Mechanical & Materials Engineering
for Particle Accelerators and Detectors

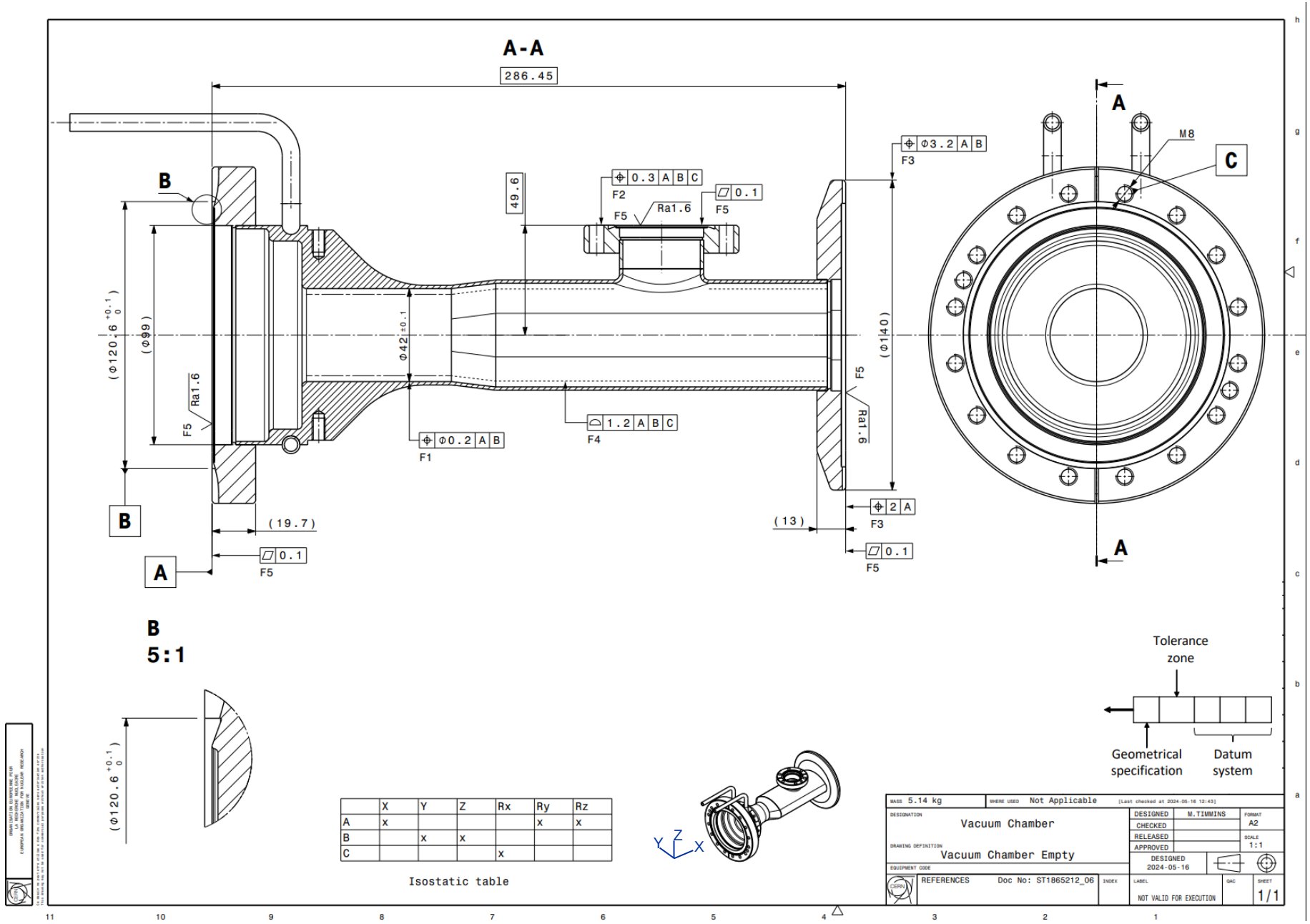
PRACTICAL SESSION

Metrology - Hands-on session

3D scanning

Prepared by: Maciej Burkowski, Ahmed Cherif & Olivier Langlois

Engineering drawing



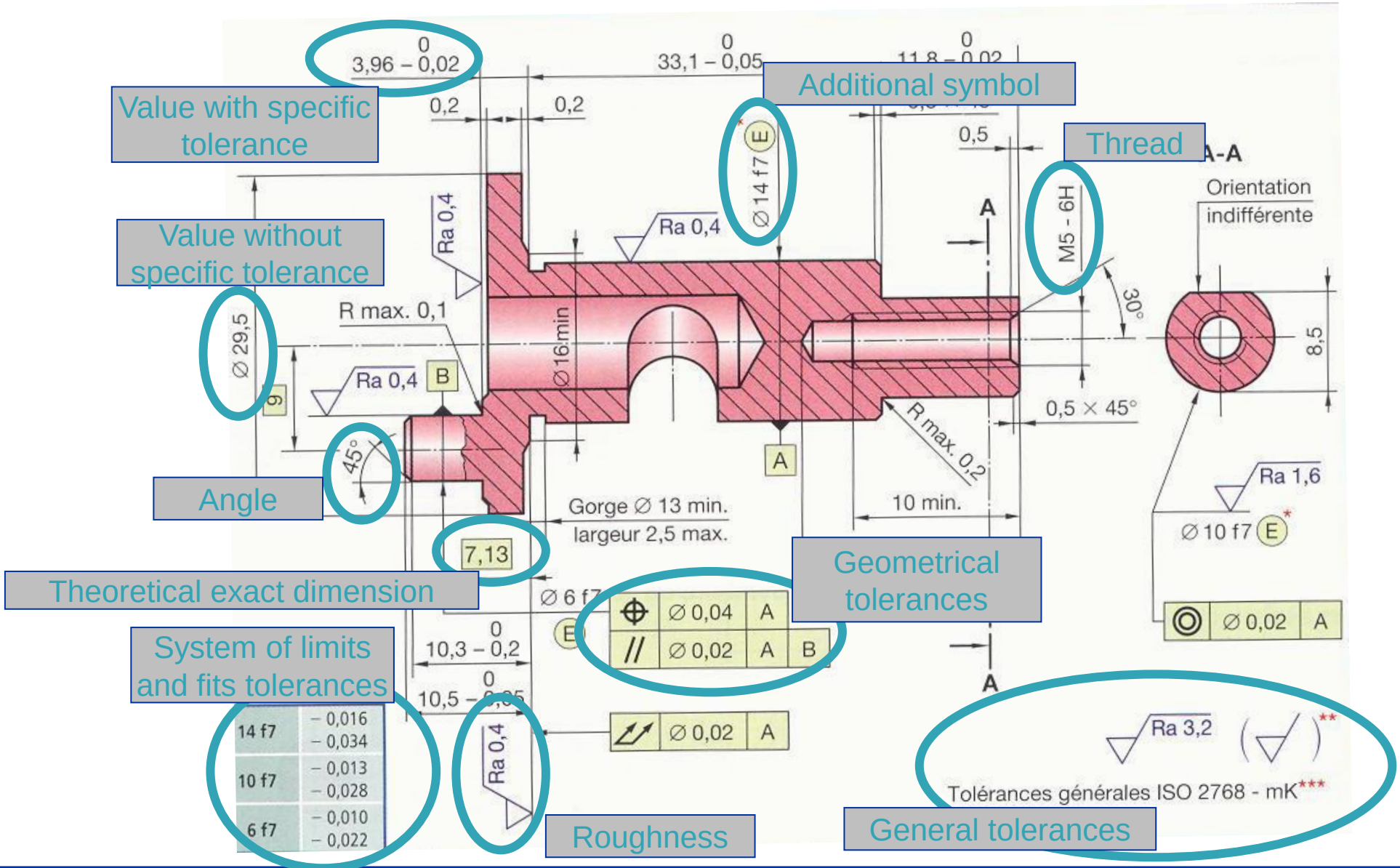
	X	Y	Z	Rx	Ry	Rz
A	x				x	x
B		x	x			
C				x		

Agenda

1. GD&T reminder
2. Part description – discussion about the reference datums and requirements
3. Measurement devices
4. Practical session part 1 – part measurement
5. Practical session part 2 – part evaluation
6. Discussion - questions

GD&T reminder

Technical drawings



GD&T reminder

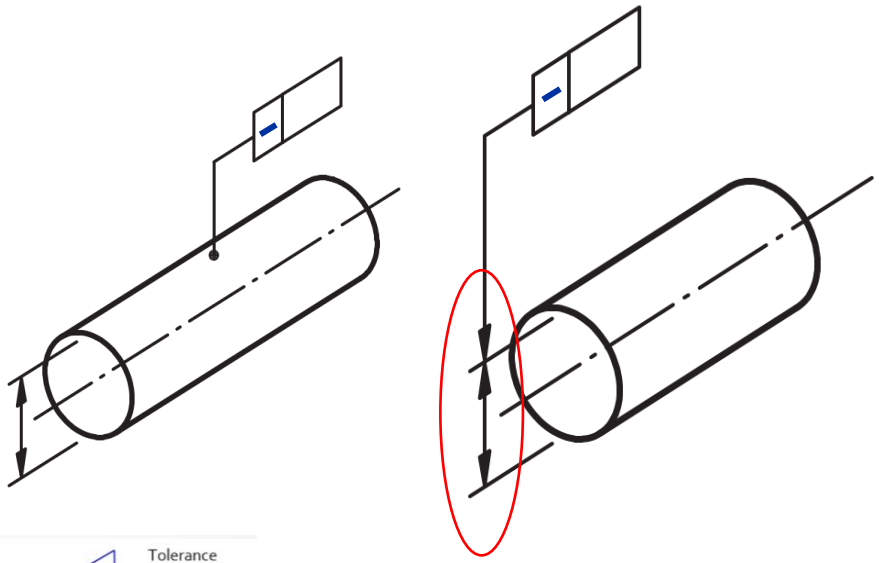
ISO 1101 - (GPS) Geometrical Product Specifications

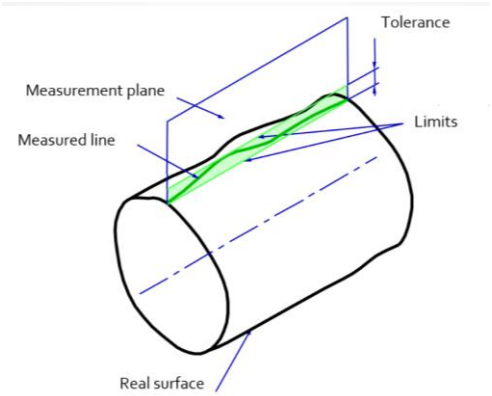
Form

Orientation

Location

Run-out





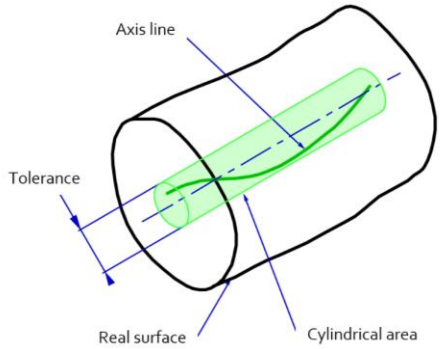


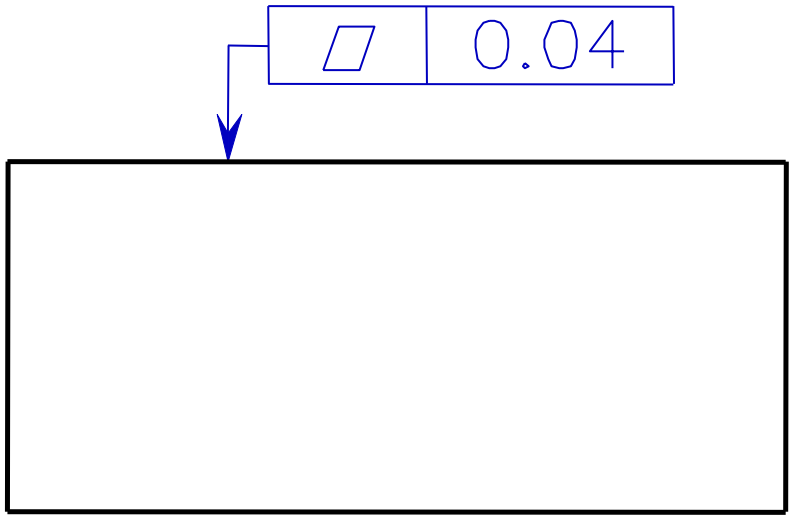
Table 1 — Symbols for geometrical characteristics

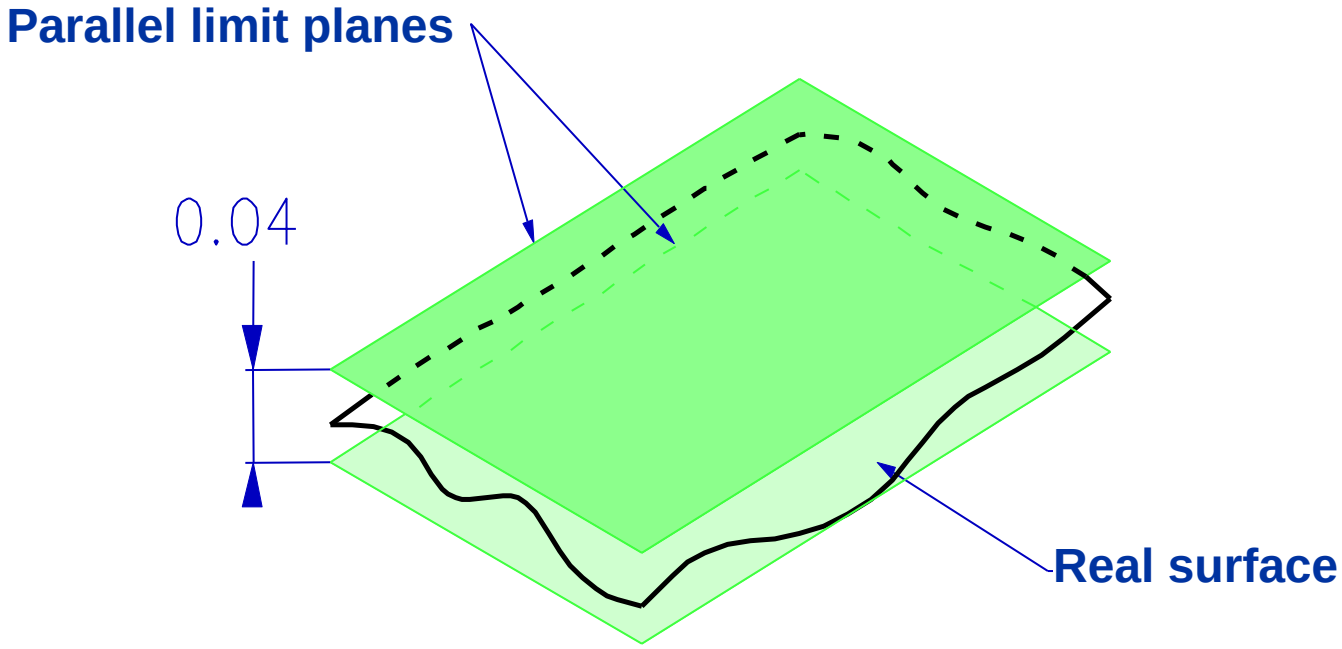
Tolerances	Characteristics	Symbol	Datum needed	Subclause
Form	Straightness	—	no	18.1
	Flatness	▱	no	18.2
	Roundness	○	no	18.3
	Cylindricity	⌭	no	18.4
	Profile any line	⌒	no	18.5
	Profile any surface	⌓	no	18.7
Orientation	Parallelism	//	yes	18.9
	Perpendicularity	⊥	yes	18.10
	Angularity	∠	yes	18.11
	Profile any line	⌒	yes	18.6
	Profile any surface	⌓	yes	18.8
Location	Position	⌖	yes or no	18.12
	Concentricity (for centre points)	◎	yes	18.13
	Coaxiality (for axes)	◎	yes	18.13
	Symmetry	⌯	yes	18.14
	Profile any line	⌒	yes	18.6
	Profile any surface	⌓	yes	18.8
Run-out	Circular run-out	↗	yes	18.15
	Total run-out	⌰	yes	18.16

