NUCLEAR RESEARCH INSTITUTE

Machine Learning Application in Ultrasonic Testing of Weld

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CORE, 20.11.2025

UJV Group
PEOPLE | INNOVATION | TECHNOLOGY

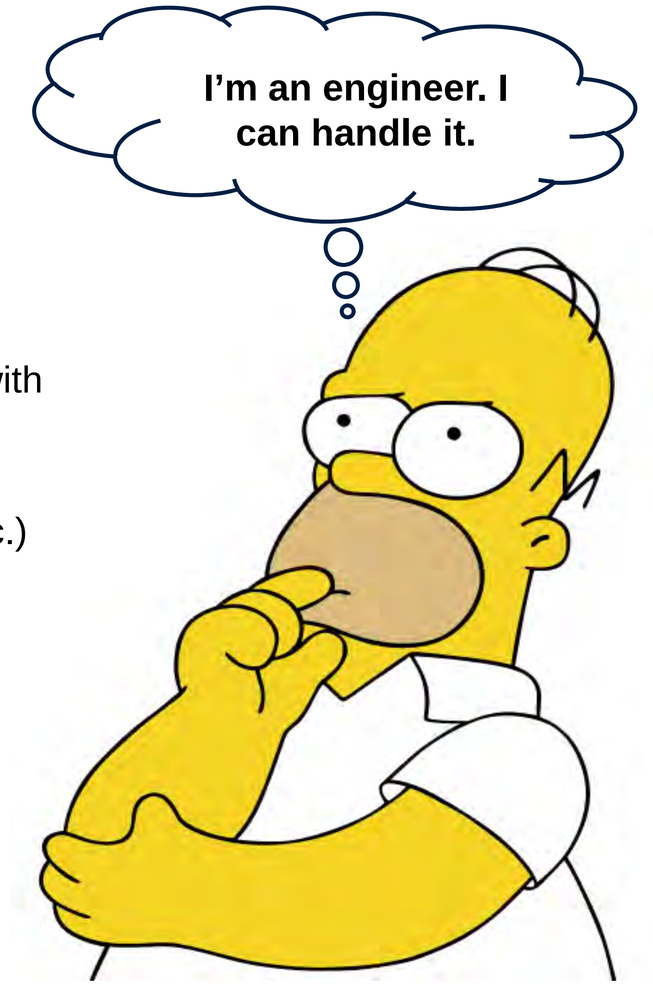
CEZ GROUP

UJV Group, a member of CEZ GROUP

A long time ago...

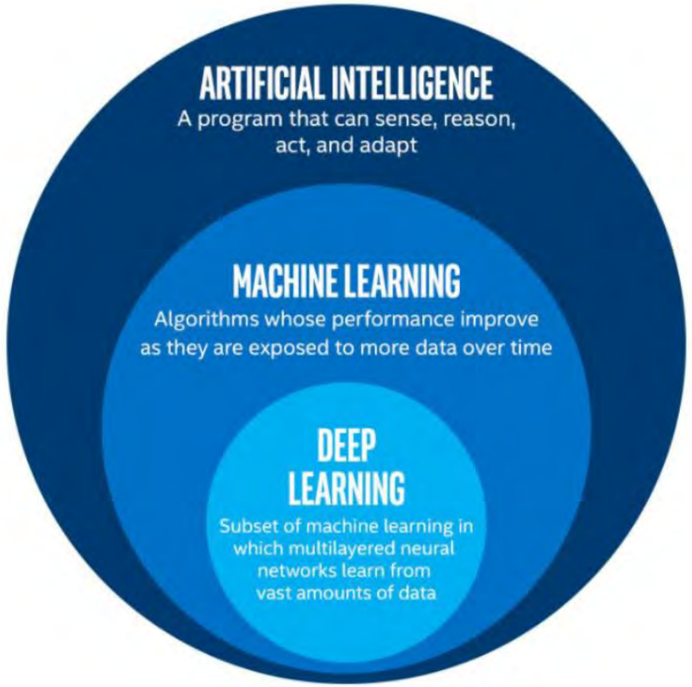
National project TAČR No. TM04000031:

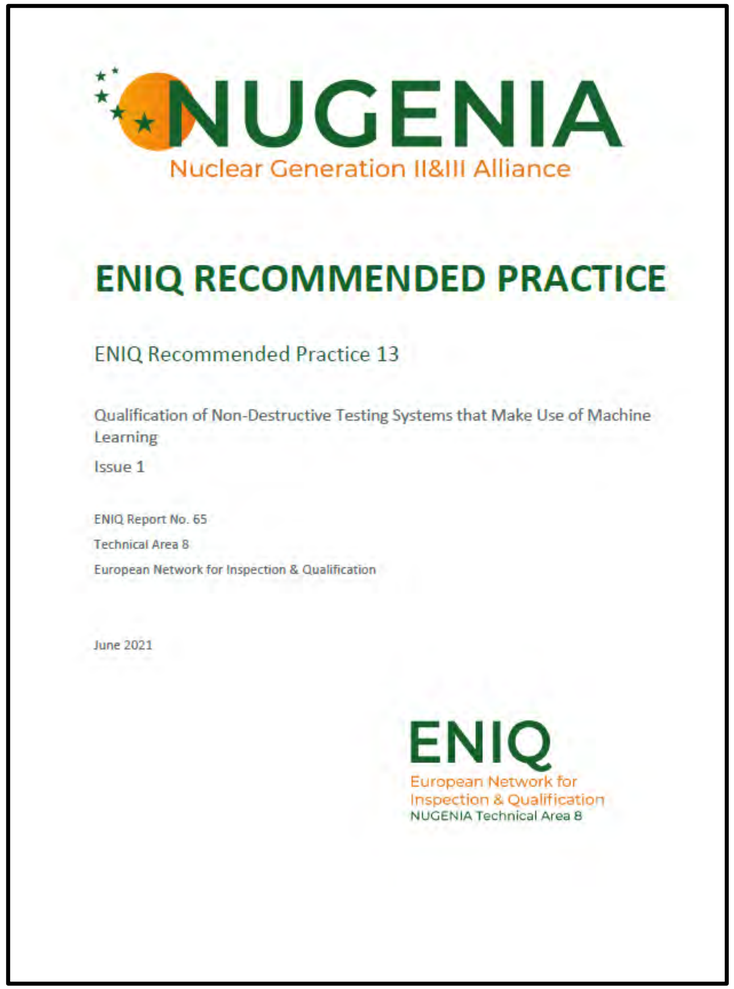
- participants: ÚJV + ZČU
- project Start: January 2023
- project End: December 2025
- main objective: to develop technology for the evaluation of flaws during UT, with a focus on Phased Array Ultrasonic Testing (PAUT). This includes:
  - integration of available PAUT equipment (ZIRCON, UltraVision, scanner, etc.)
  - enhancement of flaw detection capabilities through Machine Learning (ML)



ENIQ - RP13:

- **https://snetp.eu/eniq-reports/**
- RP13 will assist those involved in the qualification of non-destructive testing (NDT) systems that use machine learning (ML) models as part of the data analysis procedure




NUGENIA
Nuclear Generation II&III Alliance

ENIQ RECOMMENDED PRACTICE

ENIQ Recommended Practice 13

Qualification of Non-Destructive Testing Systems that Make Use of Machine Learning

Issue 1

ENIQ Report No. 65

Technical Area 8

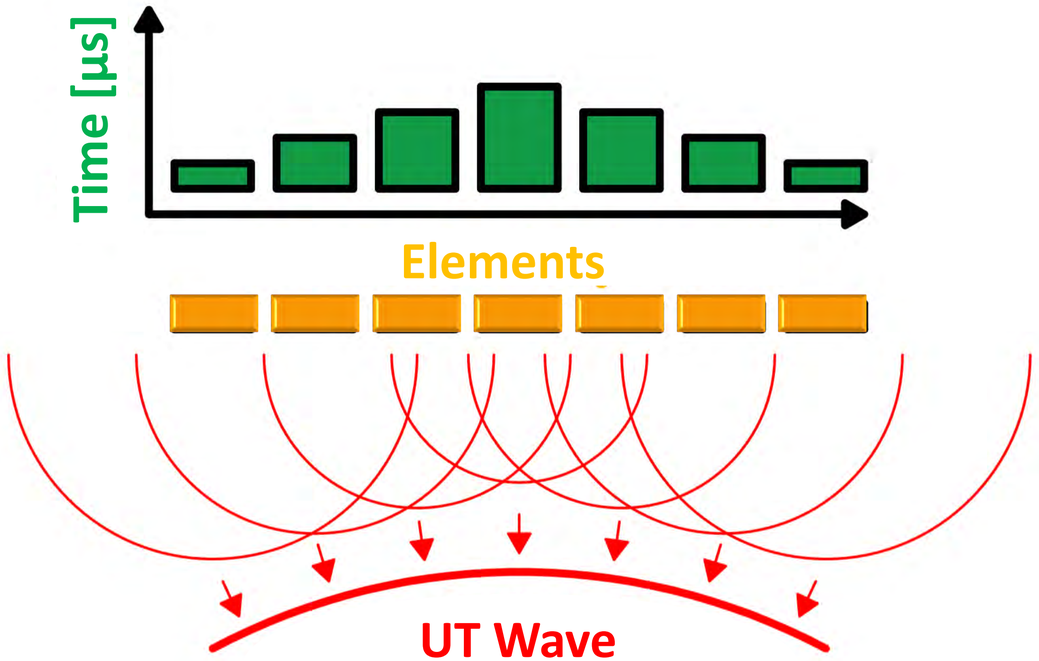
European Network for Inspection & Qualification

