



*Automated Ultrasonic Testing of Clad and Lined Pipeline Girth Welds  
Using Virtual Source – TFM*

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# Outline



- Allseas
- Automated ultrasonic testing system – *Dolphin*
  - Virtual Source
- Challenges in CRA inspections
- 4 development stages and test results
  - Stage 0-3
- Future work



- A world-leading contractor in the offshore energy market.
- Specialized in pipelay, heavy lift, subsea construction and deep-sea mineral collection.
- Designed and optimised in-house, our fleet of construction and support vessels.
- Develop state-of-the-art equipment and specialised tools to improve safety, efficiency and productivity of our vessels.
- Responsible family company that ensures its people can work safely and passionately to be productive in a sustainable way.





Non-destructive testing plays a key role in safeguarding our planet by ensuring safe and reliable offshore pipelines. For over a decade, Allseas has been advancing state-of-the-art NDT solutions to support its sustainable offshore operations.

# Oil spill as result of girth weld flaw



The NDT community must continuously elevate its standards.

# Automated Ultrasonic Testing Systems (AUT)

- Stringent criteria for offshore pipelines
  - Flaw sizing and characterization
- Time pressure due to parallel production line
  - Up to 2.5-minute cycle time: verify, cool, clean, scan, sentence and verify...

## **So, what we needed?**

- Reliable
- Easy-to-interpret
- Fast
- Robust for offshore conditions
- Safe to use NDT solution



# Dolphin AUT

- Innovative image-based technique inspired from medical industry
- Decade of development by Allseas
- DNV qualification in 2022 for carbon steel girth weld inspection
- +1000km record track

