments” are the future.

Traditional Measurement Program

Lense1-workshop (Lense1-workshop)

15	Create origin	Point (1) Z
16	Programmable stop	Move machine to the side at the right Z for circle near +X
17	Actual position into variable Actual coordinate system	X = TempX, Y = TempY, Z = TempZ
18	CNC parameters and CNC on	Movement speed = 100.0000000 Measurement speed = 2.0000000 Safety distance = 2.0000000
19	CNC parameter	Movement speed = 100.0000000 Measurement speed = 2.0000000 Safety distance = 2.0000000 Measurement length = 100.0000000 Positioning distance = 2.00000
20	Move machine Absolute movement	X = TempX Y = TempY Z = 25.0000000
21	Move machine Absolute movement	X = 39.0000000 Y = 0.0000000 Z = 15.0000000
22	Circle	Circle (2) Mean
23	Autom. element measurement Circle	No.of Pts. = 16 Projection / meas. plane = XY plane X = 0.0000000 Y = 0.0000000 Z = TempZ Diameter = 77.0000000
24	Element finished	
25	Create origin	Circle (1) XY
26	Actual position into variable Actual coordinate system	X = TempX, Y = TempY, Z = TempZ
27	Move machine Absolute movement	X = TempX Y = TempY Z = 15.0000000
28		
29		
30	Element finished	

Typical interpreter language: read a line and execute it.

Traditional Measurement Program

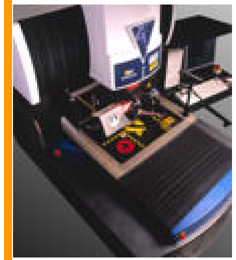
- Typical interpreter language: read a line and execute it.
- Combines the data collection with the calculation and evaluation process
  - Evaluation (calculation) of an element is typically done immediately after the data collection.
- All actions and events pre-programmed
  - Only a change to the program can cause a change in evaluation but the part needs to be re-measured

Traditional Measurement Program

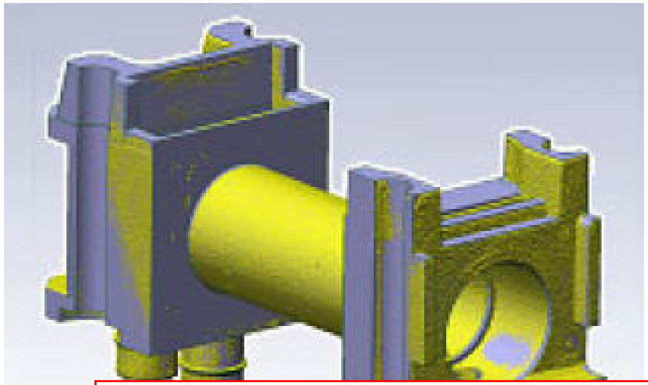
- Raw data is often lost and only calculated parameters of the feature carried forward
- Typically no interactivity
  - If interactivity is built that requires human input which puts on hold expensive measuring equipment

Measuring Device - Evaluation Environment

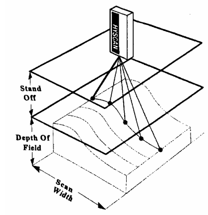
Measuring devices are used as 2D/3D digitizers to collect points from the part




X, Y, Z measured coordinates plus tip radius when applicable

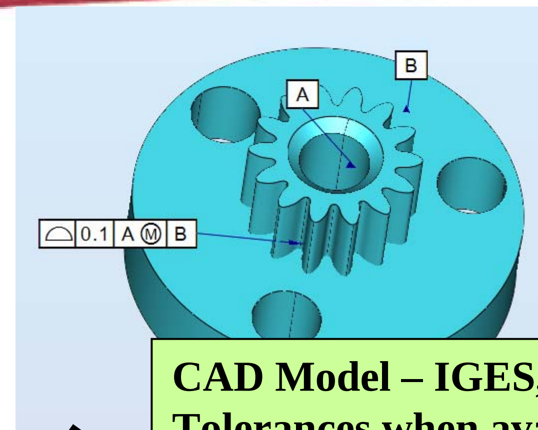



This is not a CAD model.
It is a cloud of points!



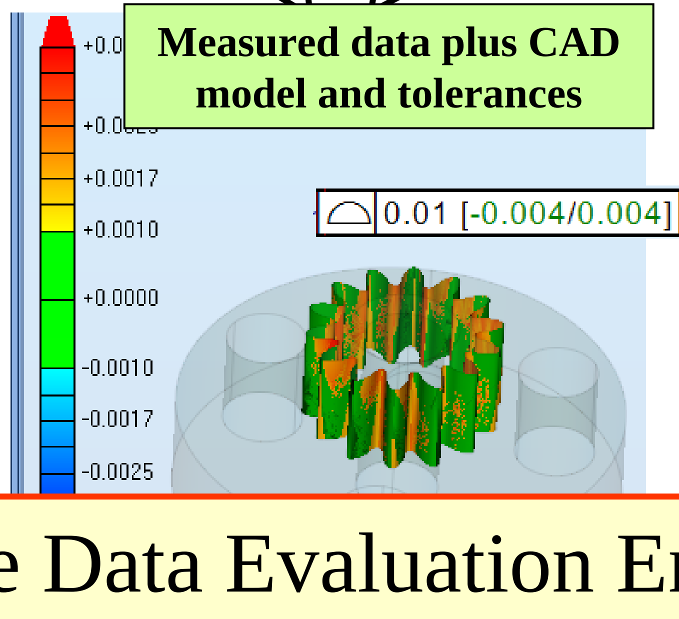
Interactive Data Evaluation Environment

X, Y, Z measured coordinates – from any measuring device



CAD Model – IGES, VDA,DXF, STL, Tolerances when available

Measured data plus CAD model and tolerances



Interactive Data Evaluation Environment

The Goal of the Measurement Determines the Evaluation Process

Tolerance Compliance

Manufacturing Process Analysis

SPC (Statistical Process Control)

Reverse Engineering

Interactive Data Evaluation Environment

Need for task specific evaluation: the analysis may lead to very different results using the same raw data!

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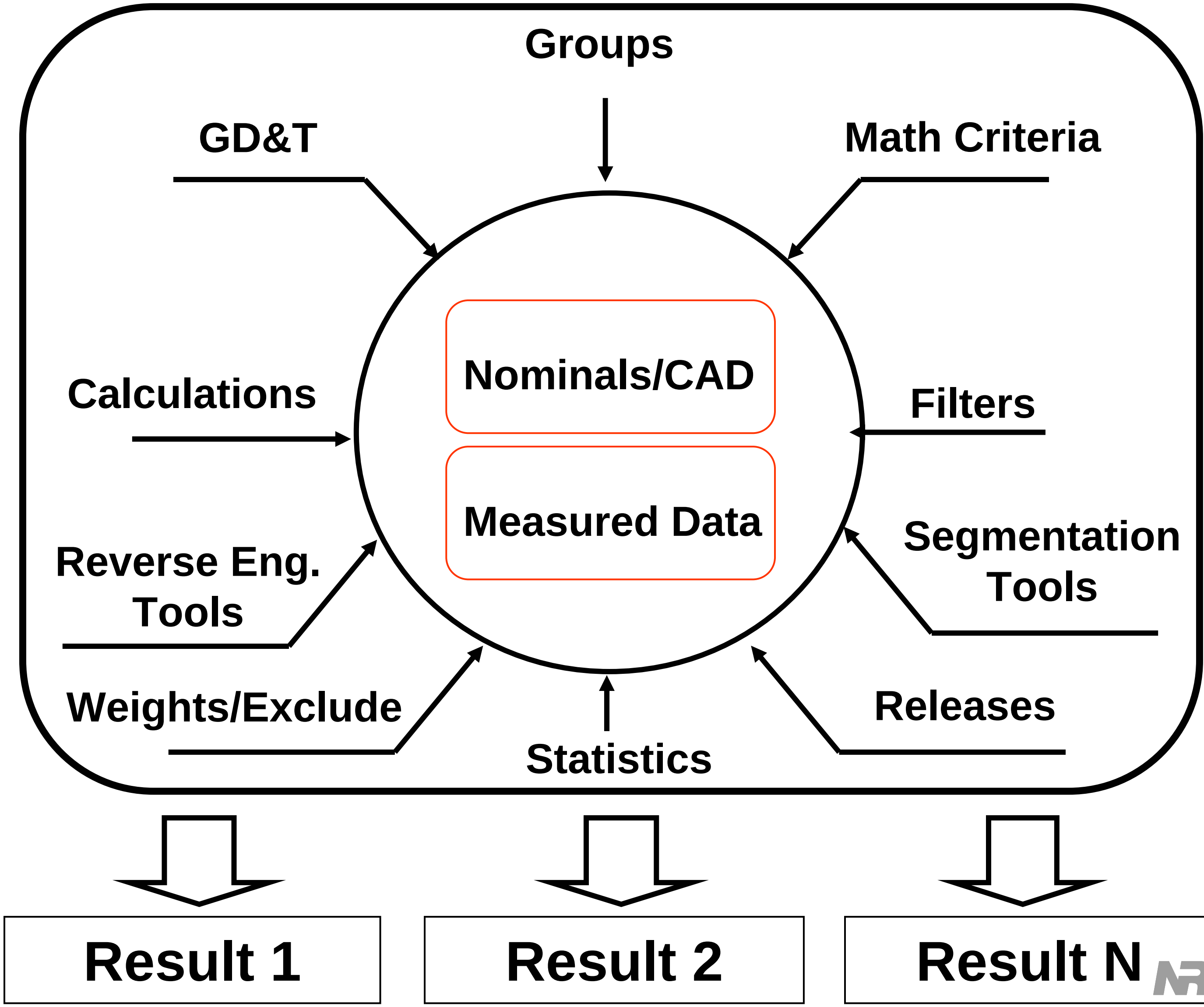
Characteristics of a Data Evaluation Environment