GD&T reminder

Geometrical tolerance

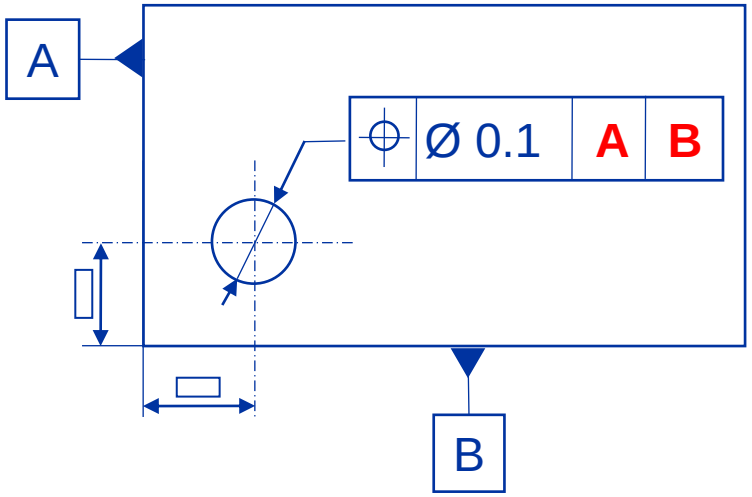
Form: **Flatness**

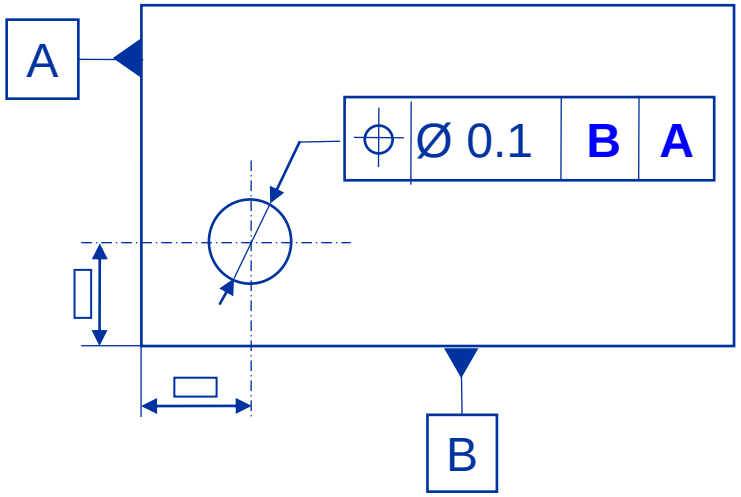


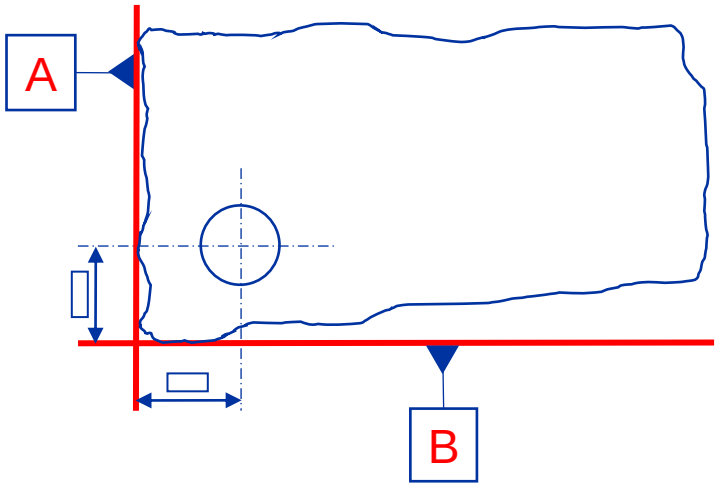


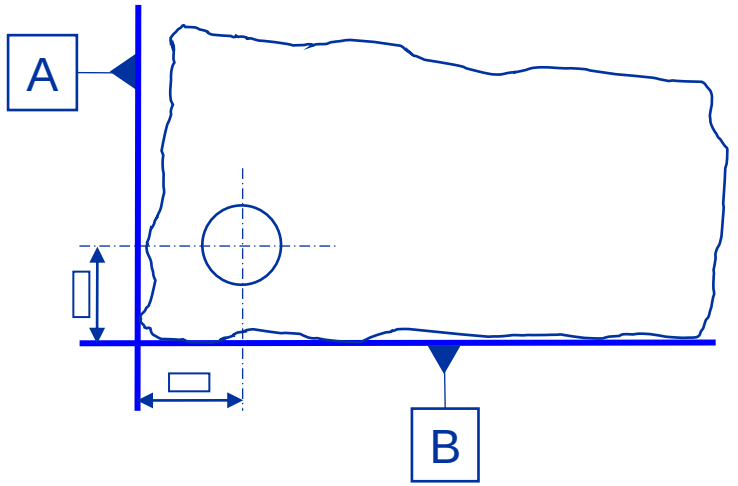
GD&T reminder

Datums order



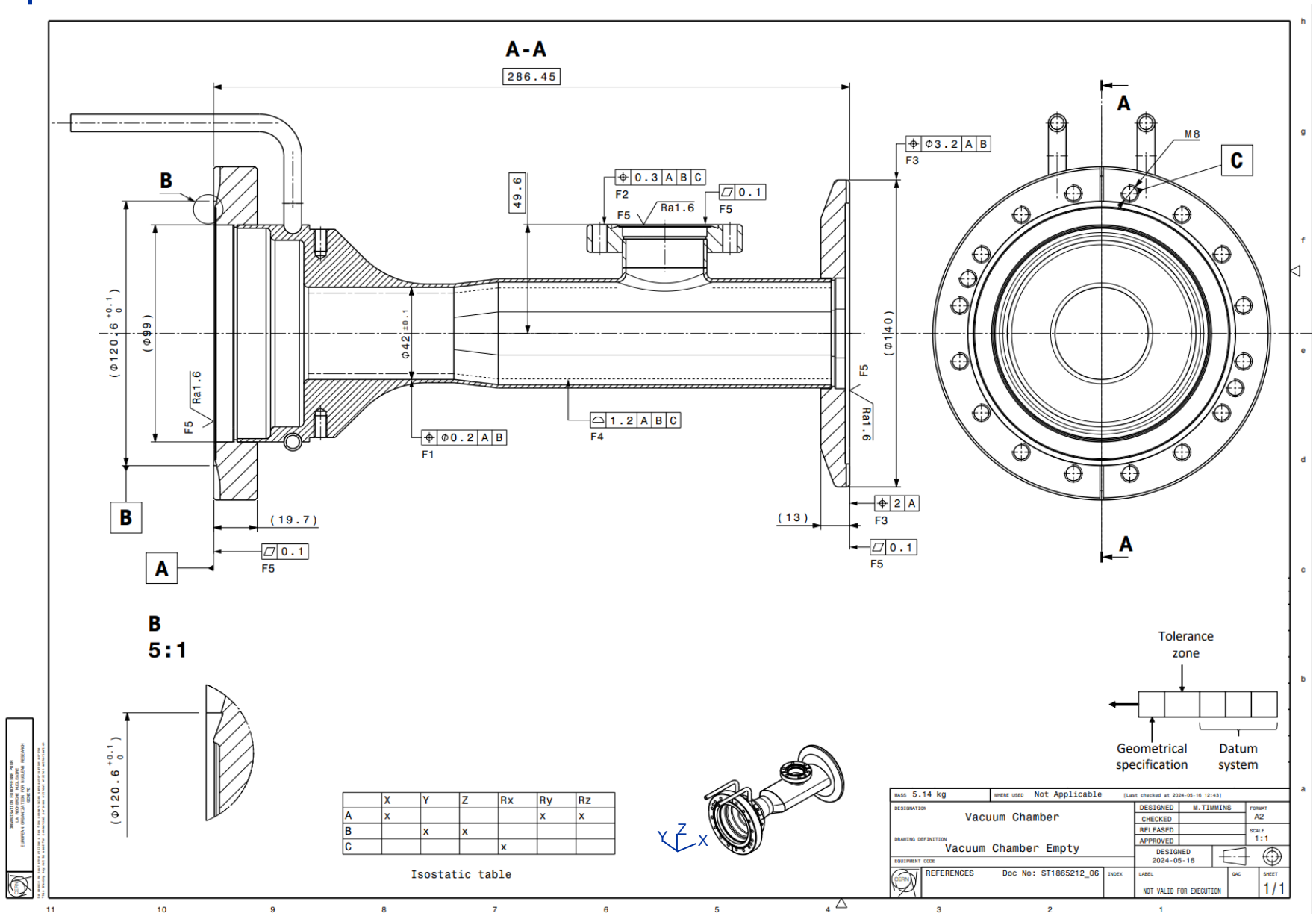






Part description

Engineering drawing



	X	Y	Z	Rx	Ry	Rz
A	x				x	x
B		x	x			
C				x		

CERN METROLOGY LABORATORY EQUIPMENT

EN

Coordinate Measuring Machines (CMM)

O-INSPECT 863 MULTISENSOR CMM
Measuring Range:
800 x 600 x 300 mm3
MPE_{E0} (3D) = 2.2 + L/150 µm

OLIVETTI
Measuring Range:
1600 x 900 x 700 mm3
Rotary table 900 mm
Max Load: 1500 kg

PRISMO Ultra 12.24.10 & 12.18.10
Measuring Range:
1200 x 2400/1800 x 1000 mm3
MPE_{E0} = 1.2 + L/500 µm
Rotary table 630 mm
Max Load: 2000 kg

Linear Height Gage

MAHR and TRIMOS Linear height gages
Measuring range: 600 mm and 1000 mm

Profiles Projector

BATY Profiles projector
Measuring Range:
400 x 300 mm2
X5, x10, x20, x50 and x100 magnification
Screen diameter 800 mm

Micro Tomography

METROTOM
Measuring Range:
Min. Focal Spot Size : 7 µm
Max. spatial resolution: 4 µm
image processing: 16-bit
max. tube voltage = 225 kV,
max. tube current = 3000 µA

ROMER Arm

ROMER Arm
Measuring range: 3,6 m

LHC QRL

AUCE Detector

Manual Devices

Different kind of instruments:

Measuring range : From 0 to few meters

- Caliper
- Micrometer
- Comparator
- Gages
- Etc.

Optical Profiling and Roughness Machine

Roughness measurement

VEECO NT 3300 3D Optical profiling and roughness system
Measuring Range:
Table: 200 x 200 mm2
Height: VSI 2 mm & PSI 150 nm
X1,5 ; x2,5 ; x5 and x20 lenses
Max Load: 30 kg

MIRAU & MICHELSON Interferometers

Formtester MAHR MMQ 400

MAHR MMQ 400
Measuring Range:
280 x 500 mm2
Rotary table Ø 300 mm
Max Load: 70 kg

Ultra high Precision CMM LEITZ

LEITZ PMM-C Infinity
Measuring Range:
1200 x 1000 x 700 mm3
Max Load: 1000 kg
External Rotary Table

Measuring room
Temperature gradients:
0.1 K / Meter
0.2 K / Hour
0.4 K / Day

CLIC Cells

Interferometer Laser

Hewlett Packard Laser Interferometer
Measuring Range:
40000 mm

Machine tool and CMM calibration

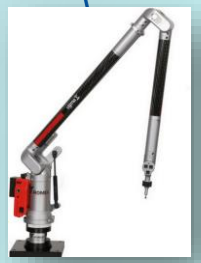
Profiles & Roughness Bretting

MITUTOYO CVS-3100 Mechanical Profiling and Roughness system
Measuring Range:
100 x 500 mm2

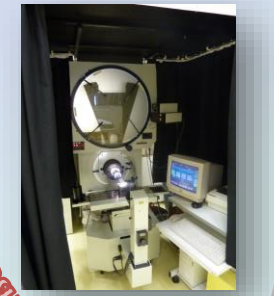
SPL Cavity

EN/MME MATERIALS & METROLOGY

Accuracy : From MPEE0 [µm]= 1.2 + L/500 To MPEE [µm]= 4+L*/500 (* L in mm)
Accuracy : ± 5 µm
Accuracy : * (x5, x10, x20) : ± 15 µm * (x50, x100) : ± 5 µm
Accuracy : MPE$_E$ [µm]= 9+L*/50 (* L in mm)
Accuracy : ± 100 µm
Accuracy : from ± 2 µm to ± 500 µm
Accuracy : VSI mode: ± 1,50 nm PSI mode: ± 0,03 nm
Accuracy : ± 0,1 µm
Accuracy : MPE$_E$ [µm]= 0,3+L*/1000 (* L in mm)
Accuracy : ± 1 µm
Accuracy : ± 10% (roughness) ± 2 µm (forms)



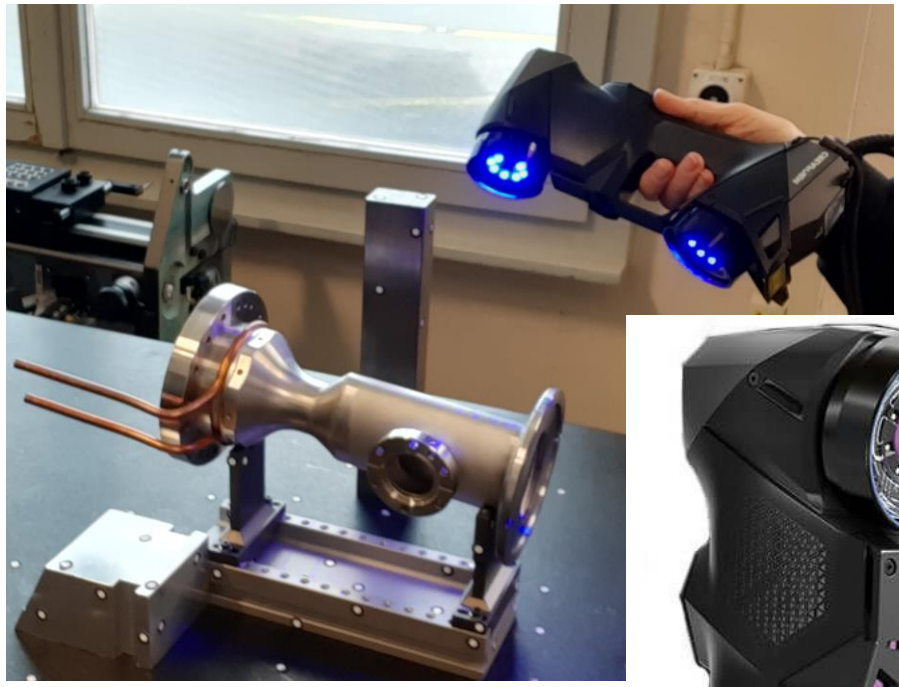





3D Laser Scanners

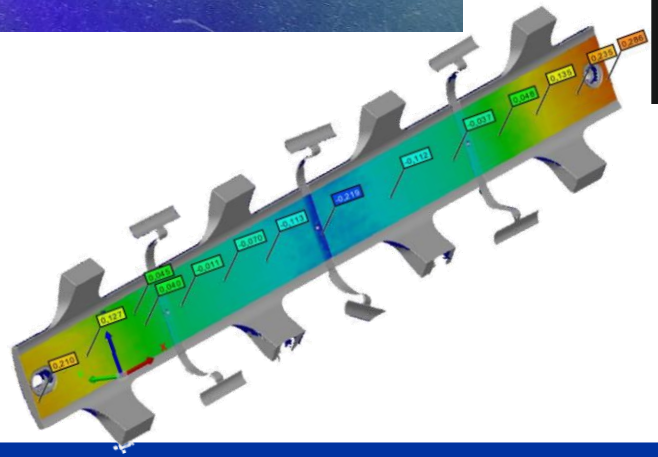
C-Track

MetraSCAN



HandySCAN

Technical Specifications HandySCAN



Technical specifications

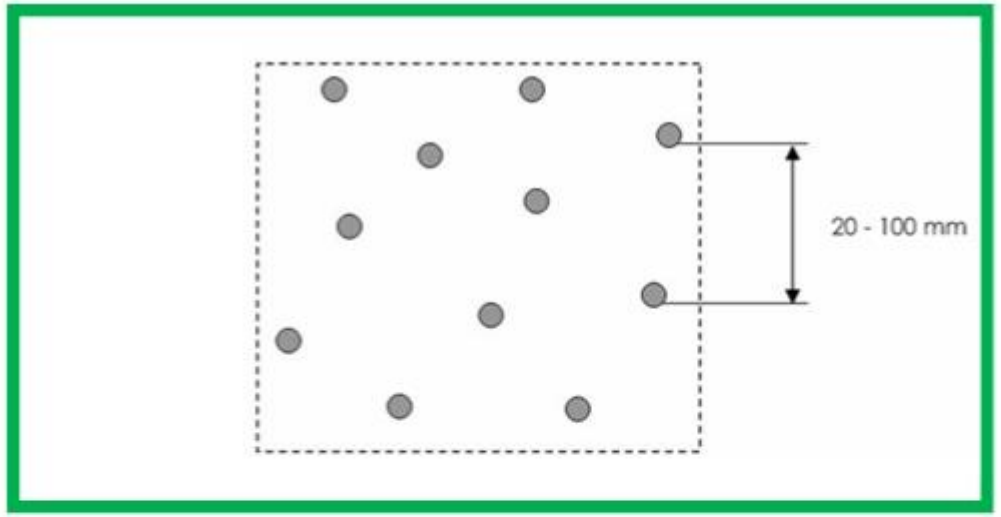
Accuracy:
0.025 mm (0.0009 in)

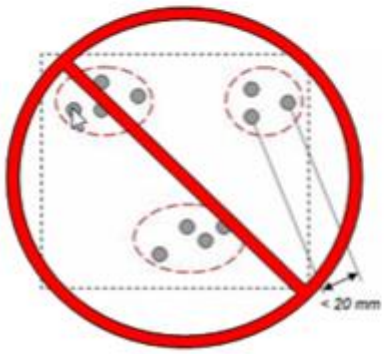
Volumetric accuracy:
0.020 mm + 0.040 mm/m (0.0008 in + 0.0005 in/ft)

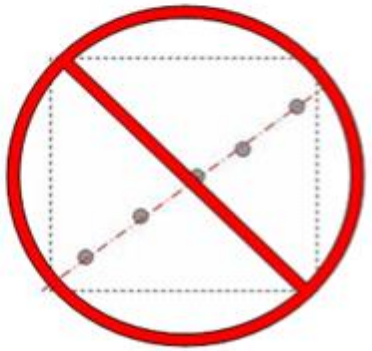
Measurement rate:
1,300,000 measurements/s

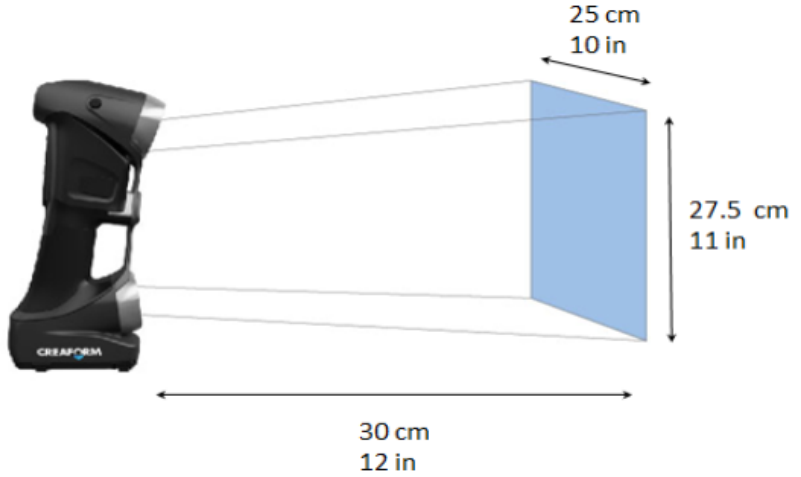
Part size range (recommended):
0.05 – 4 m (0.15 –13 ft)