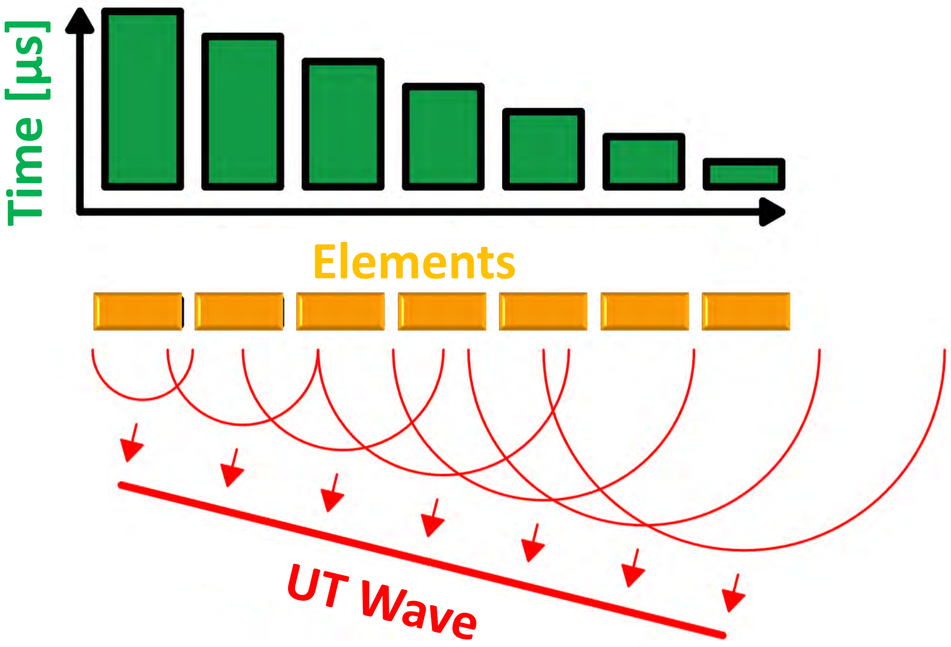
June 2021

ENIQ
European Network for Inspection & Qualification
NUGENIA Technical Area 8

How the UT-PA technique works?

- one UT-PA probe
- several elements (T/R)
- focal law (timing of elements)
- electronically control and focusing of beam





Advantages of the UT-PA technique:

B-Scan:

- SIDE - Scan/Depth axis

C-Scan:

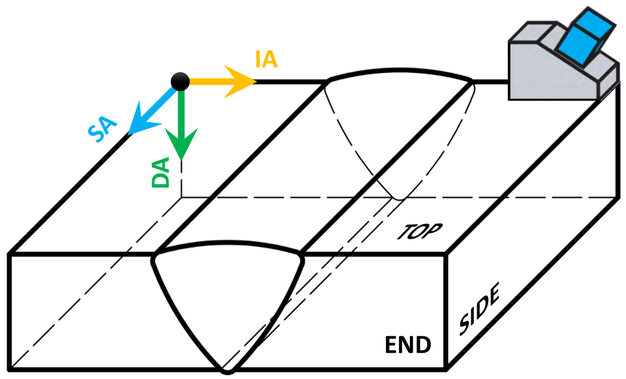
- TOP - Scan/Index axis

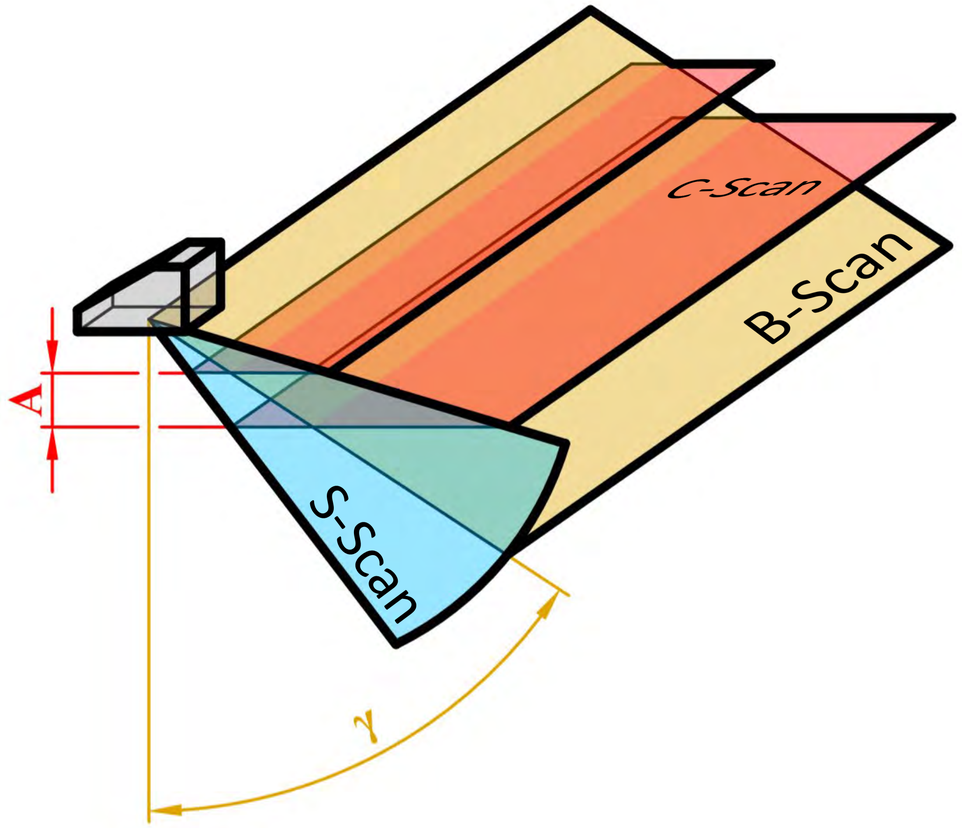
D-Scan:

- END - Index/Depth axis

S-Scan:

- Sector (Azimuthal) - Index/Depth axis + angle.



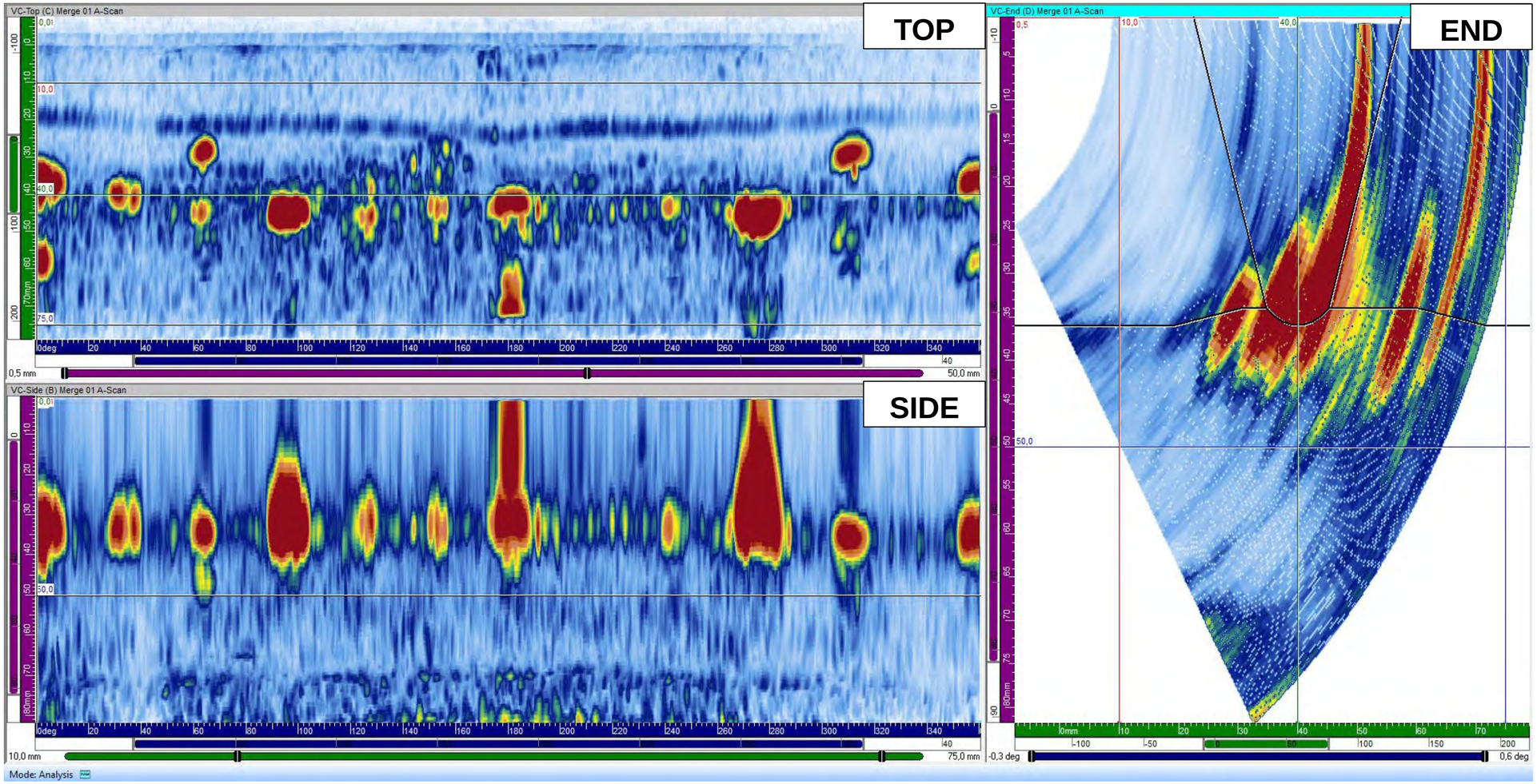


Physical mockup:

- stainless steel (DMW)
- ø351 mm, t= 34 mm
- weld symmetric V-Type + cladding
- real defects PBF-Type
- PAUT unit ZIRCON 32:128PR
- dual probe HQS 14B4-01 2.25 MHz
- sector range 35° - 89°, resolution 1°
- skew 270°, scan axis resolution 1 mm
- index offset 40 mm, couplant vaseline/water
- calibration standard PAUT IIW ISO 19675
- data acquisition in accordance with NDT procedure
- data evaluation by Level 3 in accordance with NDT procedure

Defects	Type
R1	PISC
R2	PISC
R3	PISC
R4	PISC
R5	PISC
R6	PBF
R7	PISC
R8	PISC
R9	PISC
R10	PBF

Physical mockup - .UVData file:



MVM1 tool developed by EPRI:

- **Without defining:**

the entire volume of .UVData file

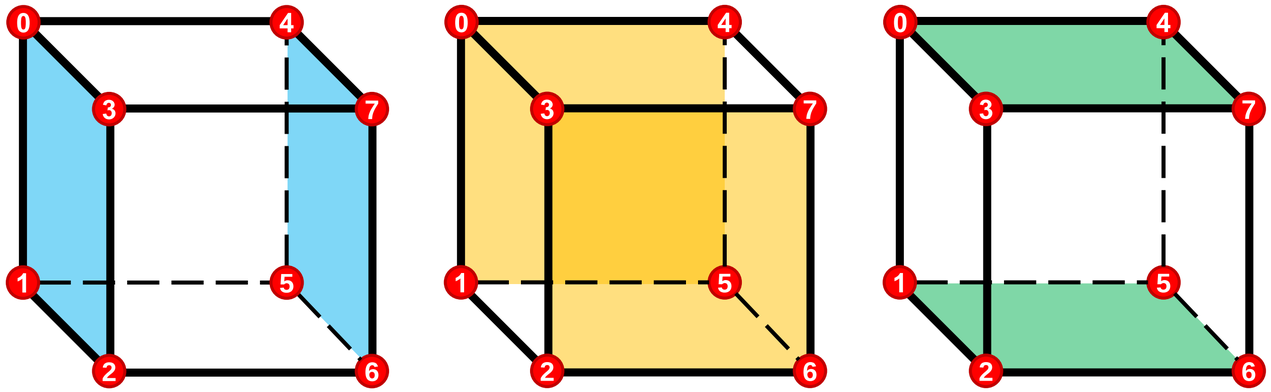
- **Edge definition:**

the volume in .UVData file is defined by its edges

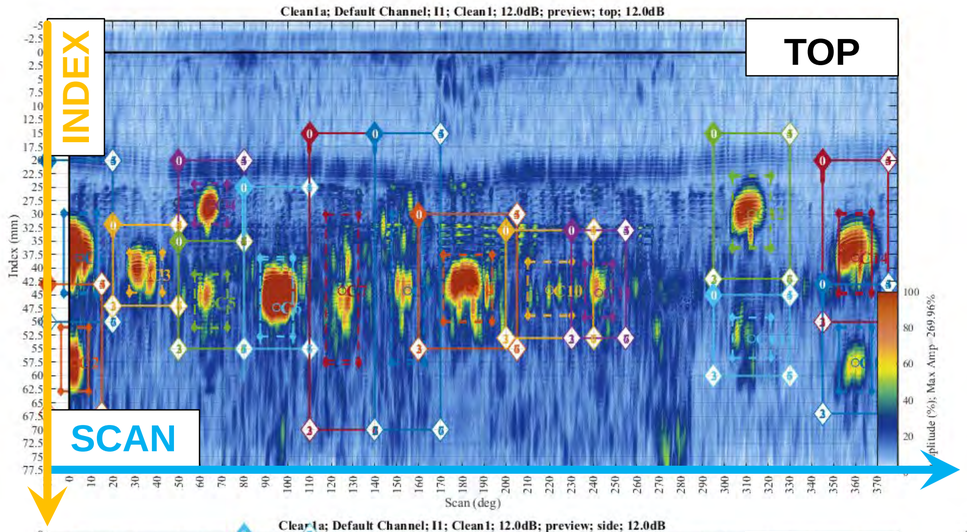
- **Vertex definition:**

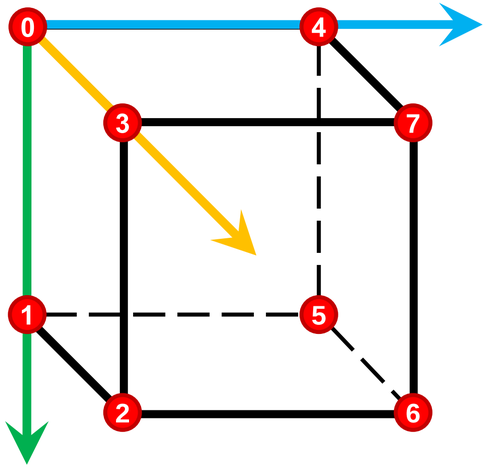
the volume in .UVData file is defined by its vertices

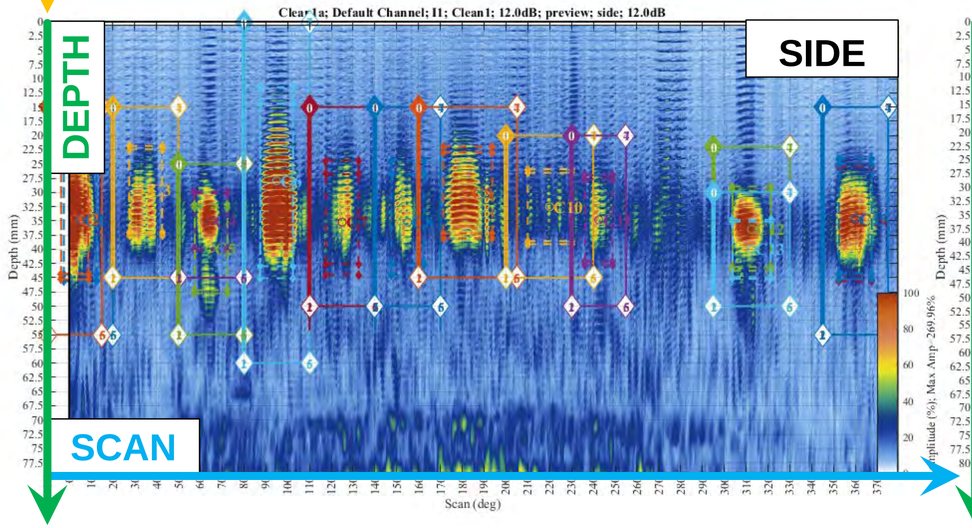
Vertex ID.	Edge definition ID		
	Scan	Index	Depth
0	0	0	0
1	0	0	1
2	0	1	1
3	0	1	0
4	1	0	0
5	1	0	1
6	1	1	1
7	1	1	0

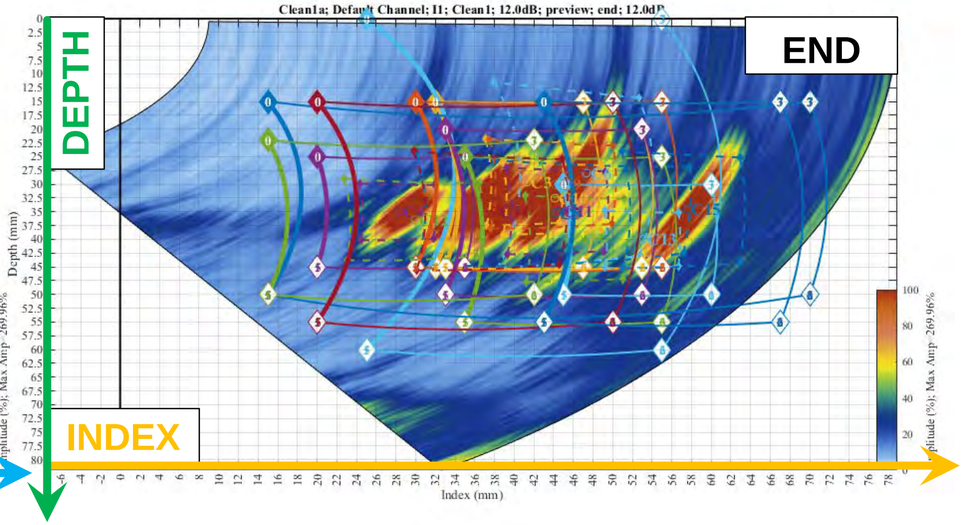


Physical mockup MVM1 file:

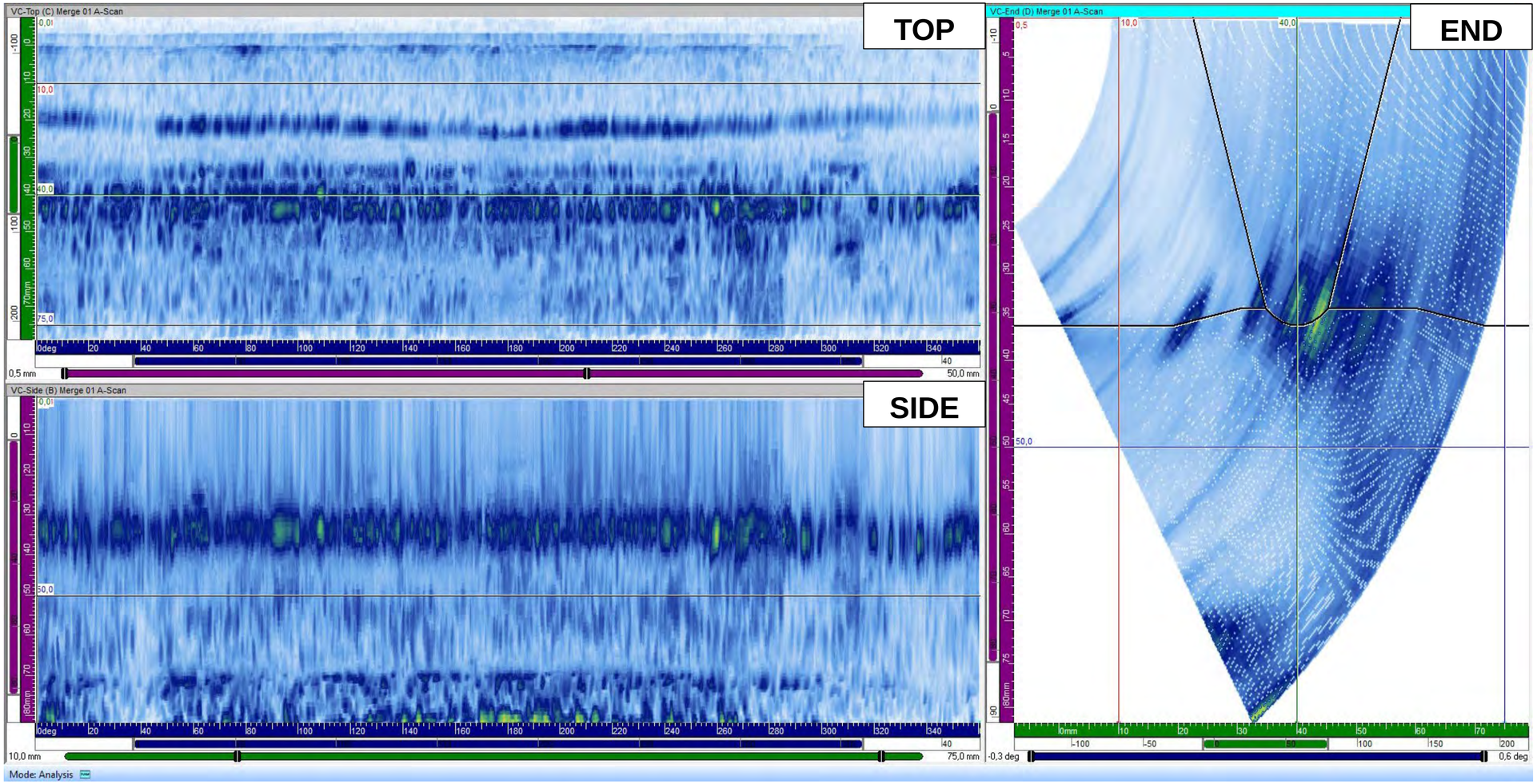








Virtual mockup - .UVData file:



„Virtual“ tool developed by ZČU:

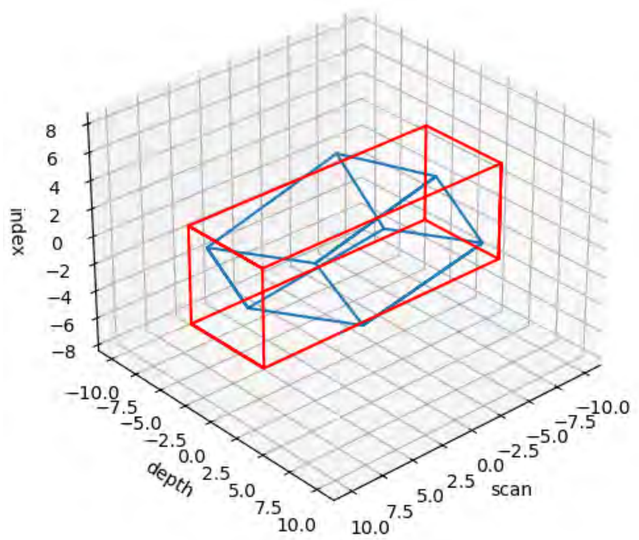
- **Inputs:**

.cfg file of indication (box)

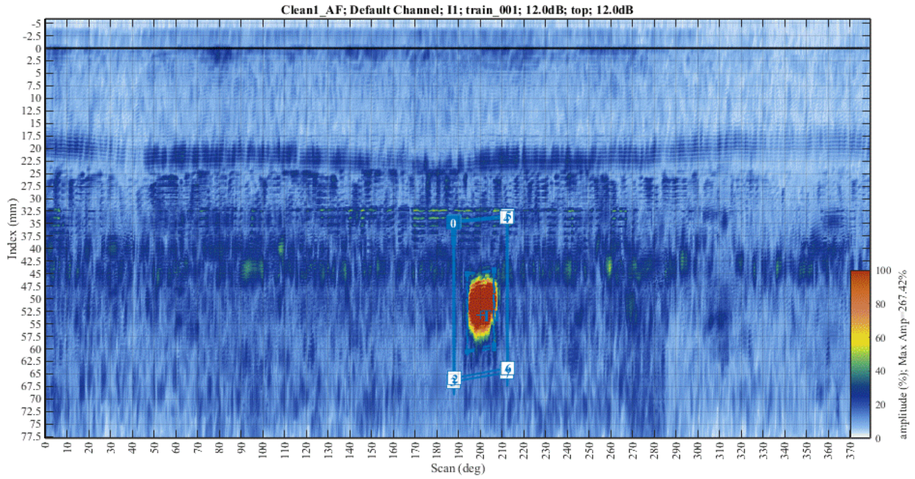
.json file (range of random scale, translation, rotation, types of random reflection)

Outputs:

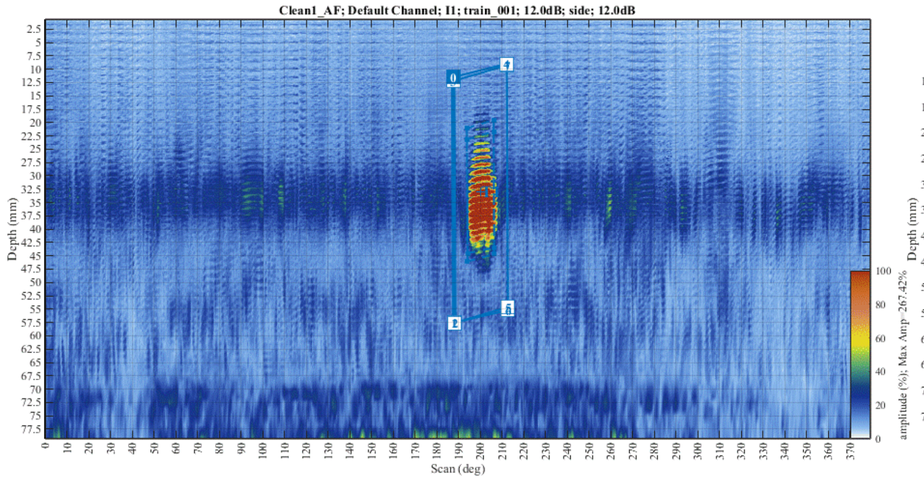
- .mat file including copied indications
- .png files for debug and visualization

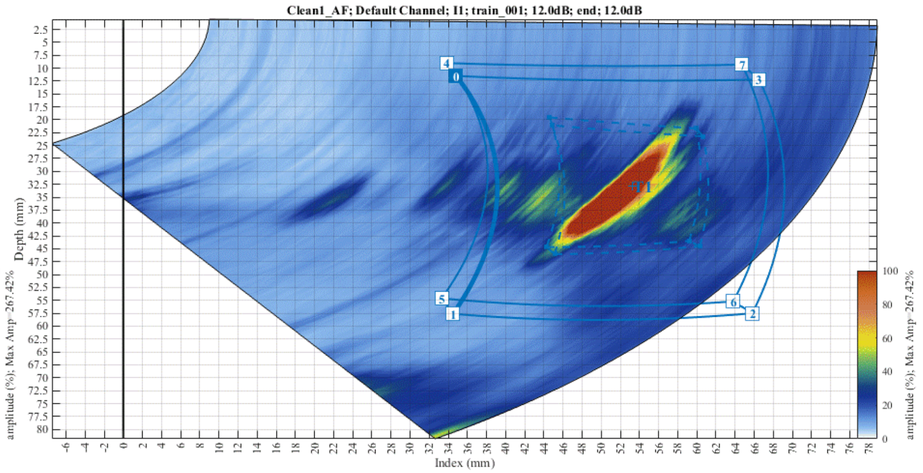


Virtual flaws - Example:

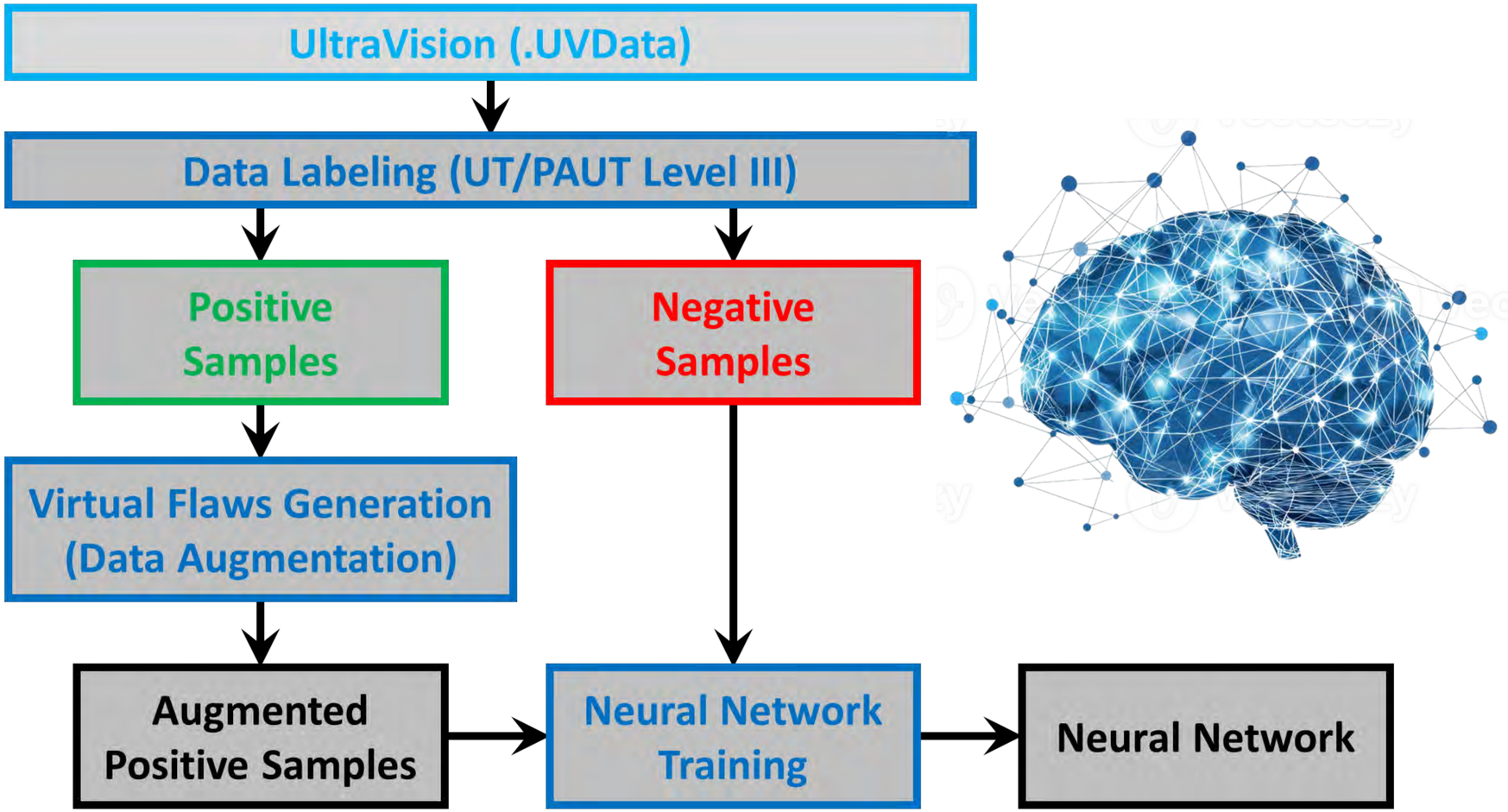


- various indications
- specific region in weld + HAZ
- hundreds of variations in minutes („Virtual flaws“)
- no limitation on variations in flaw size, position, type, amplitude, etc.

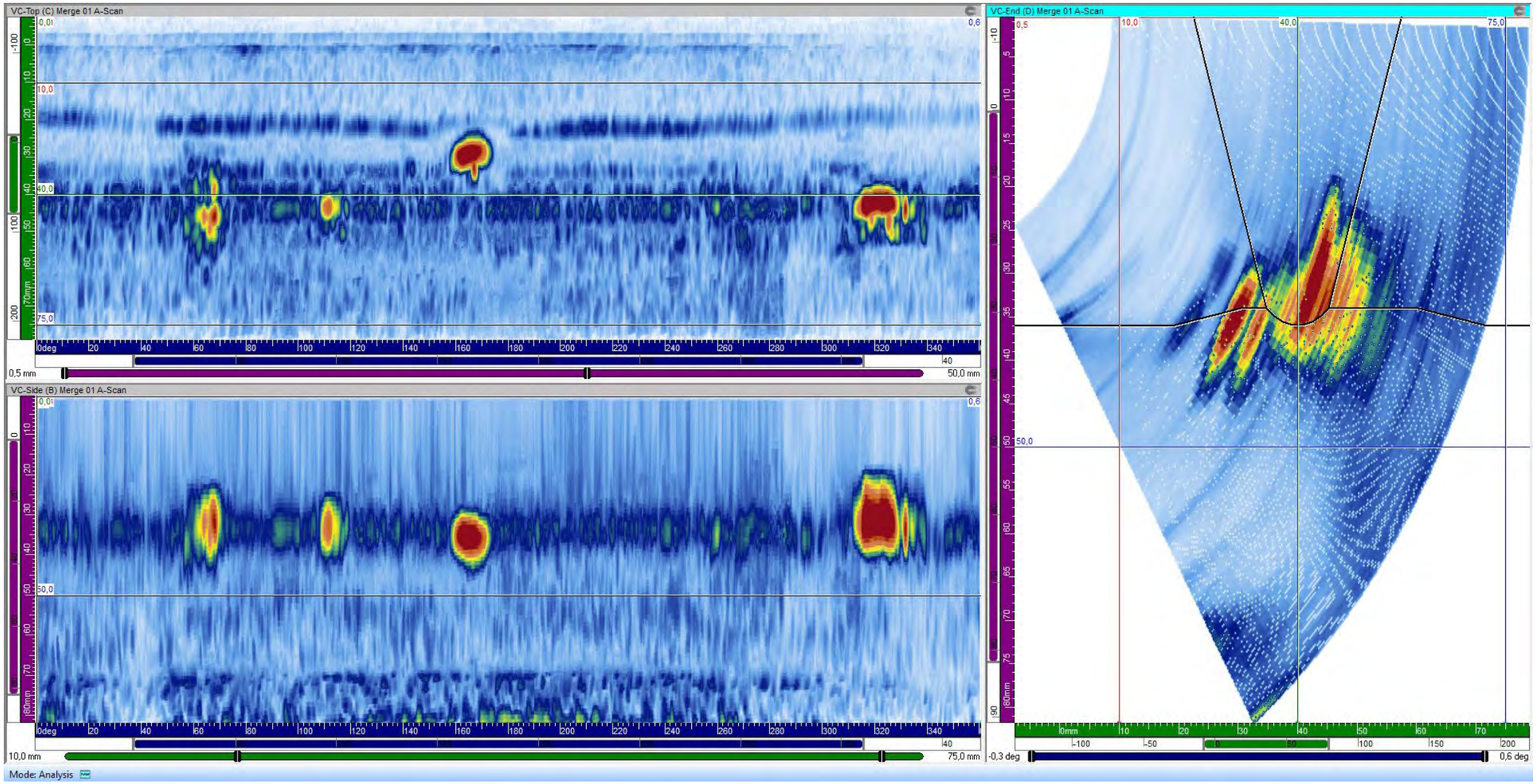




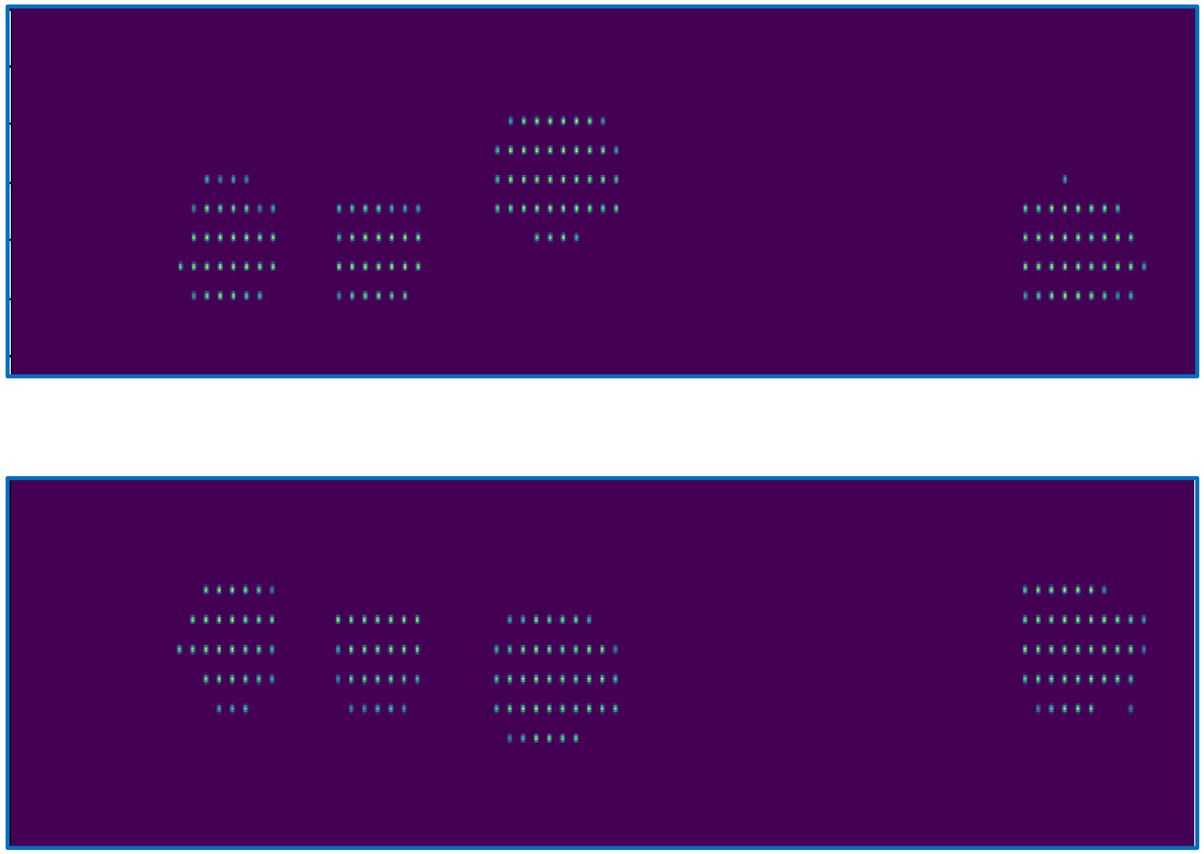
From ML to AI - Overview:



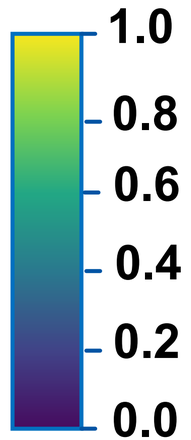
Virtual mockup - ML/AI:



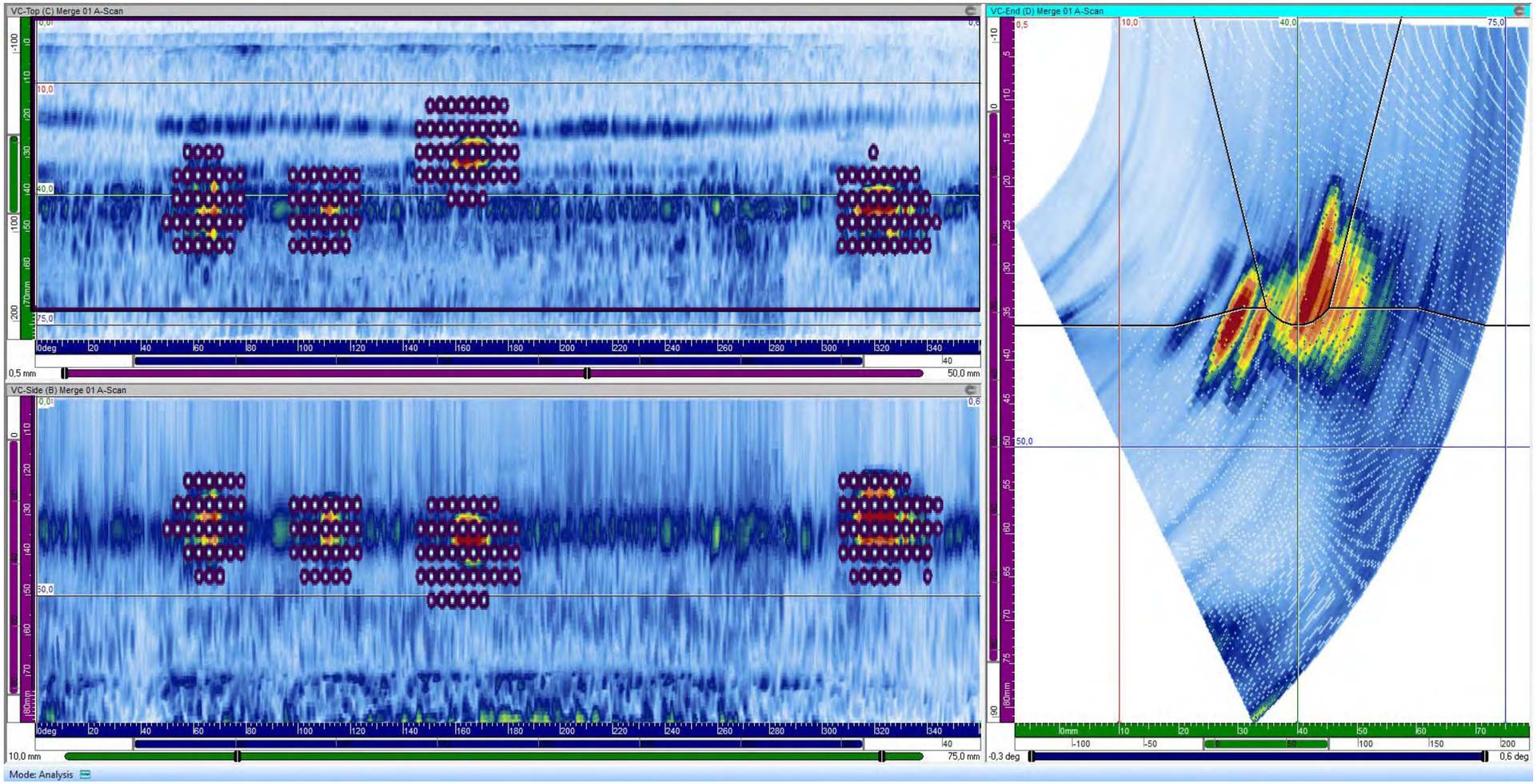
Visualization of ML/AI:



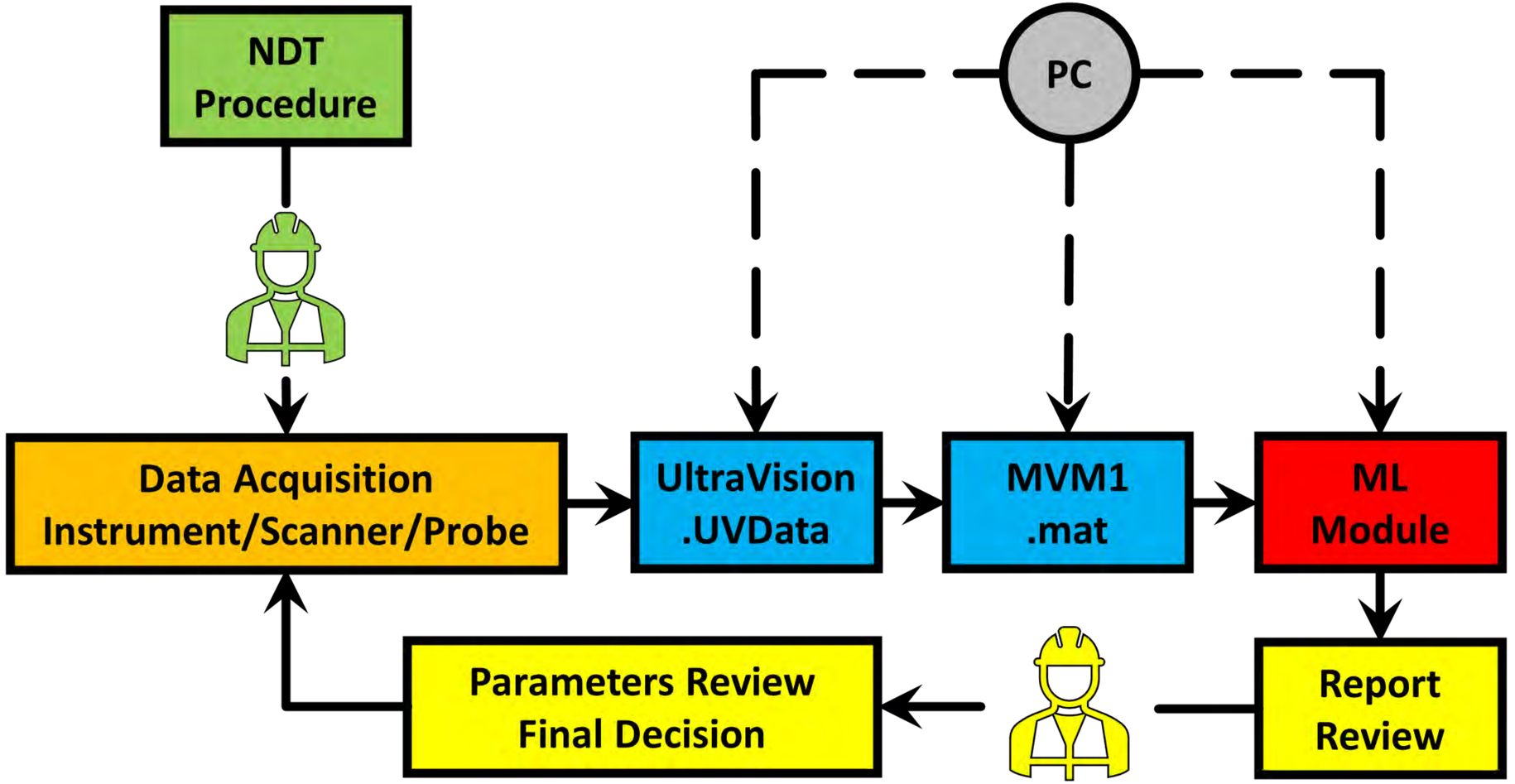
The confidence scale for a positive response decision in one of the .UVData tests is highlighted in color. The maximum value at each location is always shown as a projection (TOP and SIDE view).