- **Database** containing nominal, tolerance, and measured data
- **Interactive** Evaluation based on data **post-processing**
- Availability of task specific toll boxes
  - CAD related tools
  - Element calculation tools
  - Filtering tools
  - GD&T tools
  - Troubleshooting and analysis tools, What-if analysis tools
  - Reverse engineering tools

Characteristics of a Data Evaluation Environment

- **One** set of measured data can produce **more than one result**
- Typically stand-alone but could also be connected to a measuring device
  - `Does not tie up the expensive measuring equipment
  - Allows that the evaluation is being done by persons away from the measuring equipment – for example by the engineering department
- If needed the evaluation can also be run by a script just like a traditional program

An Evaluation Environment Tools



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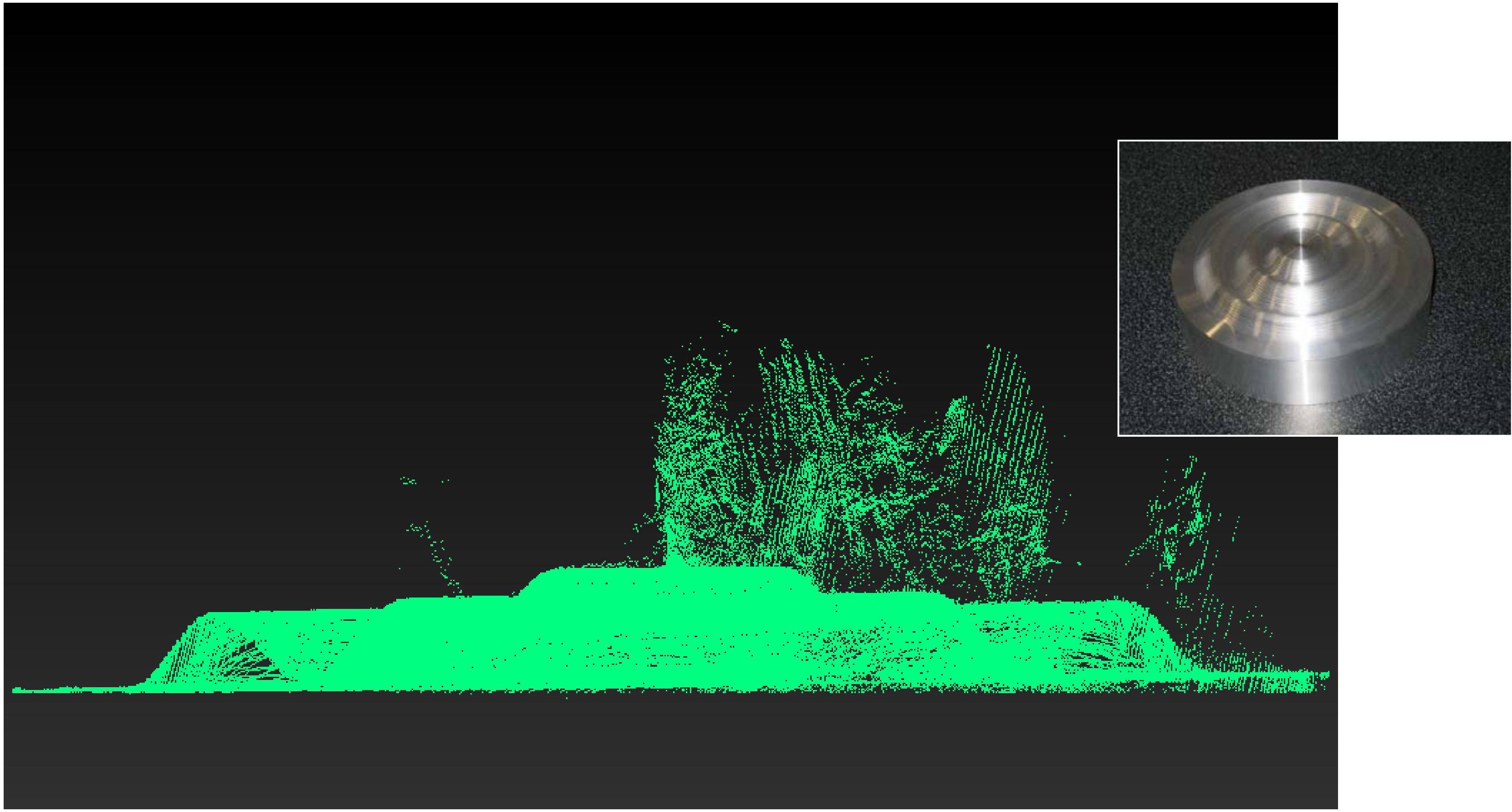
The Data Collection – Interactivity Needed

Filtering



Need for data “clean up” and segmentation of features

Courtesy: NIST

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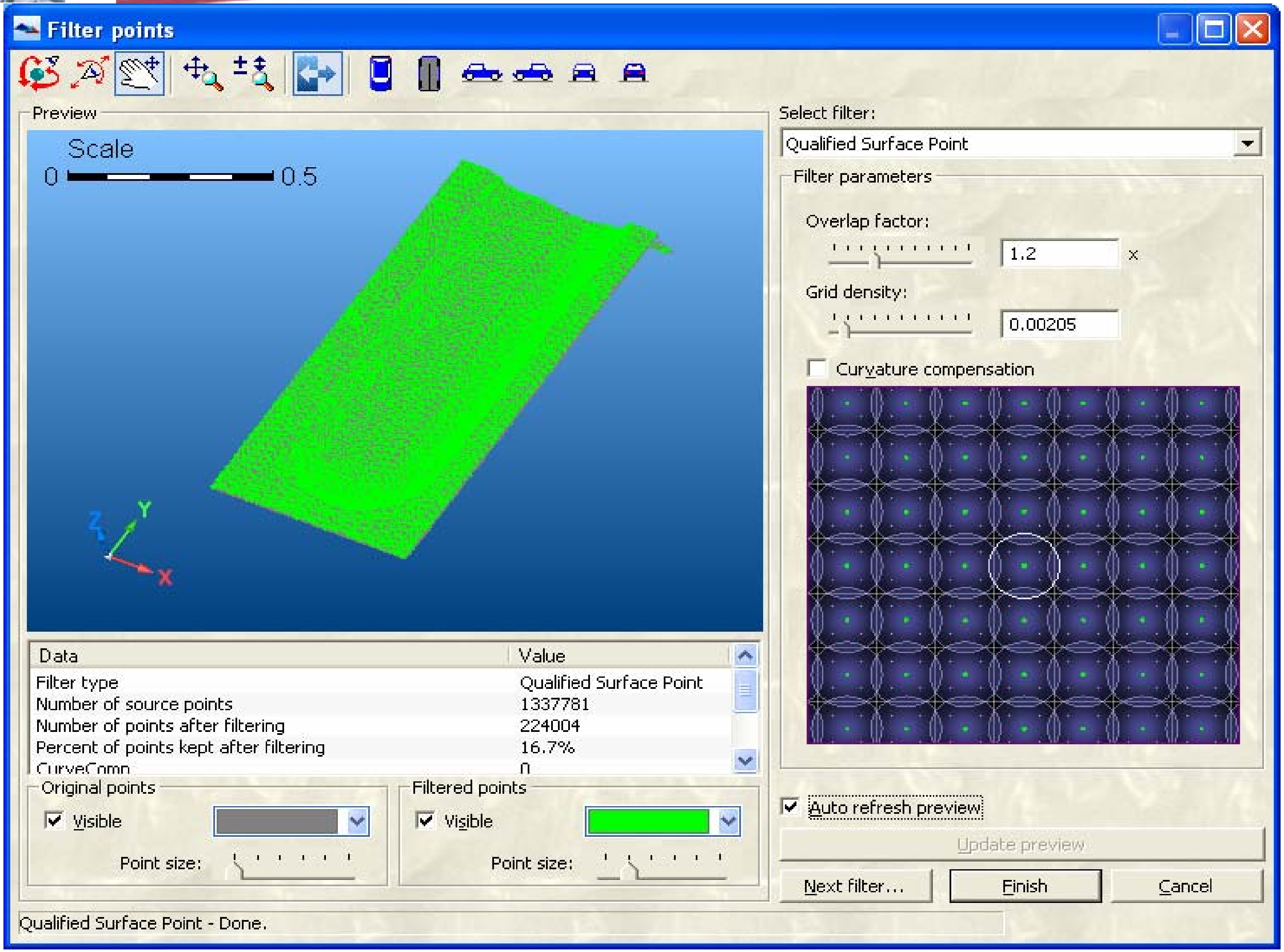
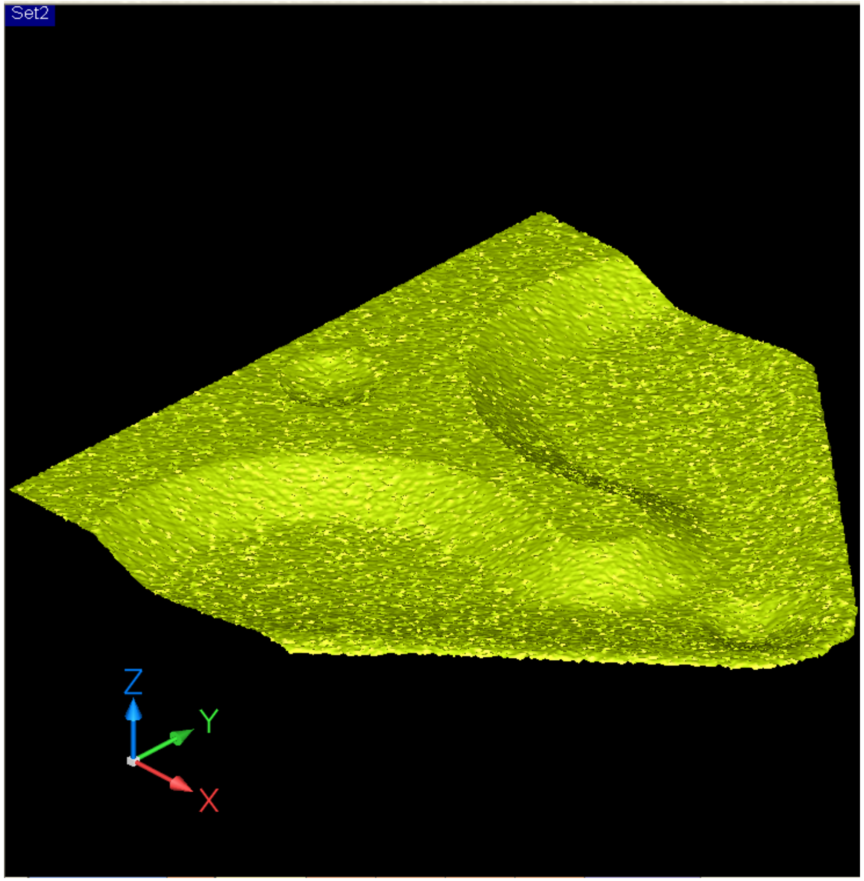
Interactive Filtering

