Form measurement for aero engine components - contact or non-contact?

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Rolls-Royce plc

Form measurement

- Is it round?
- Is it straight?
- Is it a combination of these?
  - Is it spherical?
  - Is it flat?
  - Is it cylindrical?
  - Is it conical?

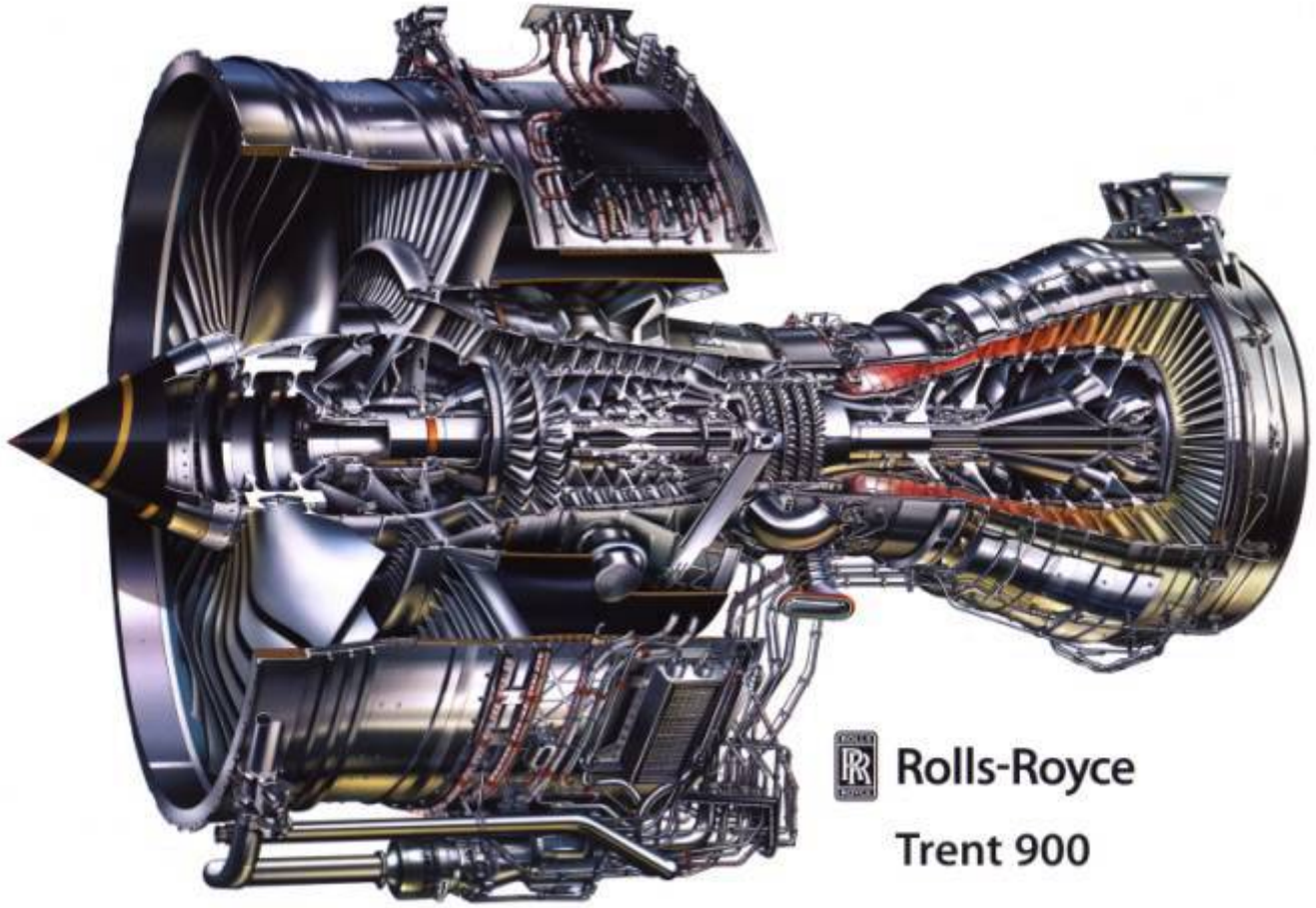
Free form measurement

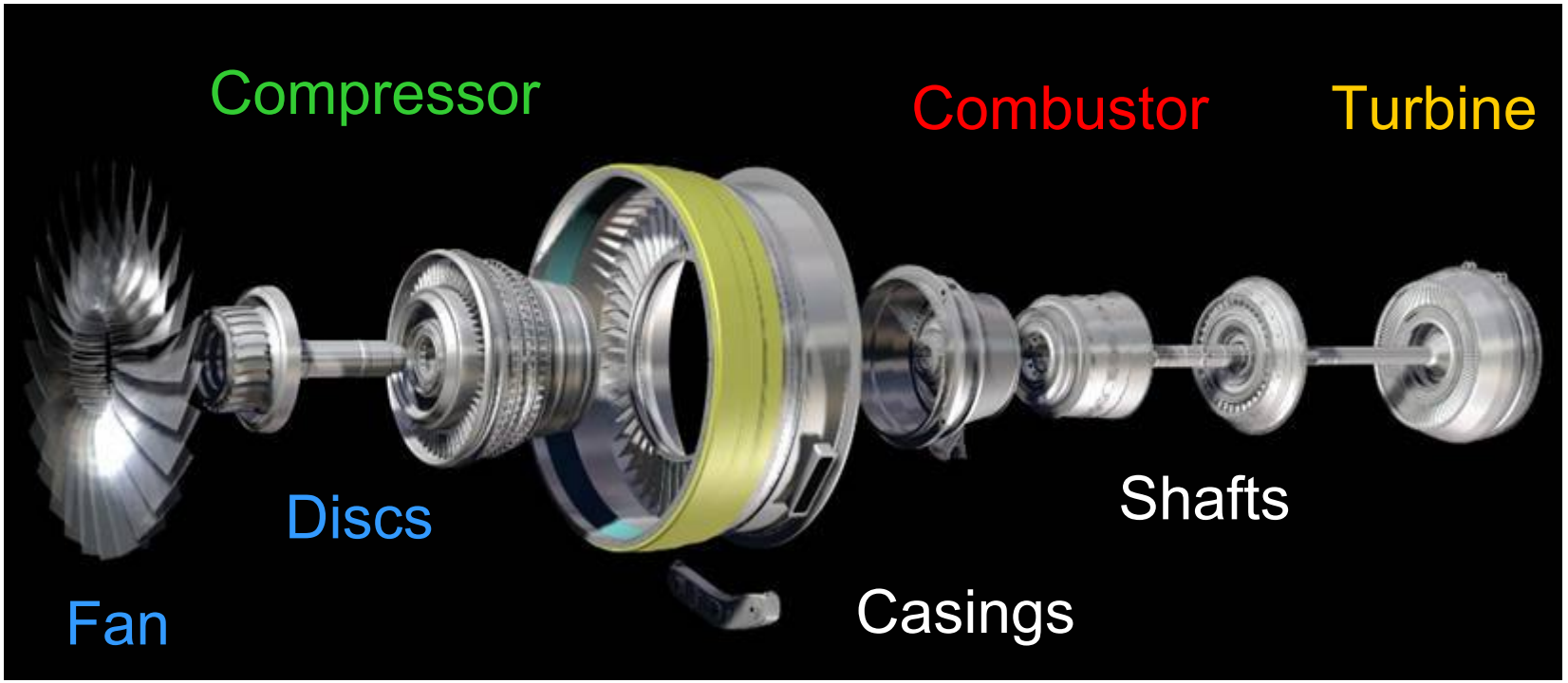
- Is it really a ‘free’ form?
  - We want to know if it conforms to what the designer asked for
  - We want to know what shape it is, but we have no master to compare it with

Why?

- Do we need to know everything about the surface, or can we make some assumptions about it?
- What is the basic function of the surface?
  - Aesthetics
  - Fit
  - Function

Trent 900 – Airbus A380 engine




Compressor
Combustor
Turbine
Discs
Shafts
Fan
Casings

What do we make that needs to be measured?

- **Answer: All of it!**
  - **100 commodity families**
  - **3,000 components (excluding fasteners)**

Fan assembly

Compressor rotor assembly

A variety of blade types

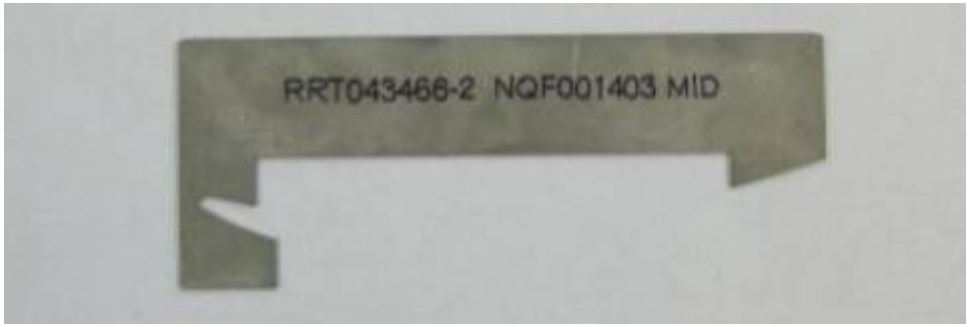
HP compressor blisk

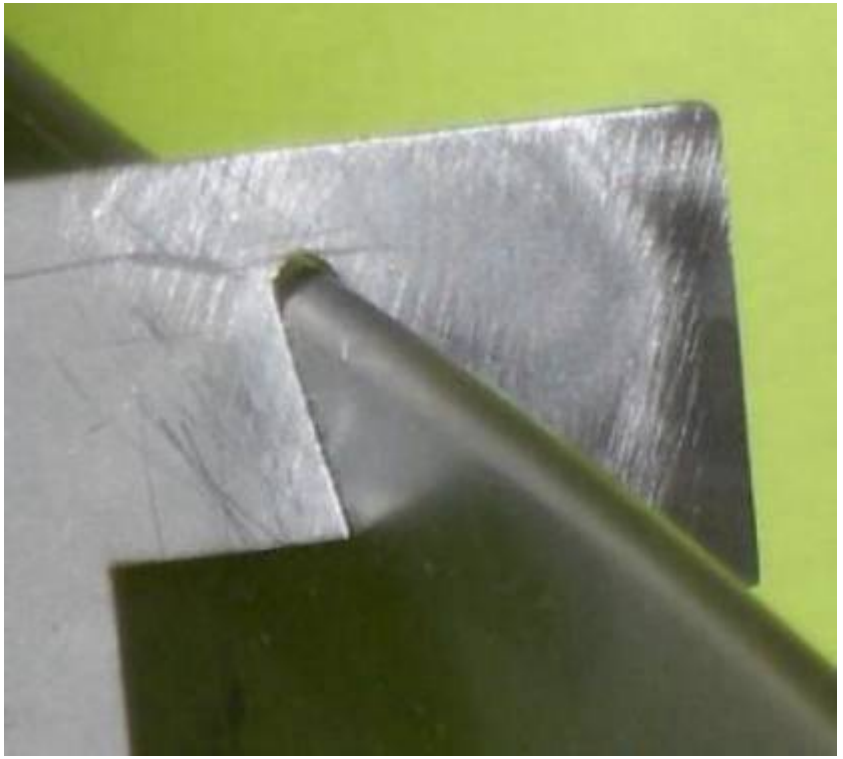
Turbine blade root form

How do we measure them today?