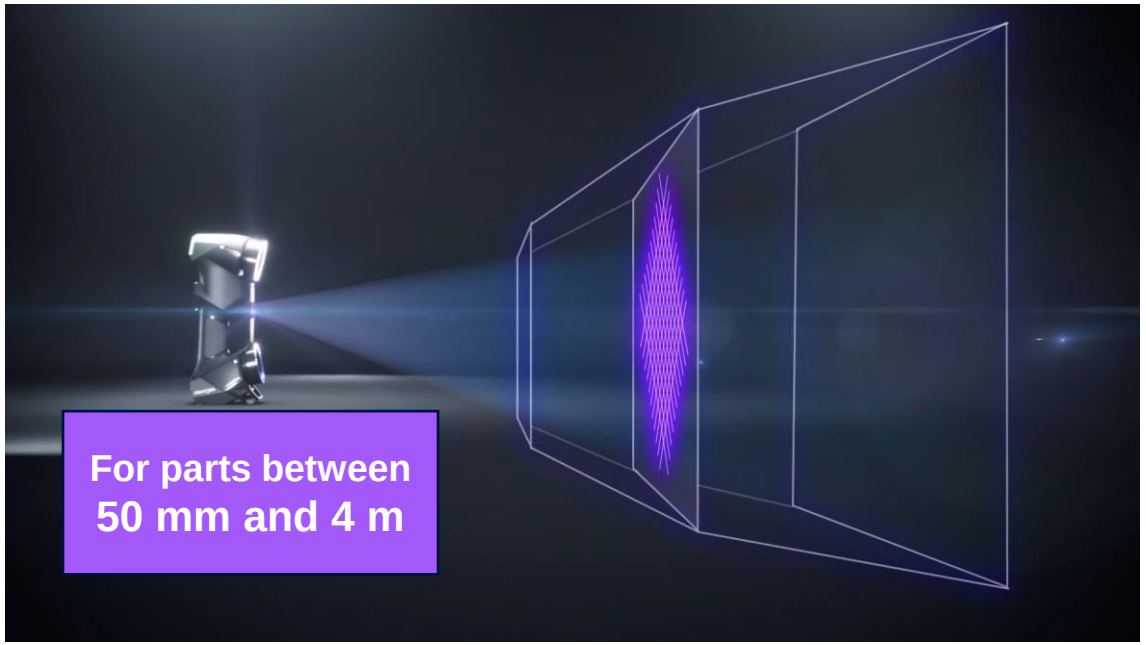
HandySCAN
targets & scanning area







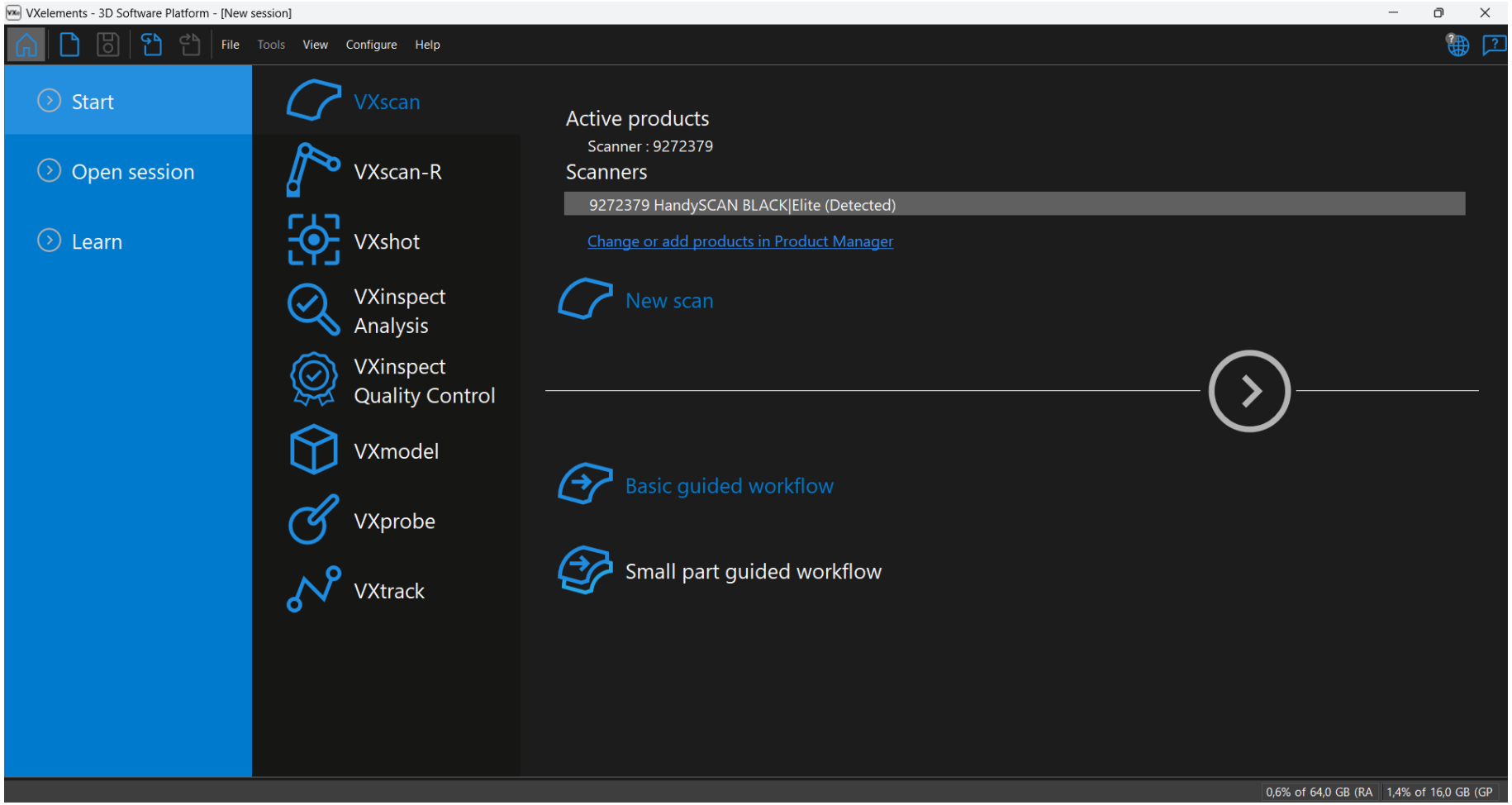




Practical session part 1 – part measurement

Scan

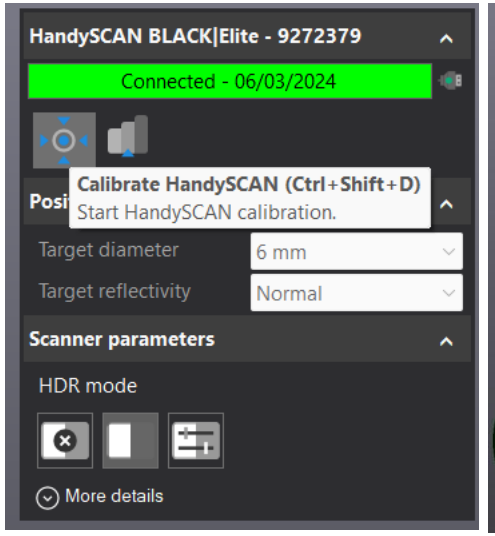
Launch the acquisition software -VXelements

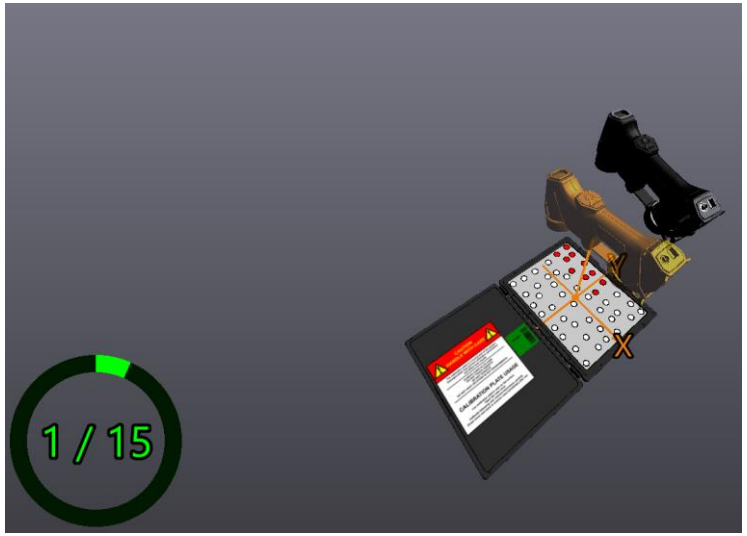


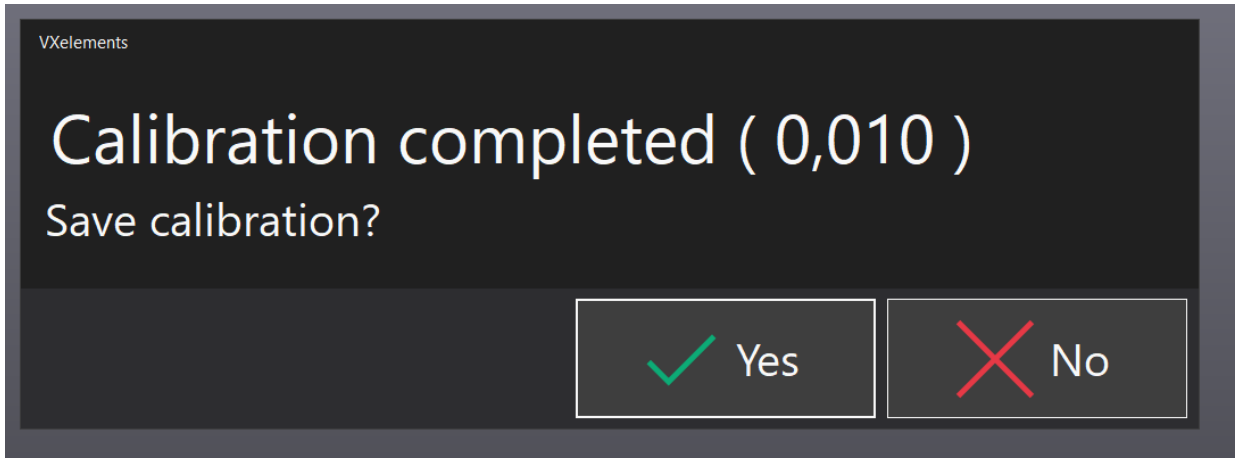
Practical session part 1 – part measurement

Calibration plate

Calibration

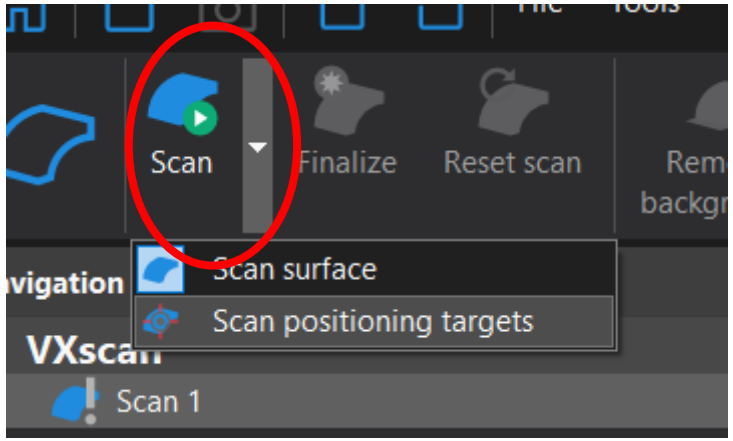


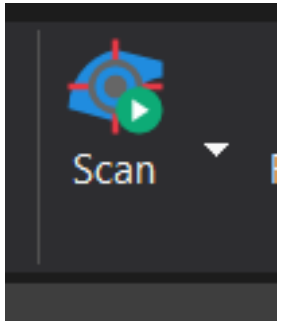




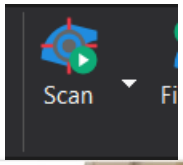
Practical session part 1 – part measurement

Scan the targets

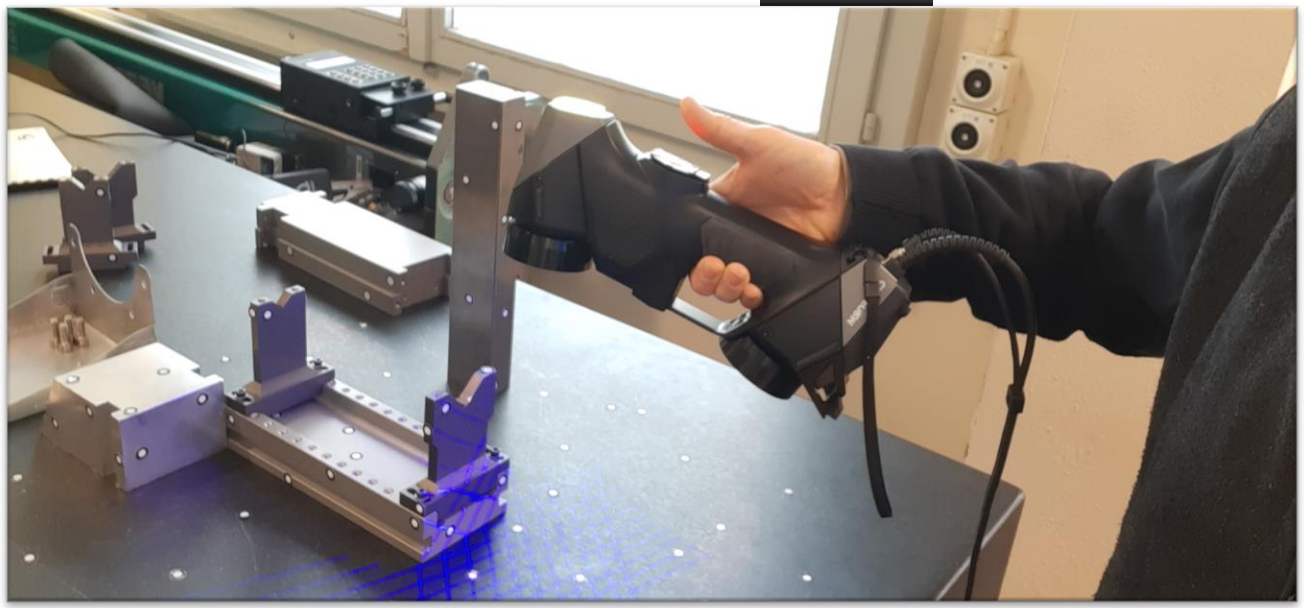




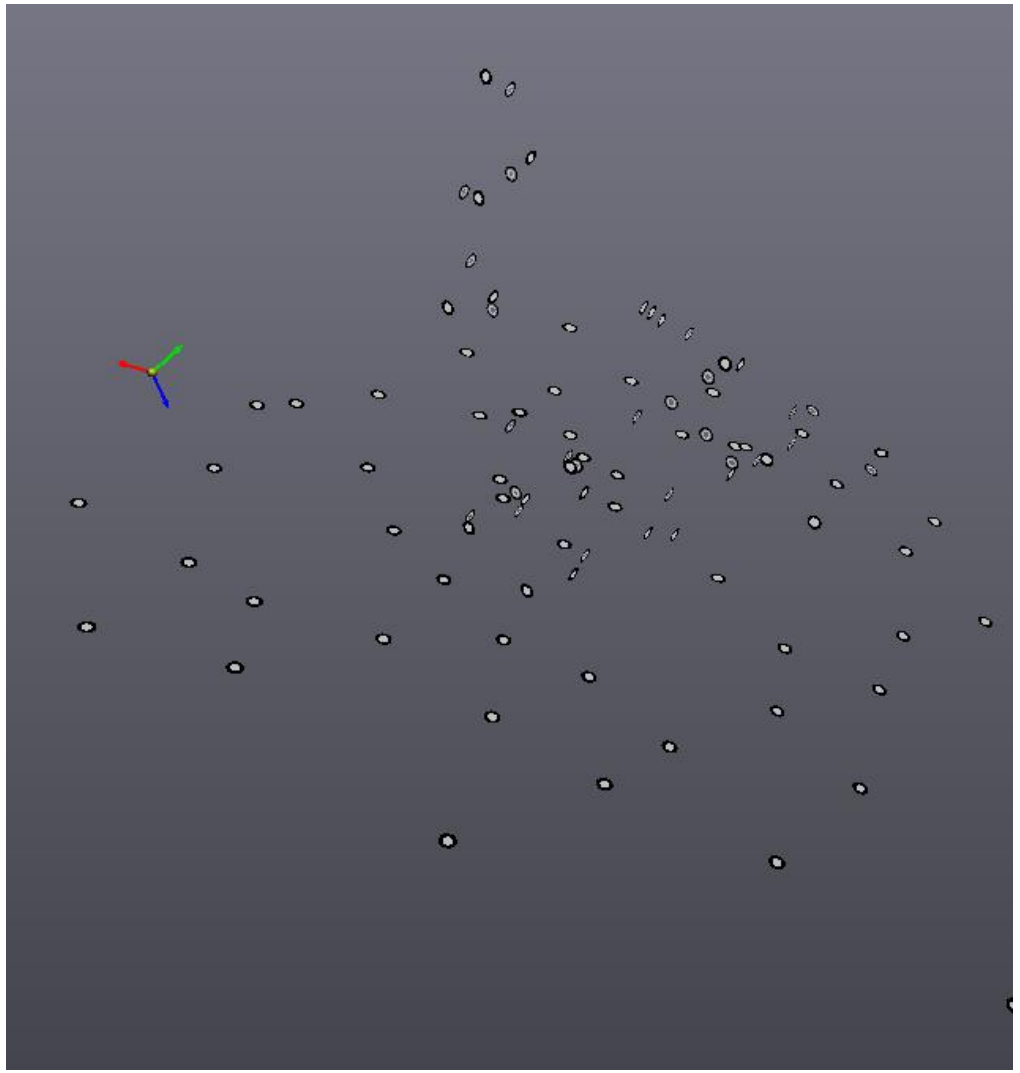
Start scanning the targets



Stop scanning the targets

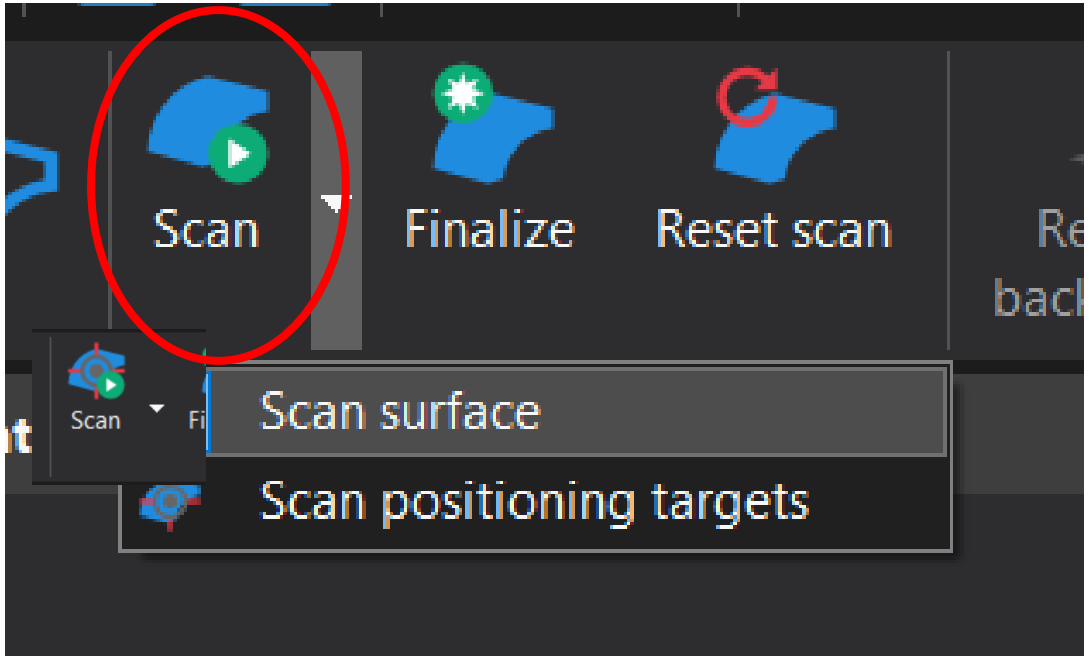


View of the targets aquired

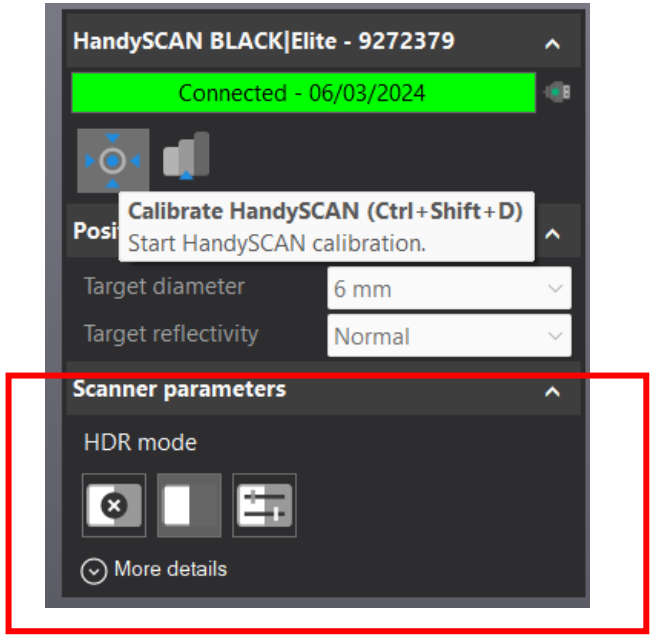


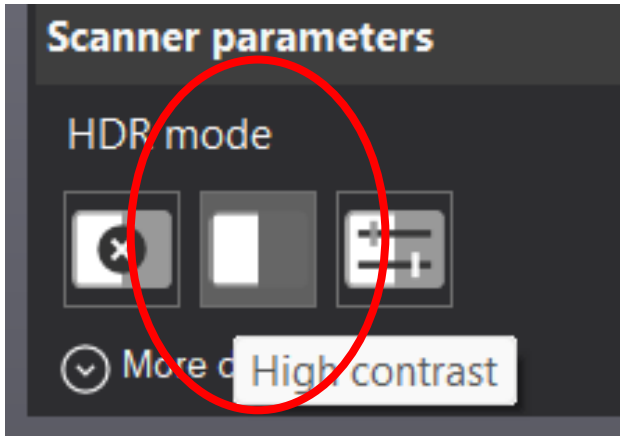
Practical session part 1 – part measurement