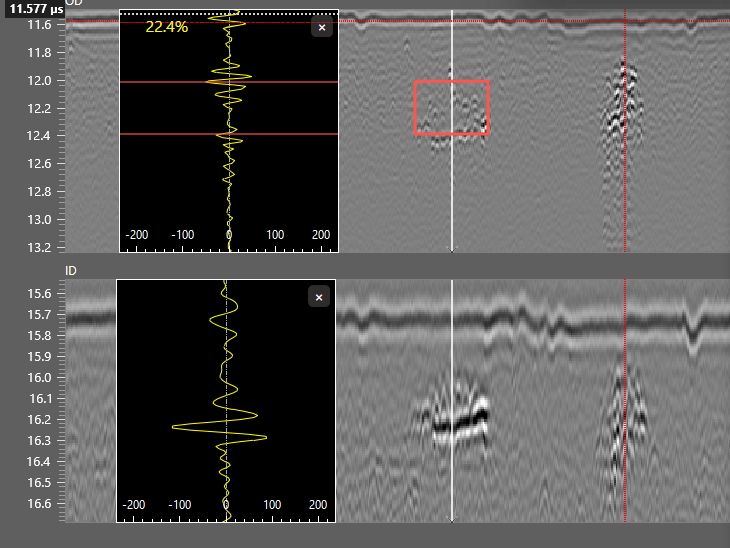
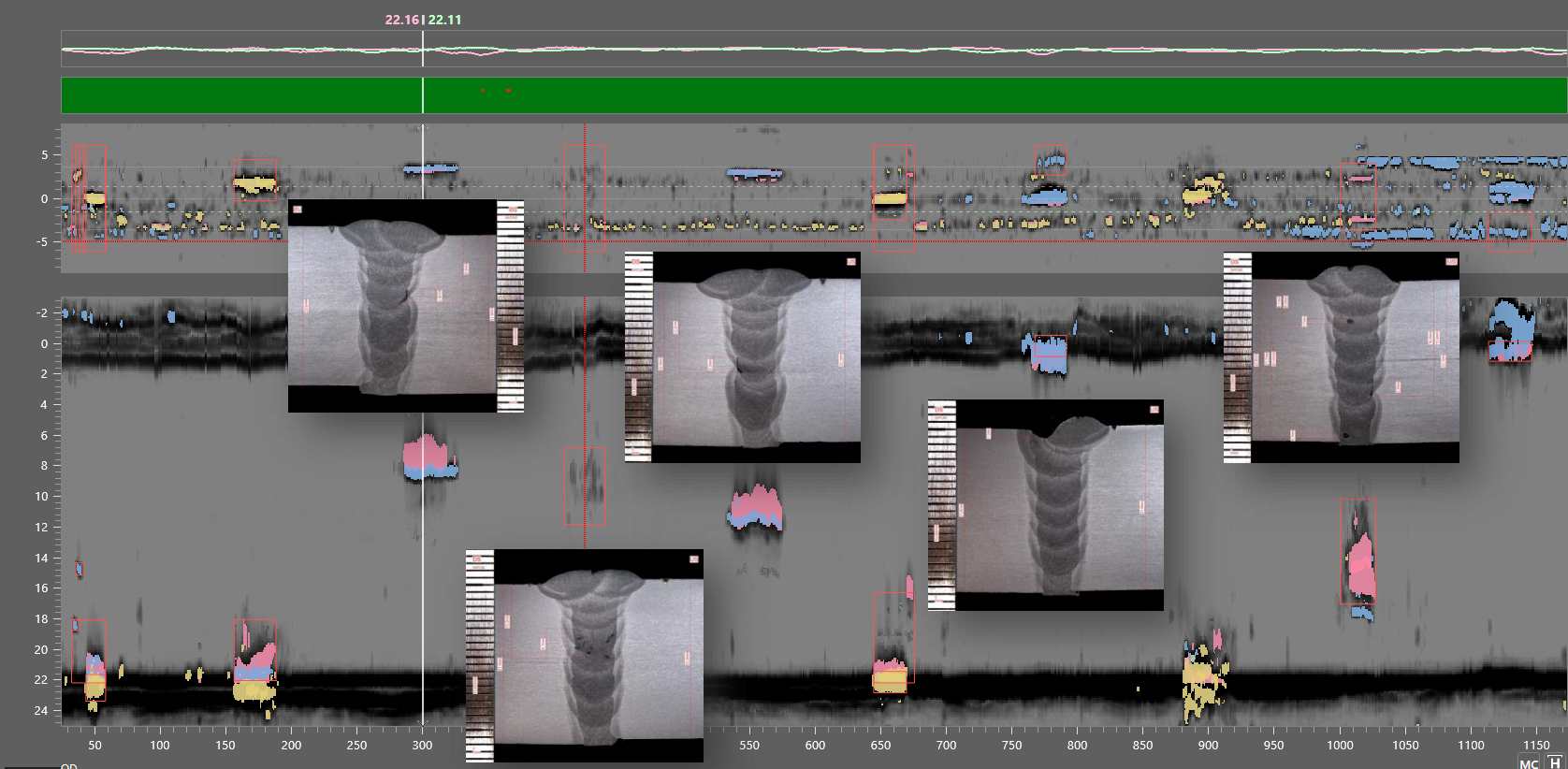
## Key Advantages

- Enhanced characterization
- Accurate sizing (std: 0.36 mm)
- Simplified interpretation
- Fast scanning (100 mm/s)
- Lightweight handling (~20 kg)