- Mk 1 eyeball
- Profile projector (direct or indirect)
- CMM
- Structured light systems

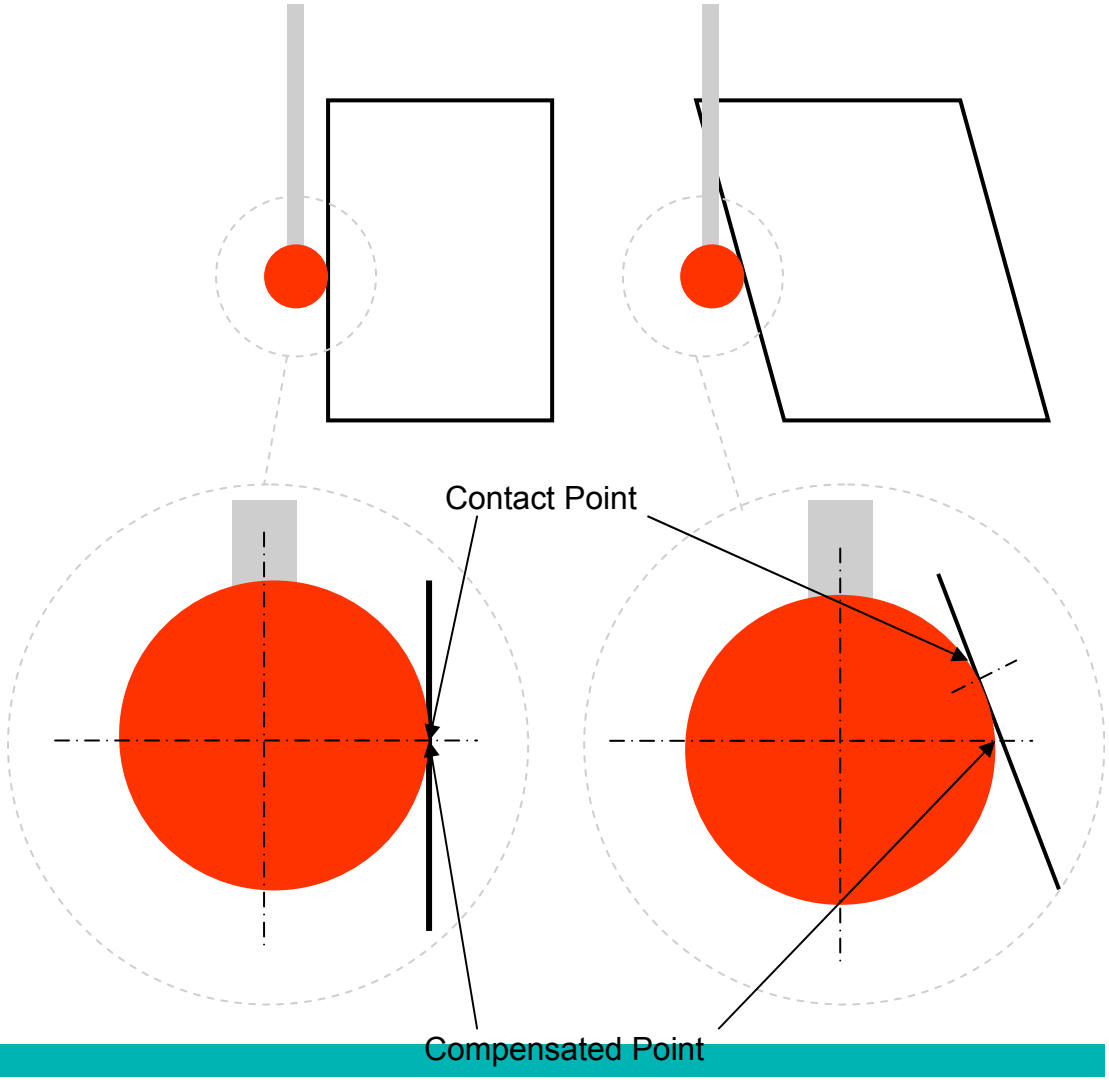
Form template





Projector

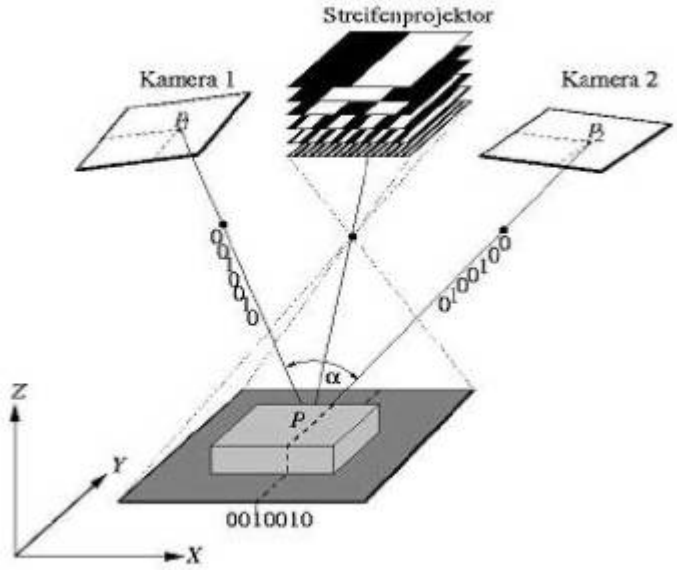
CMM

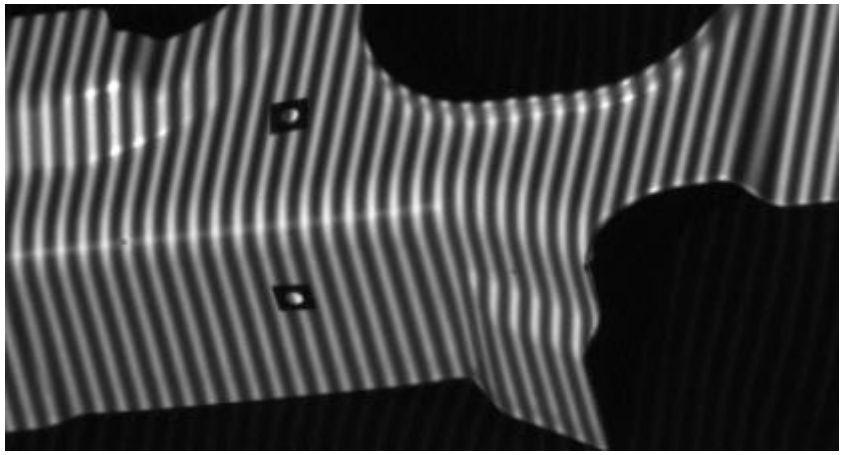


- Relatively sparse points on discrete sections
- Datums can have an effect on measured sections (thickness and edge shape)
- Cosine error – multiple scans to compensate

