



Adaptative online monitoring with X-ray imaging methods using data fusion

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Outline

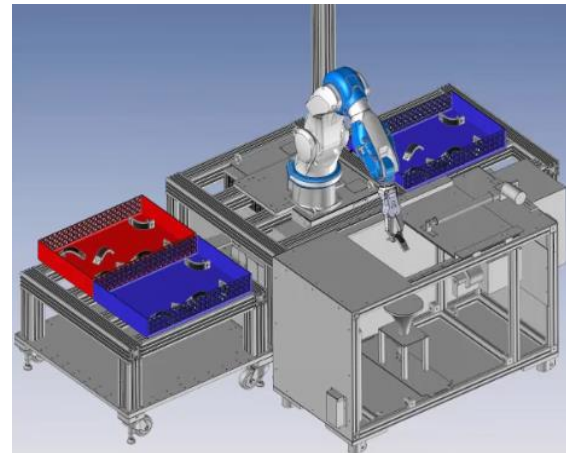
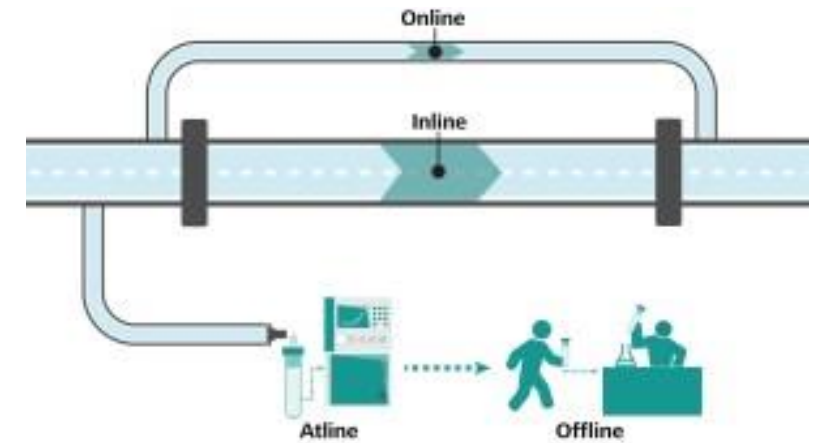
1. Introduction
2. Automatized inspection with digital radiography (DR)
3. Automatized inspection with X-ray Computed Tomography (XCT)
4. Conclusions

1. INTRODUCTION : ONLINE / INLINE MONITORING WITH X-RAY IMAGING METHODS

Industrial needs and application cases:

- Quality Control (QC):
 - A. 100% inspection for special parts / products
 - B. fast QC on sampled parts
- Adaptability : varying product geometry, materials (small series)

Monitoring → Automatized decision process

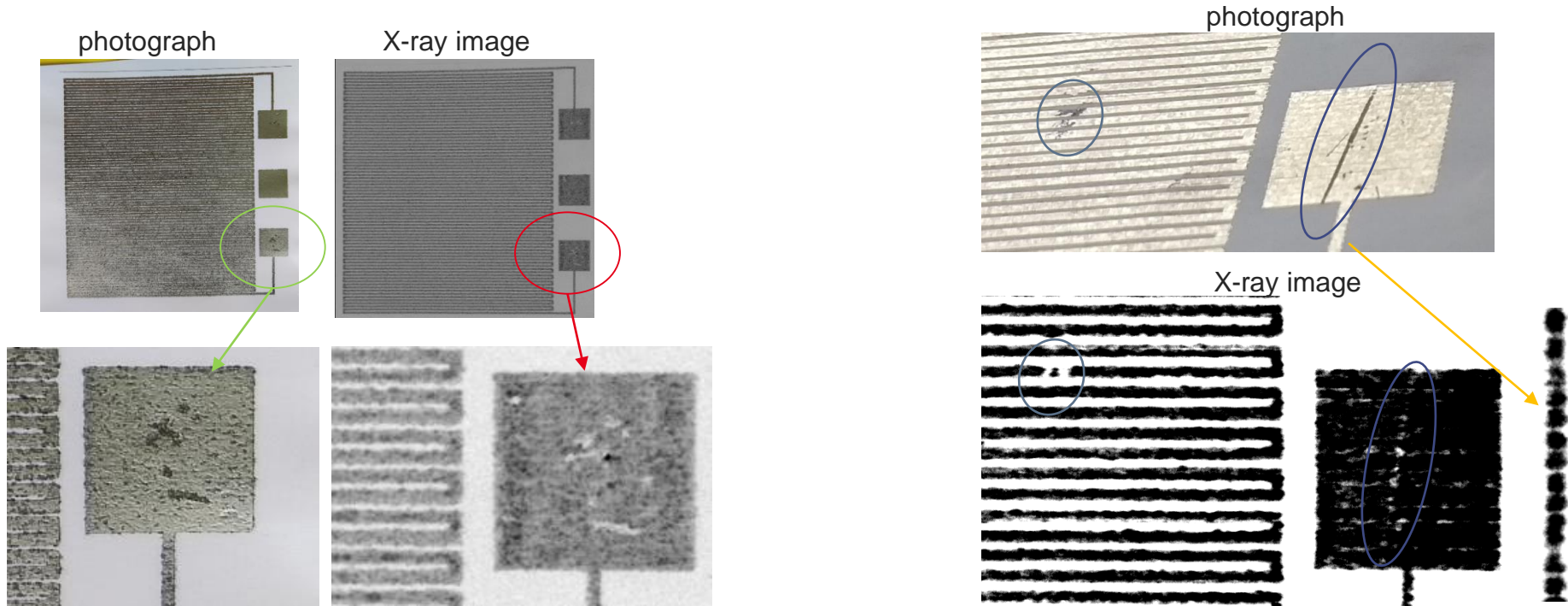


Prototype devices for online monitoring using data fusion approaches

1. INTRODUCTION : ONLINE / INLINE MONITORING WITH X-RAY IMAGING METHODS

Application and needs in 2D imaging

LEE-BED project: Quality control of lightweight printed electronic products → in-line / on-line monitoring mode



QC needs: non-destructive, high spatial resolution and high contrast resolution

Proposed solution: X-ray imaging, conveyor setup with geometrical magnification and data fusion

1. INTRODUCTION : ONLINE / INLINE MONITORING WITH X-RAY IMAGING METHODS

Application and needs in 3D imaging

DIMOFAC project: Quality control of polymer printed products → improve the QC process

QC needs: non-destructive, modular & adaptative device

Proposed solution: X-ray Computed Tomography (XCT), modular and automatized setup

Adaptative inspection for :