# **Dolphin Animation**

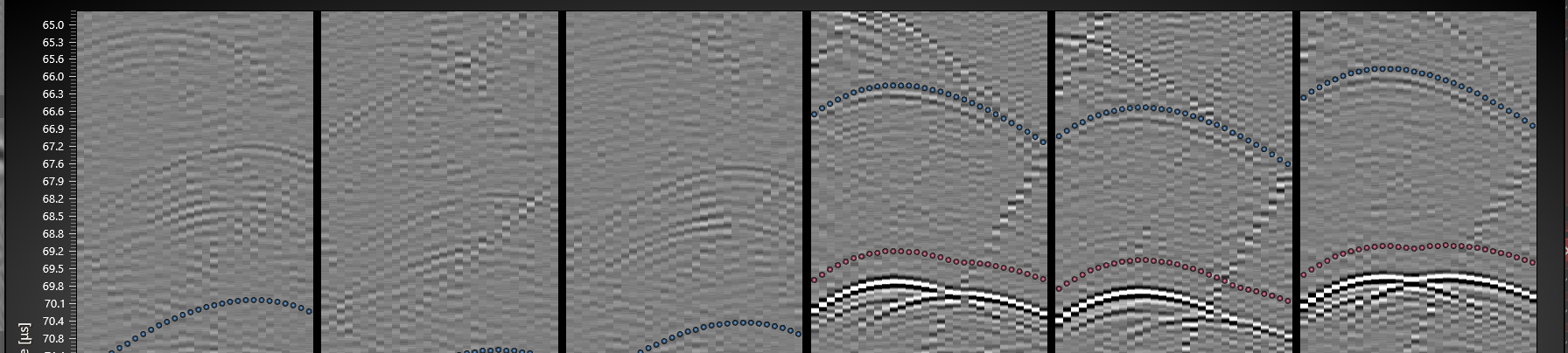




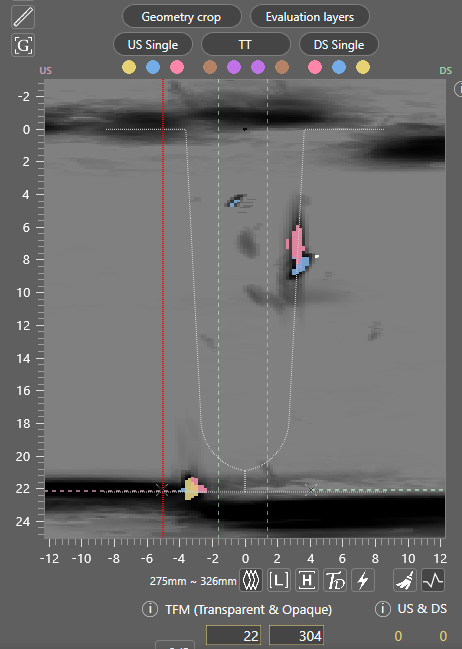
Dolphin A-scans view

Position (Y): 301 mm Offset (X): 4.4 mm Depth (Z): 7.8 mm

Display leg (TX + RX): SW 1 + SW 2



700194\_J\_26.25 inch\_W22.2 mm\_18.3 mm\_1



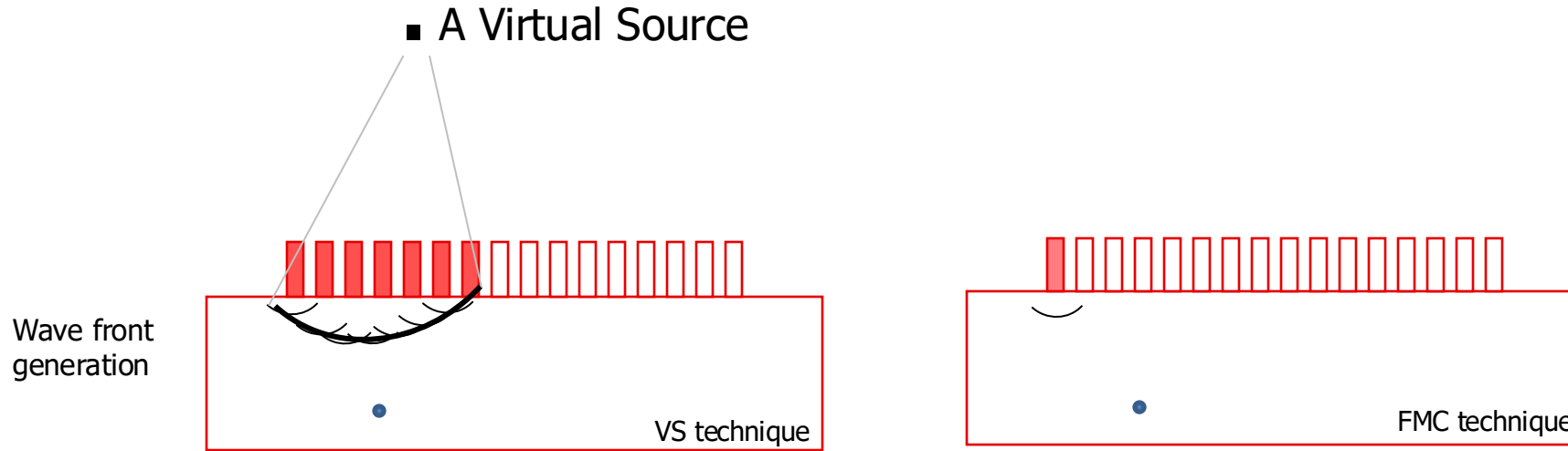
| Check interactions |                                      |                                             |                             |
|--------------------|--------------------------------------|---------------------------------------------|-----------------------------|
| Start (mm)         | 44                                   | OD length (mm)                              | 15                          |
| End (mm)           | 59                                   | Length (mm)                                 | 15                          |
| Depth (mm)         | 22.2                                 | Height (mm)                                 | 1.8                         |
| Side *             | <input type="checkbox"/> US          | <input checked="" type="checkbox"/> Central | <input type="checkbox"/> DS |
| Defect *           | <input checked="" type="radio"/> Yes | <input type="radio"/> No                    |                             |