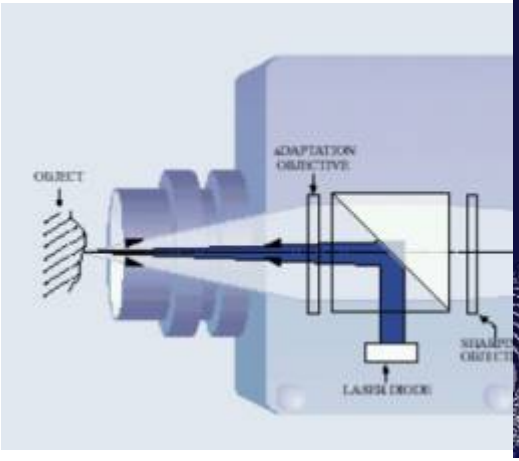
GOM ATOS System

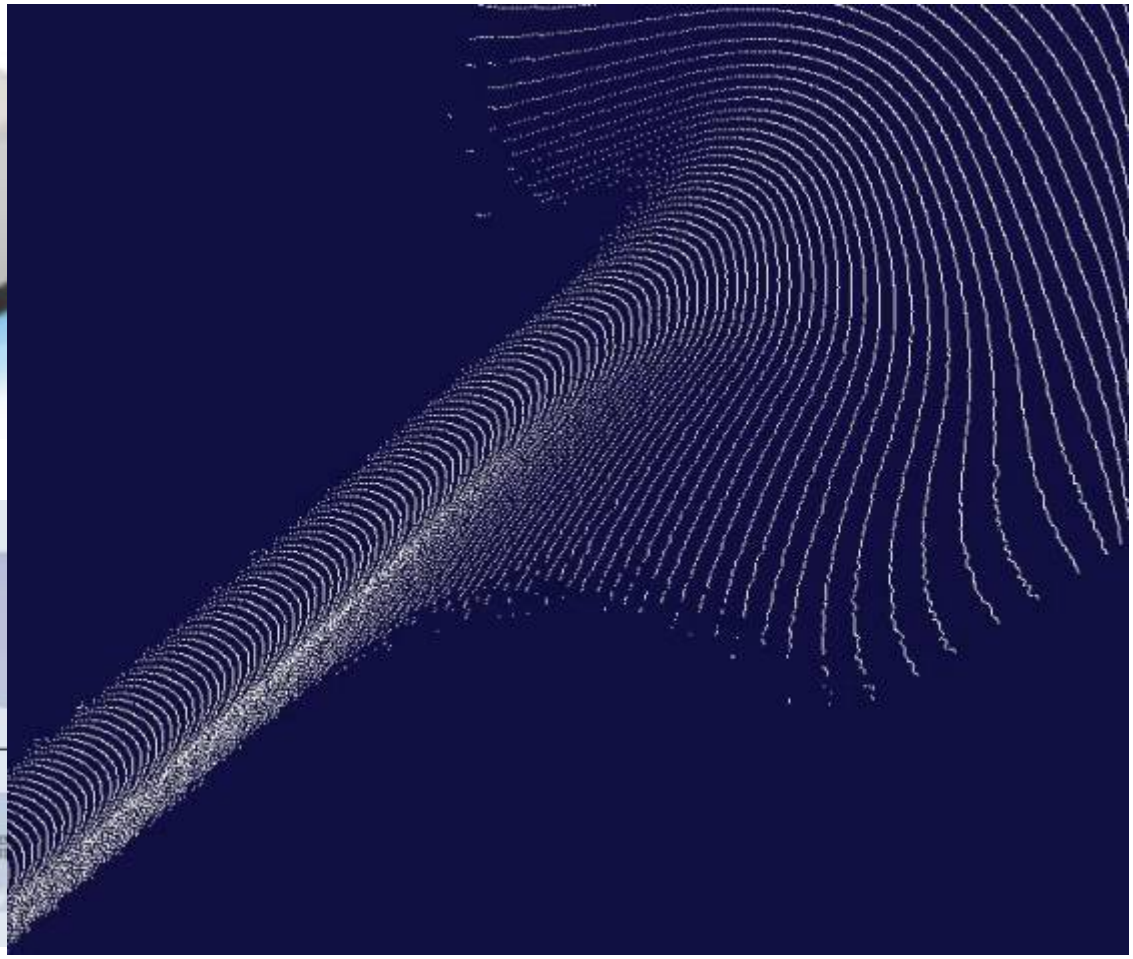
ATOS II system





Conoscopic Holography



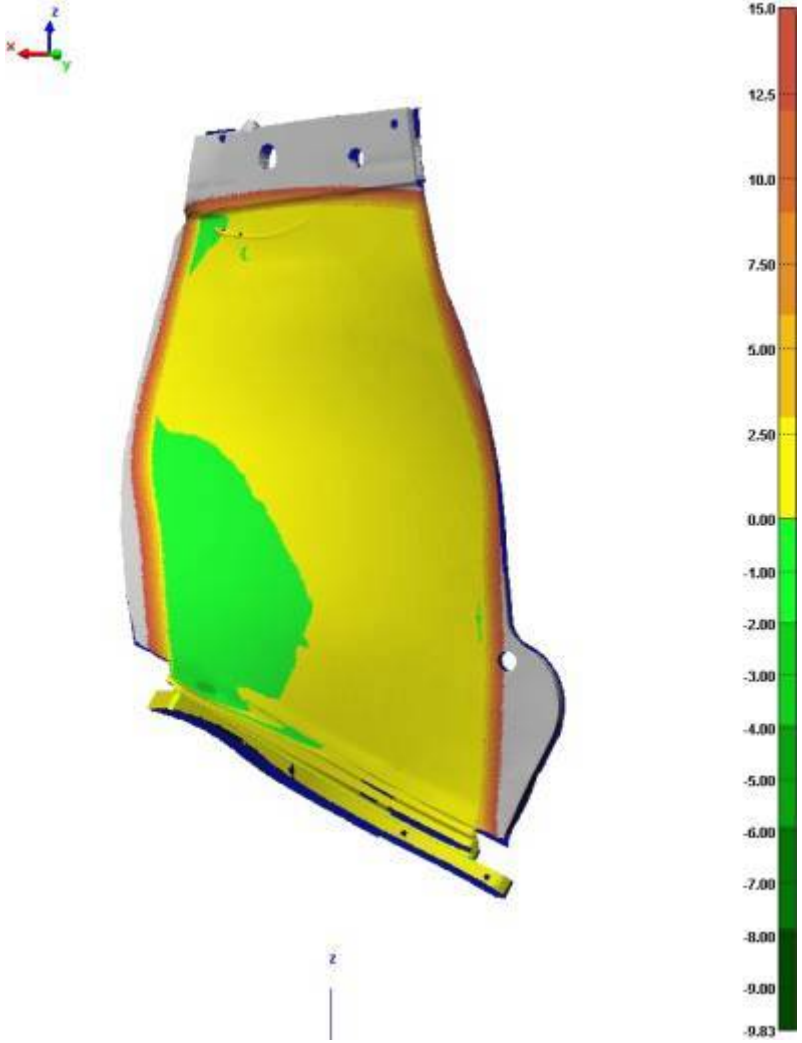


Non-contact inspection

Metris

- PH10 & ACR compatible, using Renishaw Multiwire
- Dimensions - 105 x 60 x 95 mm
- Data capture rate - Approx 19,200 points/sec
- LC50 (DOF), LC100(DOF), LC15(DOF) available soon
- Accuracy +/-29μm at 4sigma on optically good, flat plate

Prediction of Clean-up on Blade



Renishaw Revo Scanning Probe

Revo Scanning modes

Rapid head touches

Circle scans

Helix scan

Sweep scan

Gasket scan

Blade sharp edge sweep scan

Scan on curve

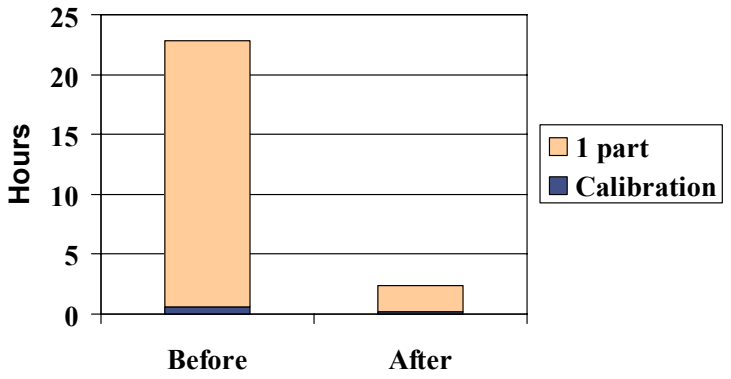
Actual Blisk Measurement Results

- The measurements
  - **9 sectional scans, 8 longitudinal scans, 2 root profile scans, 1 scan of annulus profile**
  - Before
    - **3-axis scanning at 10 mm/sec**
    - **1 blade – 46 min, all 29 blades –** 22 hours 14 min
  - After
    - REVO™ **at 200 mm/sec**
    - **1 blade – 4 min 30 sec, all 29 blades –** 2 hours 11 min

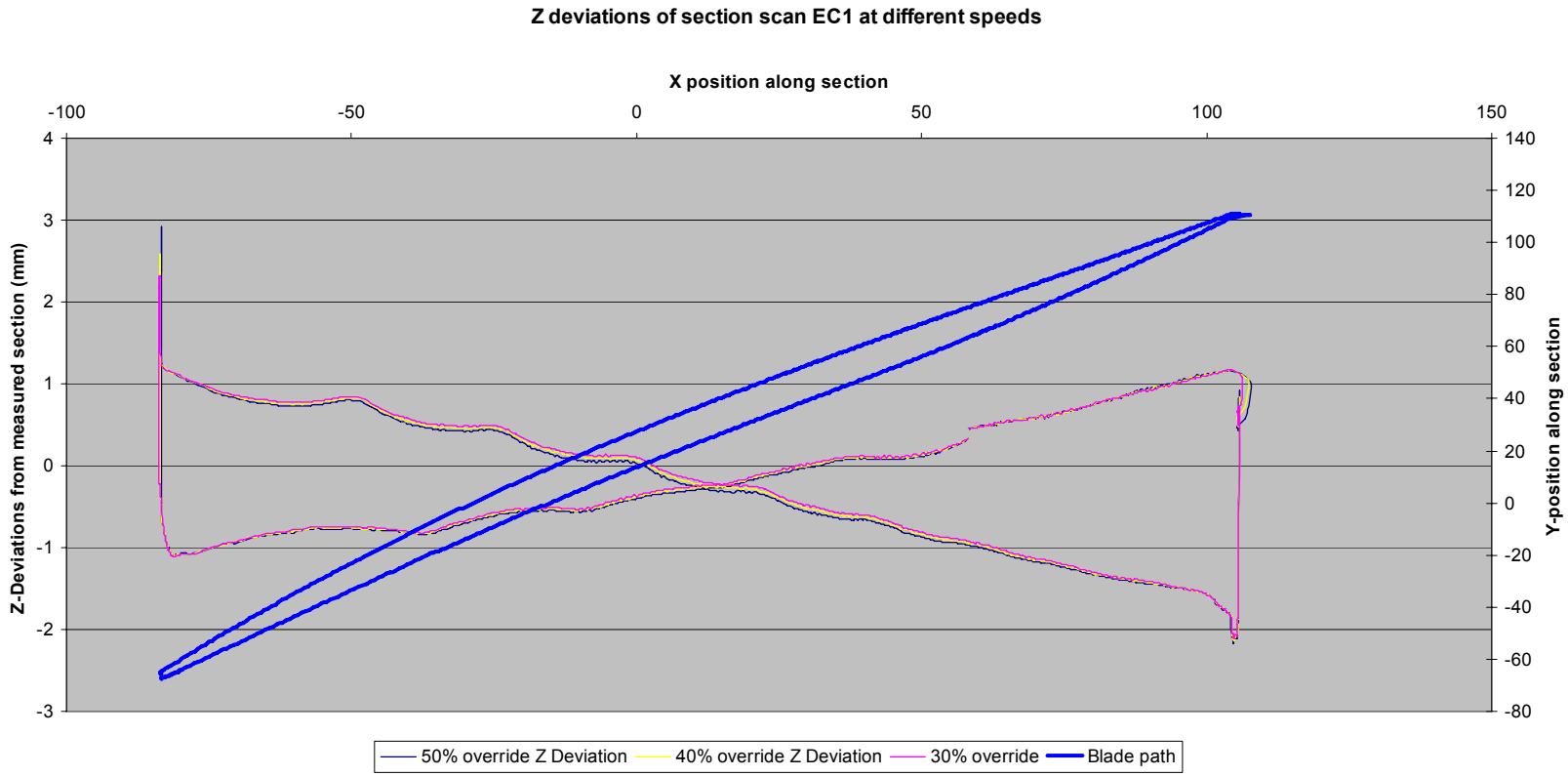
922% throughput increase

- **Calibration**
  - **Before**: 17 index positions, **33 mins**
  - **After**: **10 mins**