- A. **Dimensional conformity**
- B. **Defect analysis**

→ with DR (single or multi-view) or XCT (reduced or full dataset)



sculpteo
A brand of BASF - We create chemistry



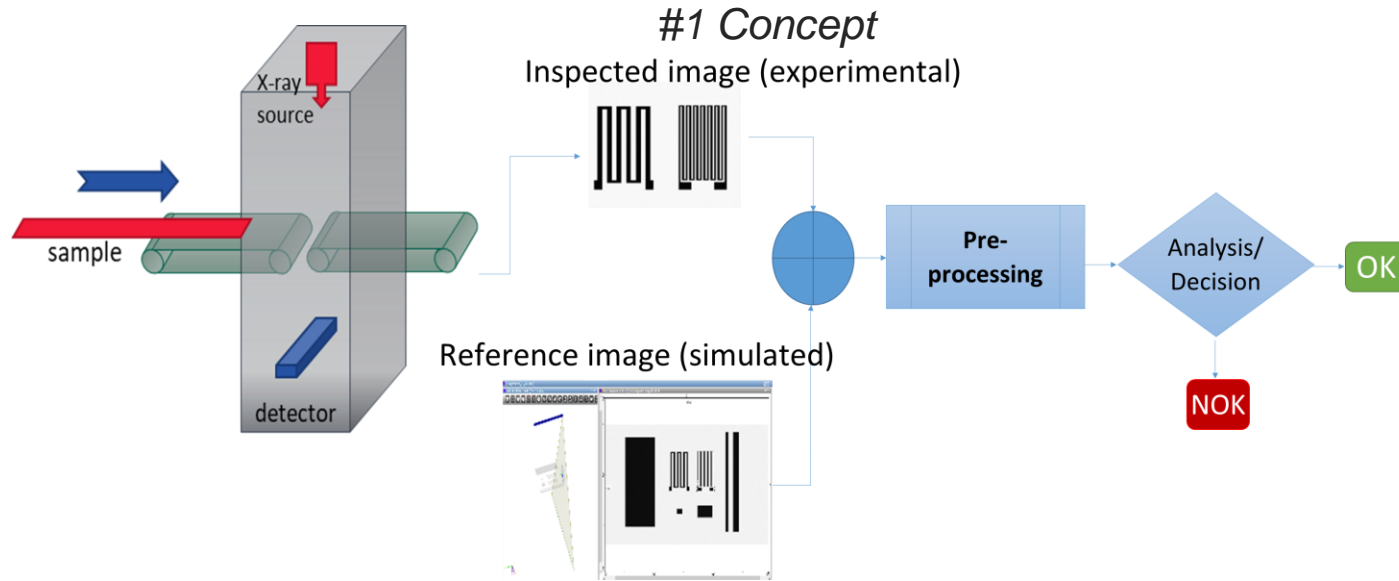
PA12 printed parts examples

Outline

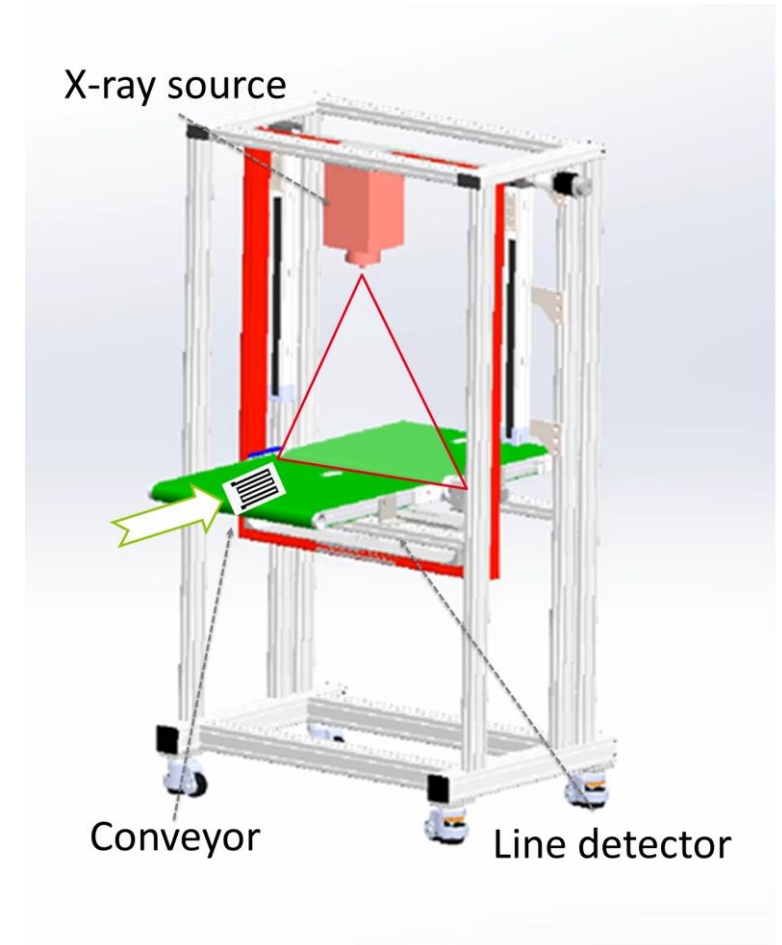
1. Introduction
- 2. Automatized inspection with DR**
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2. AUTOMATIZED INSPECTION ON RADIOGRAPHIC IMAGES

Concept for an adapted inspection device for lightweight electronic products



#2 CAD model of prototype



Source: μ focus tube 130 kVp

Detector: TDI (photon counting), pixel pitch 100 μ m, max scan speed/module 20kHz

Continuous acquisition : adjustable conveyor speed : 1 mm/s \rightarrow 100 mm/s

Sample (thickness & material): 0 \rightarrow 20 mm (e.g.: polymers \nearrow 20mm, Ag \nearrow 1mm)

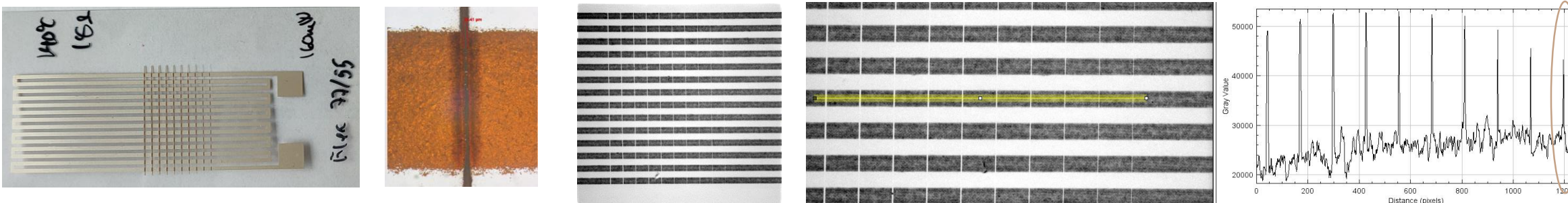
Magnification & image pixel size :

- X6 : 16.6 μ m/px, width = 100 mm
- X2 : 50 μ m/px, width = 300 mm
- X1 : 90 μ m/px, width = 600 mm