Surface scan



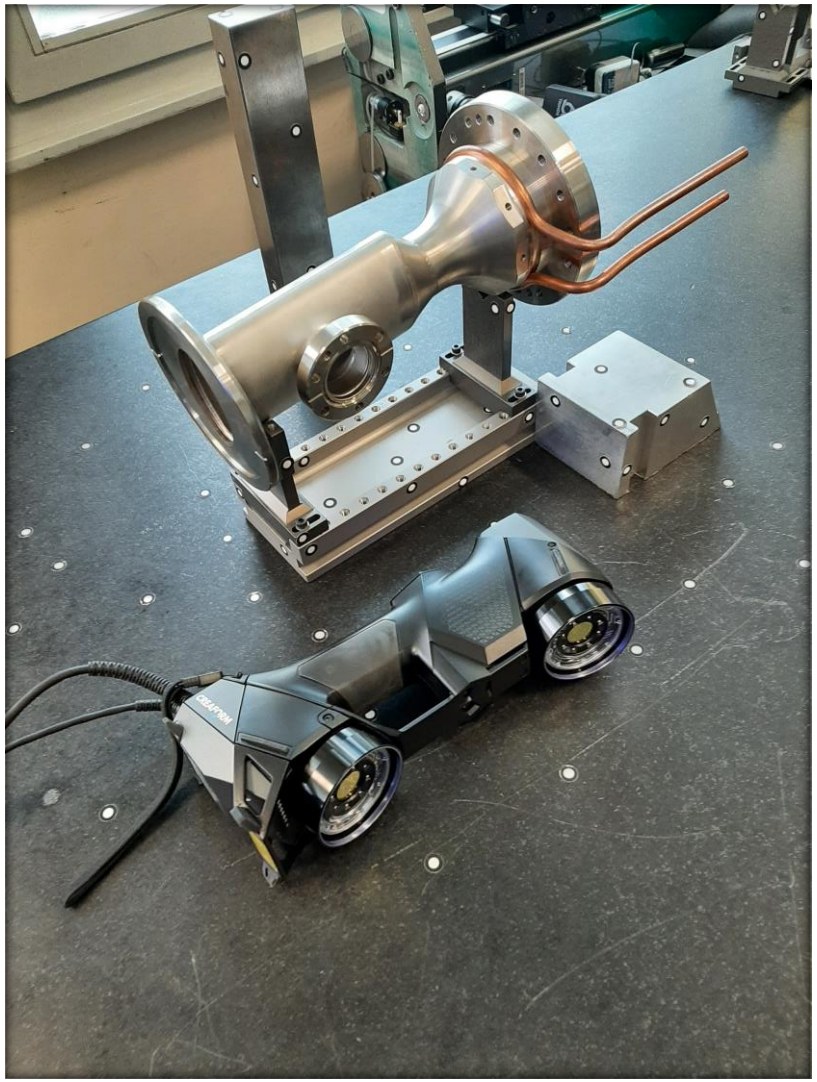
Select the High contrast mode

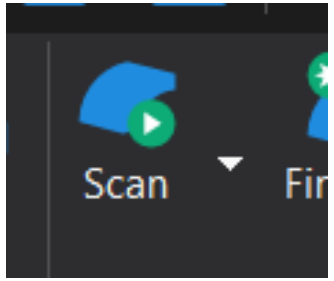




Practical session part 1 – part measurement

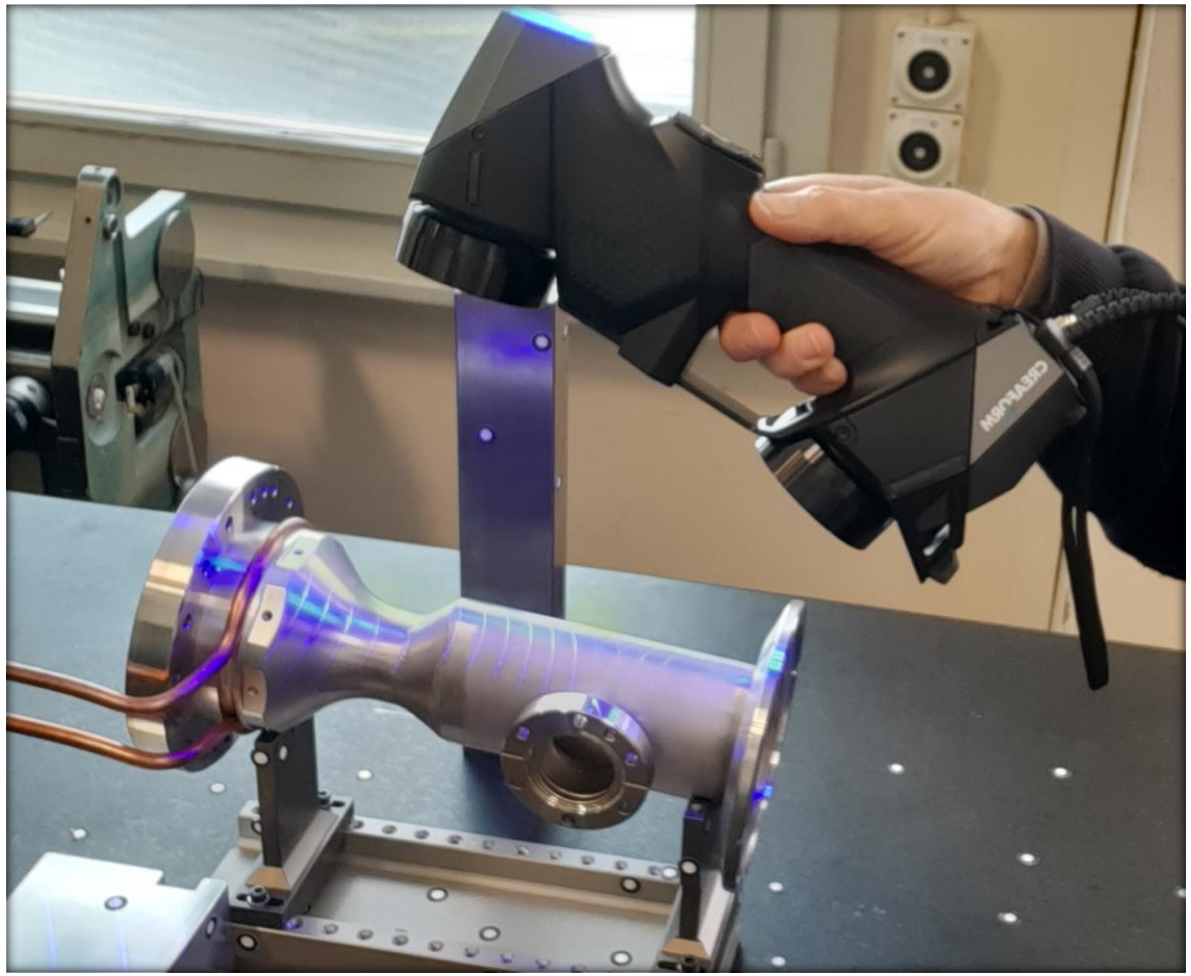
Put the part on the support

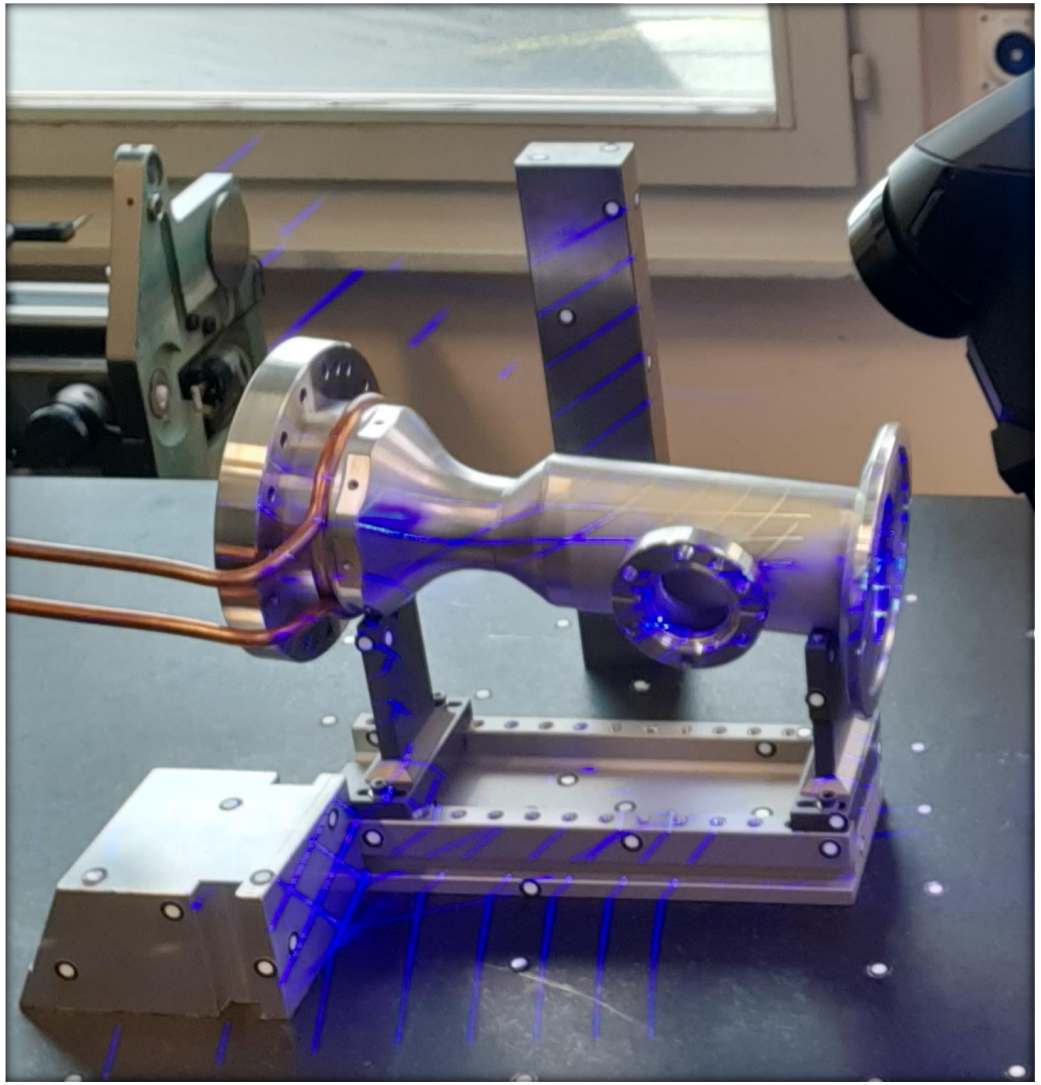




Practical session part 1 – part measurement

Scan the part

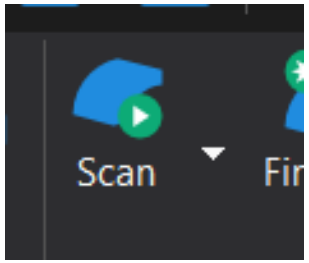




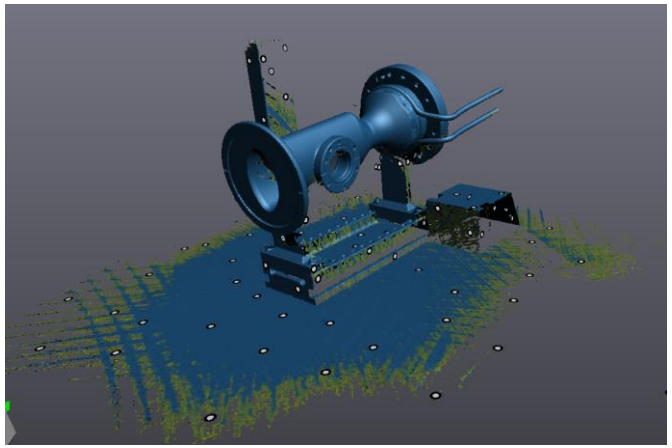
Practical session part 1 – part measurement

Scan

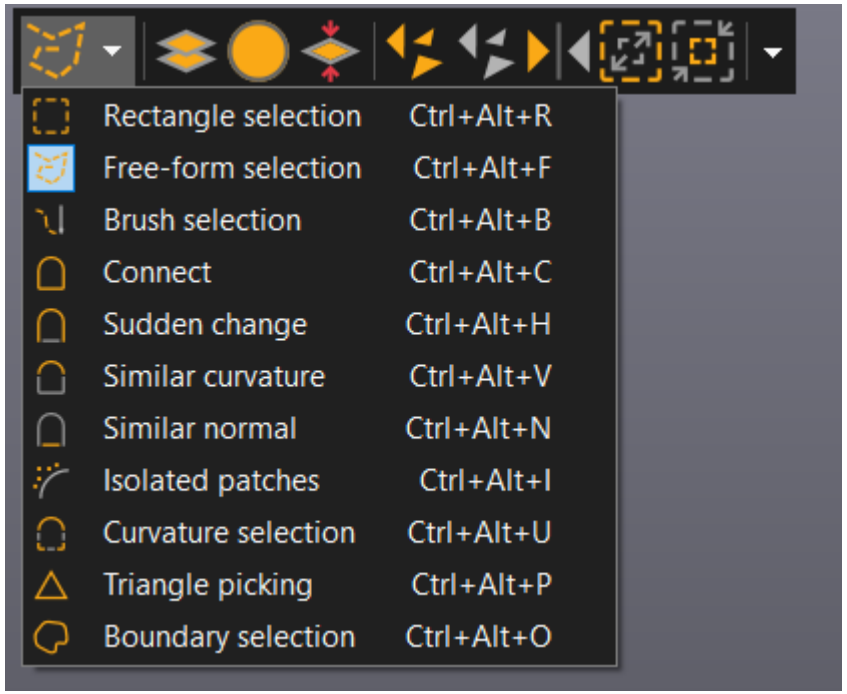
Stop scan



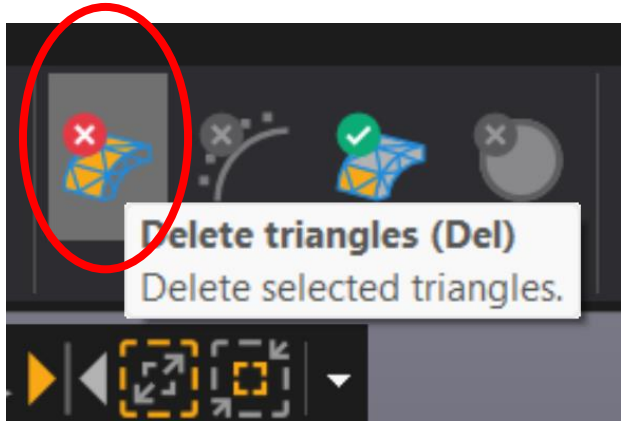
Scan view



Cleaning tool

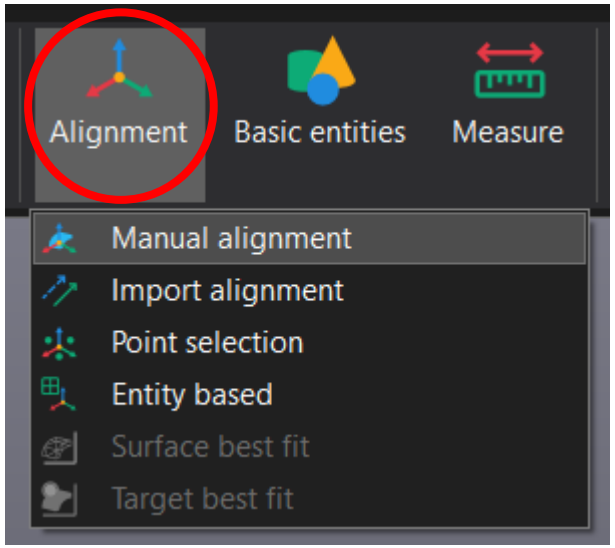


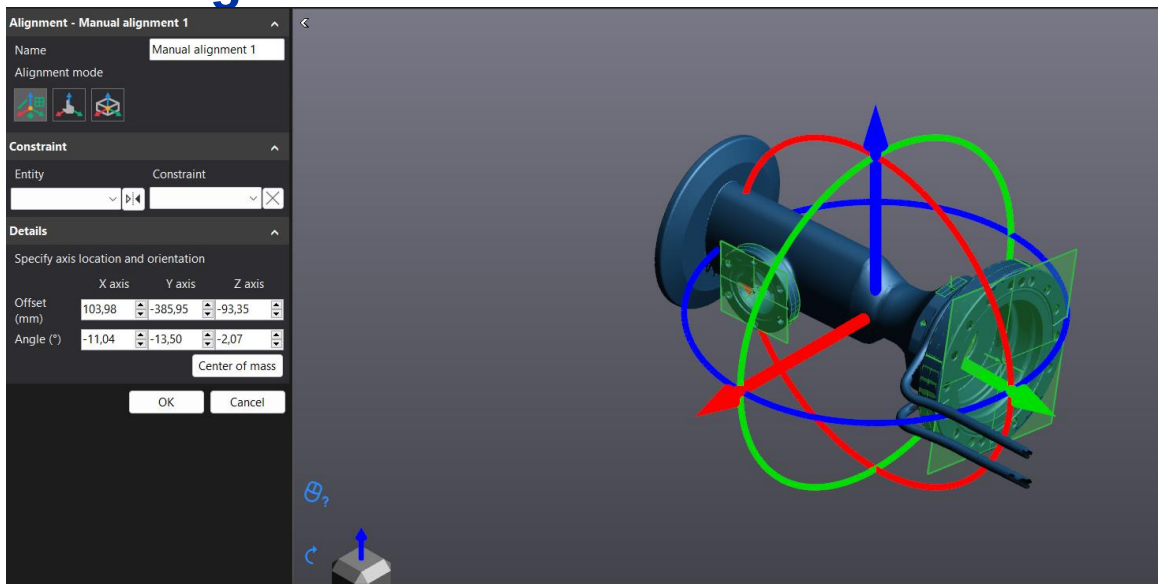
Delete

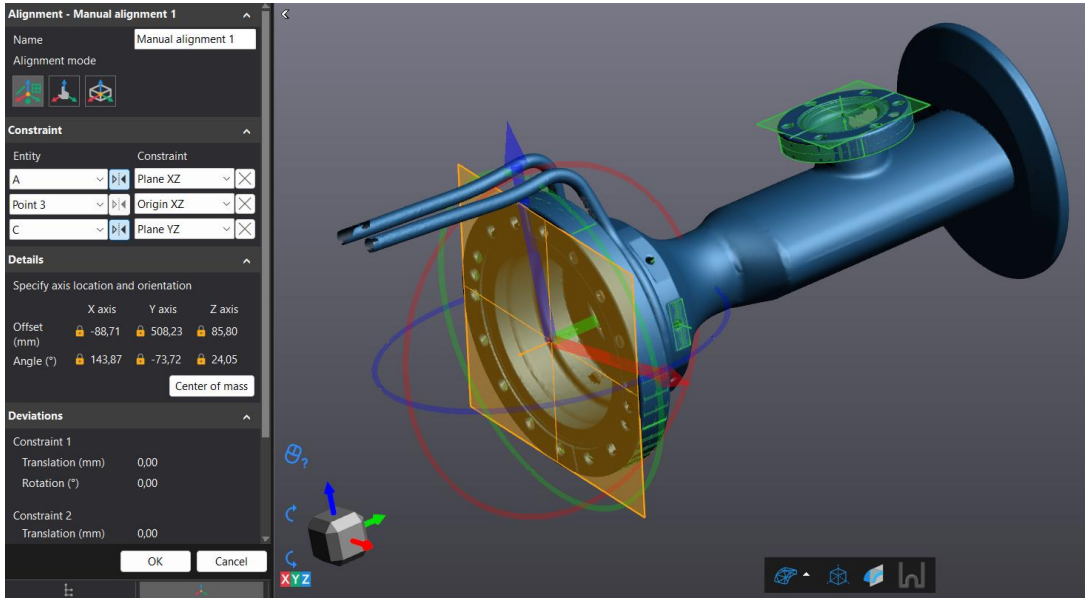


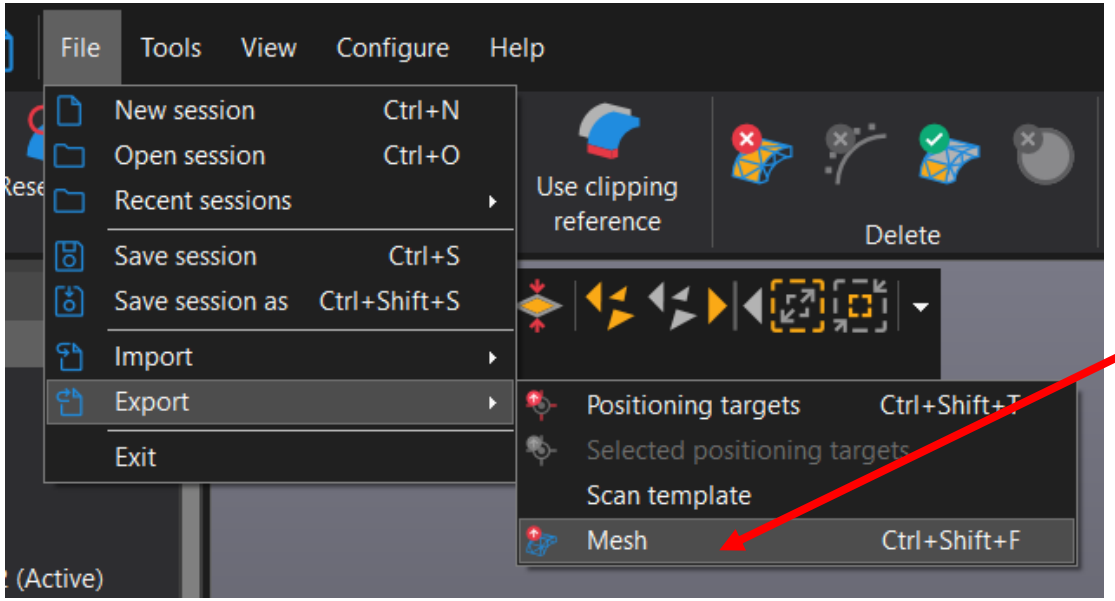
Practical session part 1 – part measurement