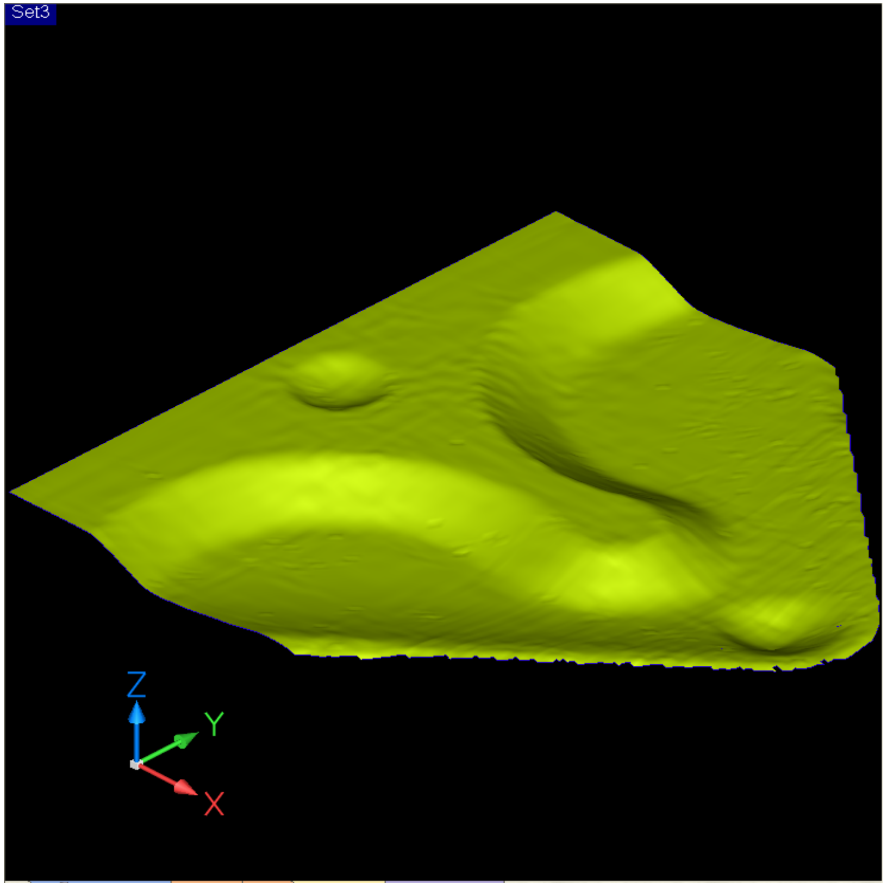


Courtesy: Kotem

Interactive Filtering



Unfiltered



Filtered

Courtesy: Kotem

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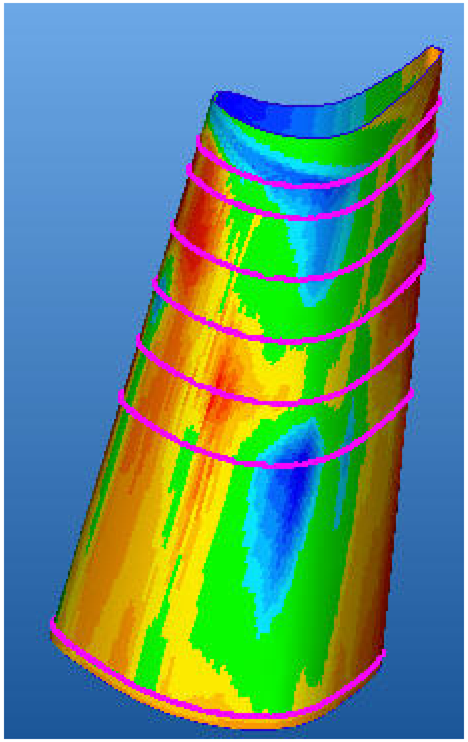
ISO/TS 16610 Series



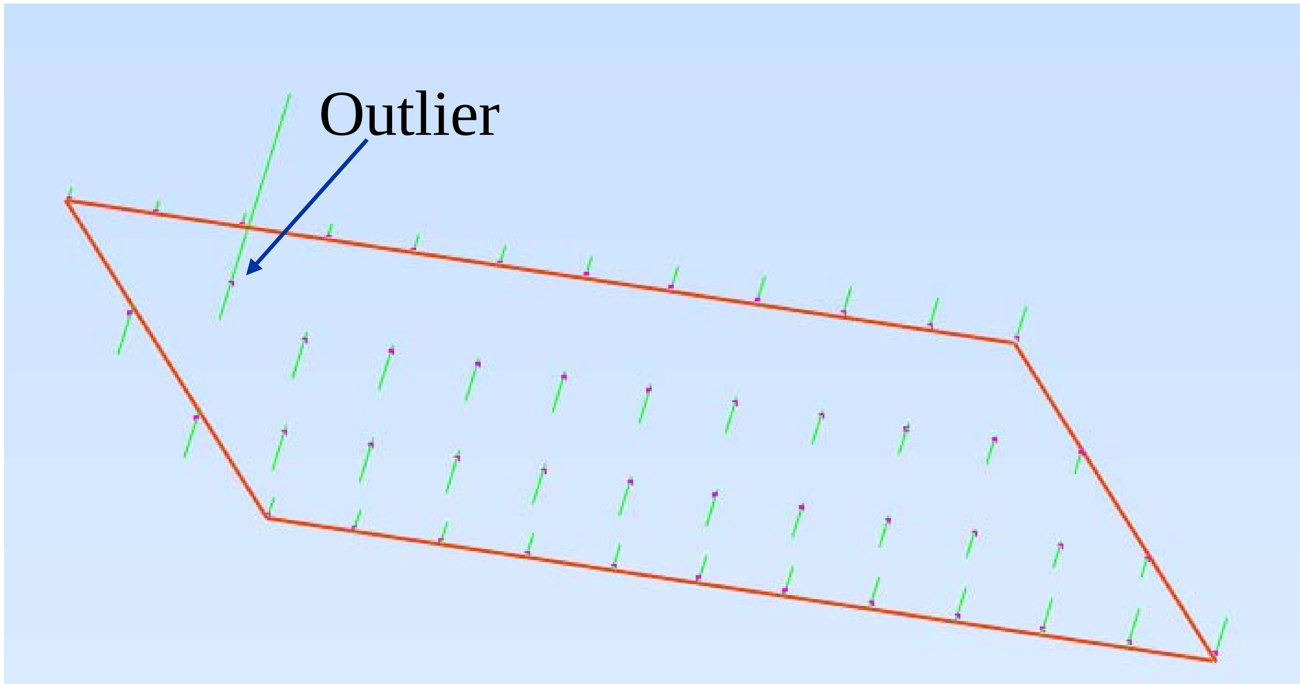
A.2 Titles of the individual part in the ISO/TS 16610 series

The individual part titles are:

- Part 1: *Overview and basic terminology*
- Part 20: *Linear profile filters; Basic concepts*
- Part 21: *Linear profile filters; Gaussian filters*
- Part 22: *Linear profile filters; Spline filters*
- Part 26: *Linear profile filters; Filtration on nominally orthogonal grid planar data sets*
- Part 27: *Linear profile filters; Filtration on nominally orthogonal grid cylindrical data sets*
- Part 29: *Linear profile filters; Spline wavelets*
- Part 30: *Robust profile filters; Basic concepts*
- Part 31: *Robust profile filters; Gaussian regression filters*
- Part 32: *Robust profile filters; Spline filters*
- Part 40: *Morphological profile filters; Basic concepts*
- Part 41: *Morphological profile filters; Disk and horizontal line segment filters*
- Part 42: *Morphological profile filters; Motif filters*
- Part 49: *Morphological profile filters; Scale space techniques*
- Part 60: *Linear areal filters; Basic concepts*

Measuring the 100,000 points on this machined part may be waste of time

Outlier Removal



Outlier are very difficult to determine in an automation fashion. It requires a human decision which is not effective in a traditional program.