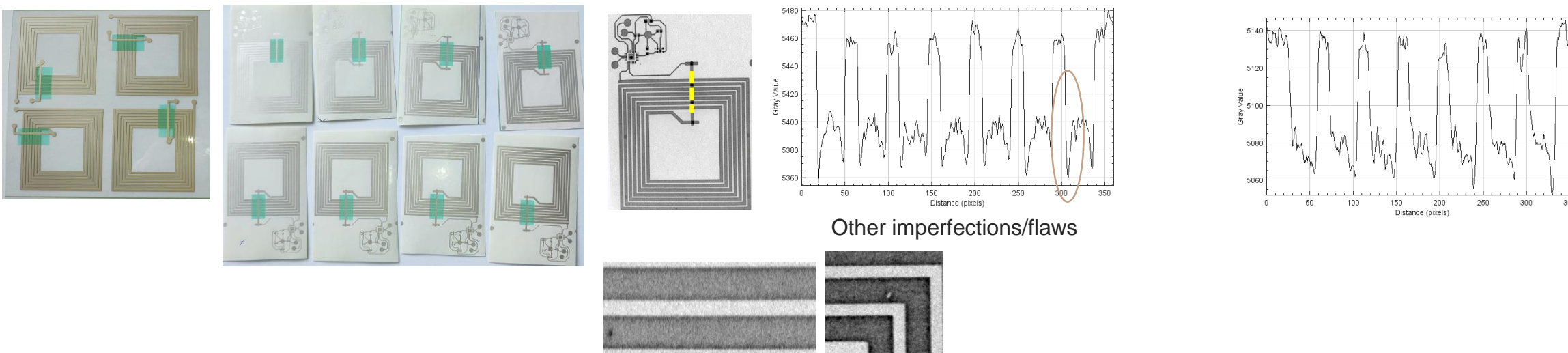
2. AUTOMATIZED INSPECTION ON RADIOGRAPHIC IMAGES

Results on printed electronics samples (X6 : 16.6 $\mu\text{m}/\text{px}$)

1. DTI produced screen print test samples + laser ablation (125 μm \rightarrow 22 μm width) \rightarrow verify device performances



2. ITENE sent OK and NOK (electrically) samples for checks \rightarrow difference observed but needs further investigation \rightarrow 20 μm cracks can be identified



\rightarrow Spatial resolution <20 μm , good contrast for tested samples

2. AUTOMATIZED INSPECTION ON RADIOGRAPHIC IMAGES



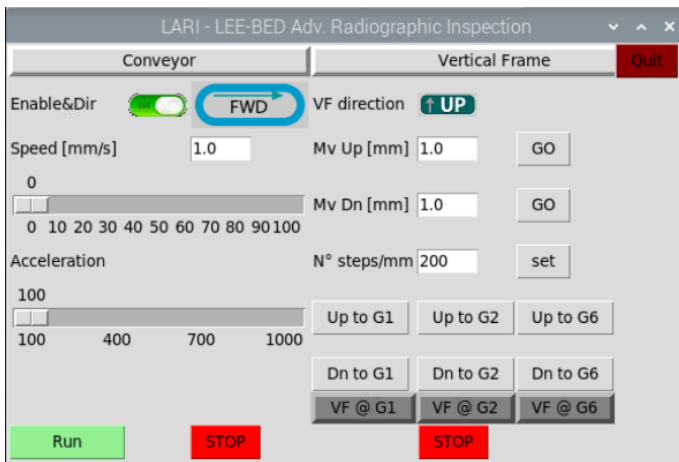
Implementation : Control and automated analysis software, demonstrator system

#5 Prototype device

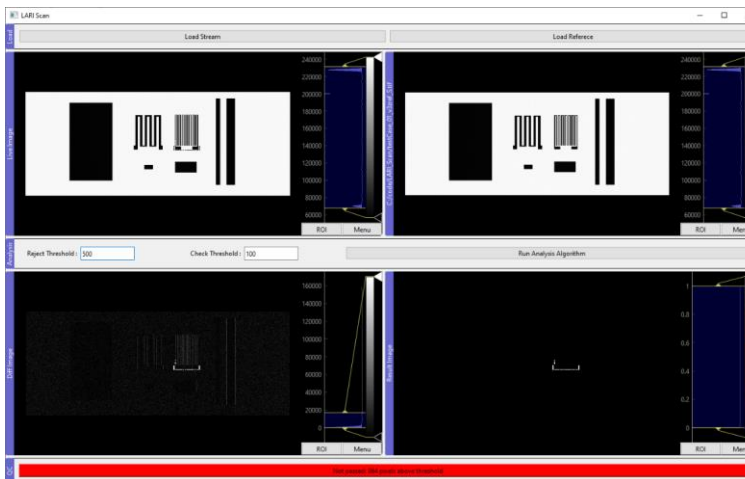
#3 Machine control software
→ RaspberryPi



- A. Conveyor
- B. Magnification factor



#4 Analysis and automated decision
→ in house software



LARI Scan: working principle

- #1 Load image folder or a stream of images
- #2 Load a reference image (flaw-free or simulated)
- #3 Run analysis algorithm (registration + subtraction)

→ if $NoPxDiff > thresholdReject$ → **Reject sample**

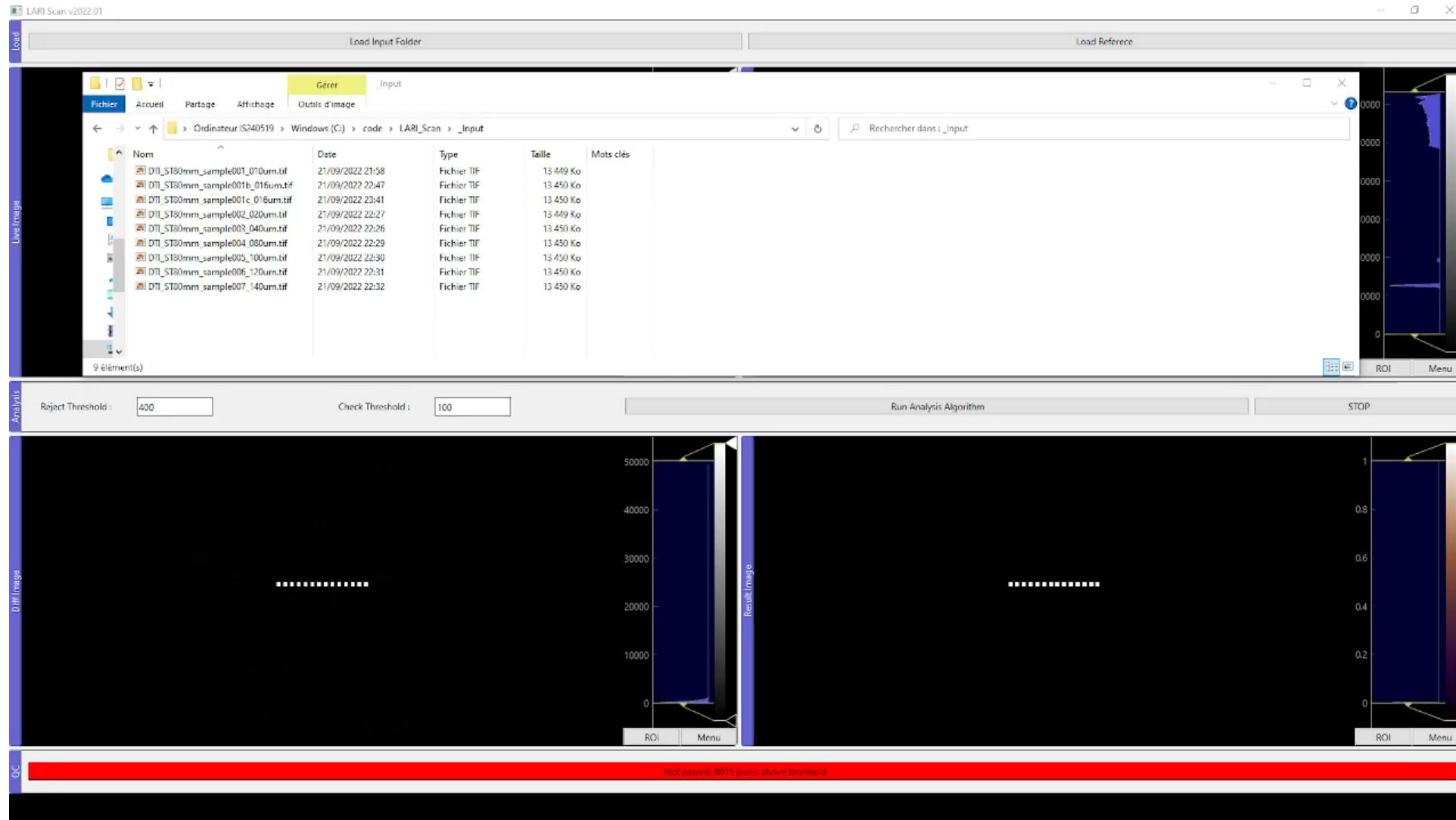
else if $NoPxDiff > thresholdCheck$ → **Check sample**