Comparation of ML/AI and .UVData file:

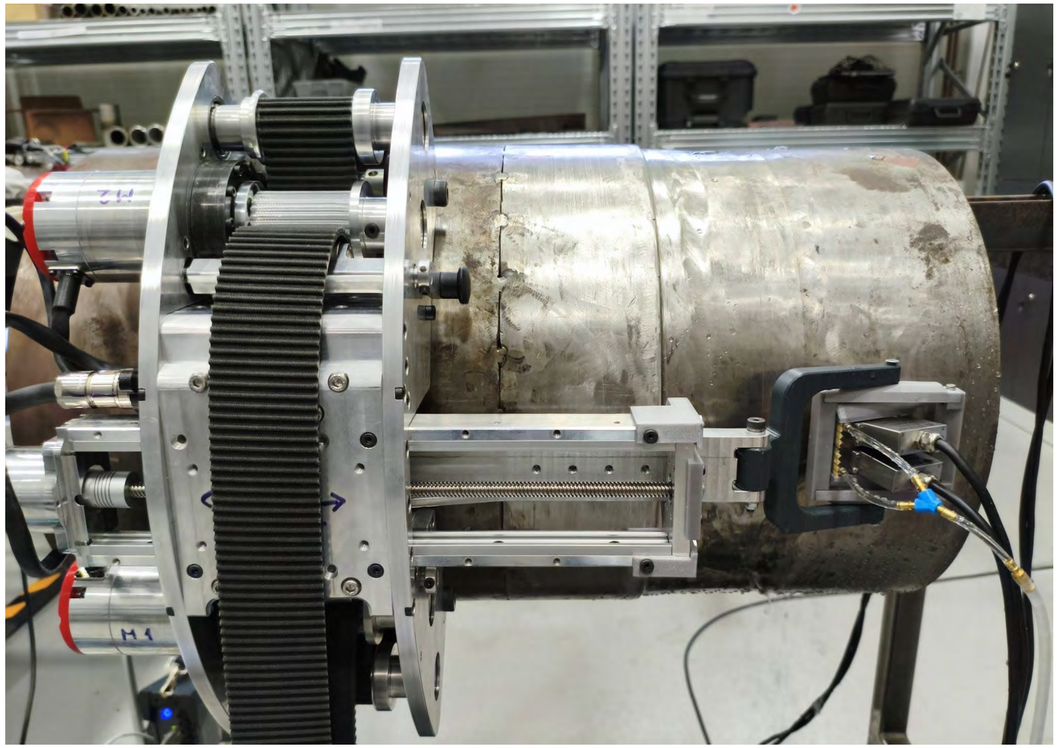


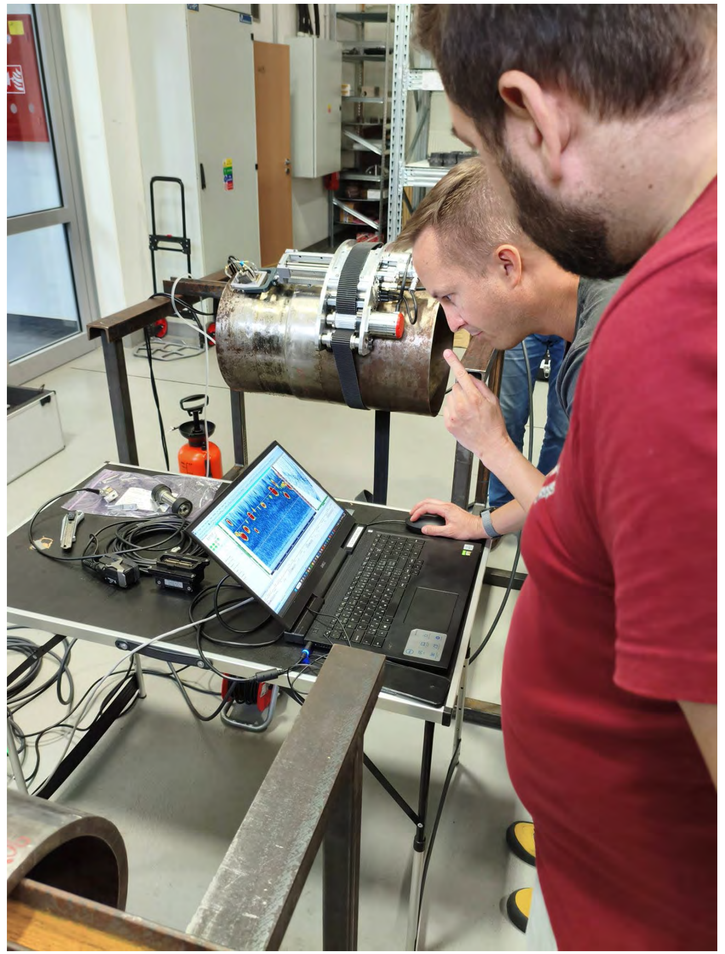
Next Step - Overview:



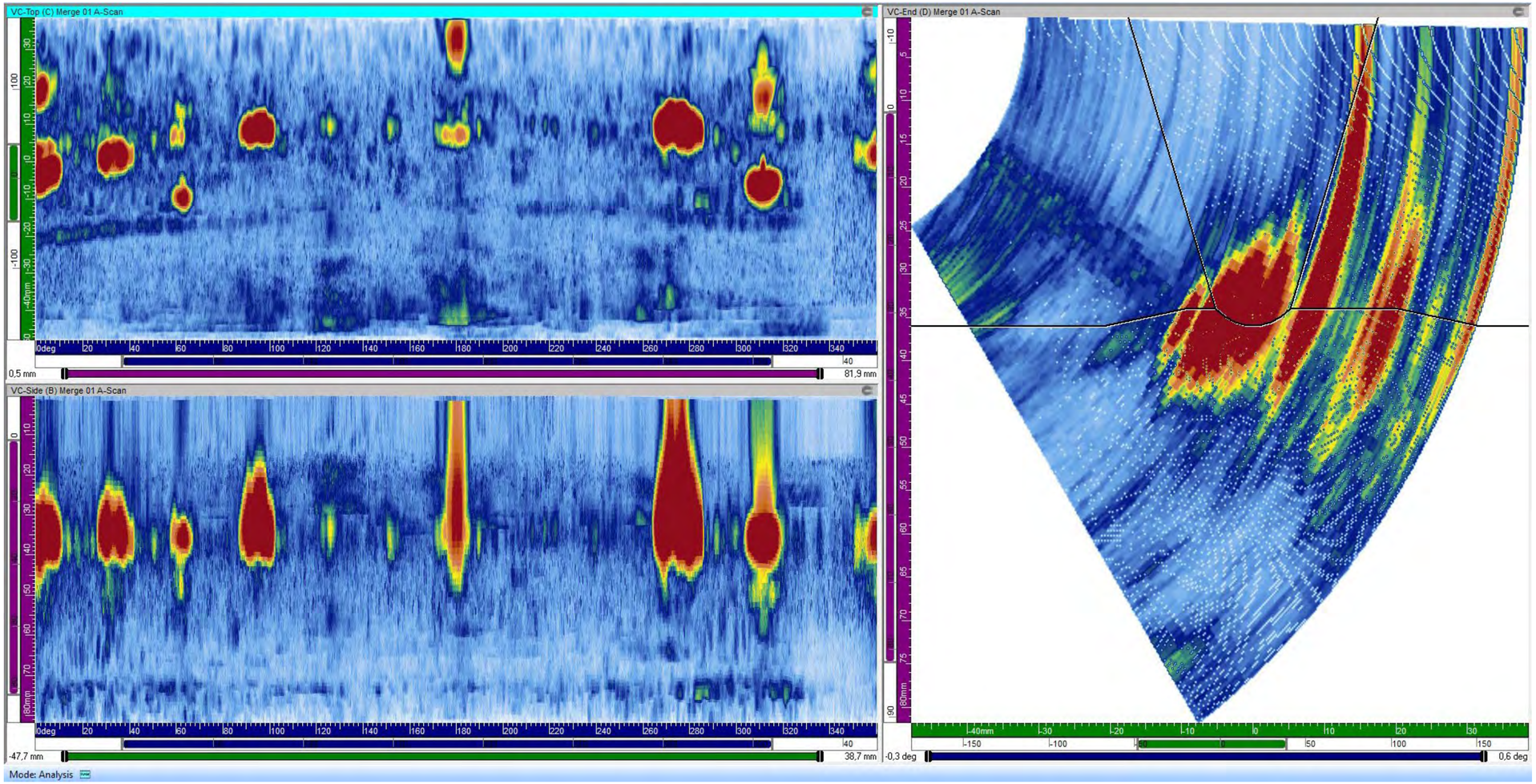
Data acquisition:

- physical mockup
- NDT procedure, manipulator
- ZIRCON unit, UltraVision software, dual PAUT probe