Courtesy: Kotem

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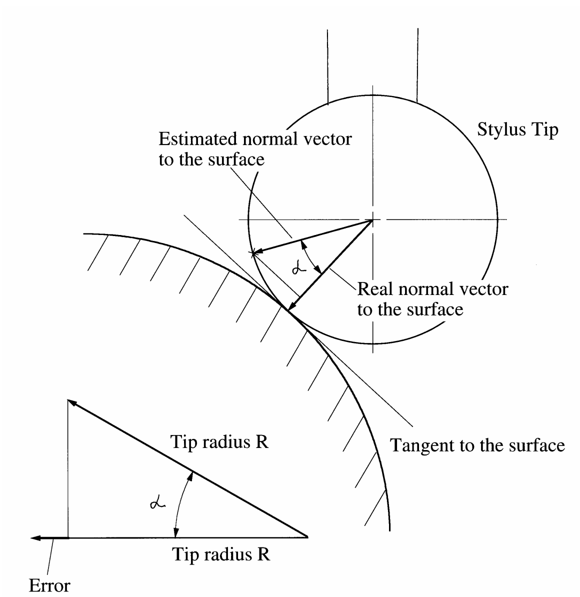
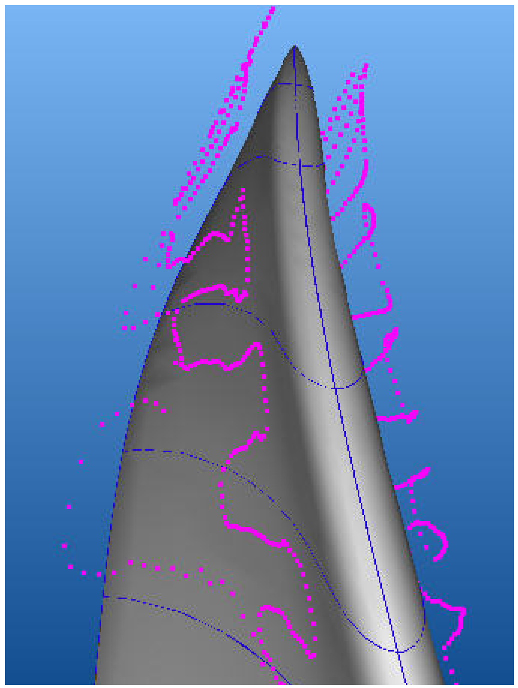
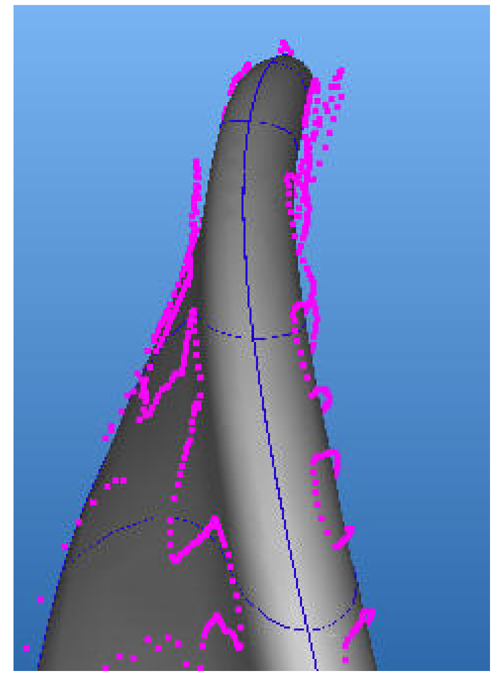
The Post-processing Capability

The correct coordinate system can only be determineed after best-fit



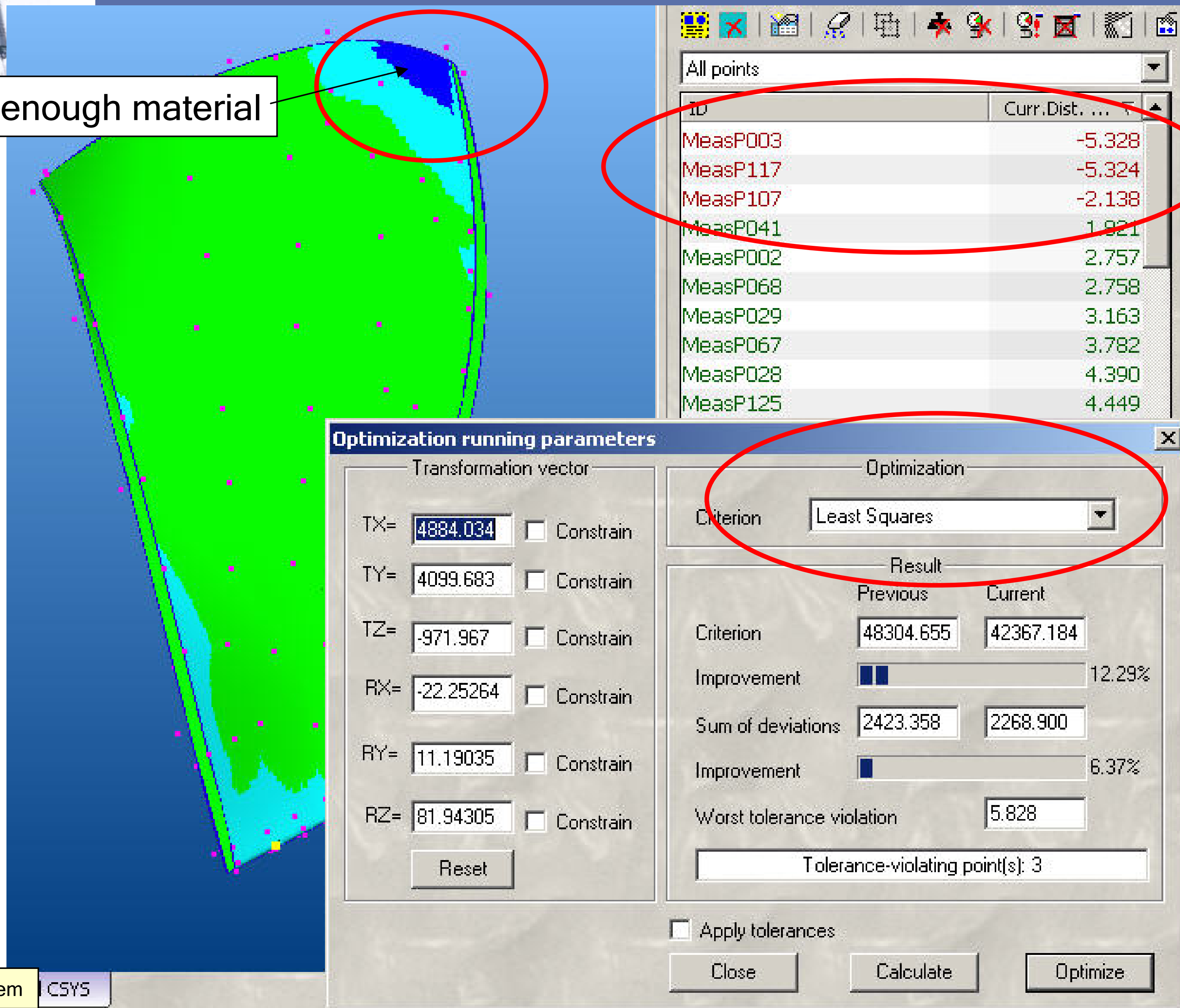




Free form surface parts without stable and reproducible datums require that the tip radius compensation is done after best-fit to the CAD model