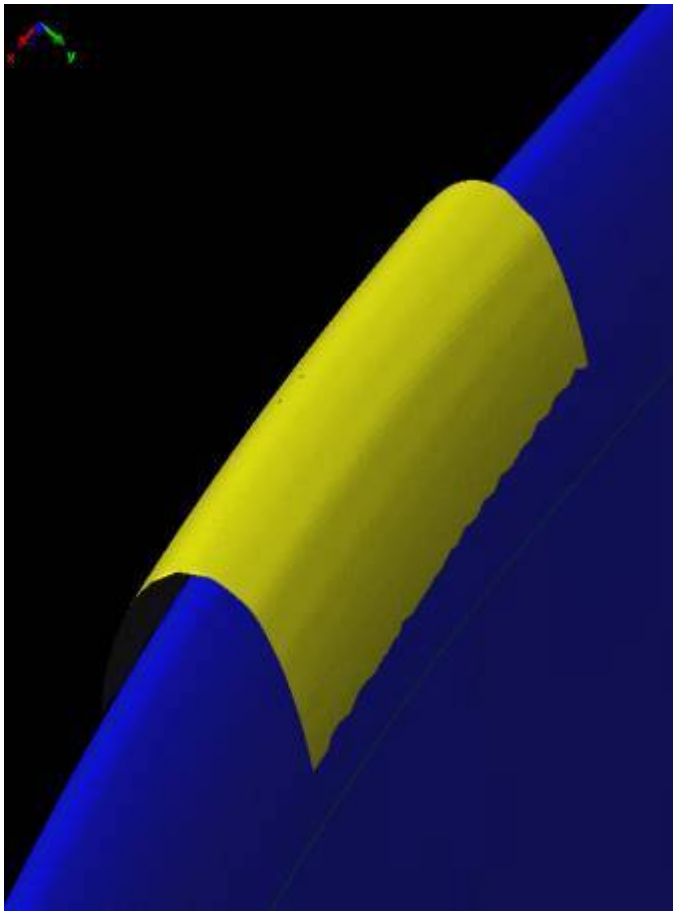
230% throughput increase



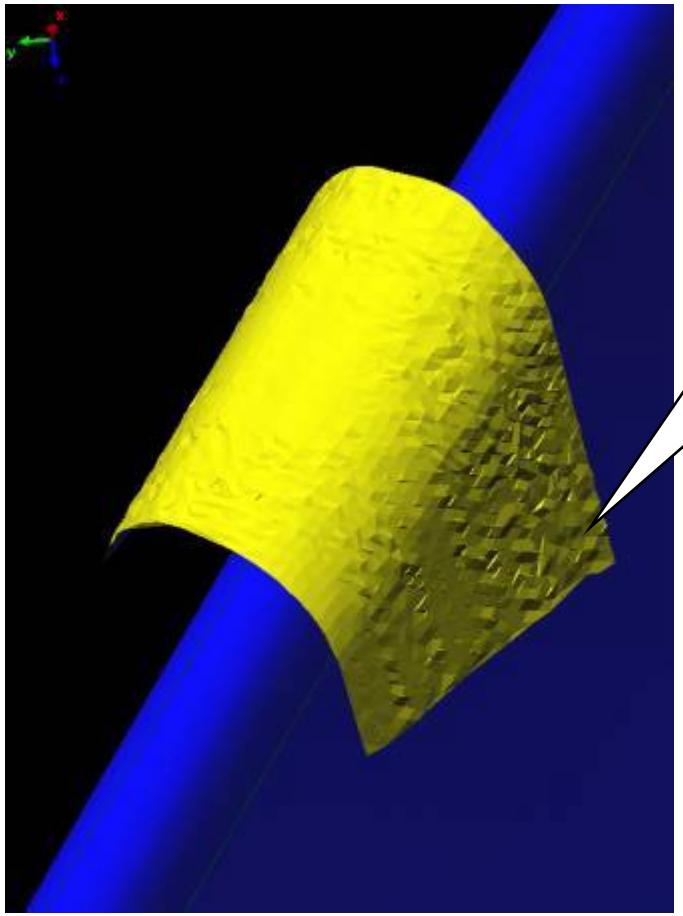
Out-of-plane Z height error



Accuracy Of Sweep Scan - PolyWorks

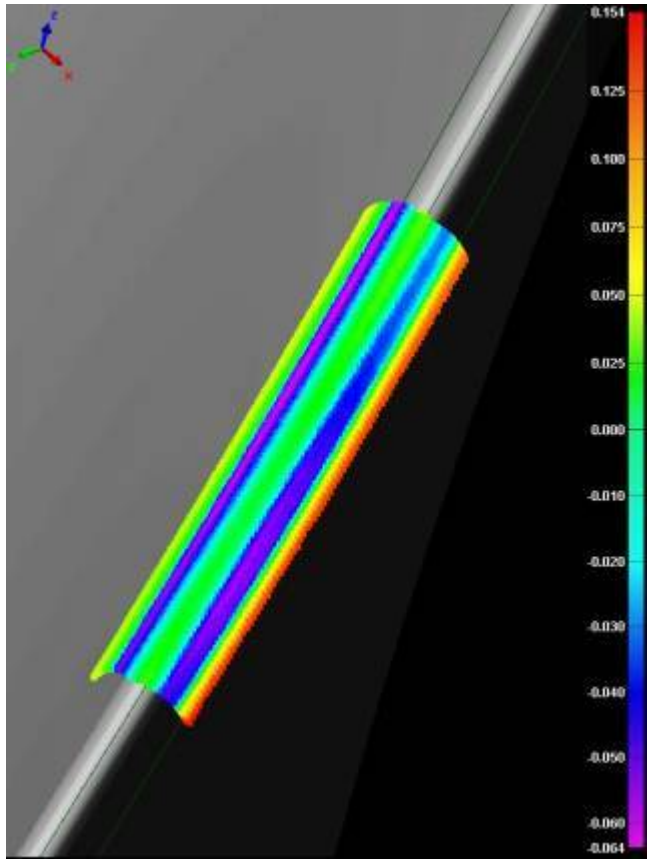


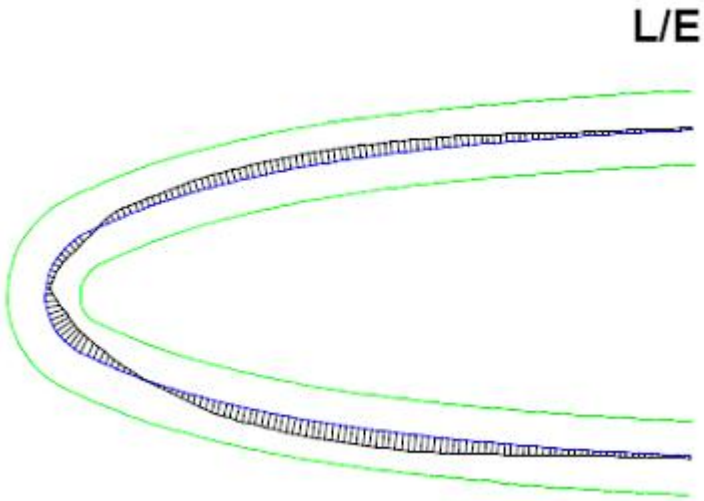
LE – Polygonised data in Polyworks



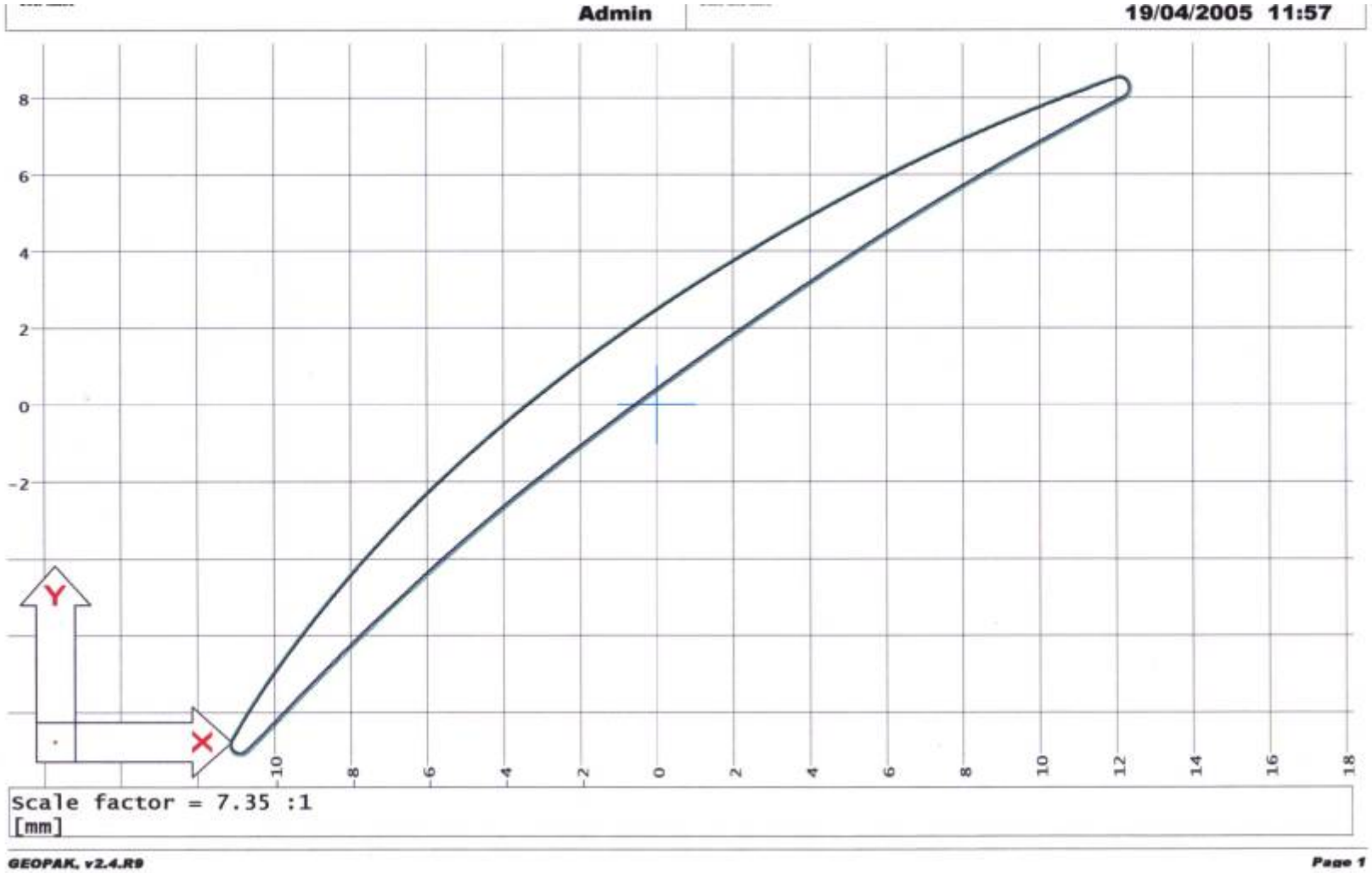
TE – challenging head orientation for sweep scanning produces more noise in data