else SampleOK → **QC Passed**



2. AUTOMATIZED INSPECTION ON RADIOGRAPHIC IMAGES

Implementation : demonstrator



The screenshot displays the LARI Scan v2022.01 software interface. At the top, there are two input fields: "Load Input Folder" and "Load Reference". Below these is a file explorer window showing a list of files in the "_input" folder. The files are TIF images with names like "DTI_ST80mm_sample001_070um.tif" and sizes around 13.450 Ko. The interface includes a "Load" button, a "Gérer" menu, and a search bar. Below the file explorer, there are two input fields for "Reject Threshold" (set to 400) and "Check Threshold" (set to 100), along with "Run Analysis Algorithm" and "STOP" buttons. The main area shows two histograms: "Diff Image" on the left and "Result Image" on the right. The "Diff Image" histogram has a y-axis from 0 to 50000, and the "Result Image" histogram has a y-axis from 0 to 1. Both histograms show a distribution of values with a peak around 10000. At the bottom, a red status bar indicates "NOT passed: 0070: pixel above threshold".

Nom	Date	Type	Taille	Mots clés
DTI_ST80mm_sample001_070um.tif	21/09/2022 21:58	Fichier TIF	13 449 Ko	
DTI_ST80mm_sample001b_016um.tif	21/09/2022 22:47	Fichier TIF	13 450 Ko	
DTI_ST80mm_sample001c_016um.tif	21/09/2022 23:41	Fichier TIF	13 450 Ko	
DTI_ST80mm_sample002_020um.tif	21/09/2022 22:27	Fichier TIF	13 449 Ko	
DTI_ST80mm_sample003_040um.tif	21/09/2022 22:26	Fichier TIF	13 450 Ko	
DTI_ST80mm_sample004_080um.tif	21/09/2022 22:29	Fichier TIF	13 450 Ko	
DTI_ST80mm_sample005_100um.tif	21/09/2022 22:30	Fichier TIF	13 450 Ko	
DTI_ST80mm_sample006_120um.tif	21/09/2022 22:31	Fichier TIF	13 450 Ko	
DTI_ST80mm_sample007_140um.tif	21/09/2022 22:32	Fichier TIF	13 450 Ko	

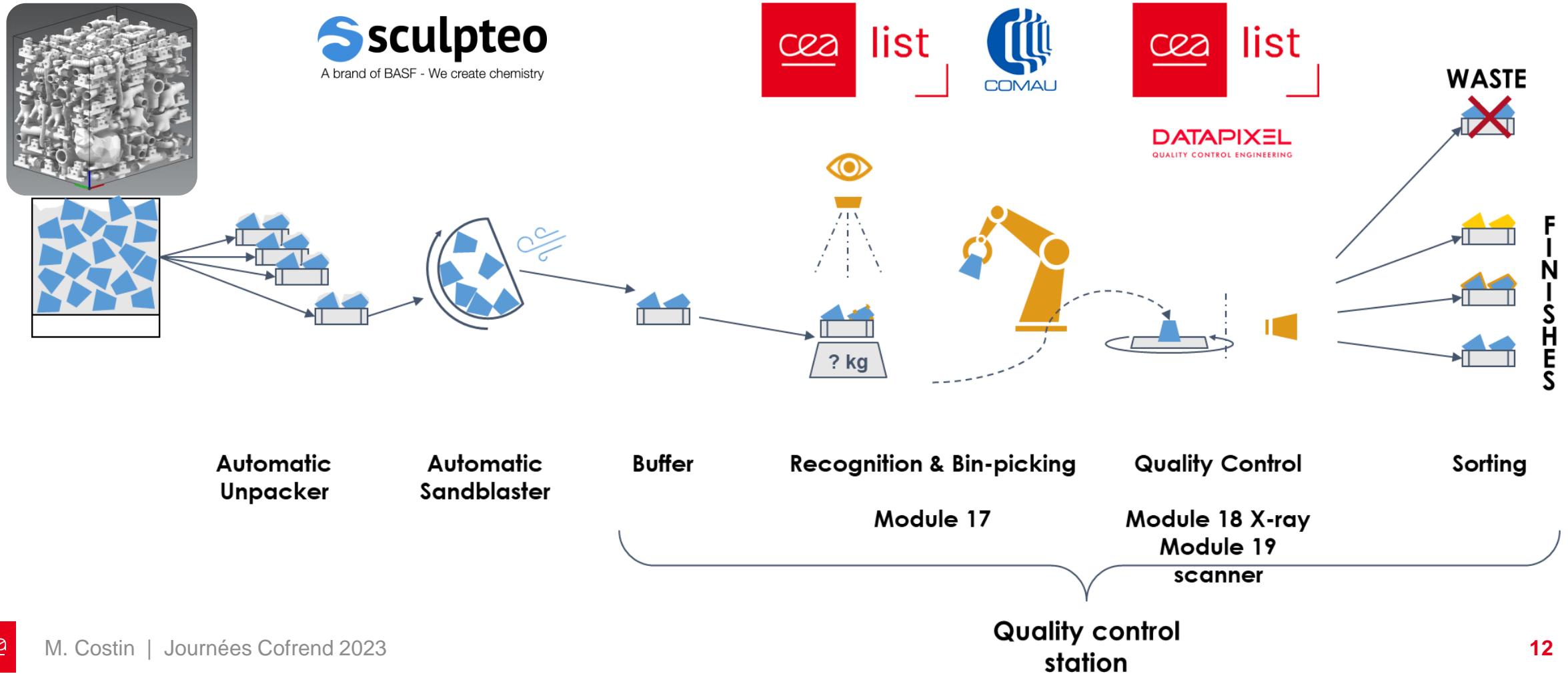
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3. AUTOMATIZED INSPECTION WITH XCT