Part alignment on VXelements

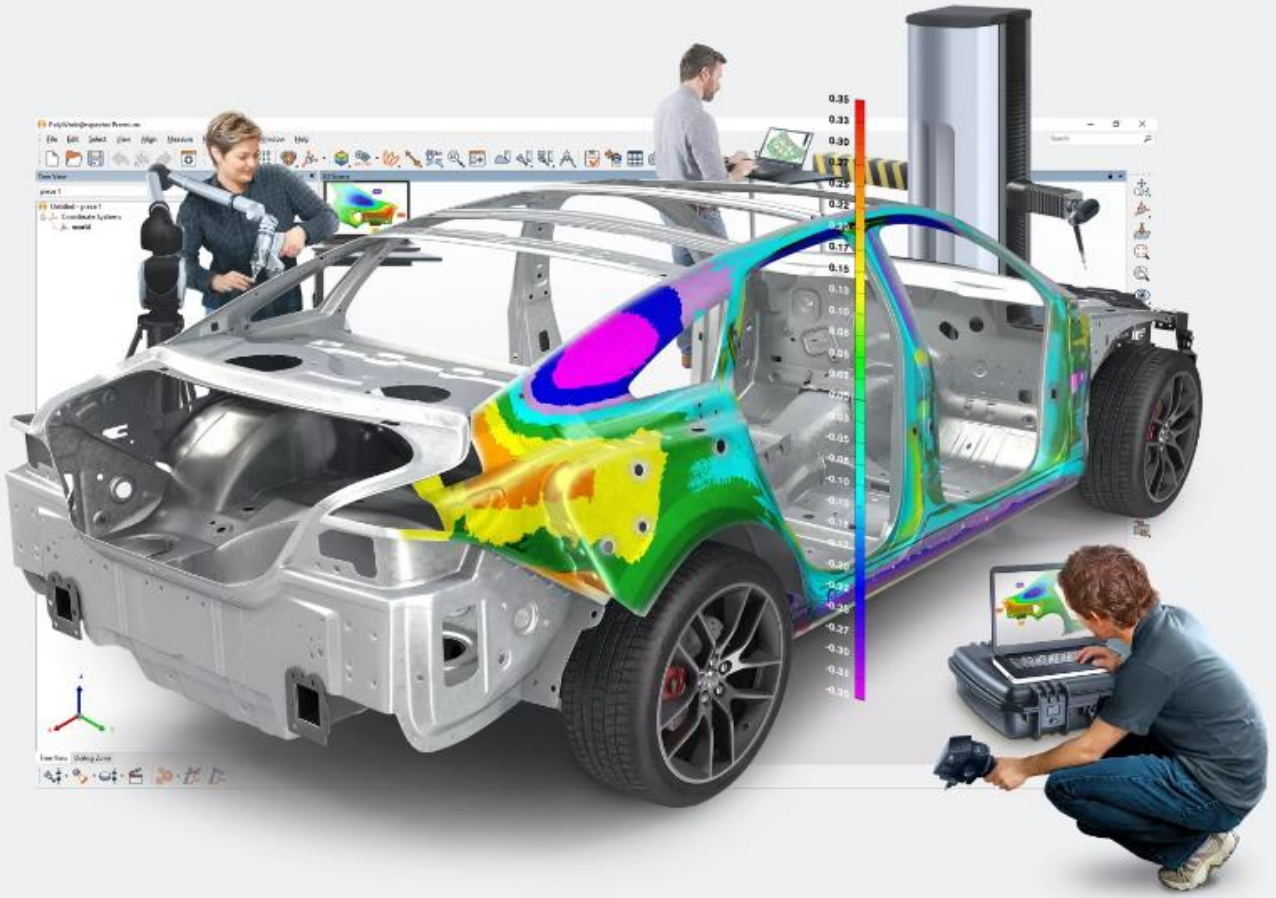








Practical session part 2 – part evaluation

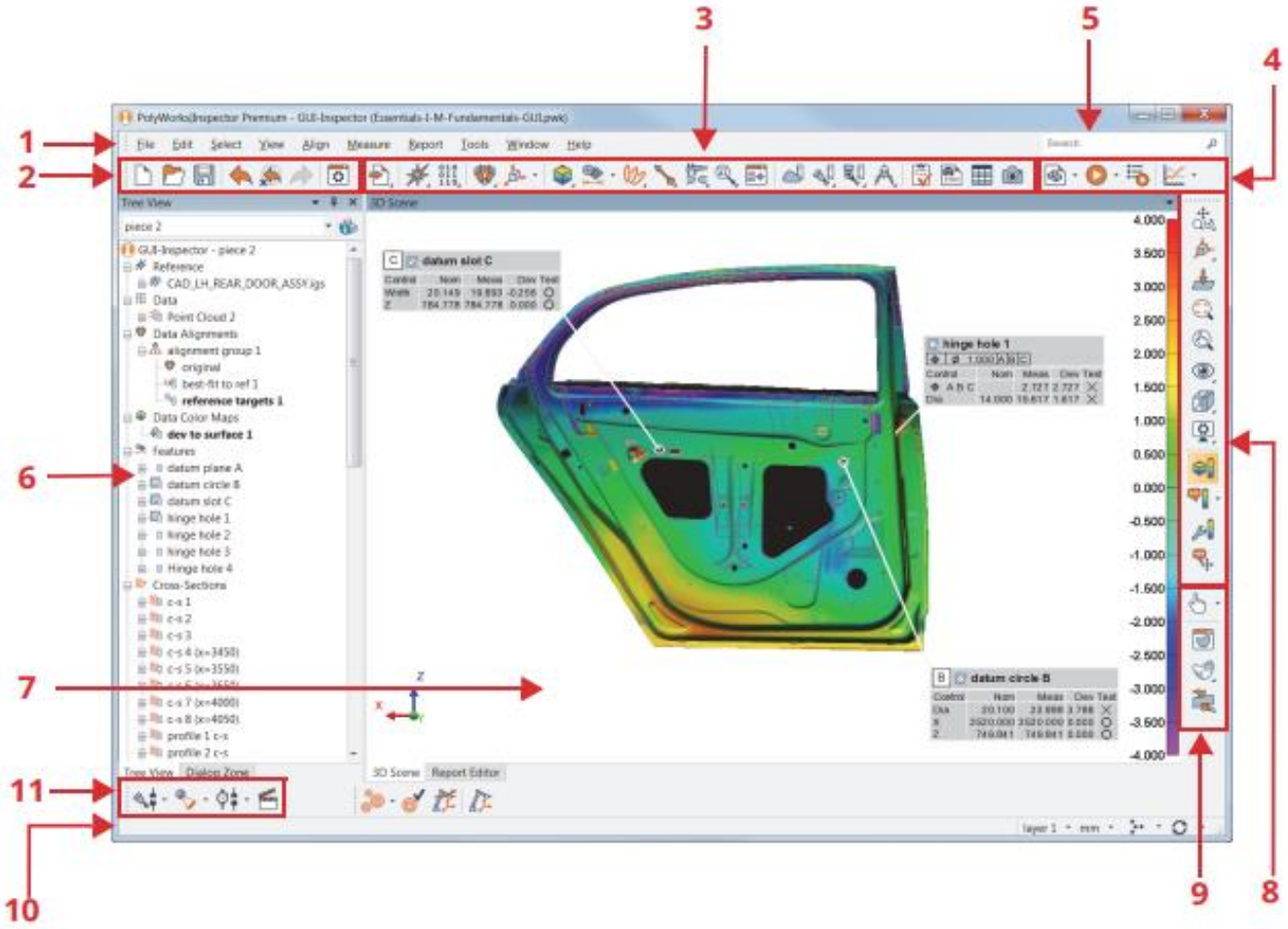


PolyWorks Inspector™

The 3D dimensional analysis and quality control solution to gain control of your product engineering and manufacturing process.

Practical session part 2 – part evaluation

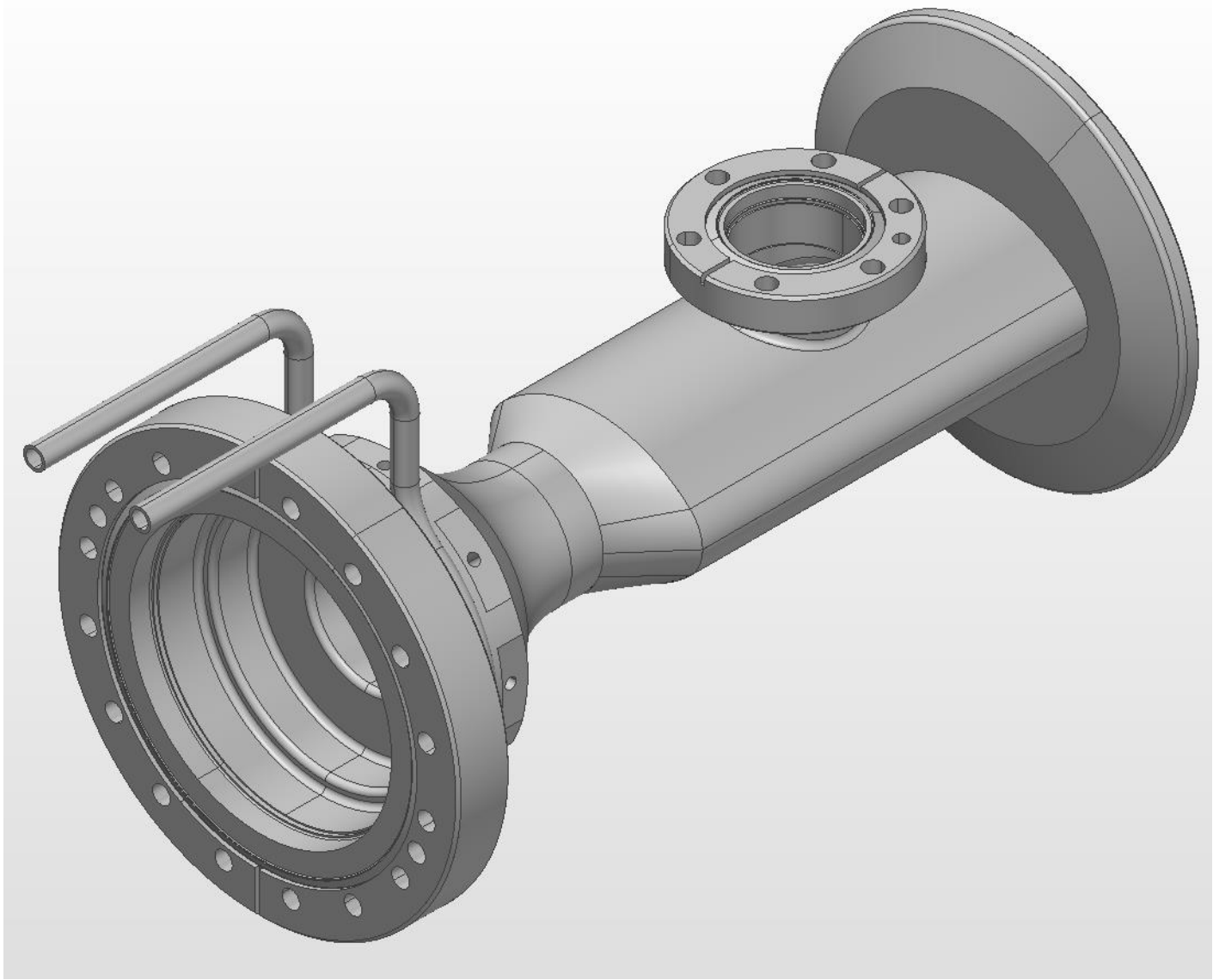
Graphic interface



1	Menu bar:	Access to all the functionalities of PolyWorks|Inspector .
2	Standard toolbar:	Quick access to common operations such as Open, Save, and Undo.
3	Main Objects toolbar:	Quick access to the most common tools for an inspection.
4	Multipiece inspection toolbar:	Quick access to the various multipiece tools.
5	Search box:	Used to enter a query and search through Tree View objects or menu items.
6	Tree View:	Pane where all the objects of the project are stored.
7	3D Scene:	3D rendering window where objects are displayed.
8	3D Scene toolbar:	Used to navigate in the 3D scene, to change the view, and to control the visibility and display of objects.
9	Selection toolbar:	Used to select objects or elements in the project.
10	Status bar:	Provides information and allows changing units, layers, and the automatic update status.
11	Devices toolbar:	Used to connect to the device for data acquisition.

Practical session part 2 – part evaluation

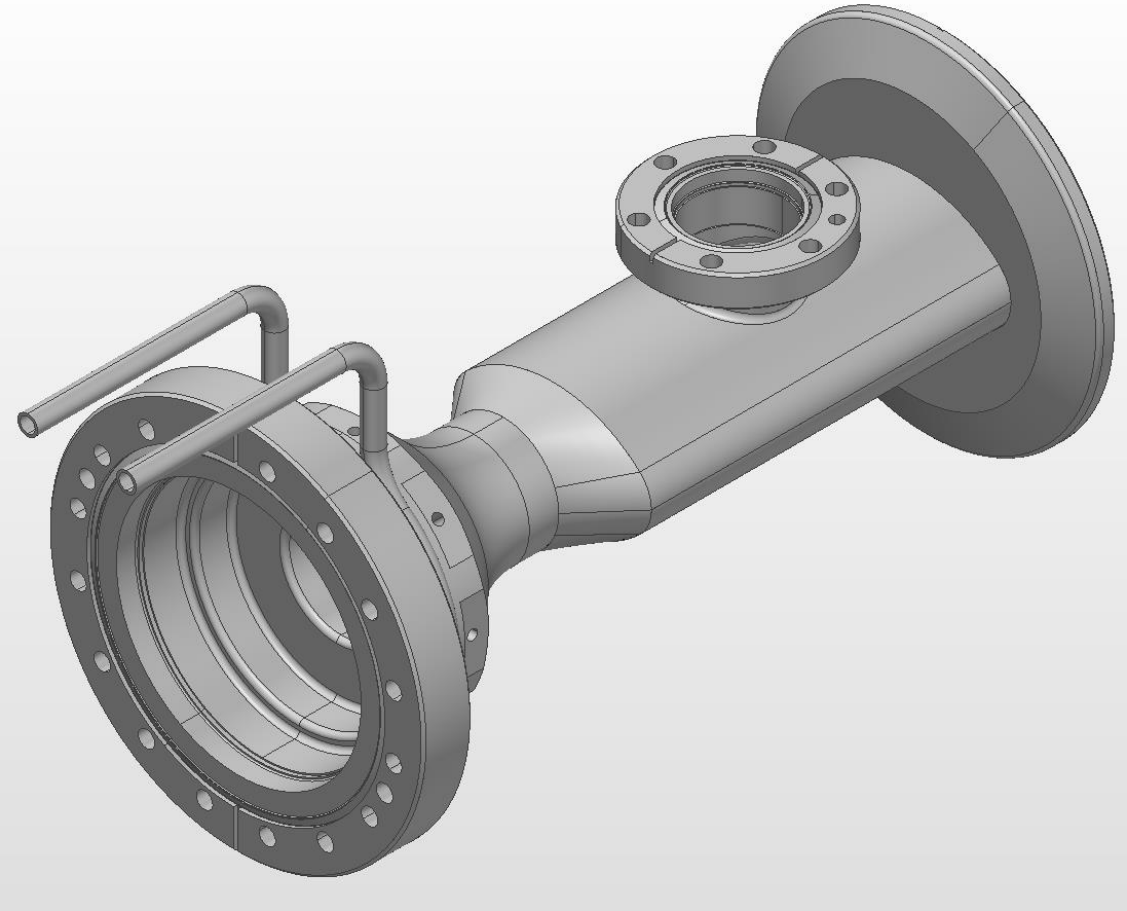
CAD



Practical session part 2 – part evaluation

The part for this exercise is the vacuum chamber with machined and formed components and finally assembled by welding.