Comparison of Revo with SP25

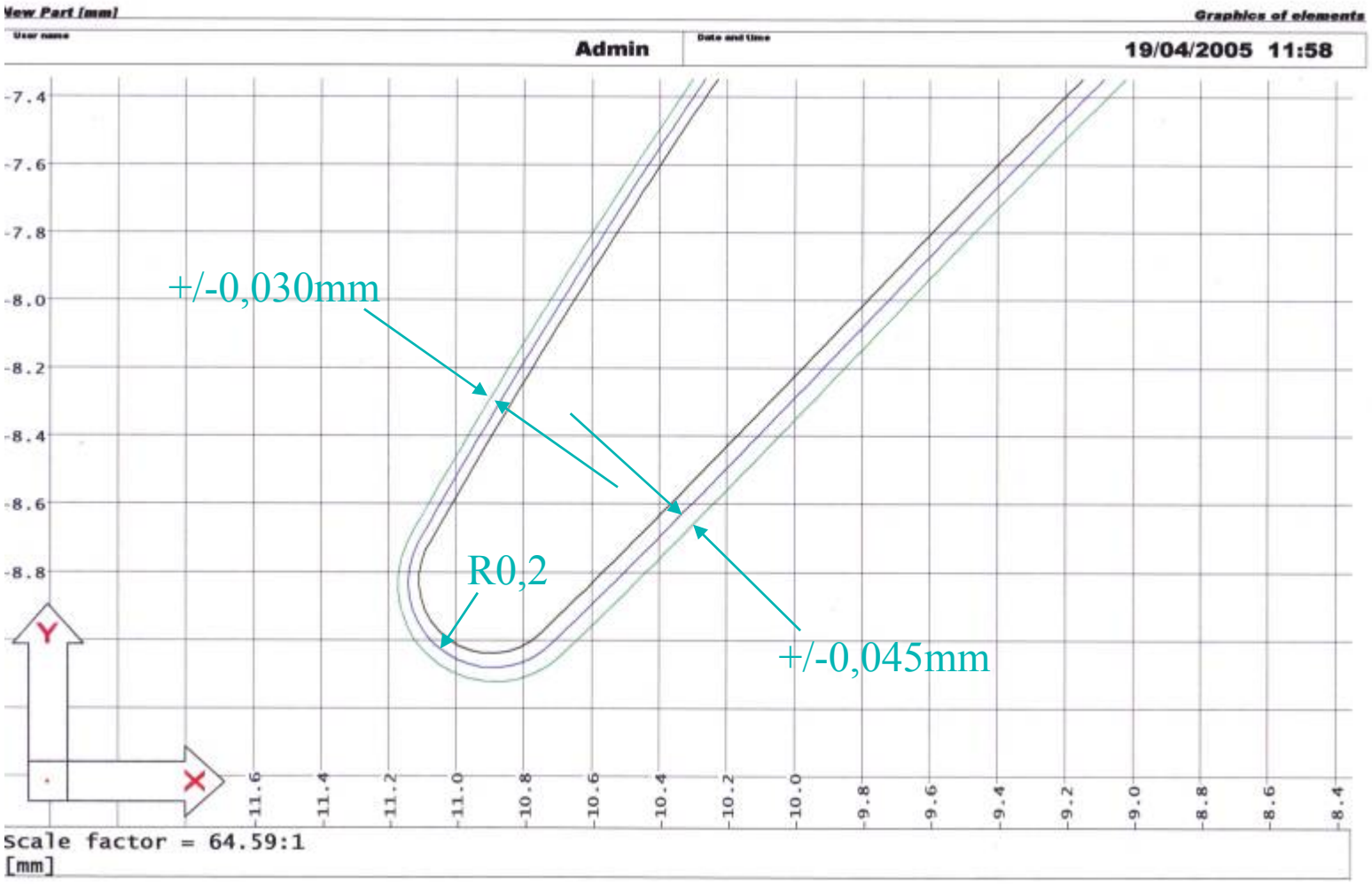




Compressor blade design – in reality



Leading edge shape

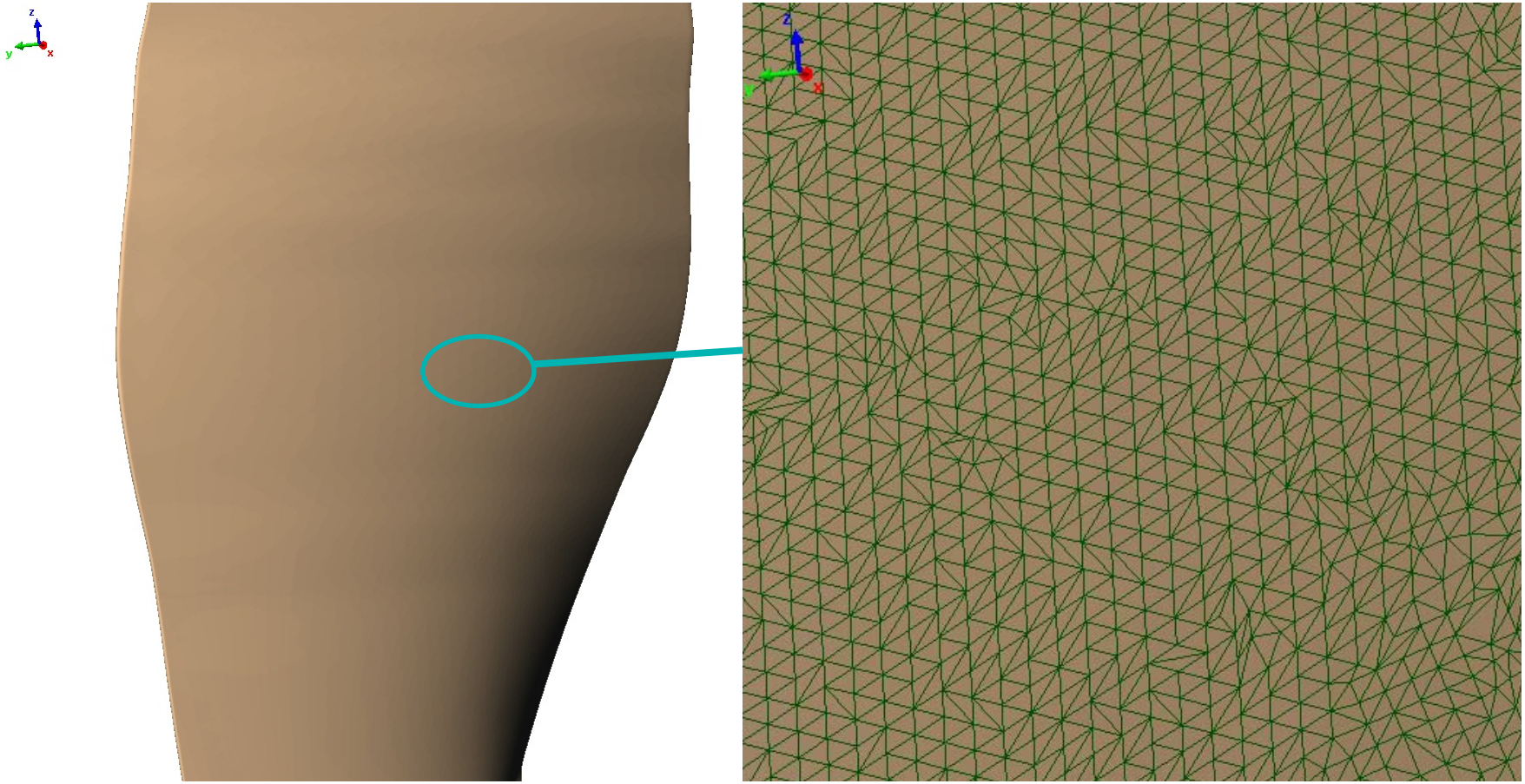


Real edge shapes

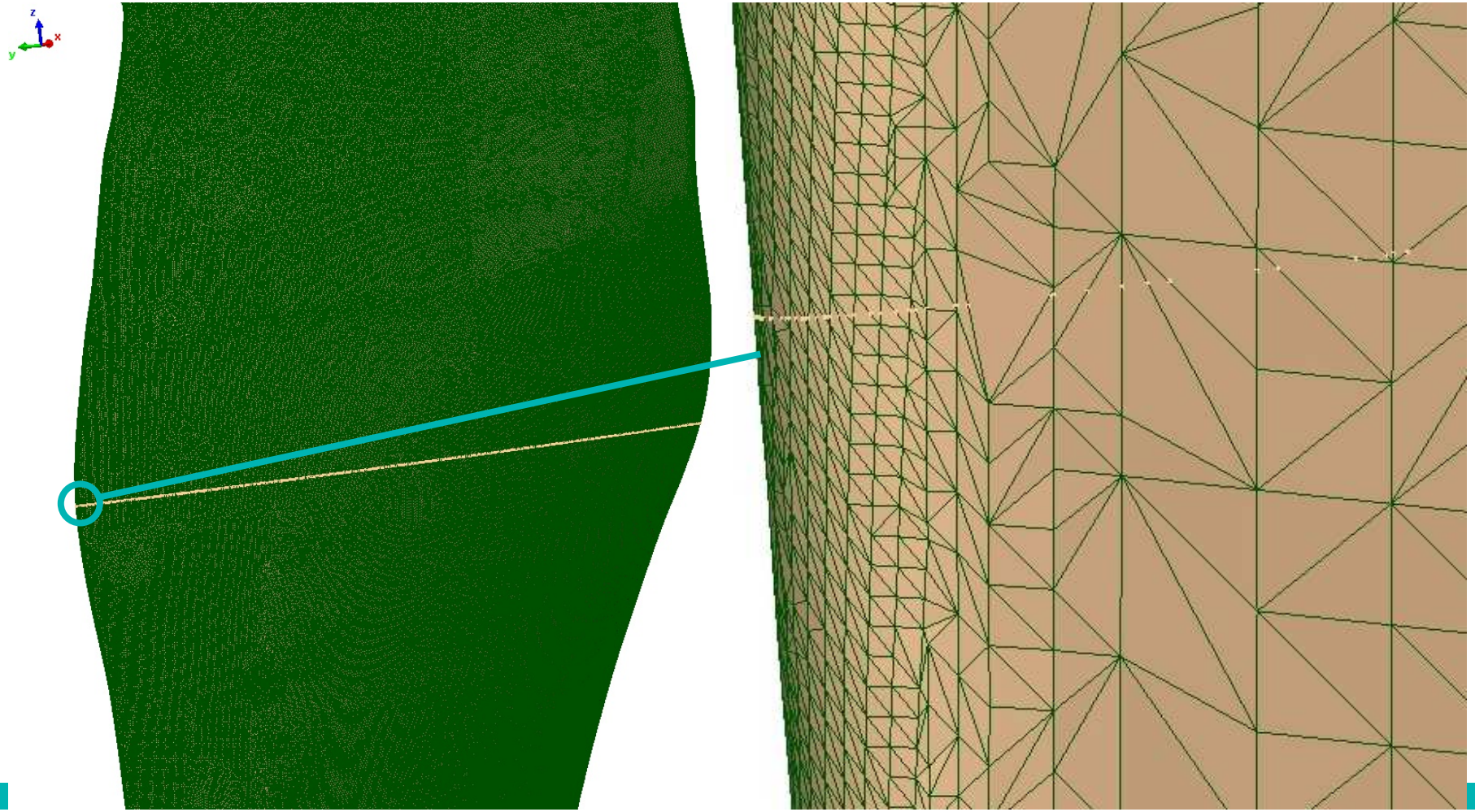
So what's the problem?