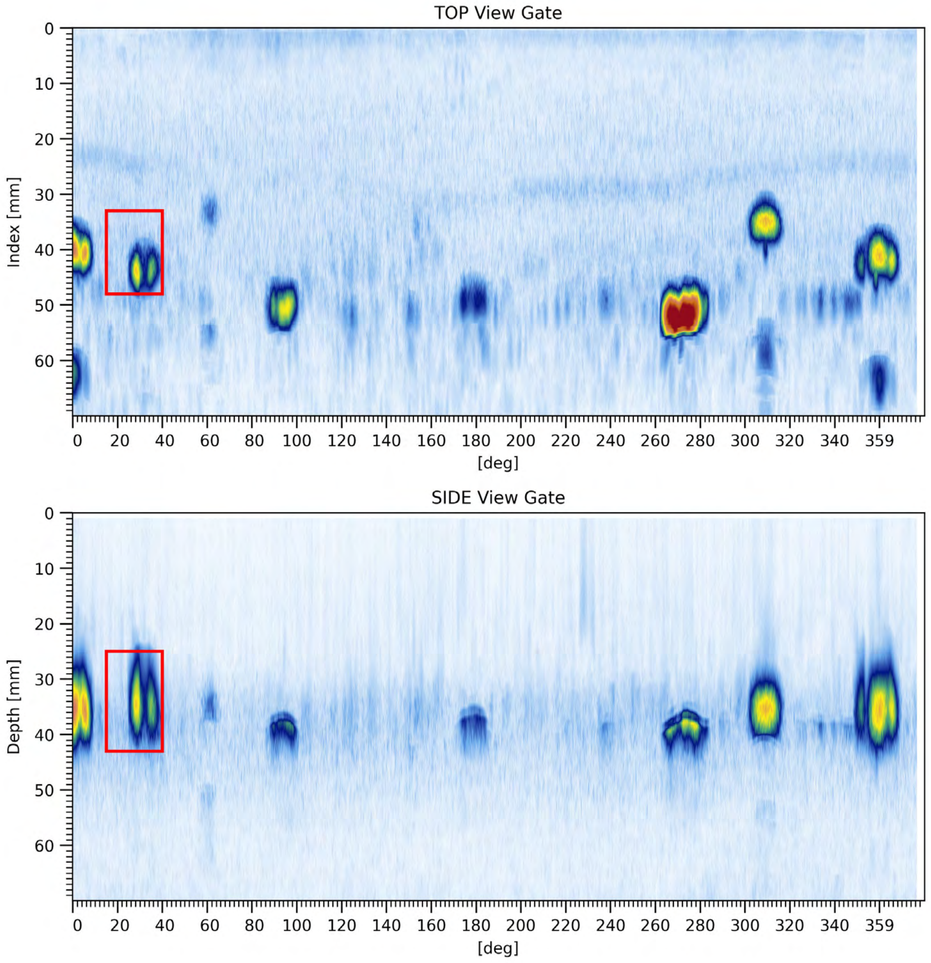


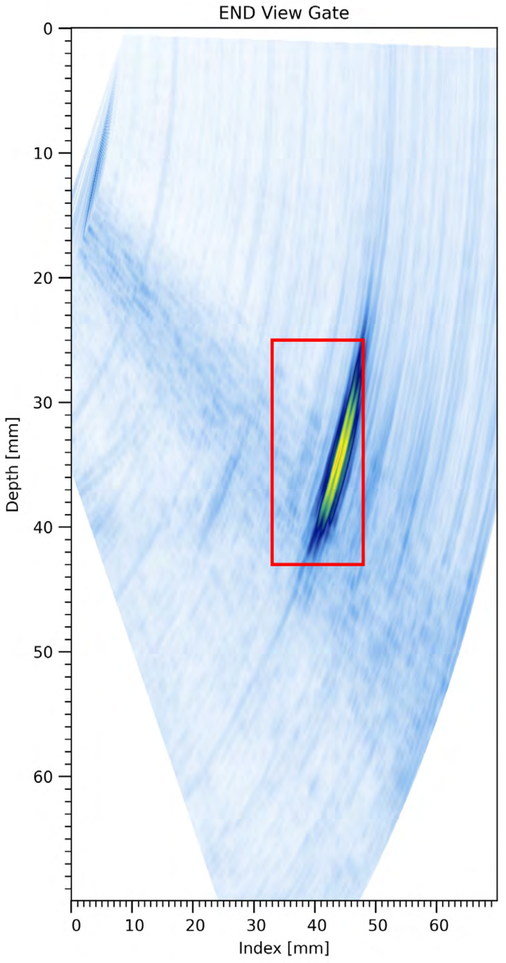


Electrical noise:



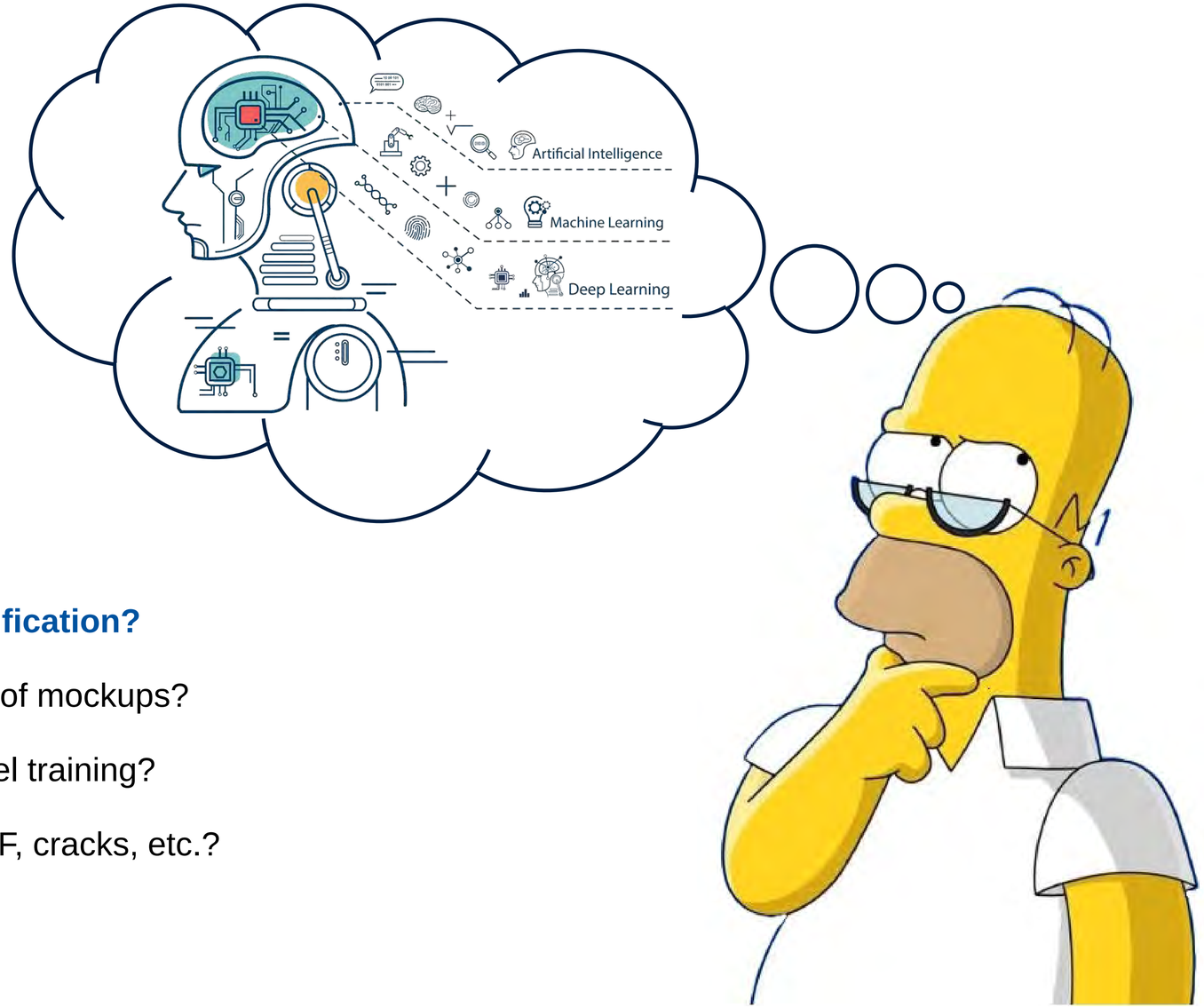
Reporting - In progress:





What's next?

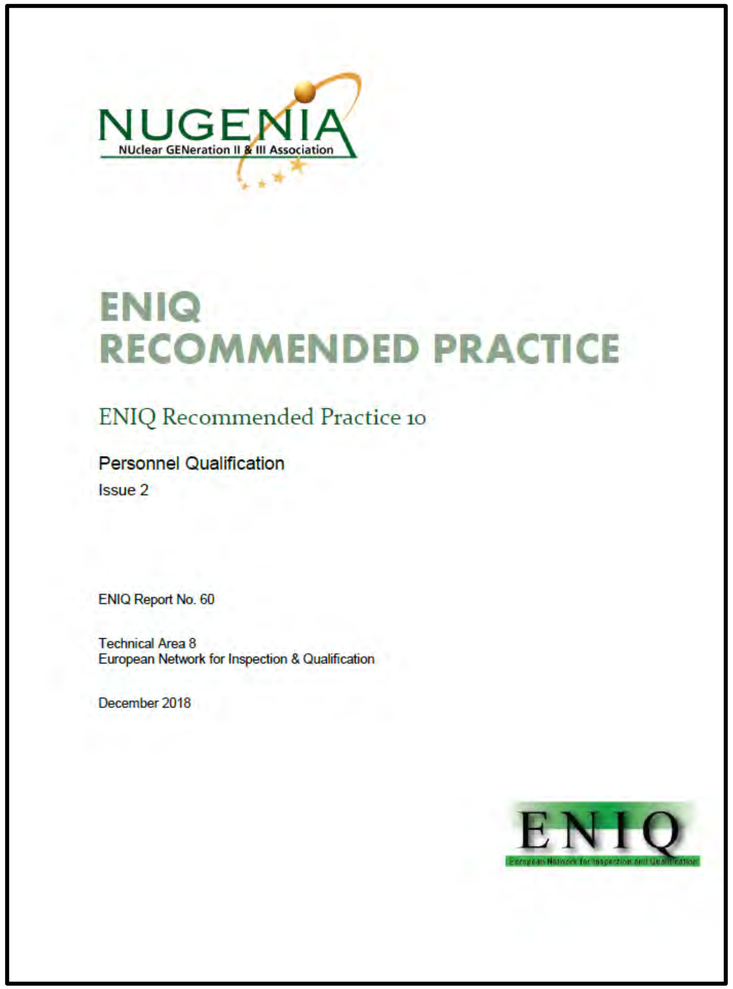
- Data security?!
- Virtual mockups?
- Data for assisted AI in NDT?
- Simulations from SW CIVA?
- Use for augmented reality?
- Other data formats than .UVData?
- **Use for UT/PAUT personnel qualification?**
- Faster and cheaper manufacturing of mockups?
- Use for demonstrations at personnel training?
- Database of sample indications LOF, cracks, etc.?



ENIQ - RP10:

- Qualification ≠ Certification
- Personnel qualification is defined as a process to demonstrate that personnel are capable of implementing specific inspections at the required level of proficiency
- This document considers the use of „virtual test specimens“ for personnel qualification. Could we utilize the virtual mockup for this purpose?

Physical mockups = Expensive = Difficult to manufacture
Alternative = Virtual flaws (mockups)



Thank you for your attention.

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