Your task is to check/measure the geometrical (GD&T) and dimensional characteristics highlighted on the drawing



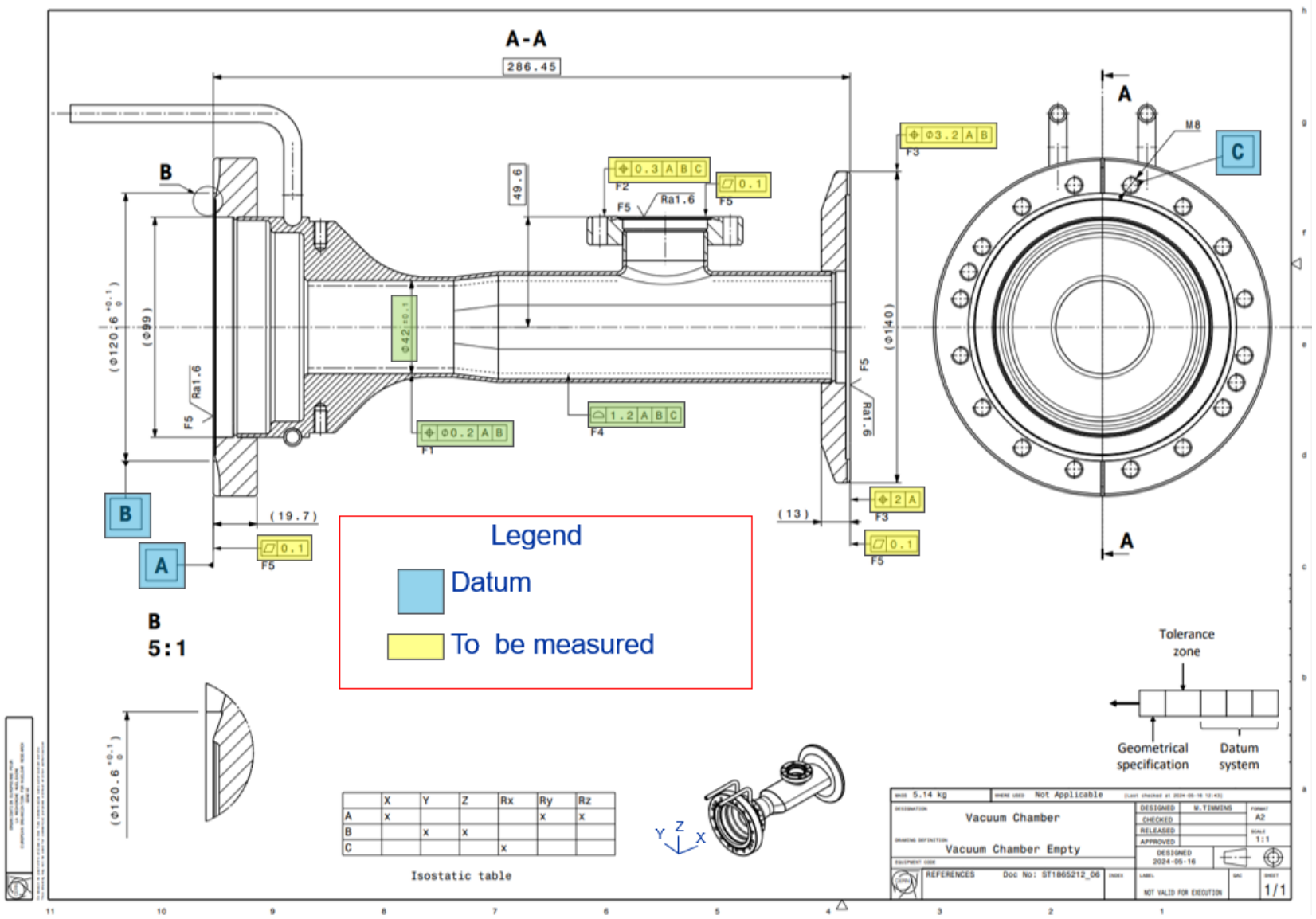
Practical session part 2 – part evaluation

- Define the relevant entities and necessary datums following the information provided on the technical drawing

- Get the results and deviations for the GD&T characteristics and report the measurement results

Practical session part 2 – part evaluation

Drawing



	X	Y	Z	Rx	Ry	Rz
A	x				x	x
B		x	x			
C				x		

Practical session part 2 – part evaluation

Required files

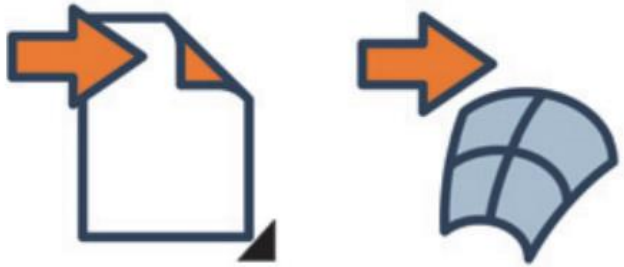
Reference Object (CAD Model) : CAS Vacuum Chamber.stp

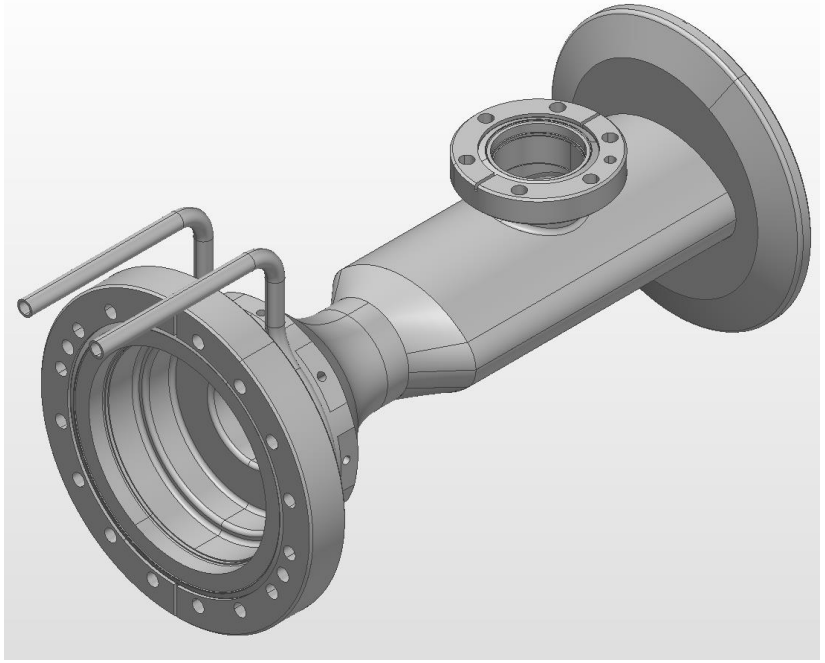
Object data : CAS Vacuum Chamber 1.stl

Practical session part 2 – part evaluation

Import CAD

Create a new project and import the CAD model of the part.



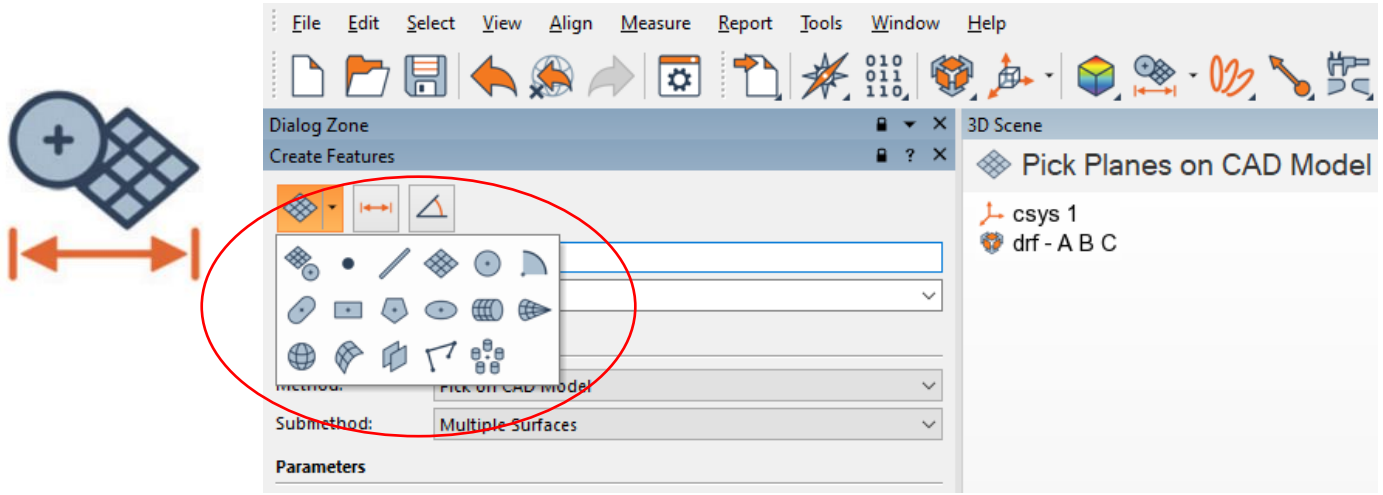


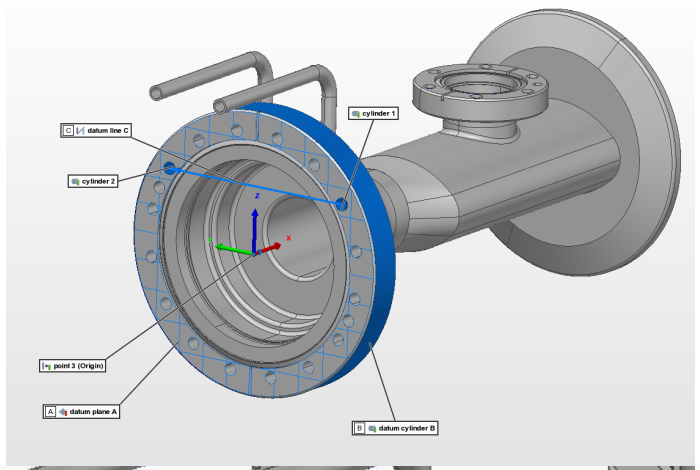
Practical session part 2 – part evaluation

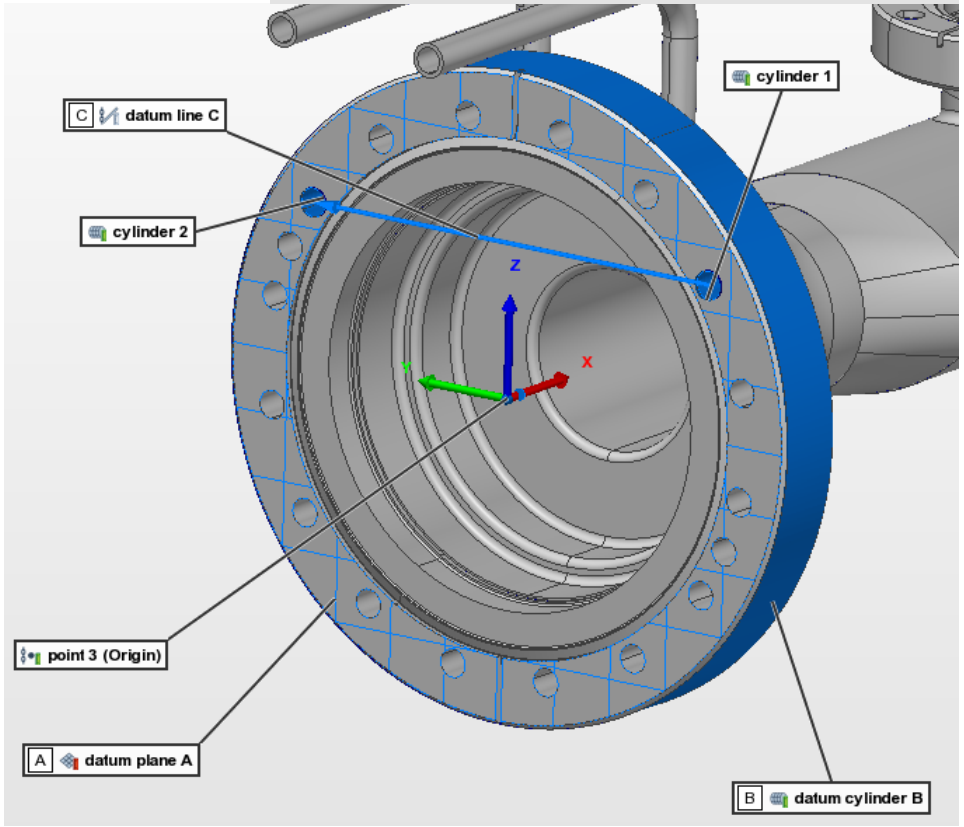
Alignment features

Create the features required to obtain the entities to create a reference system as specified on the engineering drawing.

Datum labels can be assigned when creating features or in the feature properties.





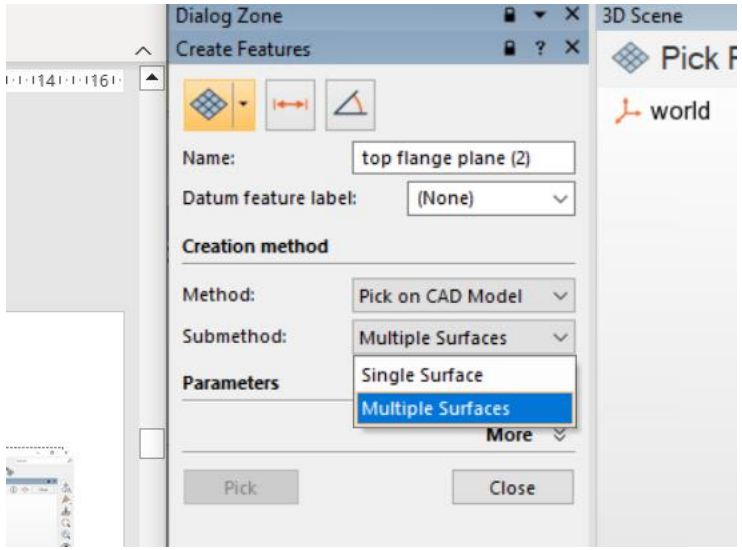


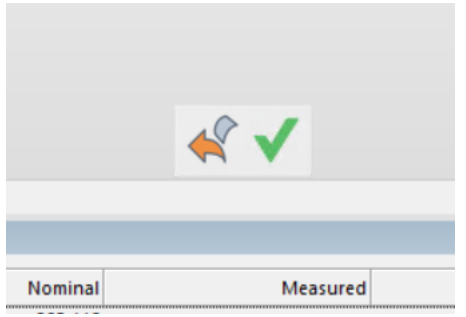
Datum labels must be assigned to the appropriate features in order to be able to create specific GD&T controls in the following steps.

Practical session part 2 – part evaluation

Tips & tricks

- **Select single surface or multiple surfaces depending on the case**
- **Once the selection is done, click on the green icon or press right button of the mouse**
- **Press space bar to toggle from the selection mode and the 3D scene manipulations**

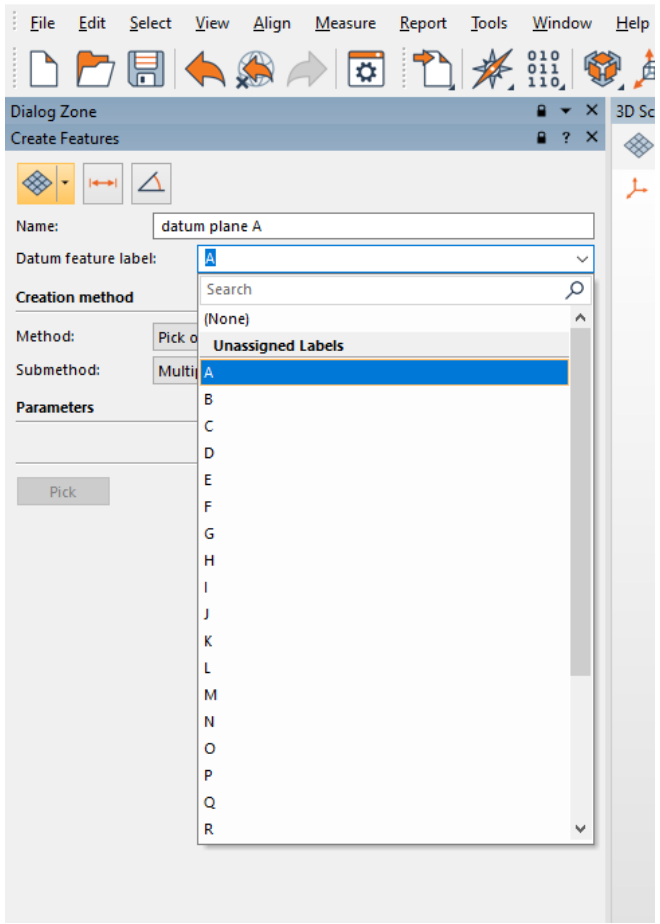




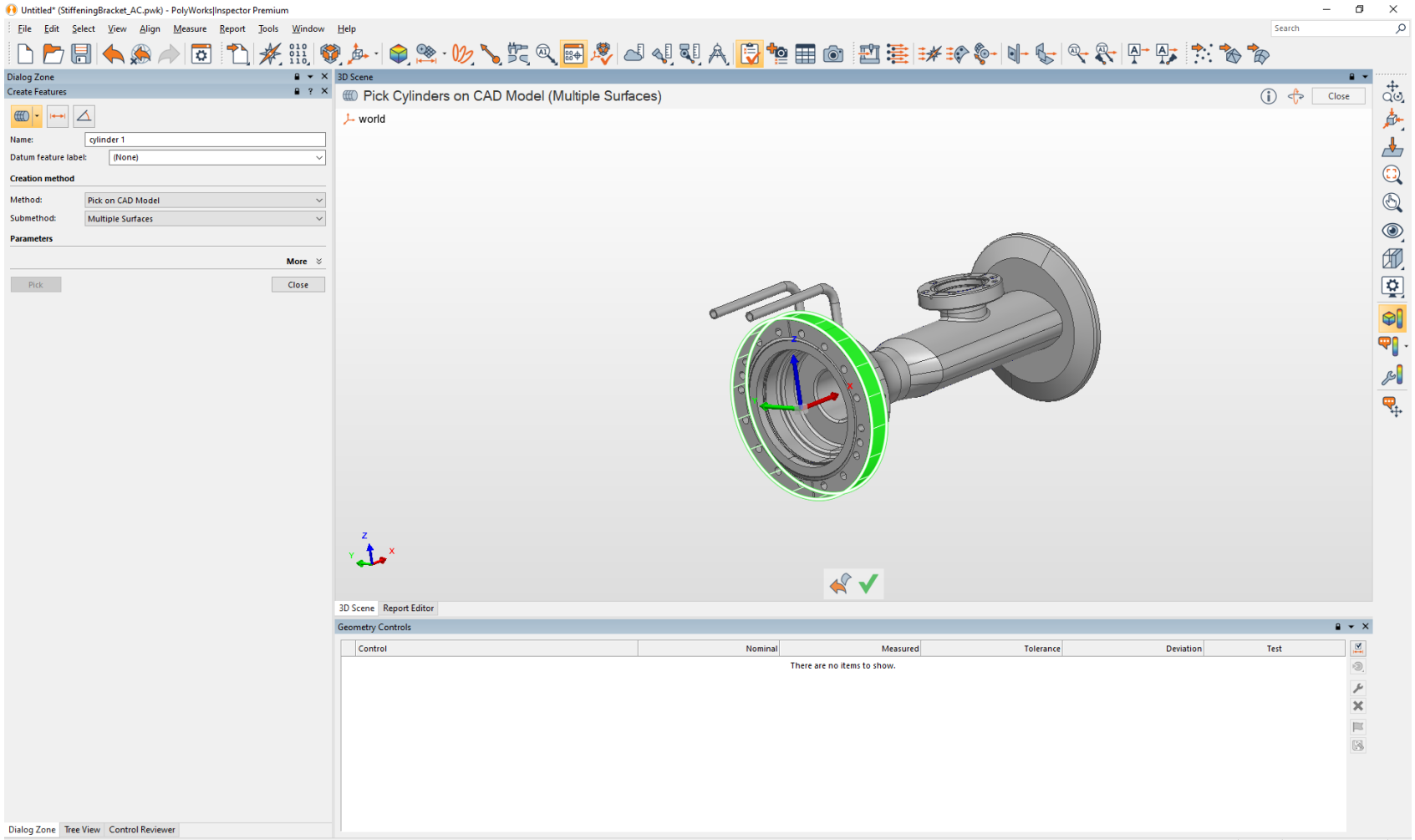
Practical session part 2 – part evaluation