- It's very difficult to create a specific le shape – it's currently a product of process + hand dressing
- It's very difficult to measure the edge profile accurately, particularly if it's a blisk
- Even if you can measure it, it's very difficult to assess its conformance

Polygon mesh

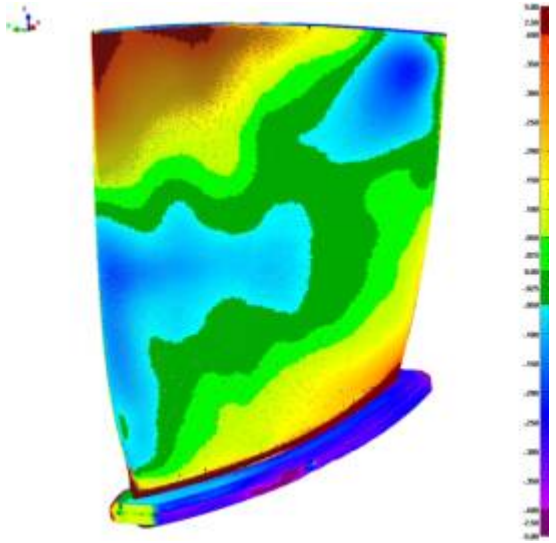


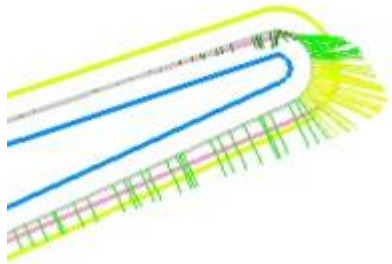
Plane intersection with polygons



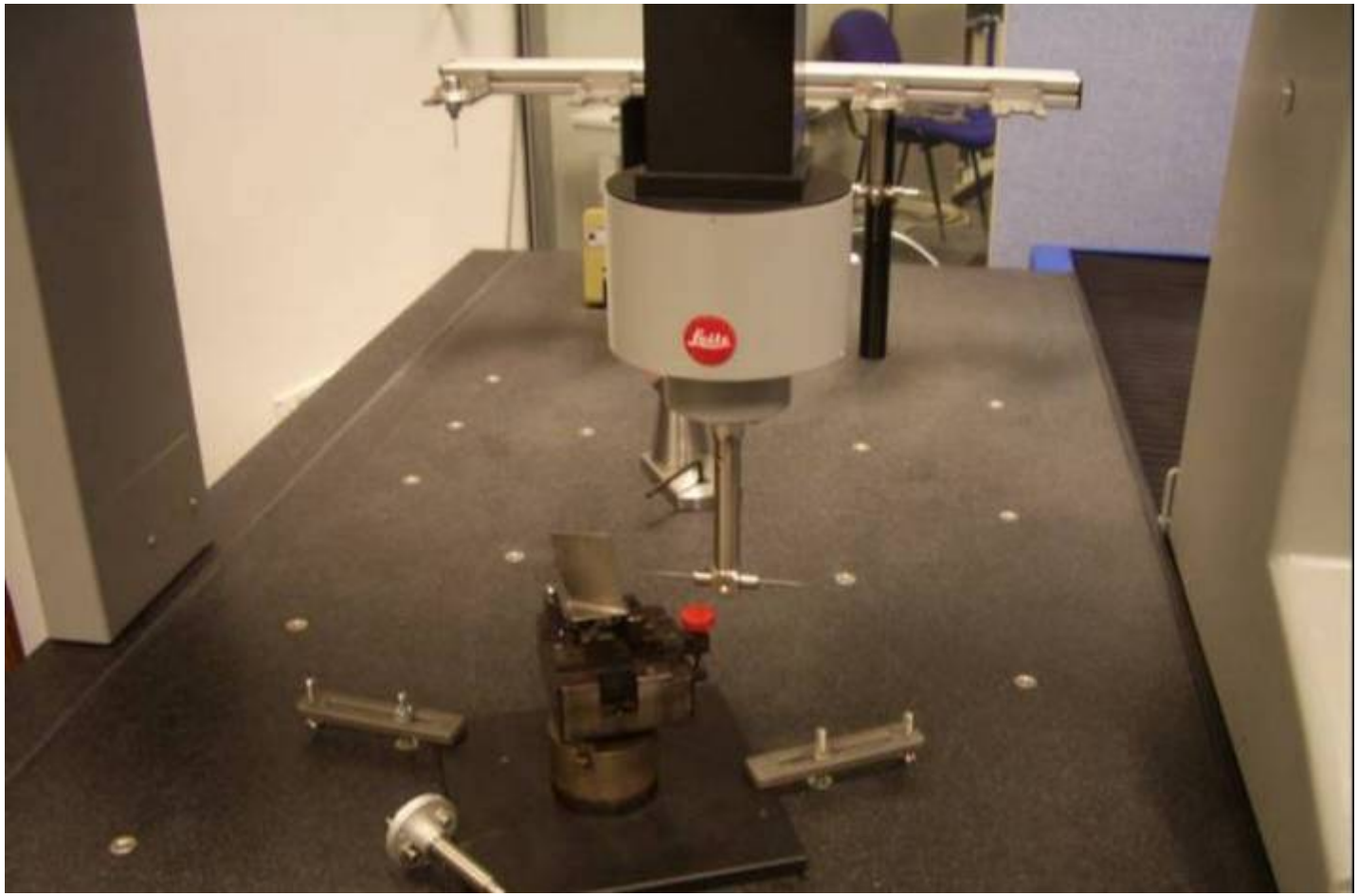
Blade cross-section analysis using Polyworks

- Chord
- Camber
- Stagger
- Displacement
- Thickness
- Gauge Points
- GD&T
- Comparison to 3D CAD definition