Needs and production chain : Selective Laser Sintering in batch mode

QC : *Modular (used only when requested by order, work in synchronization with bin-picking module, interchangeable)*
Adaptative / flexible for new part geometries



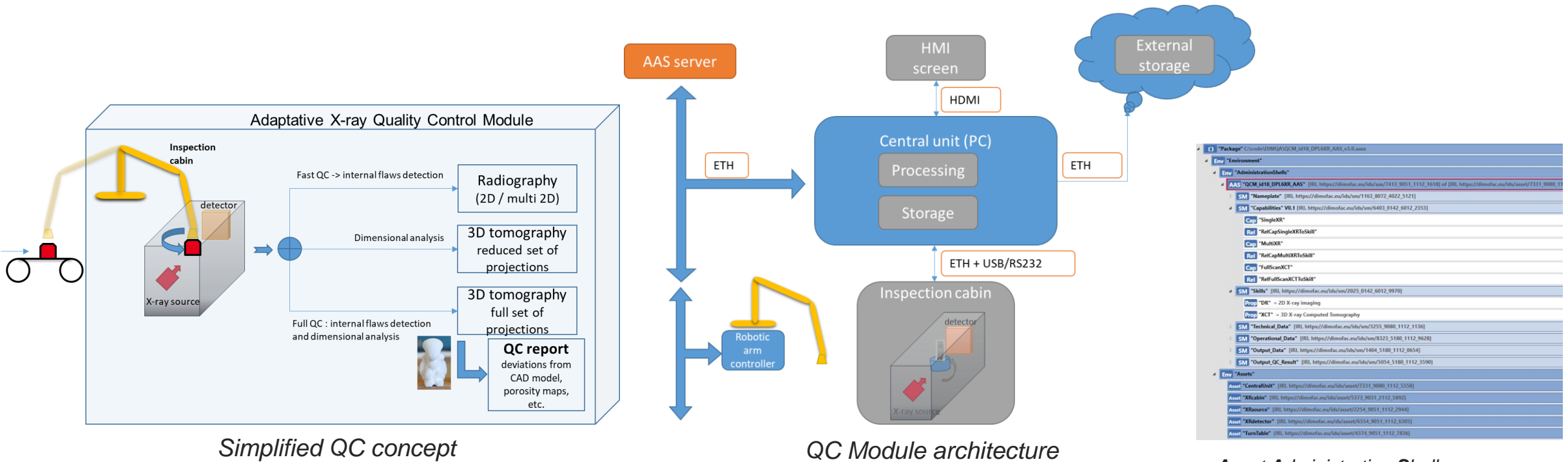
3. AUTOMATIZED INSPECTION WITH XCT



Concept and design : Automated inspection cabin, samples transferred with a pick-and-place robotic arm

→ Modularity (plug-and-play) : connection to a production chain through the *DIMOFAC software platform*

→ Adaptability : use the CAD model of the inspected parts

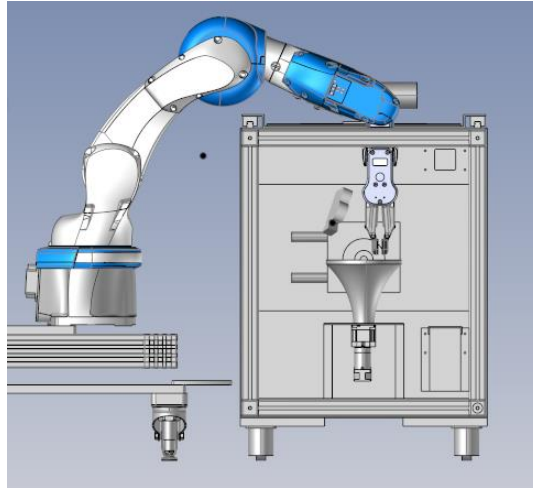
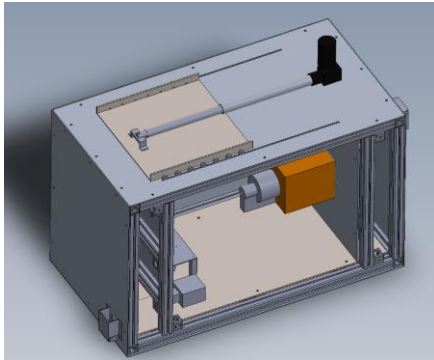


*Asset Administration Shell
intercommunication & data exchange*

3. AUTOMATIZED INSPECTION WITH XCT



Concept and design : automated inspection cabin



Main elements :

- Source: μ focus tube 130 kVp
- Detector: Digital Detector Array (cone-beam configuration), 1024x1024 pixels, pitch 200 μ m
- Turntable: min step 0.0225°, max load ~45 kg
- Automatic door

Samples : \varnothing \nearrow 160 mm low attenuation materials (e.g.: polymers)

Magnification & image pixel size : fixed magnification 1.25x, voxel size 160 μ m³