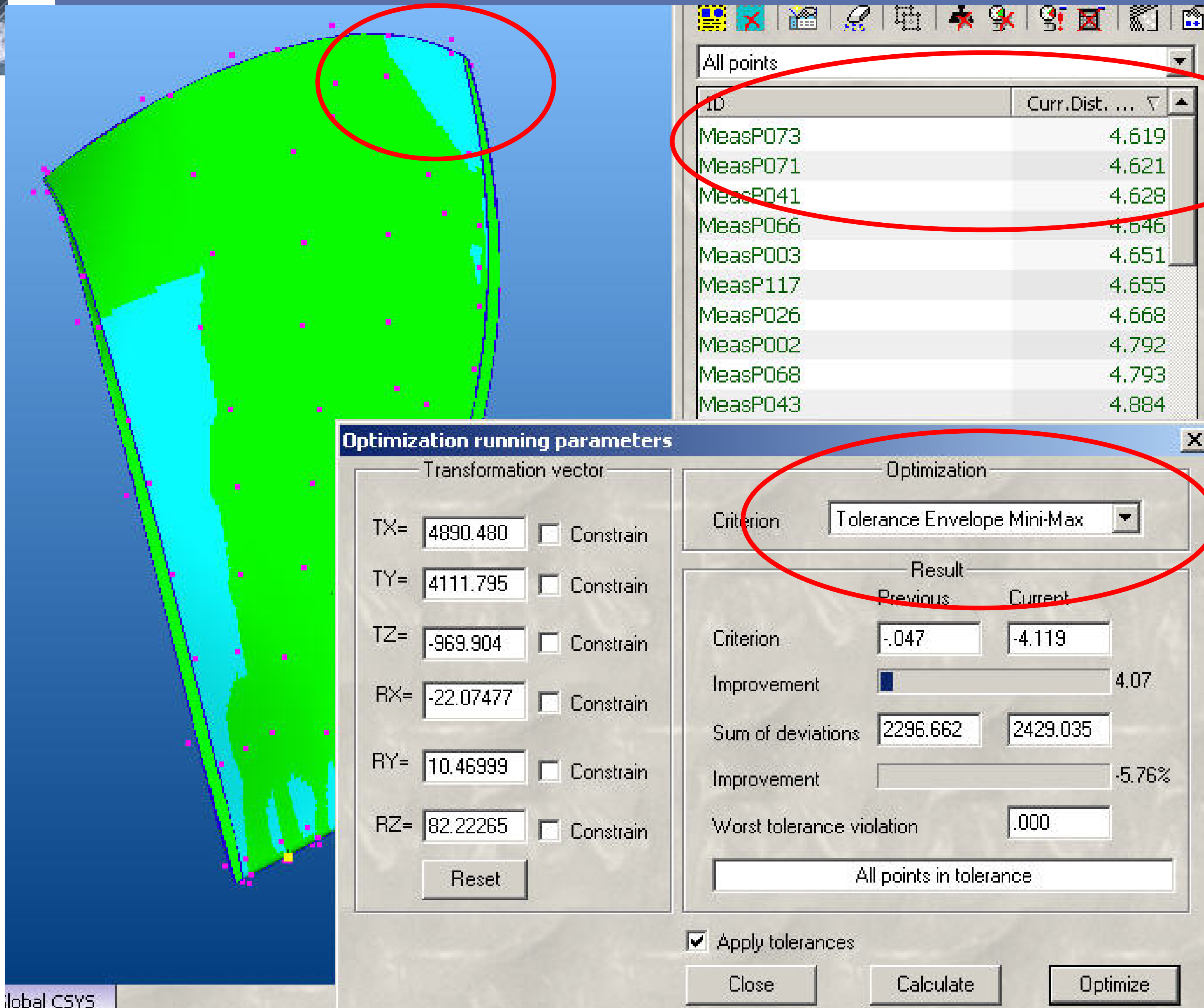
Courtesy: Kotem

Blade – Least Squares



Courtesy: Kotem

Blade – Special Criterion



Courtesy: Kotem

Same Data, Different Tool – Different Result

Blade Machinning Study							
	Least Squares		Tolerance Fit		Special Criterion		Diff. LS - Special
Three worst Points	mm		mm		mm		mm
Point 1	-5.328		0.547		4.619		9.947
Point 2	-5.324		0.548		4.621		9.945
Point 3	-2.138		0.579		4.628		6.766

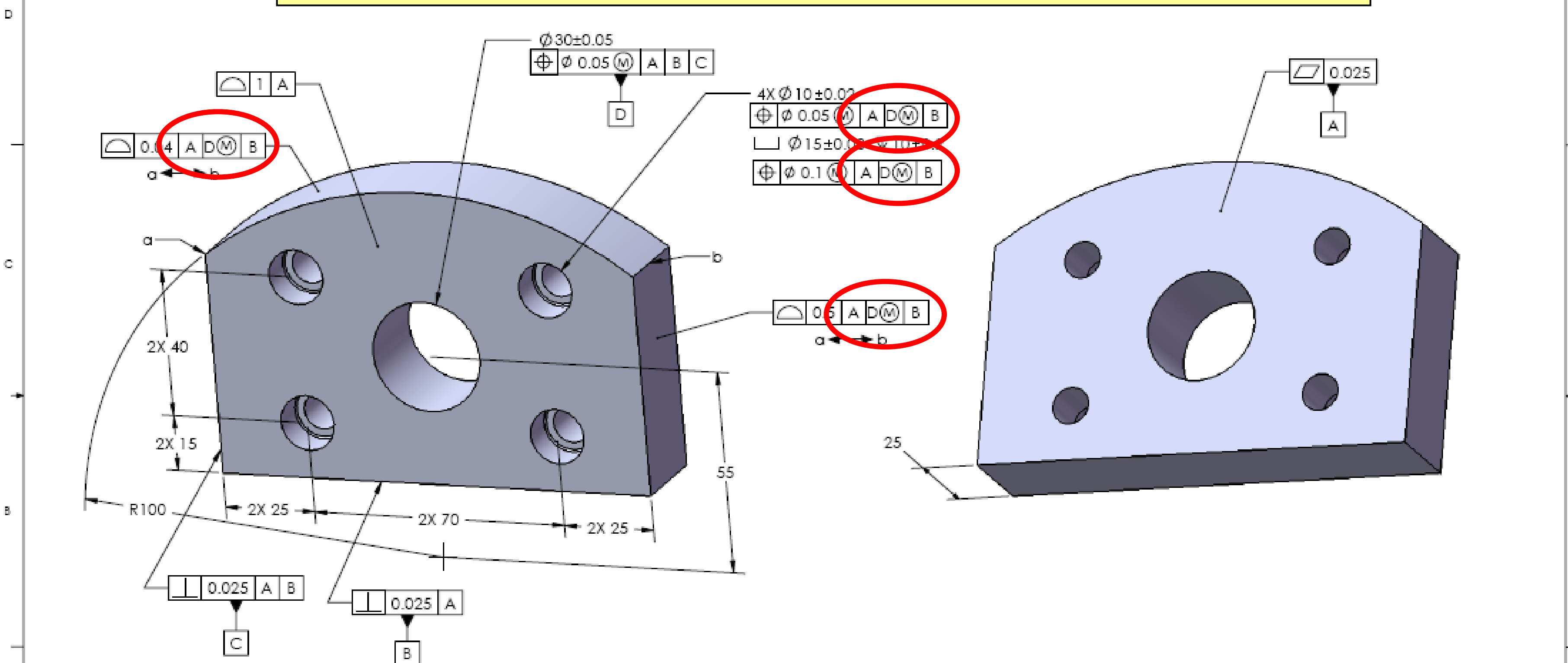
Rem.: Tolerance set to 0.5 to 60 mm

This is a difference of 10 mm with data collection uncertainties in the range of about 0.1 mm - 0.15 mm!

The post-processing capability combined with interactivity and the knowledge of the goal provides the opportunity to extract the best.

DRF Simultaneous Requirement

These groups of features, although with different tolerances, must be treated as a single pattern



All tolerances referring to a common DRF must be satisfied simultaneously! These groups of features, although with different tolerances, must be treated as a single pattern. Best done with post-processing.

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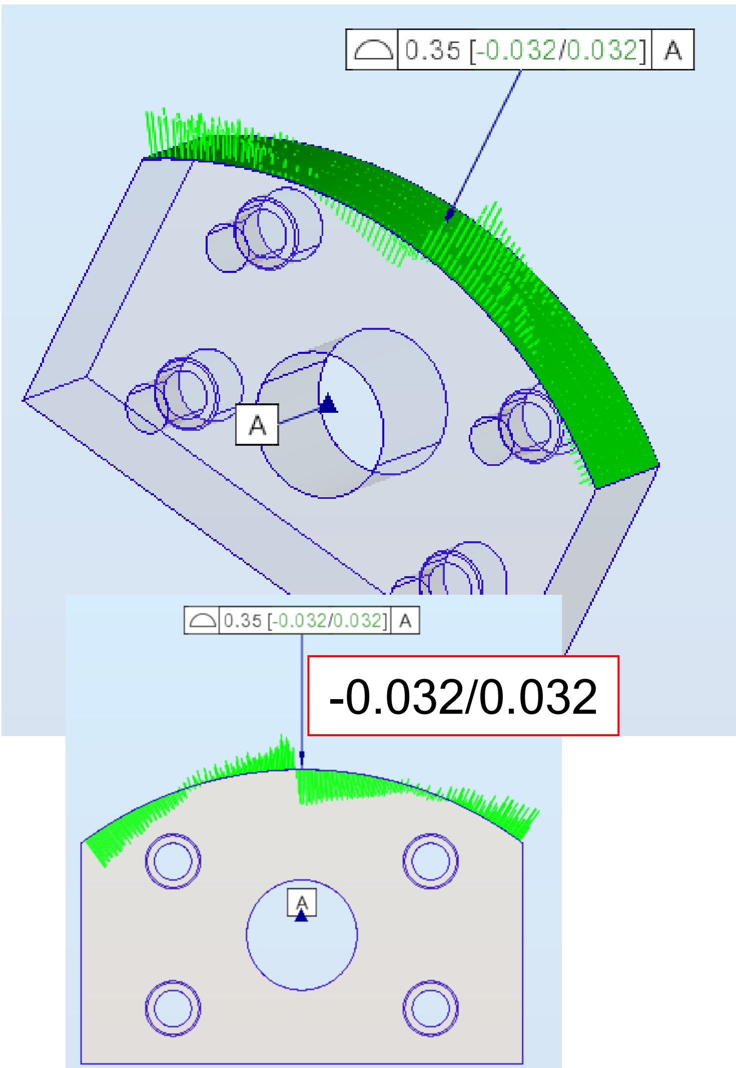
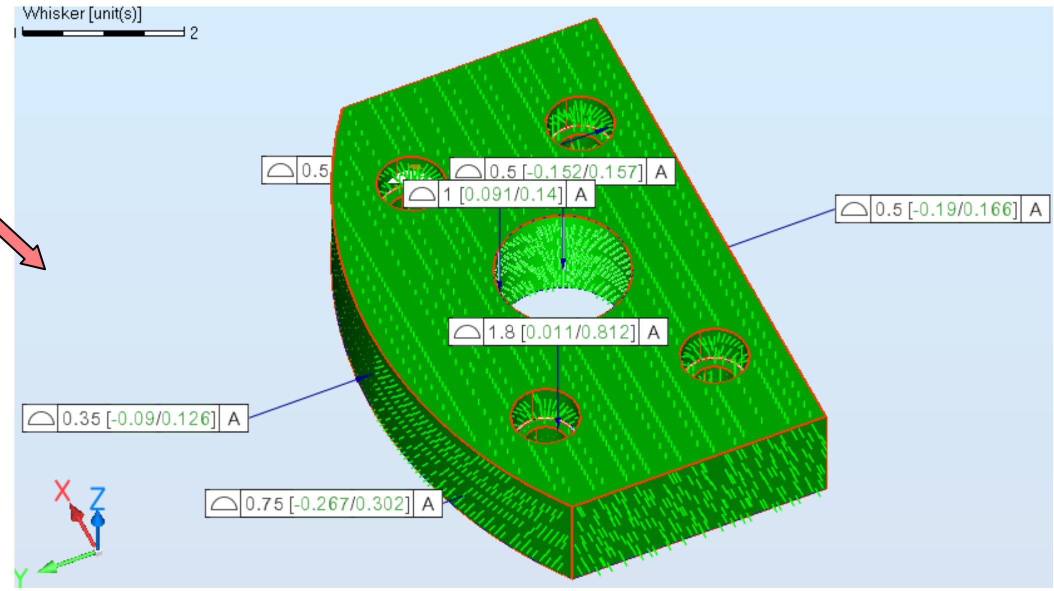
Separate Requirement – What-If