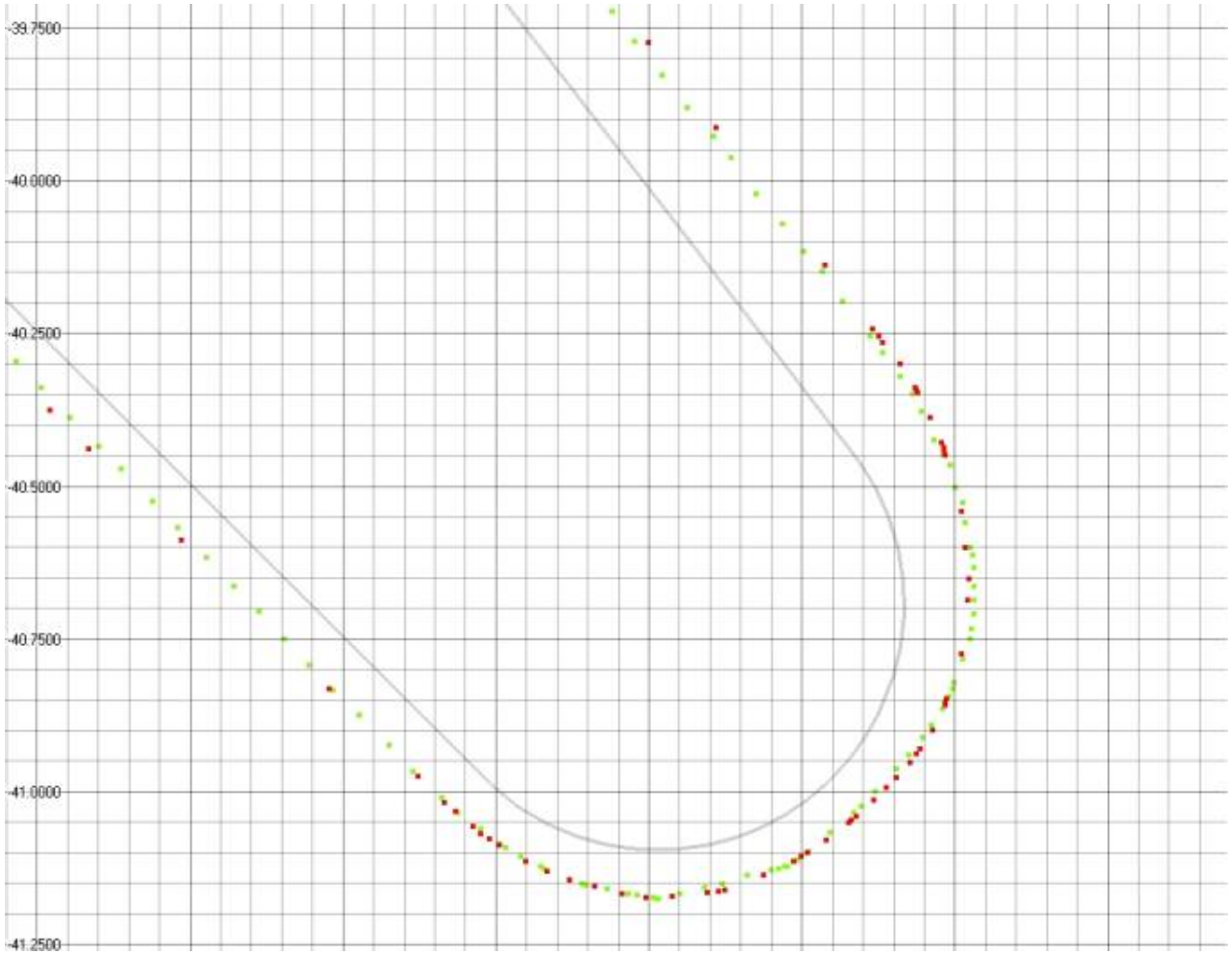
CMM Reference measurement



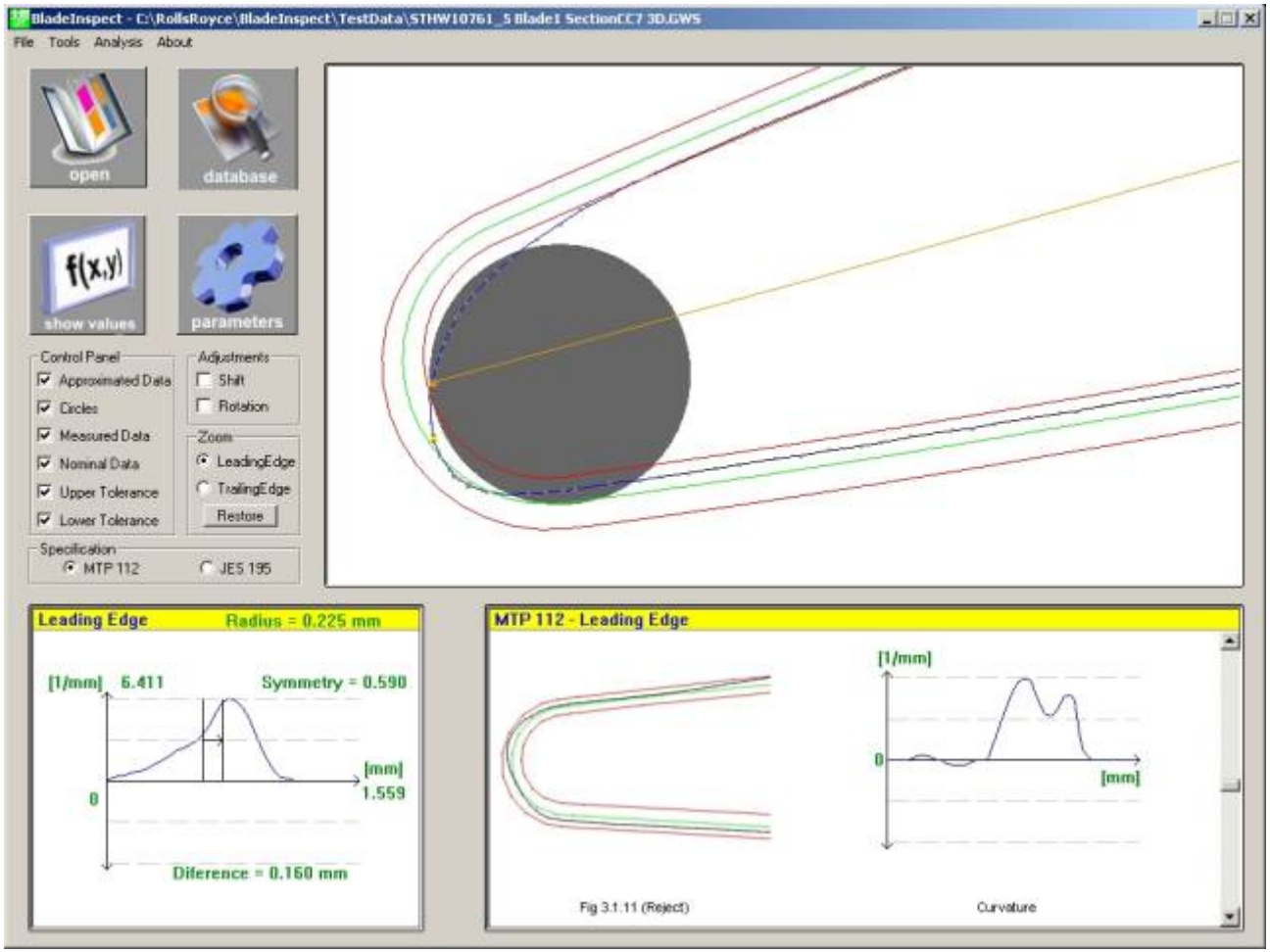
GOM ATOS III – Optical Digitiser

Red = CMM

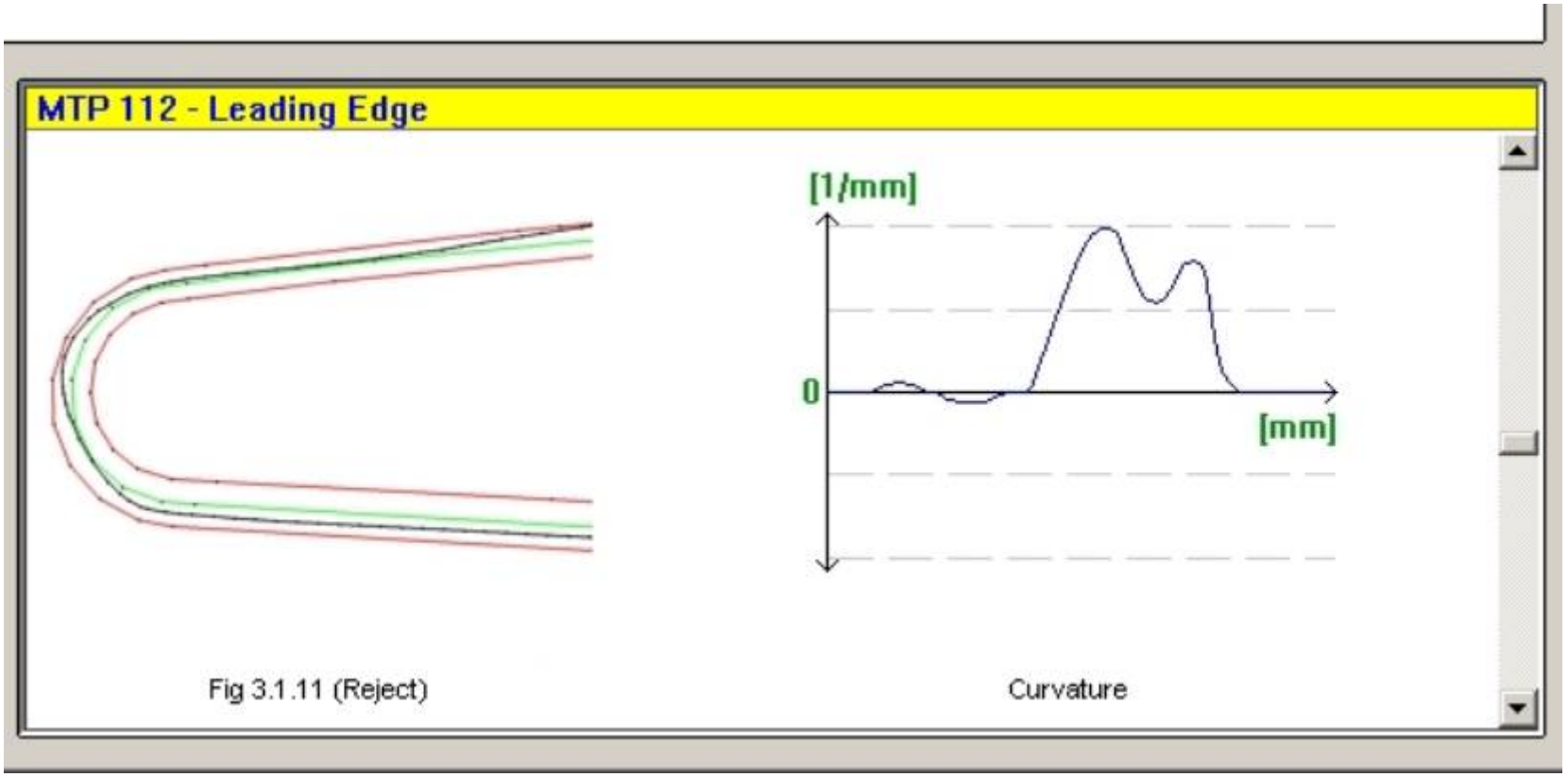
Green = GOM



Automated blade edge assessment

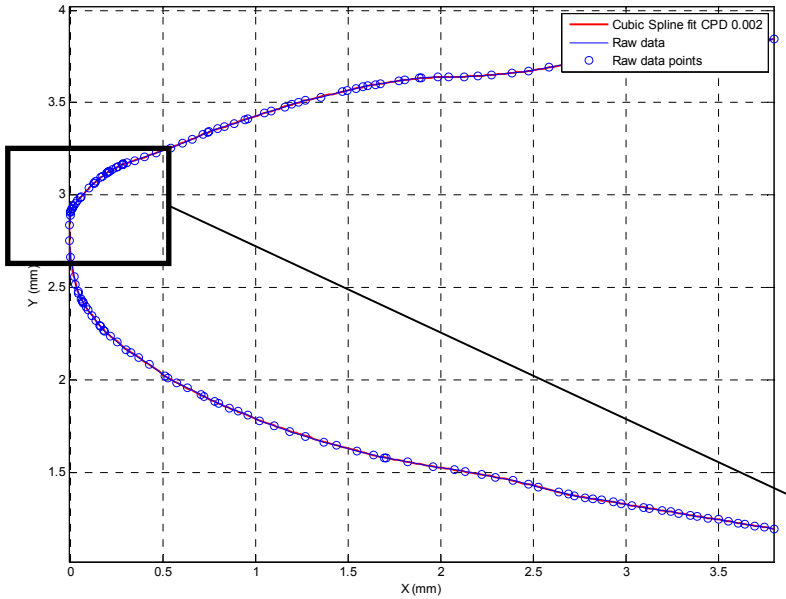


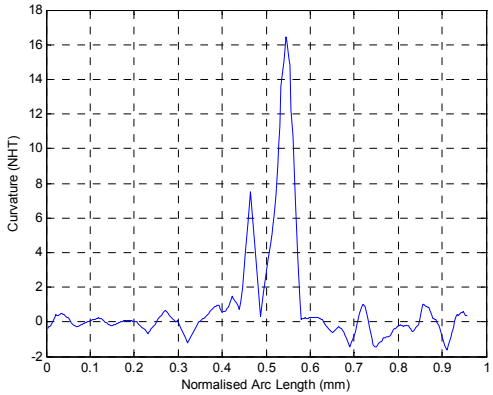
Automated blade edge assessment

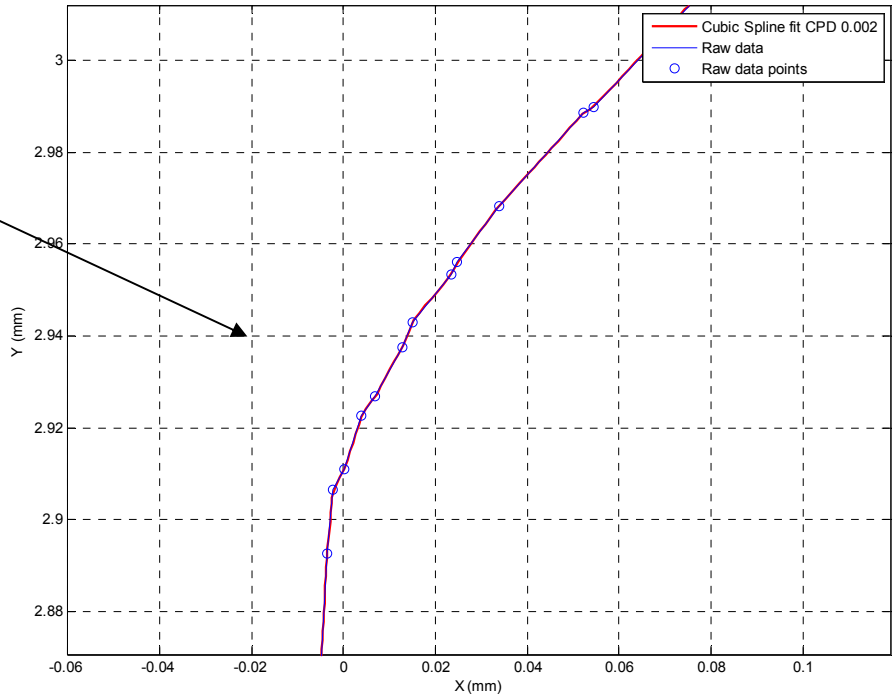


Control Point Distance(CPD) =0.002mm

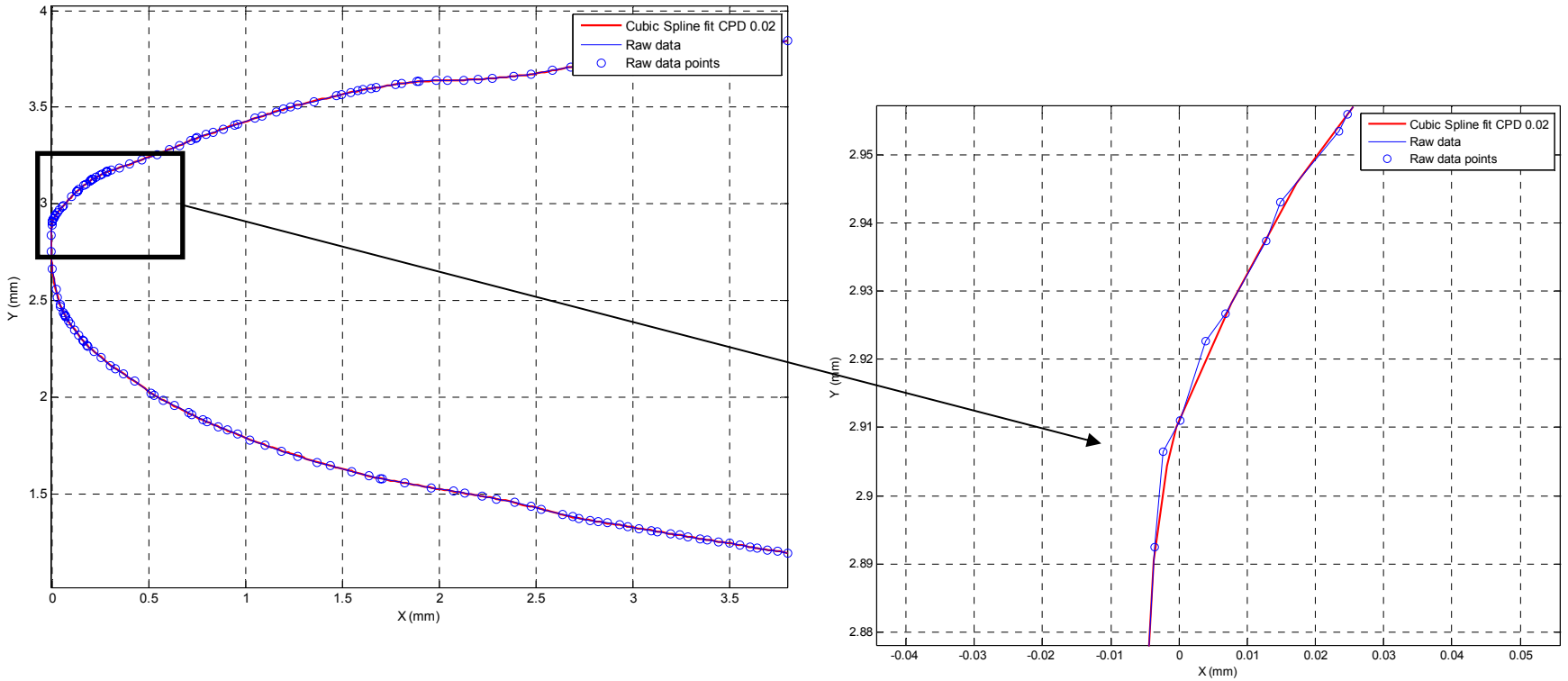
1-Linear interpolation resampling for equidistant point distribution
2-Cubic spline fit as a function of CPD along Arc Lenght

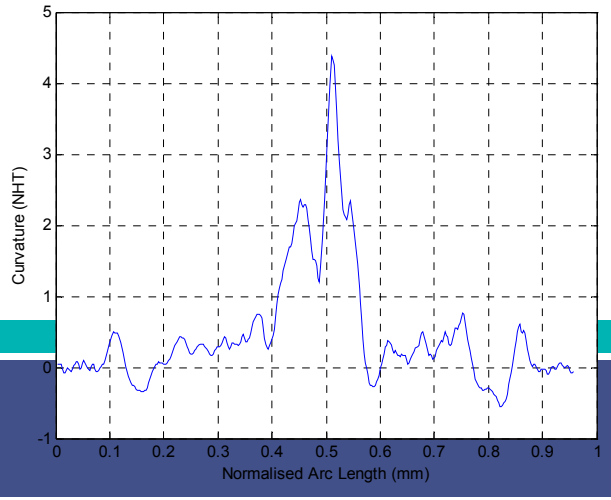






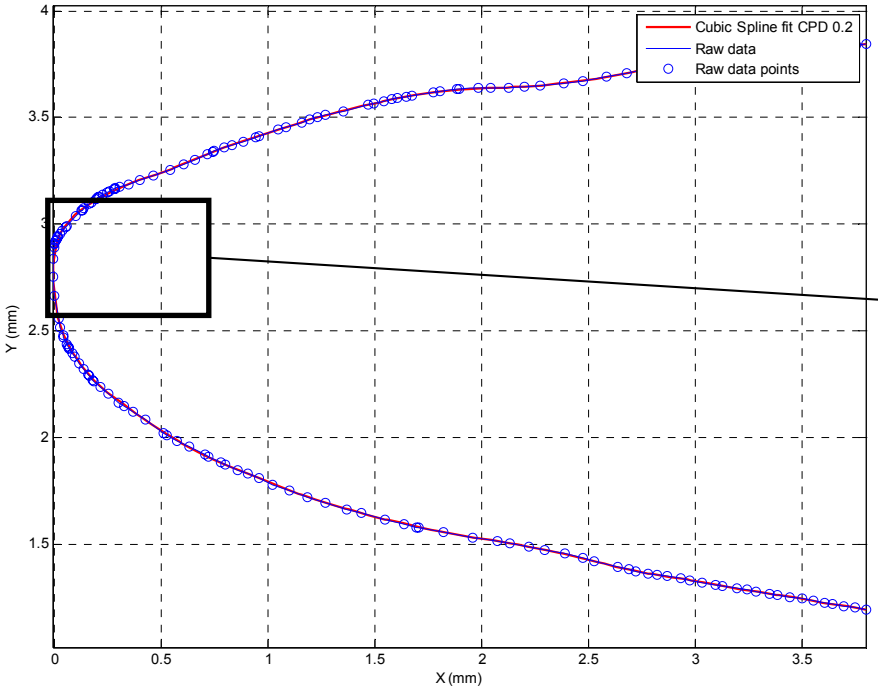
Control Point Distance(CPD) =0.02mm