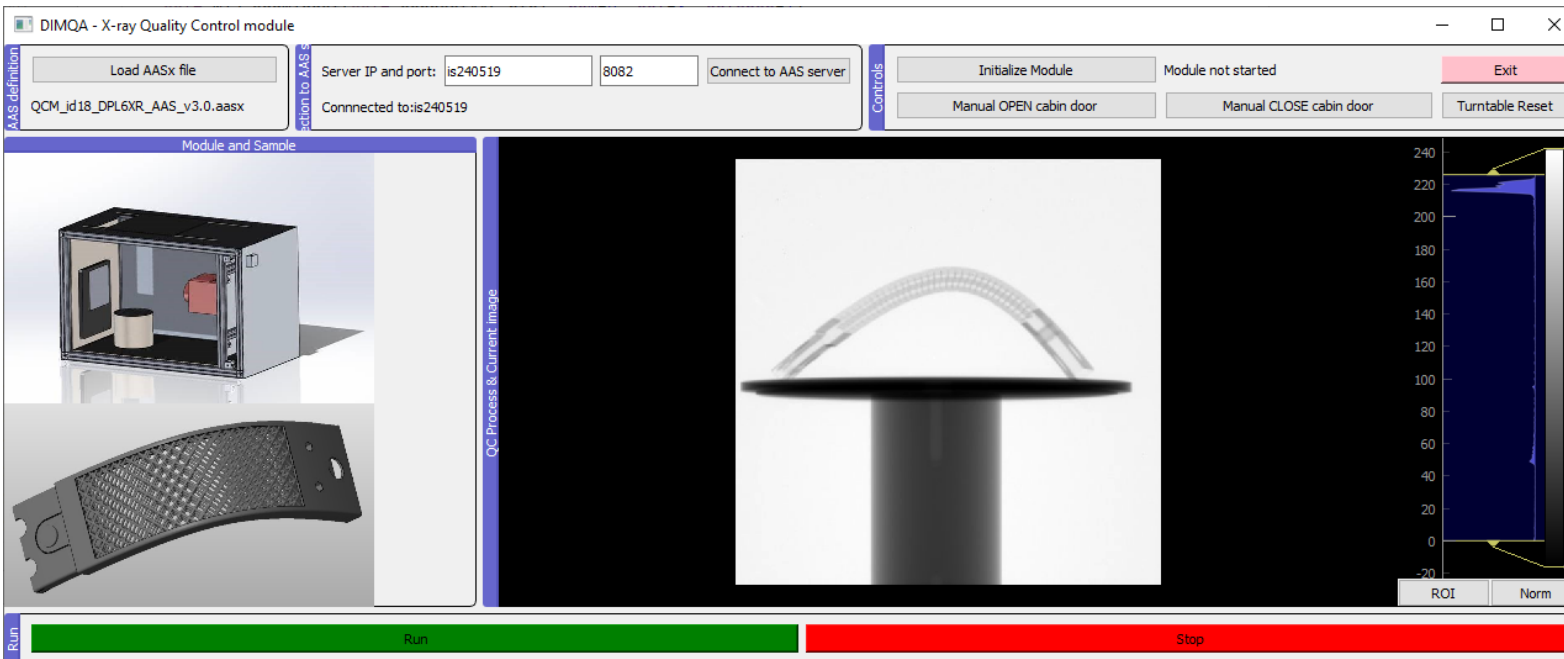
3. AUTOMATIZED INSPECTION WITH XCT



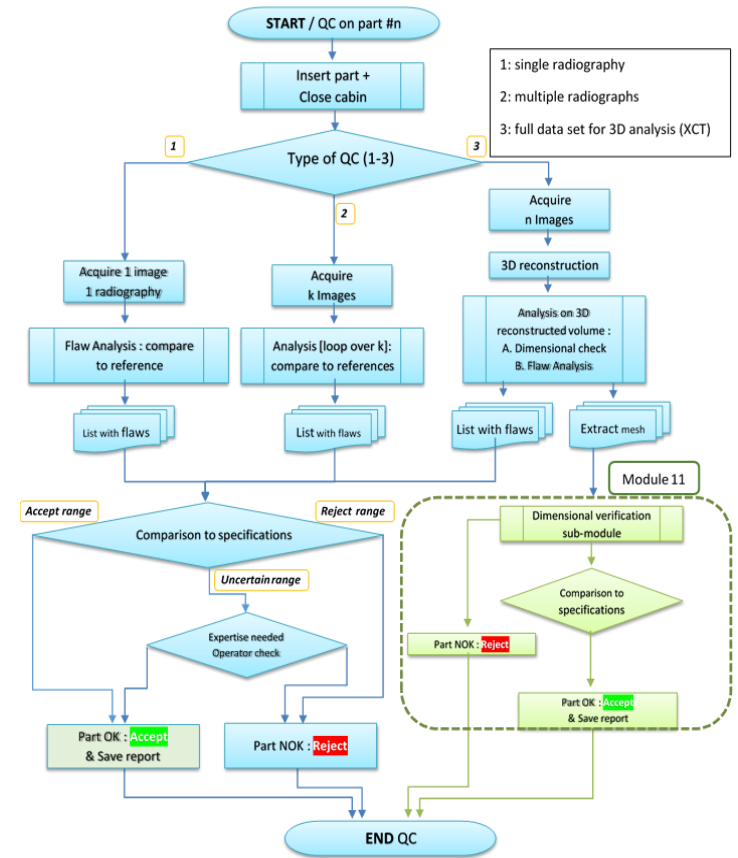
Implementation : Control GUI and inspection procedure

Main functionalities :

- Module initialization (load basic information from AASx model)
- Access door, turntable controls
- Connection to DIMOFAC server instance and manage operation following the flags on the orchestrator (sequential production)
- Run analysis on current part