Tips & tricks

Datum

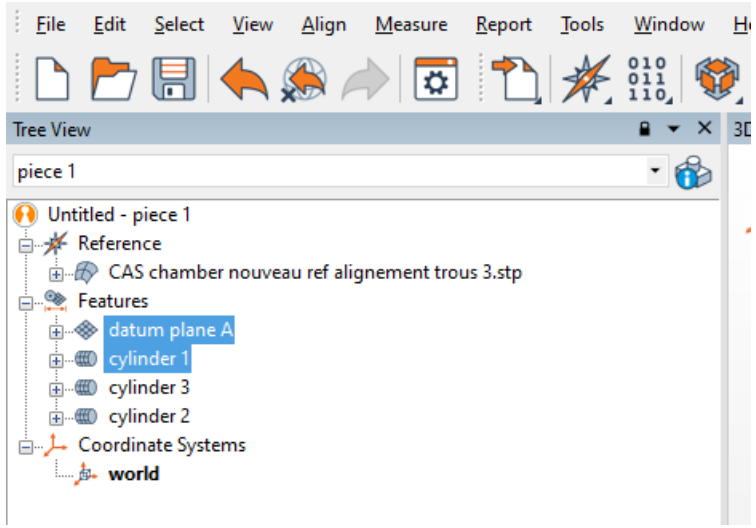


Feature selection

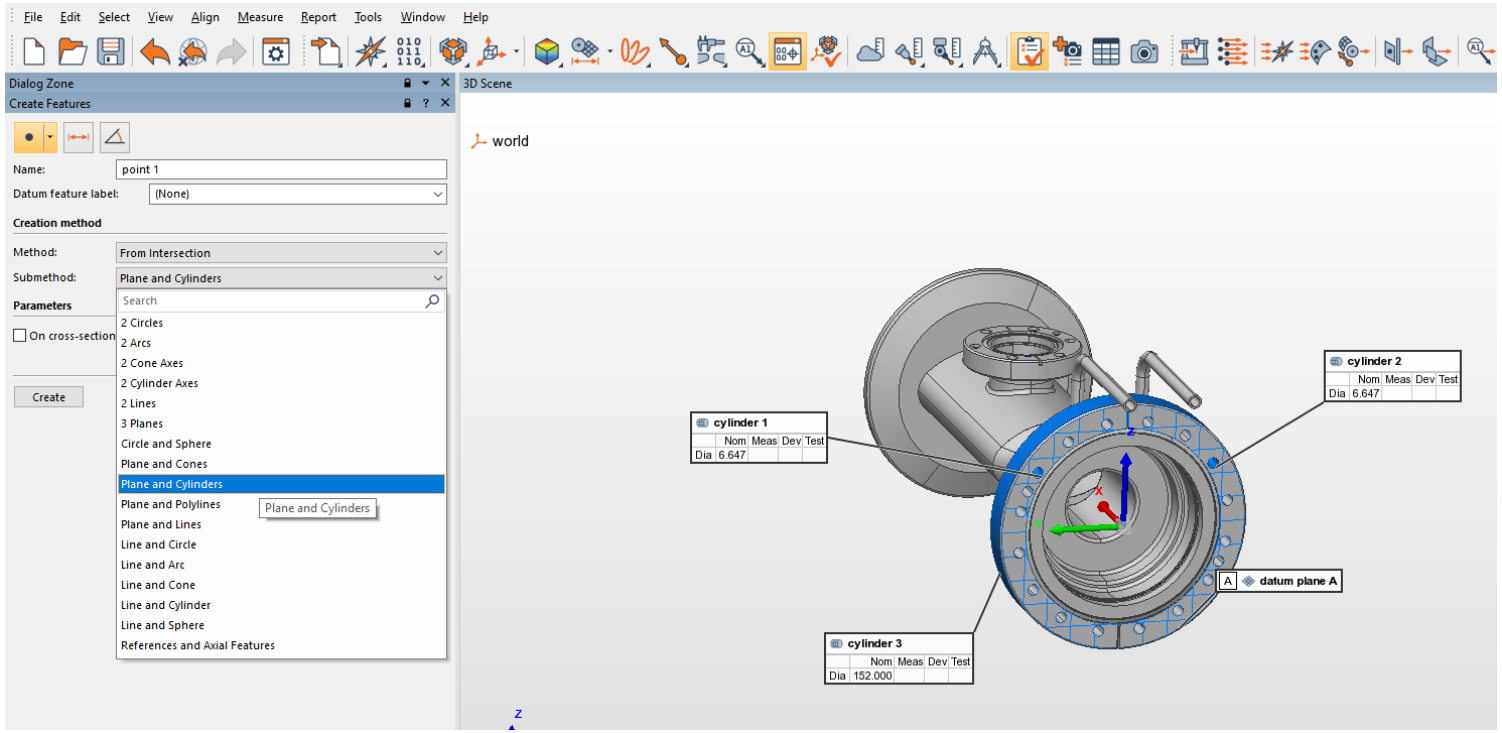


Practical session part 2 – part evaluation

Alignment features



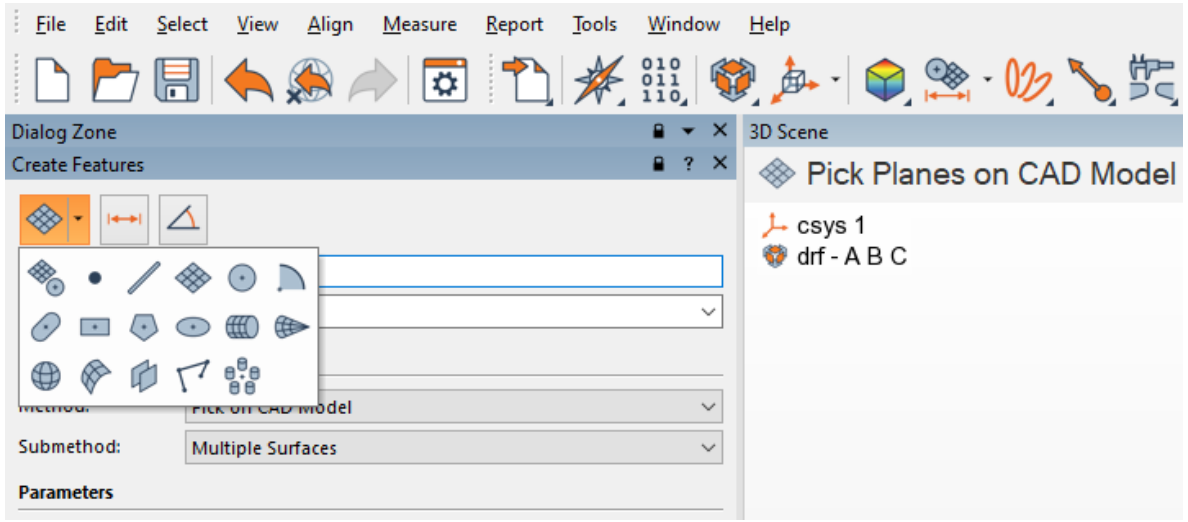
First select in the Tree View the features to be used for intersections

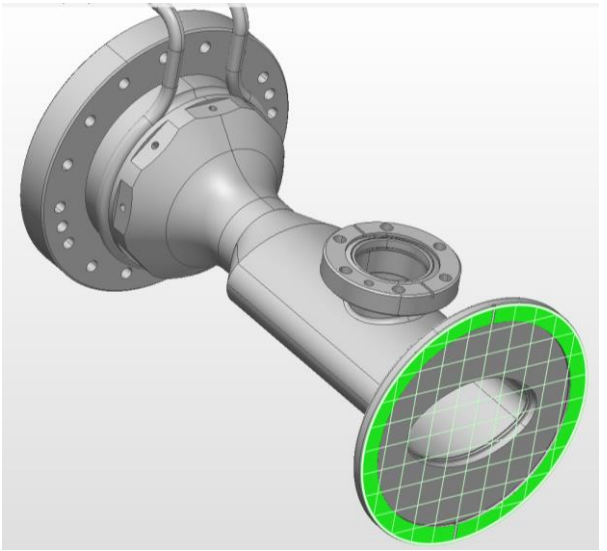


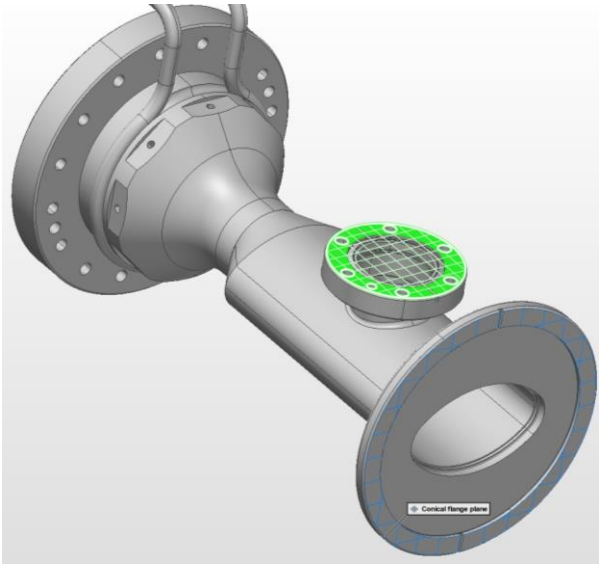
Practical session part 2 – part evaluation

Measurement features

Create the features required to obtain the measurements specified on the engineering drawing.

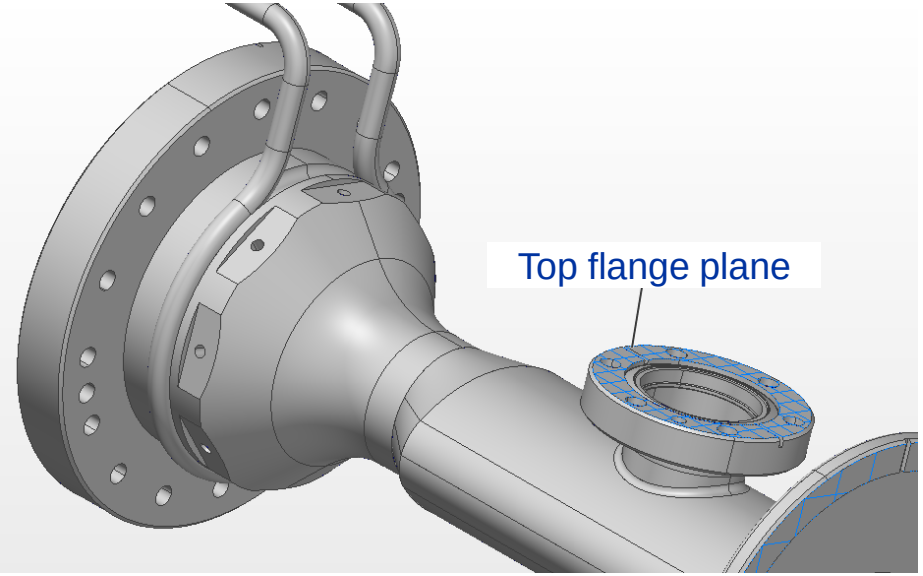


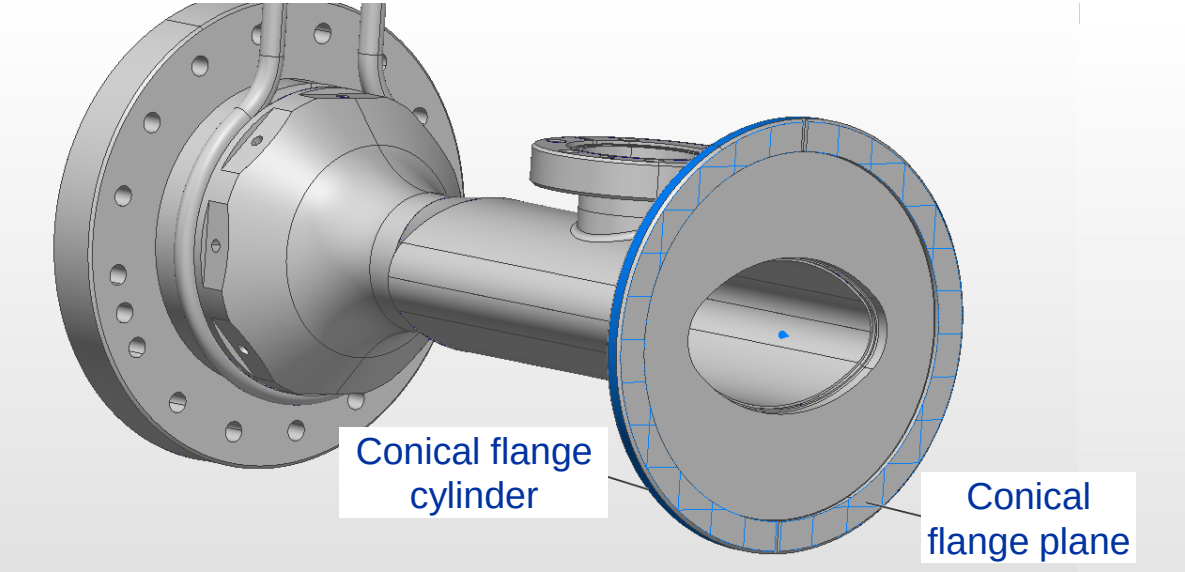




Practical session part 2 – part evaluation

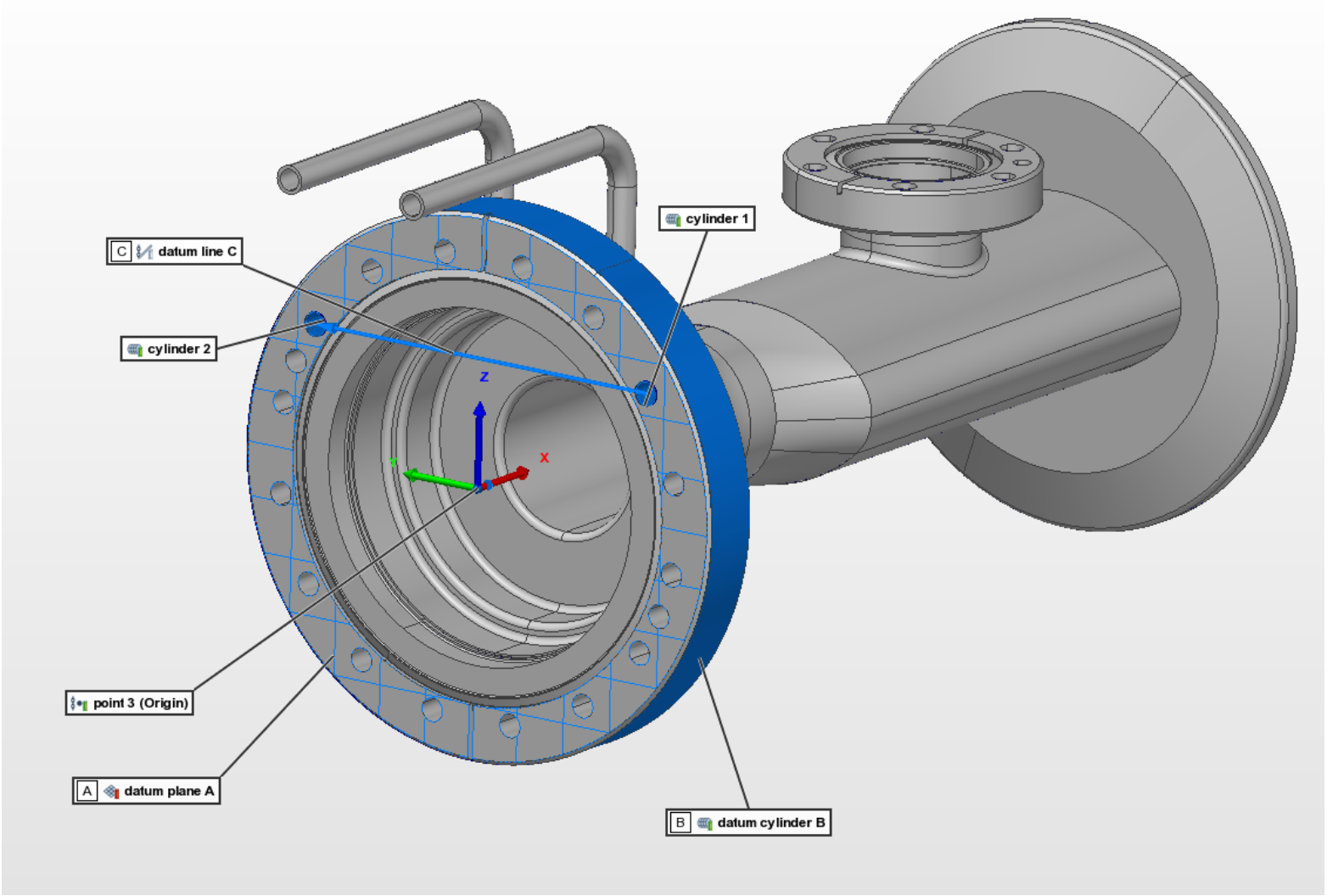
Measurement features





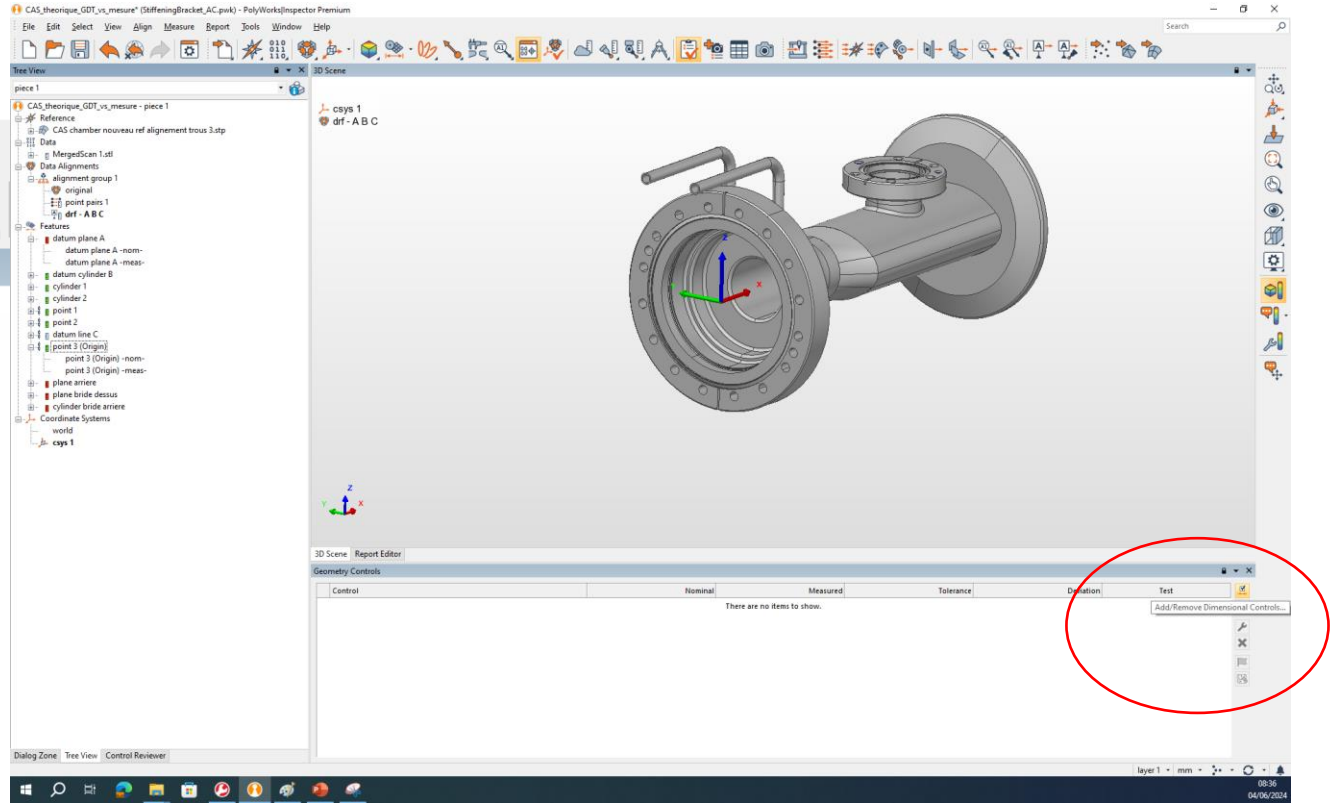
Practical session part 2 – part evaluation

Alignment features



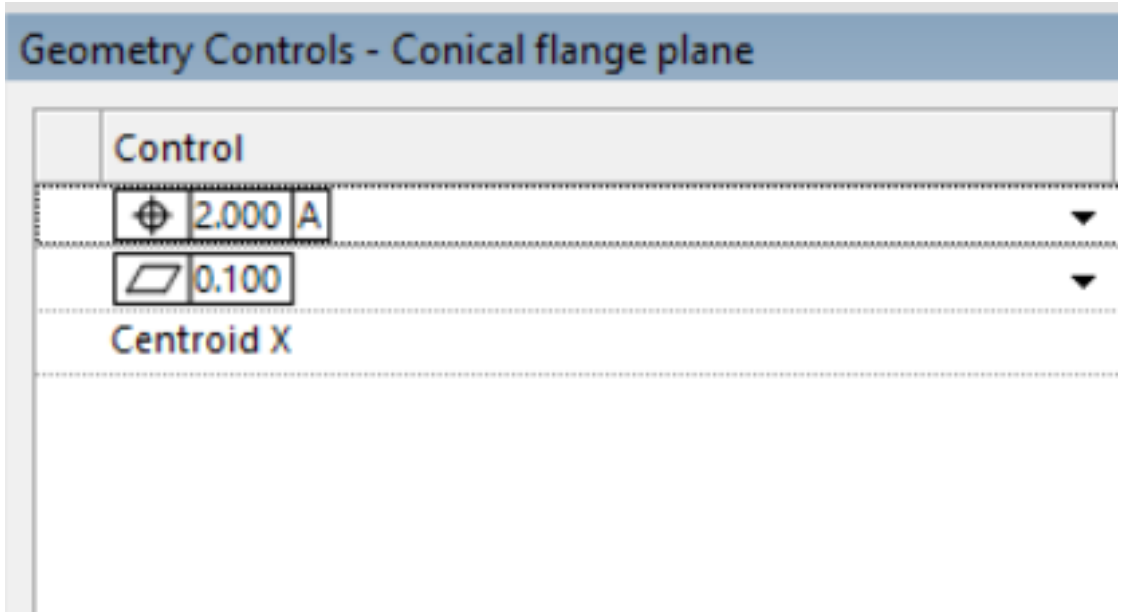
Practical session part 2 – part evaluation

Tolerances and GD&T controls



Tolerances and GD&T controls

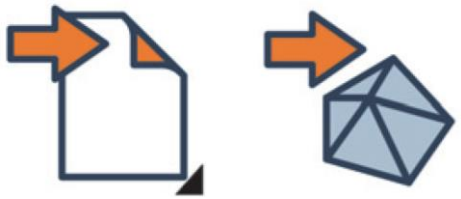
Set the appropriate tolerances for the dimensional and GD&T controls using the information provided on the engineering drawing.