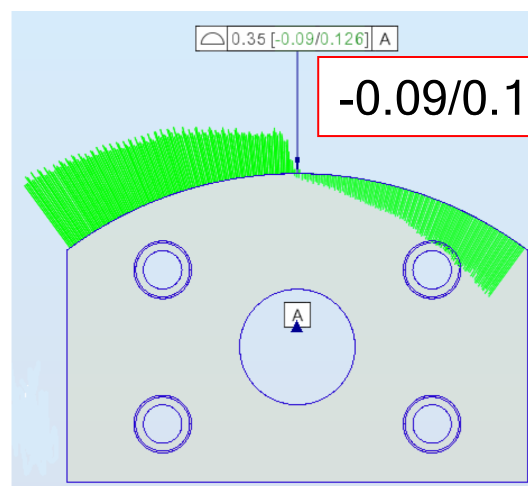
Separate Req.

Simultaneous Req.



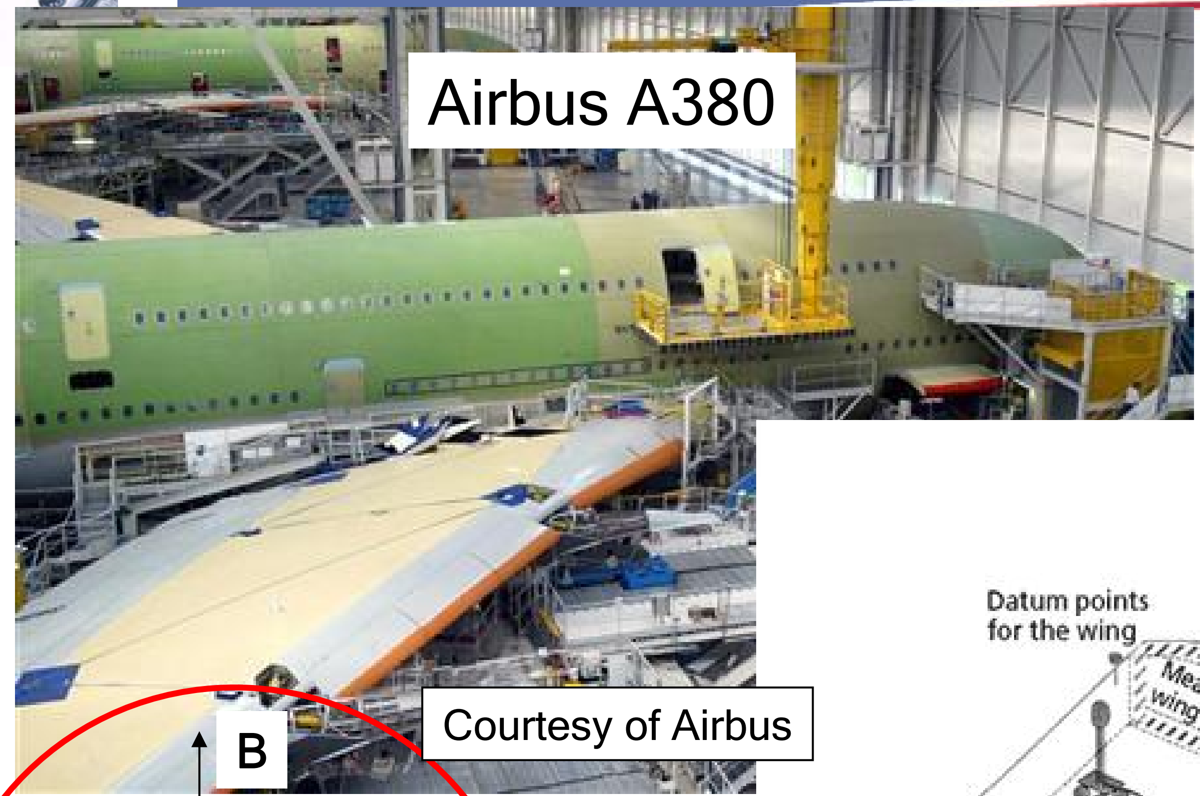
-0.032/0.032

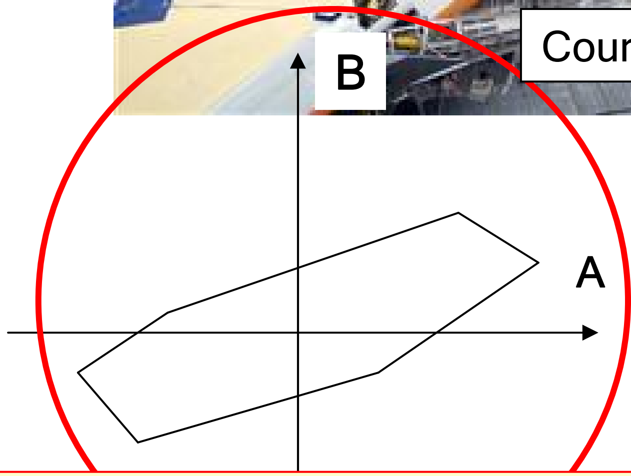


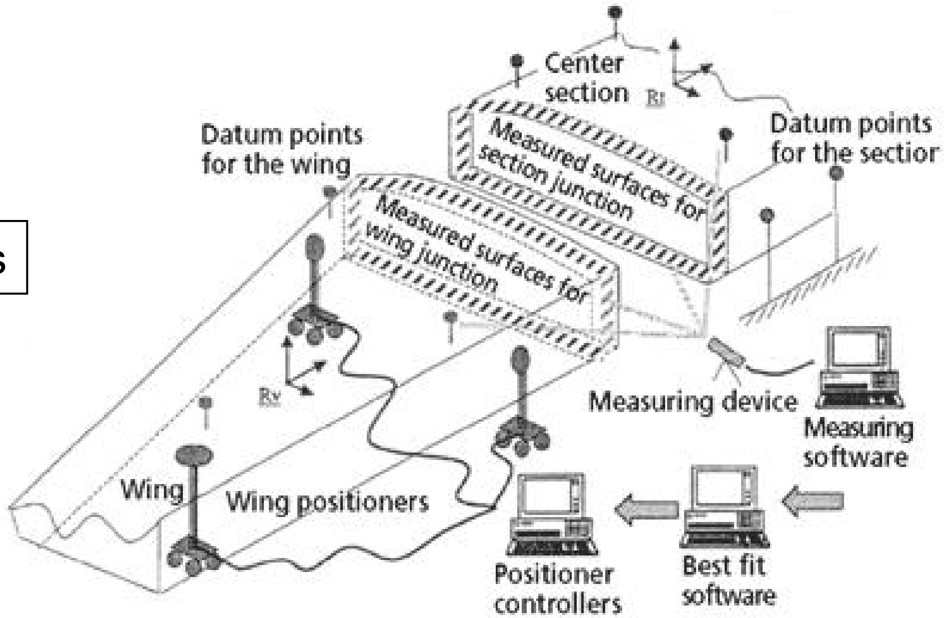


-0.09/0.126

Analysis and What-If Tools

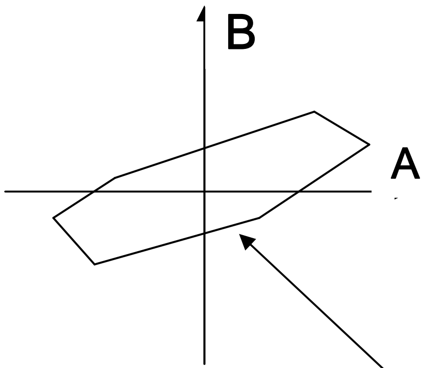


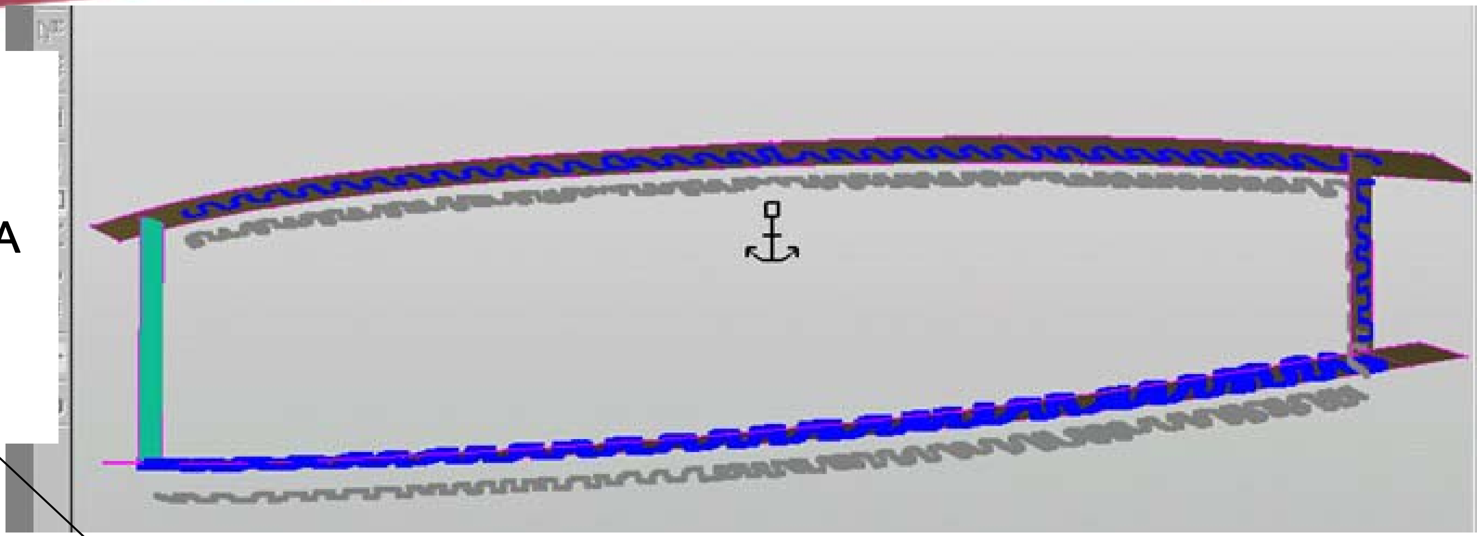




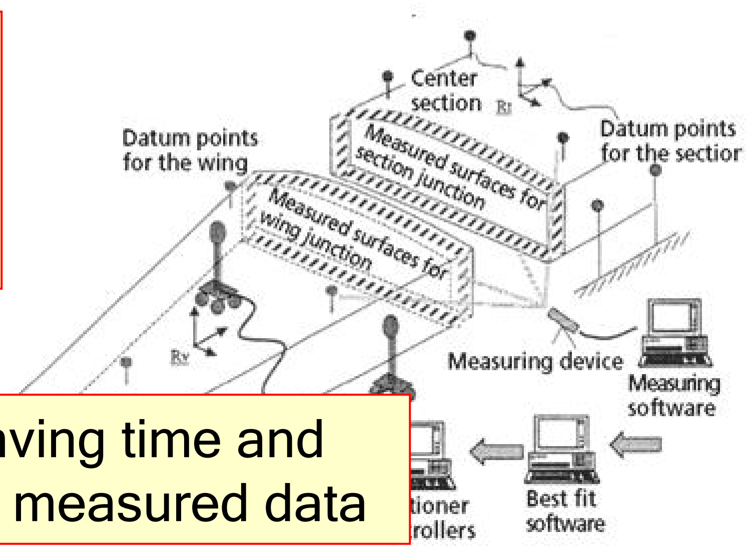
Best-fit must satisfy the tolerance graph for parameters A B

Analysis and What-If Tools



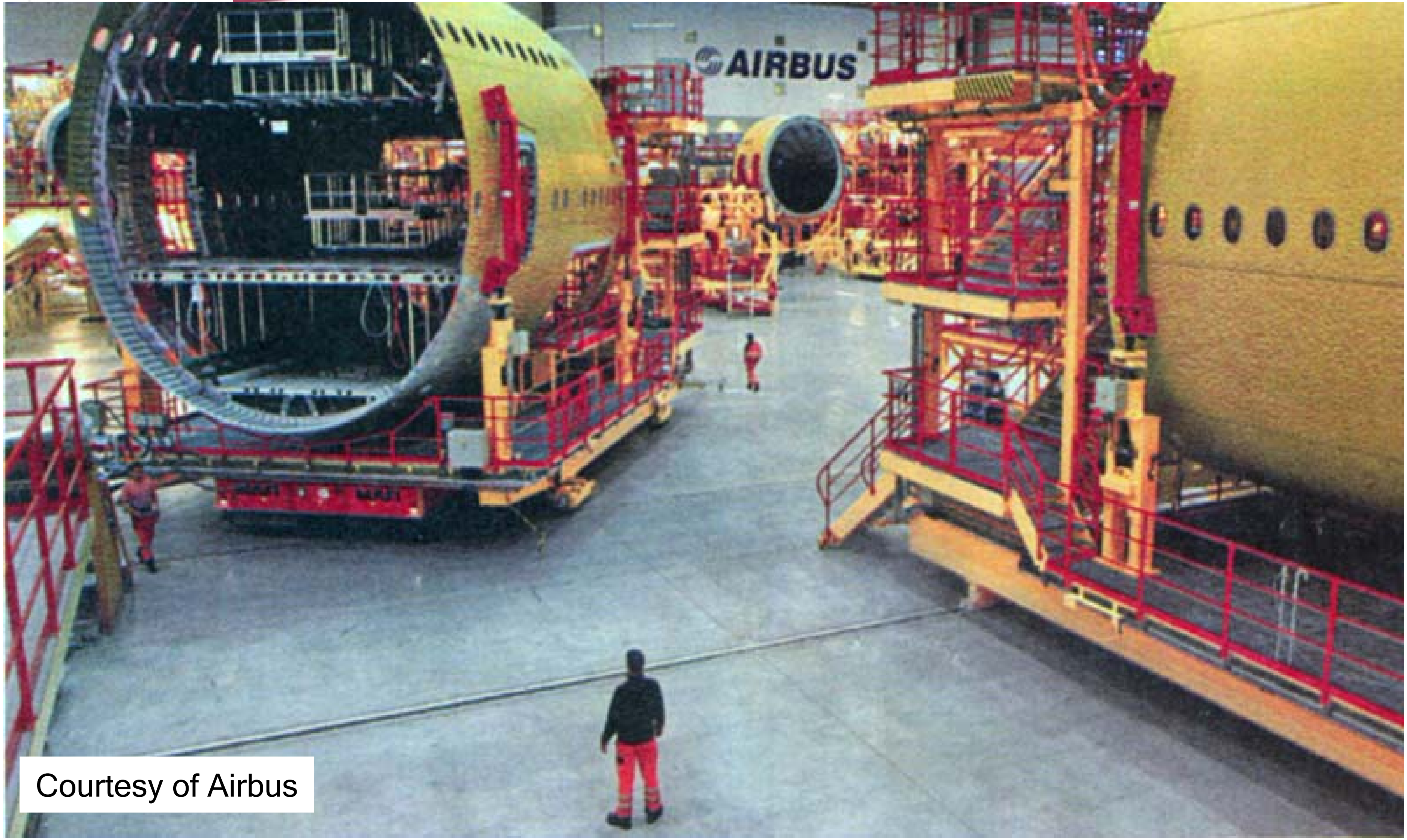


Example: Simultaneous requirements for an UNIFORM GAP while keeping parameter A an B to remain within the tolerance area as safely as possible



The Interactive Data Environment allows saving time and money through simulation of action based on measured data

Analysis and What-If Tools



Courtesy of Airbus

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Tools - Using Weight Factors Interactively

- We can move errors to areas of the part where we can re-work them easily
- Avoid or reduce welding required to re-work tooling

Using weight factors is a very important tool helping to find the right compromise and save money and time

Tools - Using Weight Factors

Original Result

P005				#1314 Hole
	X = 22.600	X = 22.386	X = 22.214	
		DX = −0.214	DX = −0.386	
	Z = 114.600	Z = 114.455	Z = 114.257	
		DZ = −0.145	DZ = −0.343	

Weighted Result with w = 0

P005				#1314 Hole
	X = 22.600	X = 22.386	X = 22.197	
		DX = −0.214	DX = −0.403	
			xw = 0.000	
	Z = 114.600	Z = 114.455	Z = 114.257	
		DZ = −0.145	DZ = −0.343	
			zw = 0.000	

Using weight factor = 0 is a very important tool in eliminating outliers and determining their correct positions after optimization