Inspection procedure



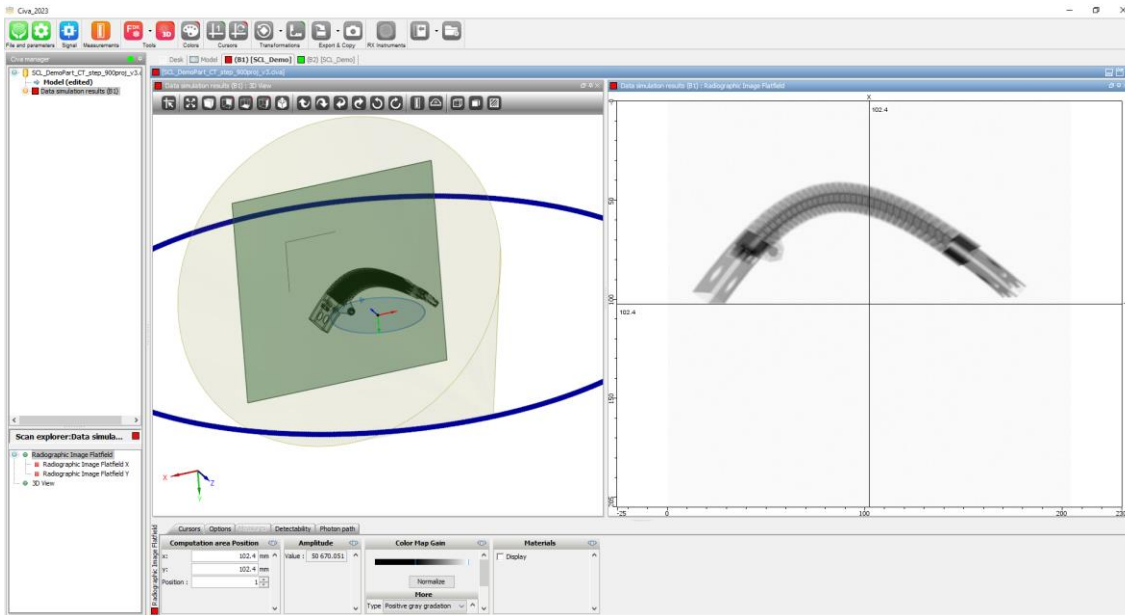
3. AUTOMATIZED INSPECTION WITH XCT



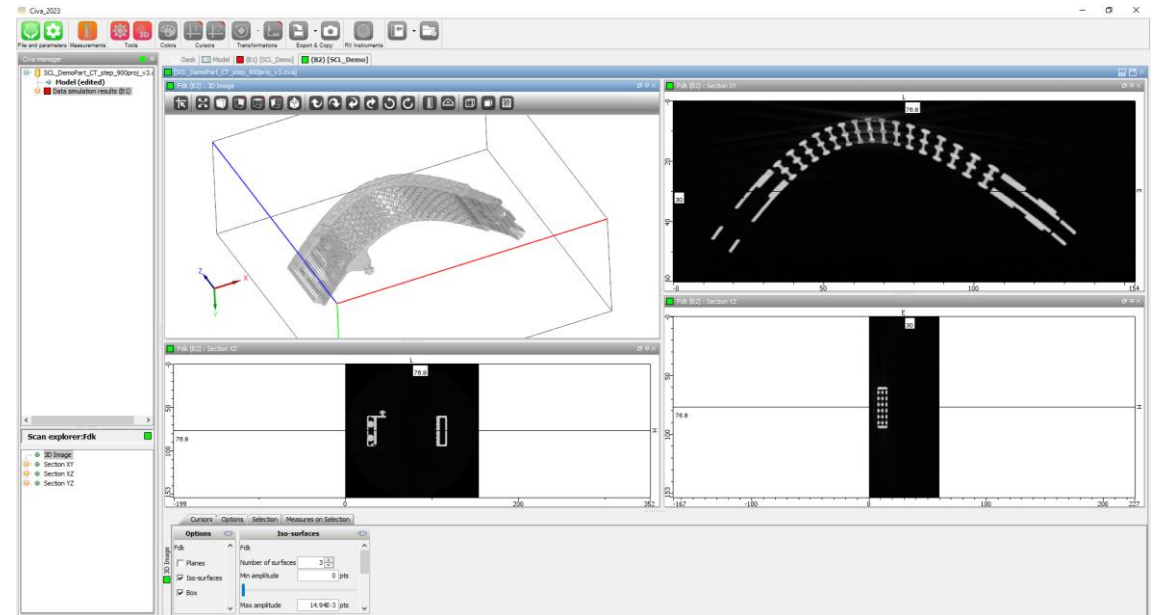
Simulation tools : CIVA CT

- Digital Twin : pre-configure / re-configure scan parameters
- simplified ray-tracing for volume registration and analysis
- reconstruction algorithm : FDK (classical/analytical) and/or iterative (reconstruction from reduced datasets → future)