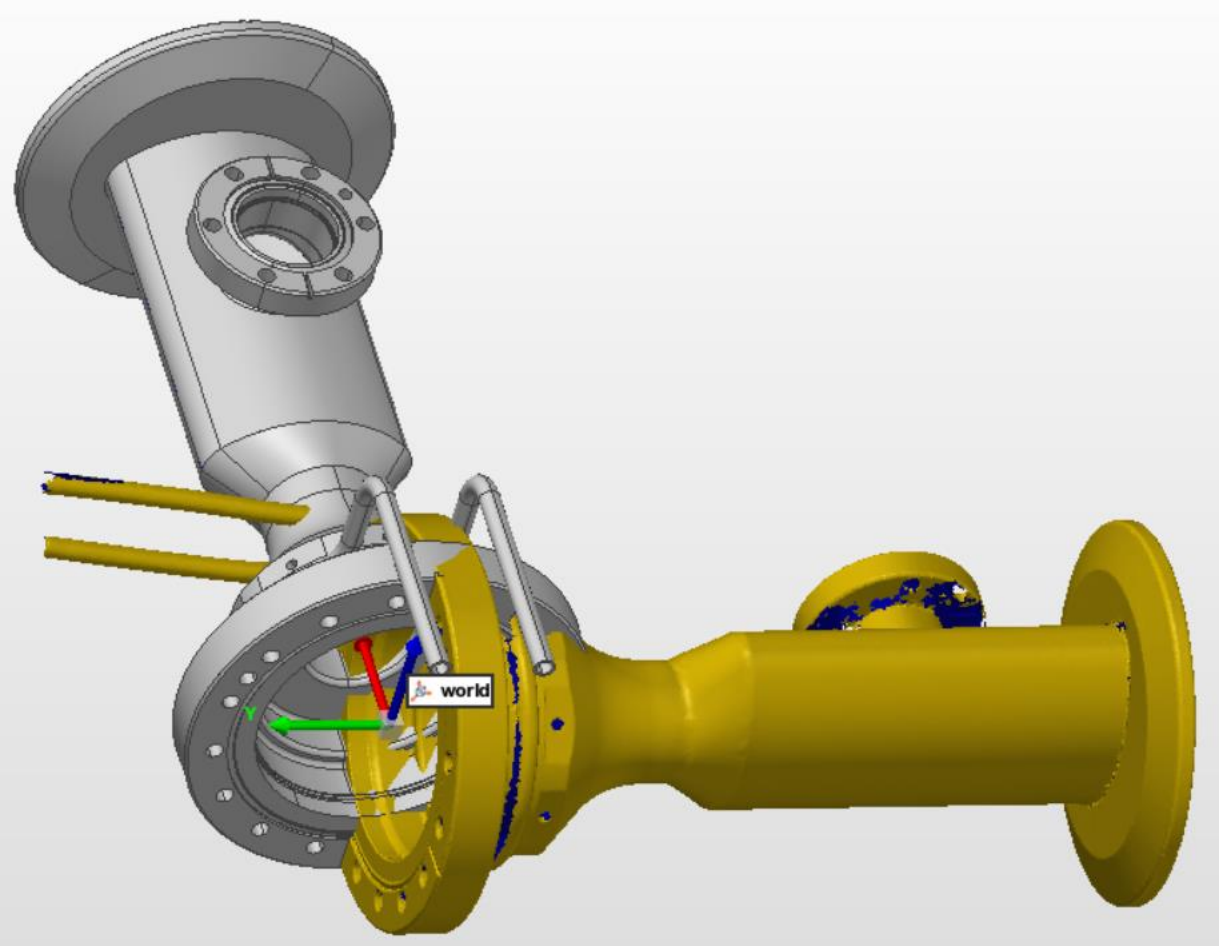


Practical session part 2 – part evaluation

Data import

Import the meshed scan of the part into the project.

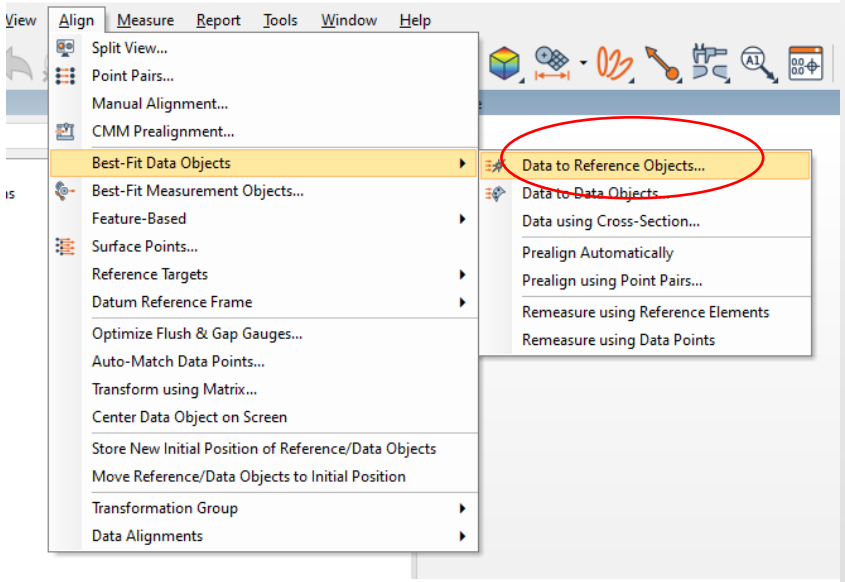


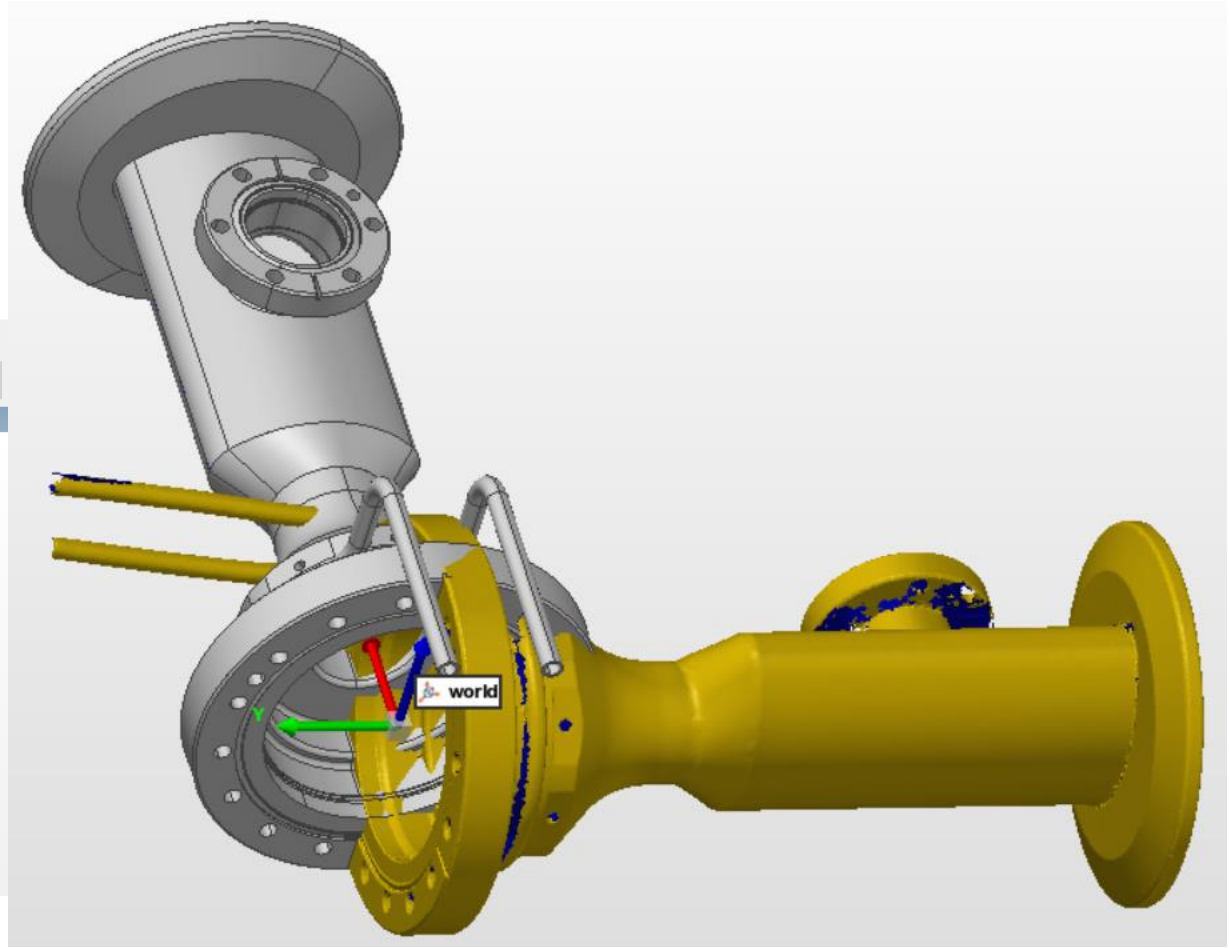


Practical session part 2 – part evaluation

Pre-alignment

Align the scan of the Vacuum chamber scan to the CAD model using a best-fit alignment.

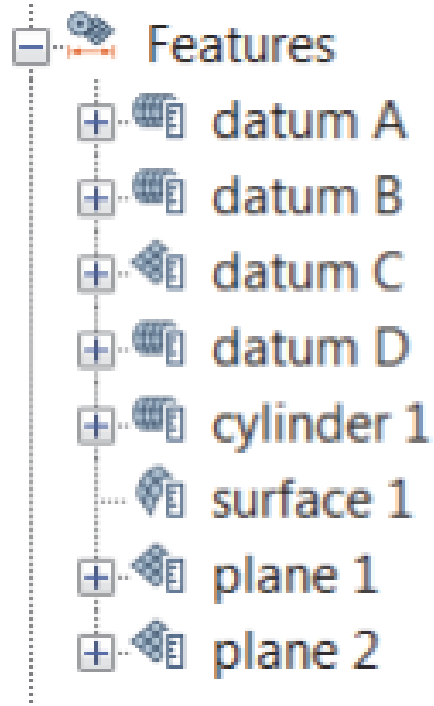




Practical session part 2 – part evaluation

Extract measured components

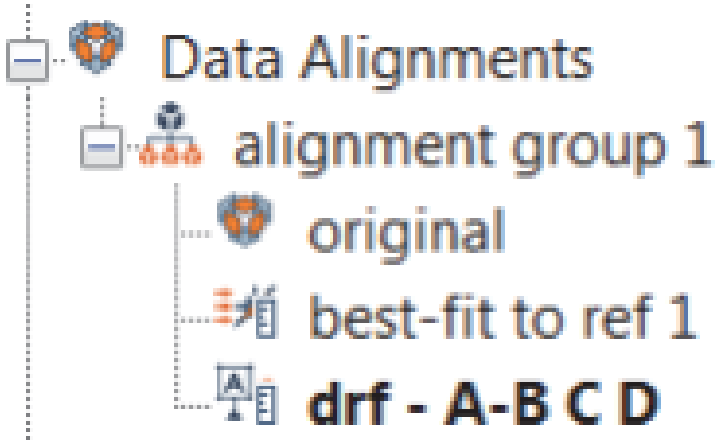
Select the features in the Tree View and extract their measured components.



Practical session part 2 – part evaluation

Create ABC alignment

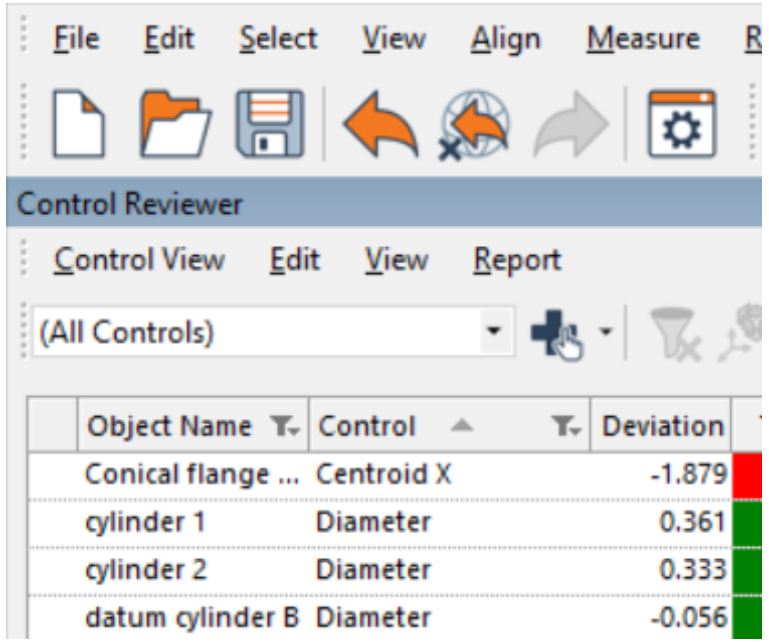
Perform a Datum Reference Frame alignment that uses datum composite A, B, and C.



Practical session part 2 – part evaluation

Extract measured components

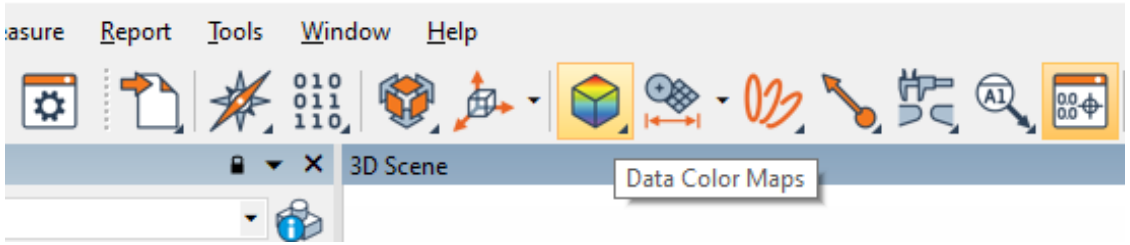
Review the measurement results.

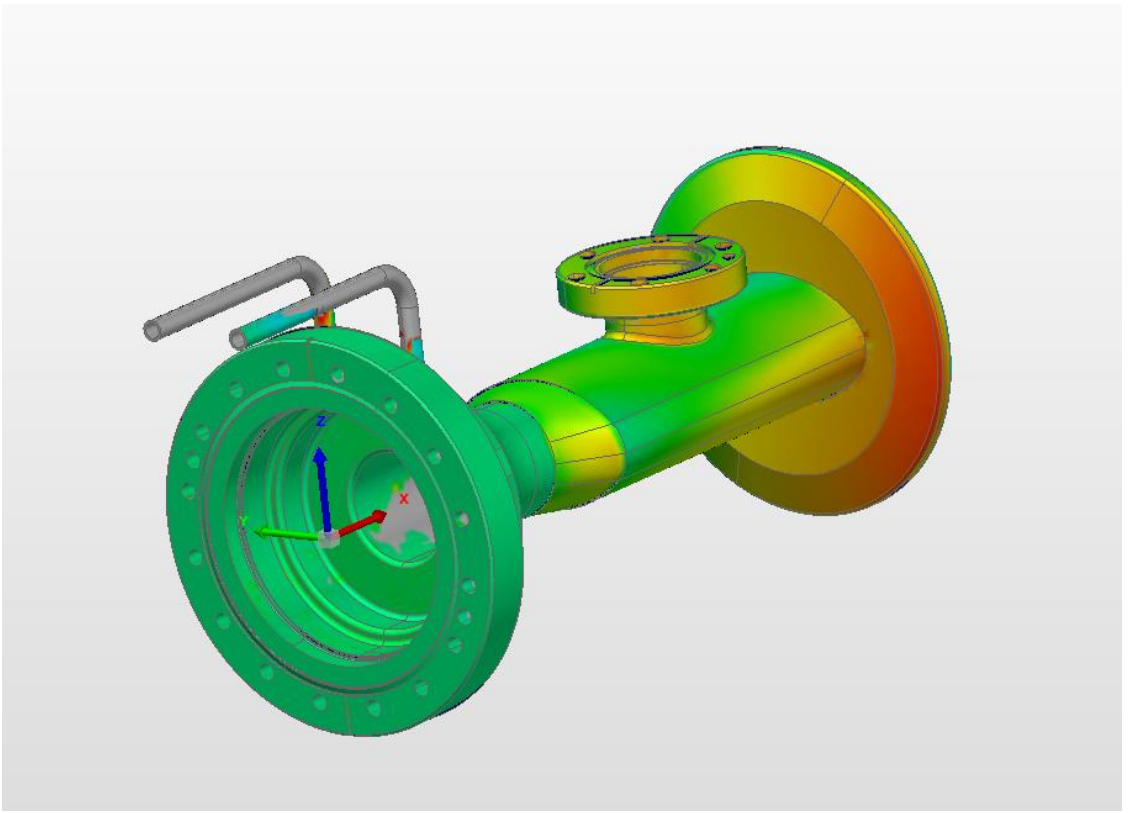


Practical session part 2 – part evaluation

Color mapping

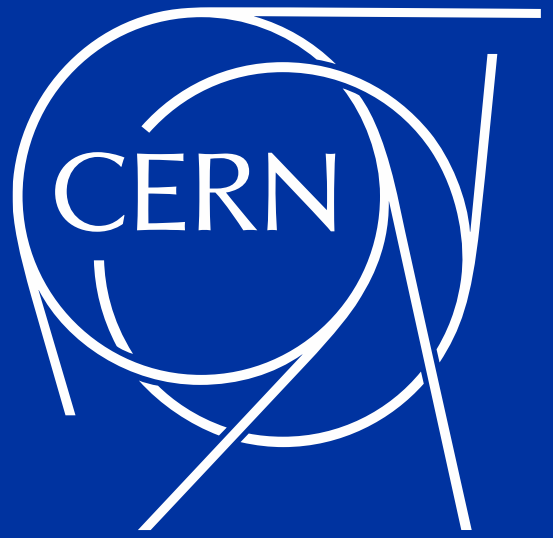
Create a data color map to visualize deviations.





Discussion - questions

Based on the results, can you please justify if the alignment was correctly performed ?


CERN