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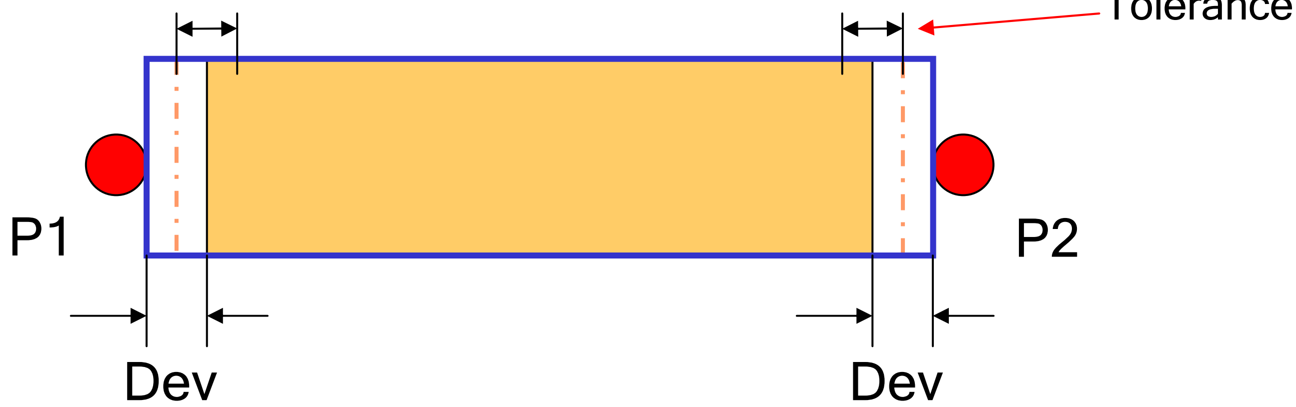
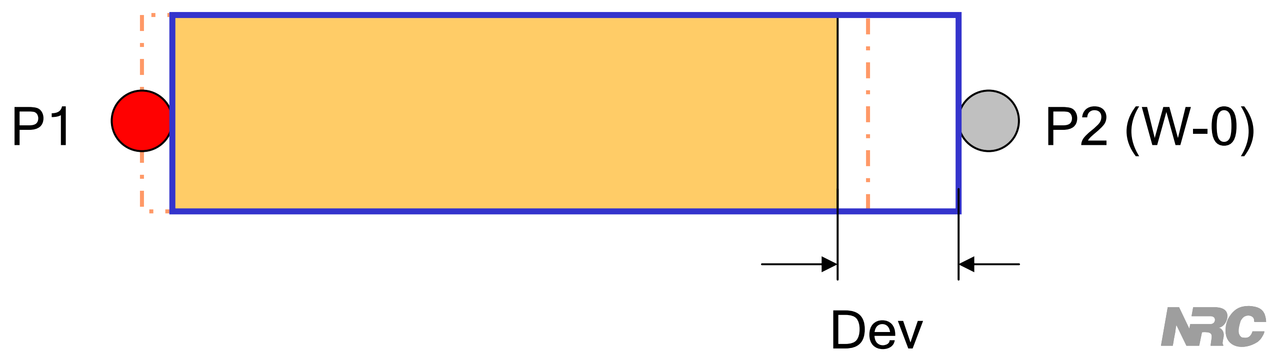
Tools - Using Weight Factors

Example: P1 and P2 are both of tolerance after best-fit. This would mean both need to be fixed



After excluding P2 there is only one point to be fixed



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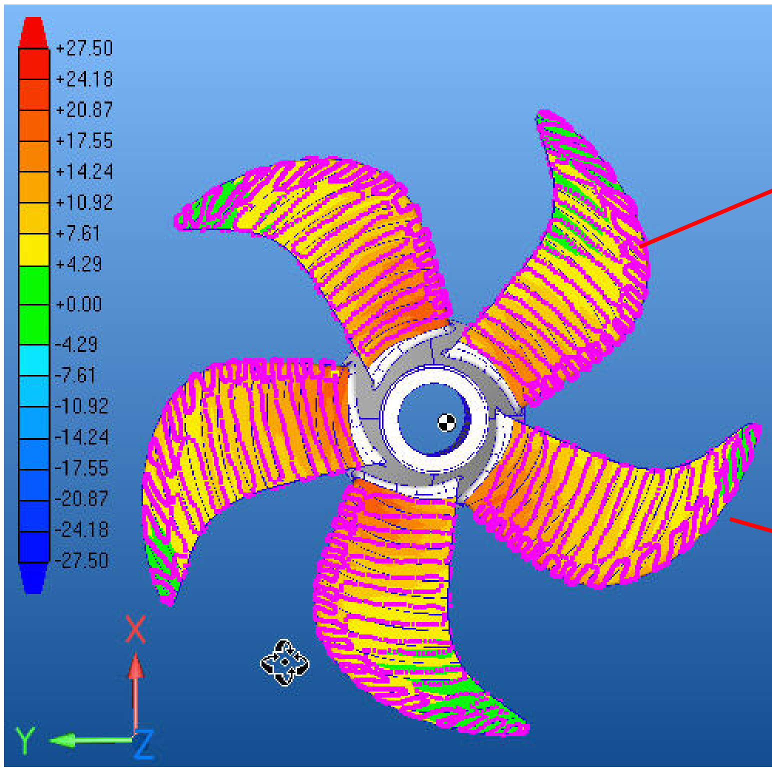
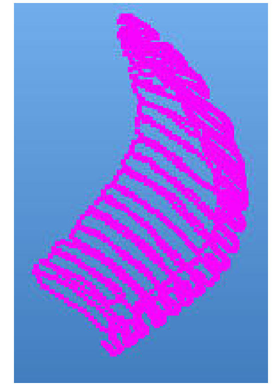
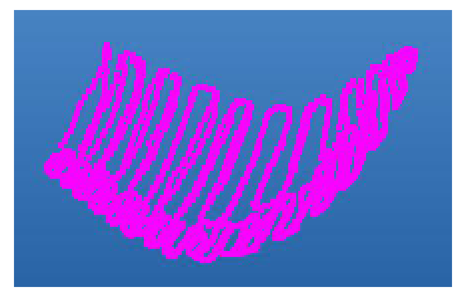
Same Data, Different Goal - Different Result

Result 1





Result 2

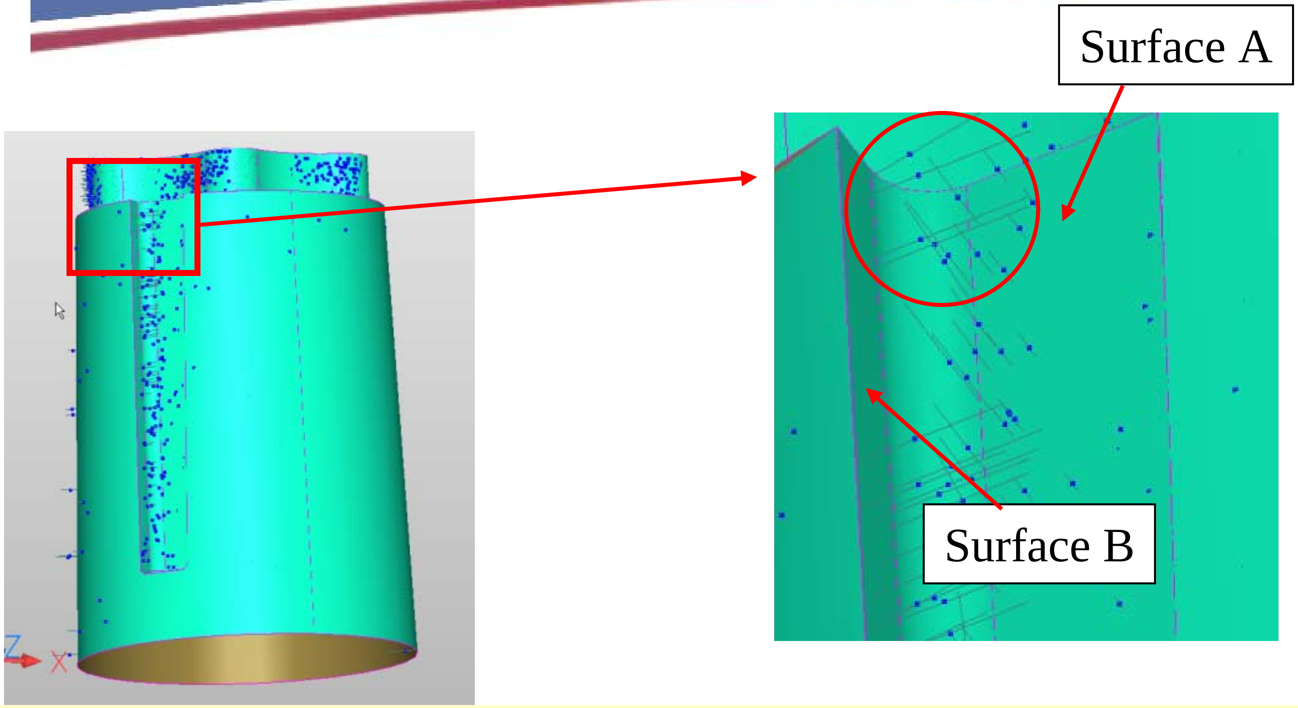


Result 3

The right software tools are not readily available

Courtesy of Kotem

Problems with Points-to-Surface Association



Problem: During best-fitting points measured on surface A are closer to Surface B and a deviation is formed from surface B instead of surface A

In an Interactive Evaluation Environment
Metrology is an Engineering Tool!

An Interactive Evaluation Environment
helps to save money and time
It Provides a Choice!

Summary

- A proper “software evaluation environment” is able to do everything “traditional software program” can do.
- The interactivity and the post-processing nature of the “software evaluation environment” gives it a clear advantage.

Thank You!