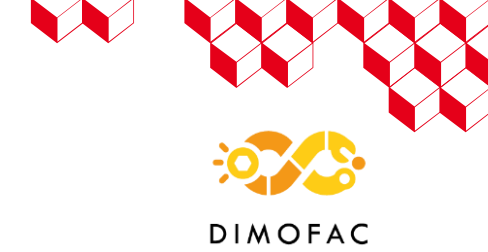
CIVA CT – simulation scene



CIVA CT – reconstruction results

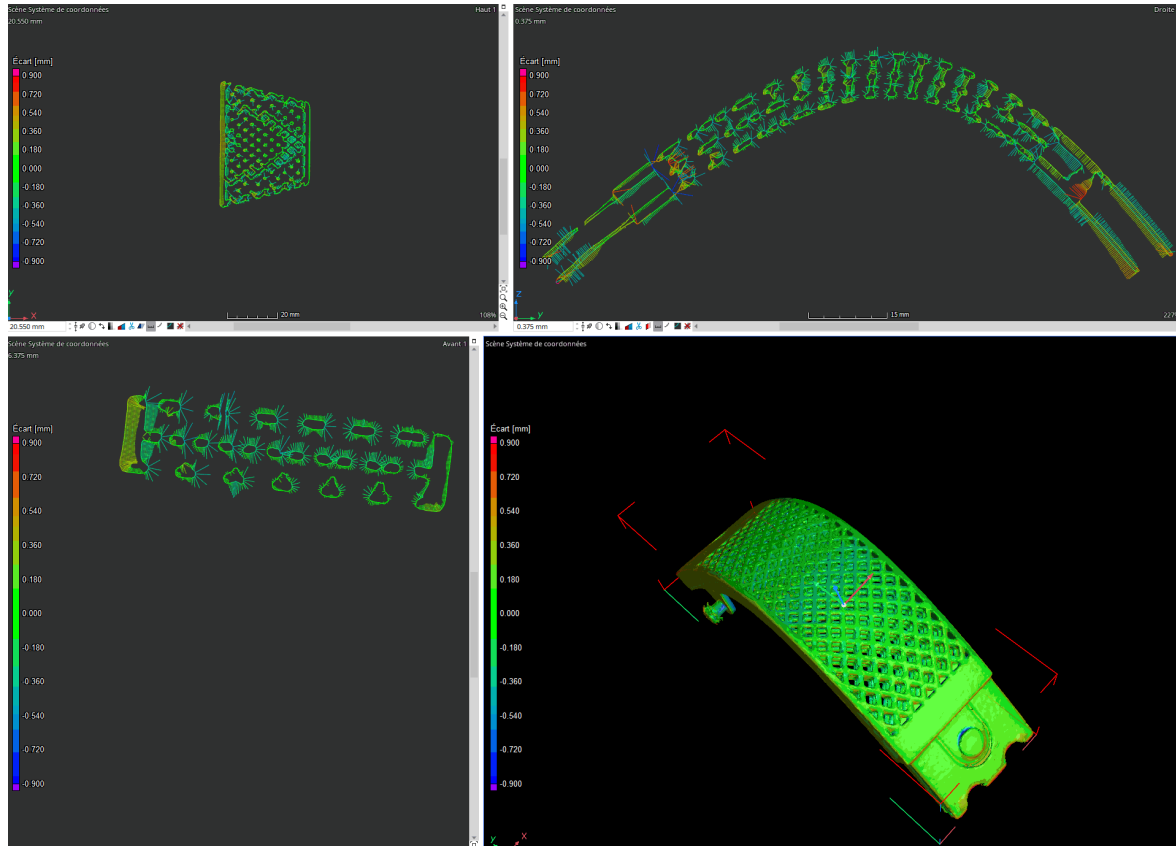


3. AUTOMATIZED INSPECTION WITH XCT

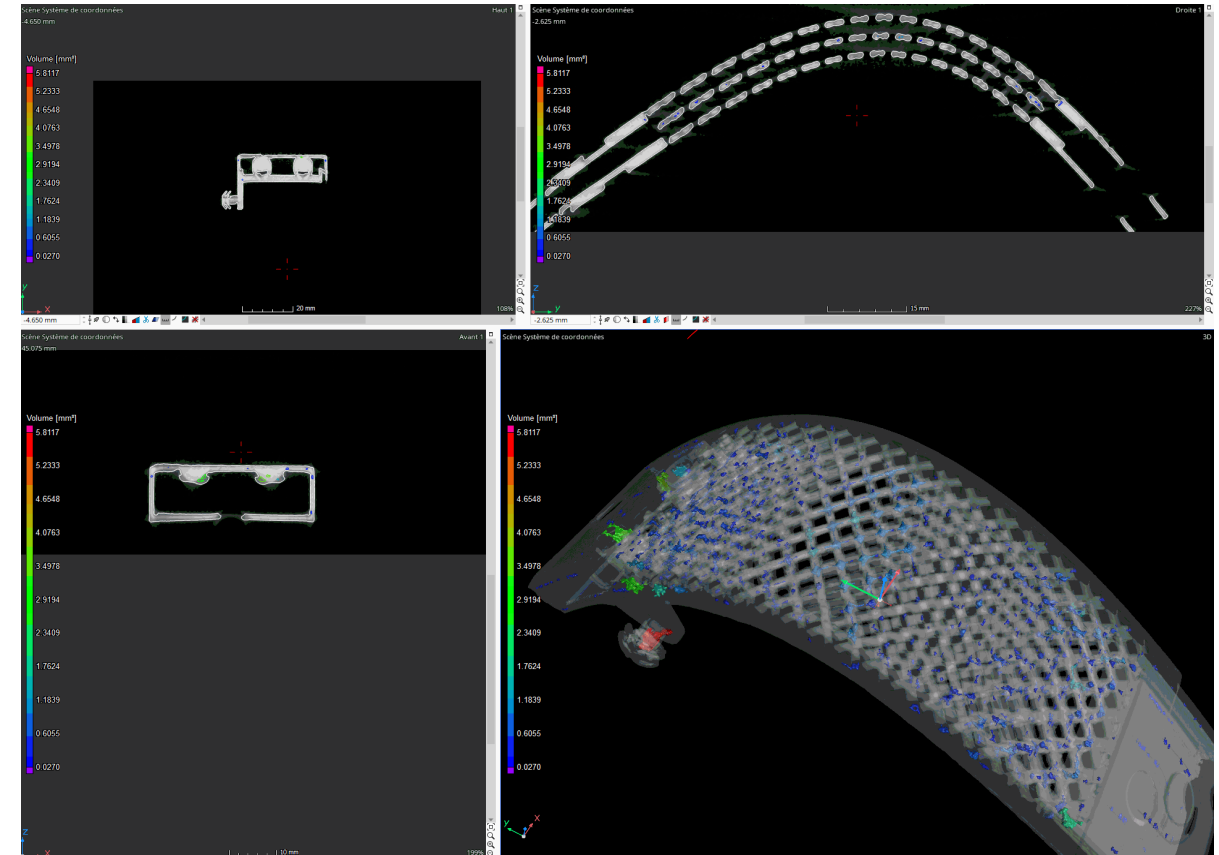


Results

A. Dimensional conformity → deviation map (3D)



B. Defect analysis → porosity map (3D)

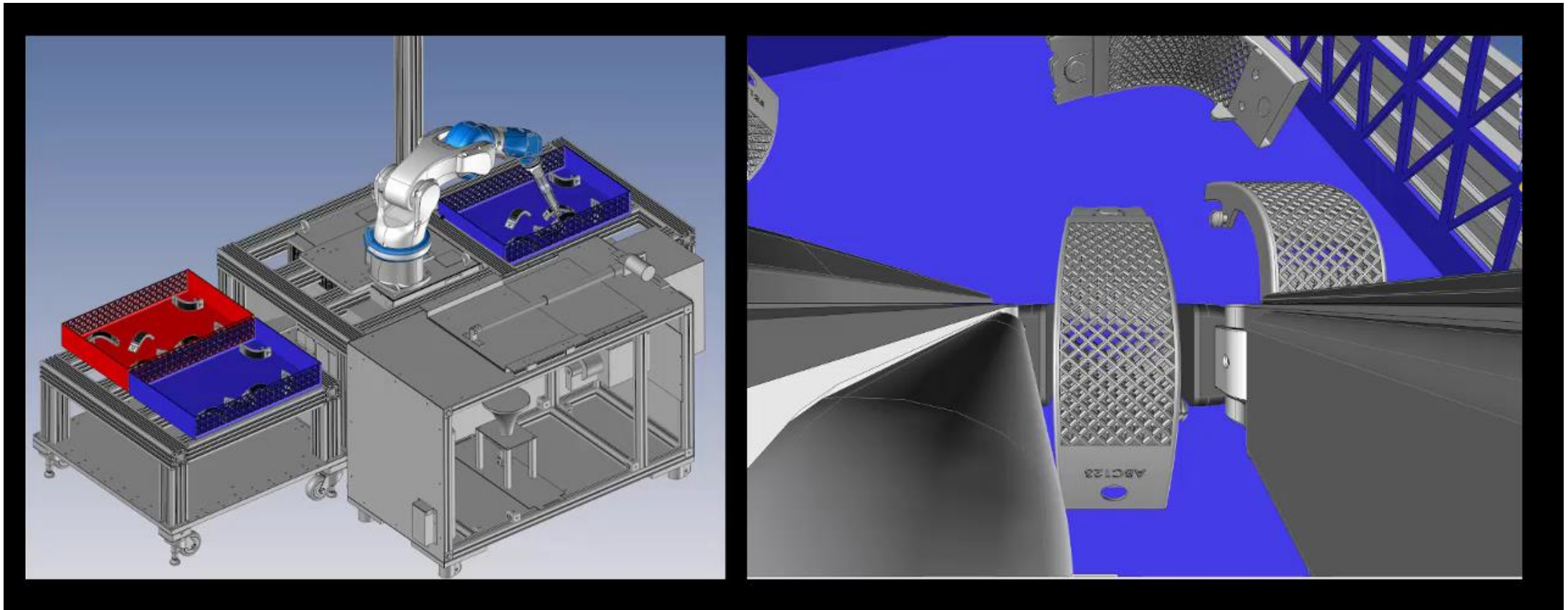


3. AUTOMATIZED INSPECTION WITH XCT

Implementation : foreseen use, Q4 2023 at CEA List (Paris-Saclay)

TopSolid

DIMOFAC



DIMOFAC Open Pilot lines : <https://dimofac.eu/expression-of-interest/> Submission deadline: 20th June 2023

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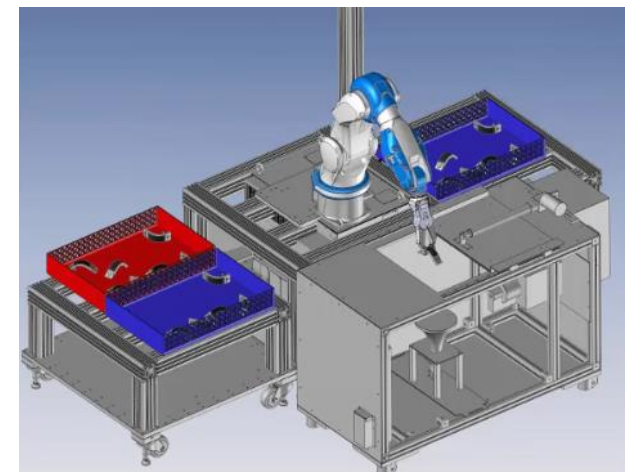
4. CONCLUSIONS

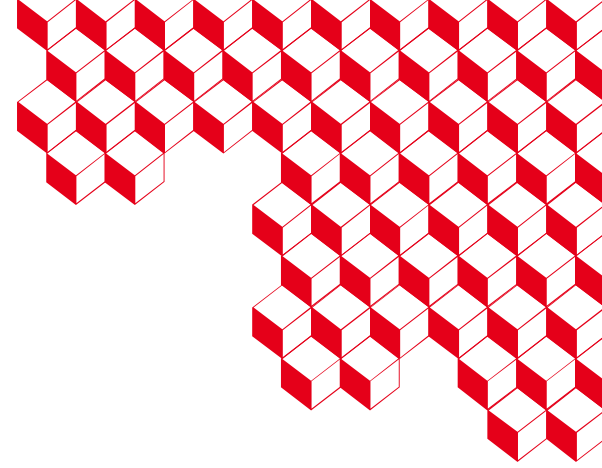
Conclusions

- ✓ Proof of concepts in 2D and 3D for automated inspection (monitoring) using data fusion (experimental and simulated)
- ✓ High level of adaptability for new configurations and samples
- ✓ Modularity

Future work:

- Optimize the software workflow
- Demonstration as a module within a pilot line





Thank you !



Acknowledgements & contacts



<https://www.lee-bed.eu/>



DIMOFAC

<https://www.dimofac.eu/>



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