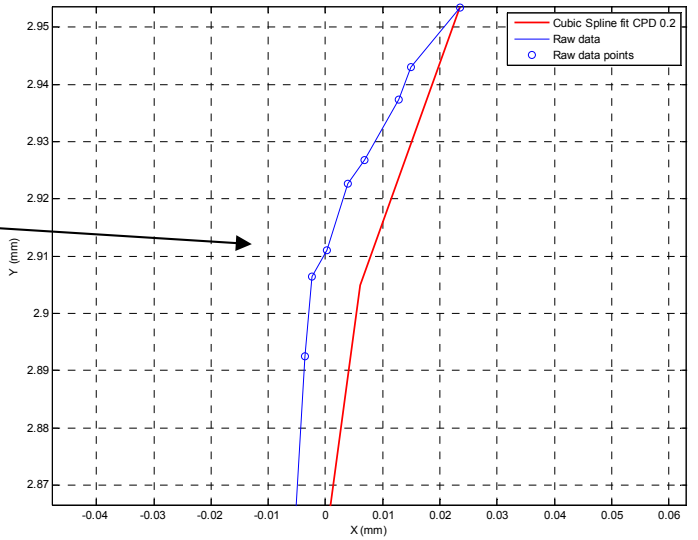


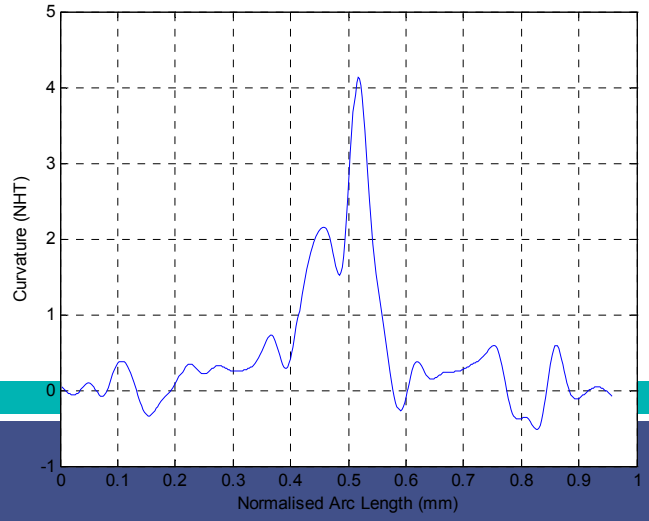


Rolls-Royce

Control Point Distance(CPD) =0.2mm







Contact v non-contact

- Non-contact – the good:
  - Very high data density
  - No ball radius compensation issues
  - Easy to set up and program
  - Take the measurement system to the job
- The bad:
  - Accuracy limited – measurement uncertainty?
  - May need to coat the object
  - Ambient light variation can be a problem

Contact v non-contact

- Contact – the good:
  - Very high resolution and accuracy
  - Demonstrable measurement uncertainty
- The bad:
  - Limited date quantity
  - Ball radius compensation can be a problem
  - Programming can be complex

Thank you for your attention.

Any questions?