| 157 - Lack of penetration |                                      |                                             |                                        |
|---------------------------|--------------------------------------|---------------------------------------------|----------------------------------------|
| Type *                    | Weld flaw                            |                                             |                                        |
|                           | Lack of penetration                  |                                             |                                        |
| Location *                | ID surface breaking                  |                                             |                                        |
| Start (mm)                | 157                                  | OD length (mm)                              | 32                                     |
| End (mm)                  | 189                                  | Length (mm)                                 | 31                                     |
| Depth (mm)                | 22.2                                 | Height (mm)                                 | 4.0                                    |
| Side *                    | <input type="checkbox"/> US          | <input checked="" type="checkbox"/> Central | <input checked="" type="checkbox"/> DS |
| Defect *                  | <input checked="" type="radio"/> Yes | <input type="radio"/> No                    |                                        |
| LOP + LOF                 |                                      |                                             |                                        |

| 275 - Lack of fusion |                                      |                                  |                                        |
|----------------------|--------------------------------------|----------------------------------|----------------------------------------|
| Type *               | Weld flaw                            |                                  |                                        |
|                      | Lack of fusion                       |                                  |                                        |
| Location *           | Embedded                             |                                  |                                        |
| Start (mm)           | 275                                  | OD length (mm)                   | 52                                     |
| End (mm)             | 327                                  | Length (mm)                      | 51                                     |
| Upper tip (μs)       | 12.01C                               | LW (μs) *                        | 11.520                                 |
| Lower tip (μs)       | 12.39C                               | LW (μs) *                        | 11.520                                 |
| Depth (mm)           | 9.9                                  | Height (mm)                      | 2.6                                    |
| Side *               | <input type="checkbox"/> US          | <input type="checkbox"/> Central | <input checked="" type="checkbox"/> DS |
| Defect *             | <input checked="" type="radio"/> Yes | <input type="radio"/> No         |                                        |

US & DS TT Couplant

# Dolphin is a Virtual Source (VS-TFM) based imaging system



## VS against Full Matrix Capture (FMC)

- Stronger wave front, better SNR/penetration
- ~10 times less data, much faster scanning speeds
- Flexible options
  - Steering for optimum angles
  - Choose area to or not to insonify
  - Edge cases: can be used as FMC and PWI
- Requires complex setup procedure

# VS optimization example



Probe

Number of elements

60

Pitch size (mm)

1.00

Frequency (MHz)

7.50

Digital filter

Band pass 3.75-15.0 MHz

Path selection

1L-1L

1L-2L

Path:

Add as single stream

Add as TT

Scan parameters

Stand-off (mm)

15.00

Virtual sources

Add VS

Generate VS

| Name | X (mm) | Y (mm) | PE                                  | TT                                  | TX start | TX end | Wave | Display                             |
|------|--------|--------|-------------------------------------|-------------------------------------|----------|--------|------|-------------------------------------|
| VS 1 | 0.0    | 100.0  | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | 1        | 60     | CW   | <input checked="" type="checkbox"/> |

Display mode

All skips

PA acquisition

Receiver start element

1

Receiver element step

1

Sampling frequency

☐ 62.5 MHz

☒ 125 MHz

Motion

Scan speed (mm/s)

70

≤ 100

Overlap scan distance (mm)

100

Encoder resolution (ticks/mm)

100

Couplant shot and threshold

First TX element

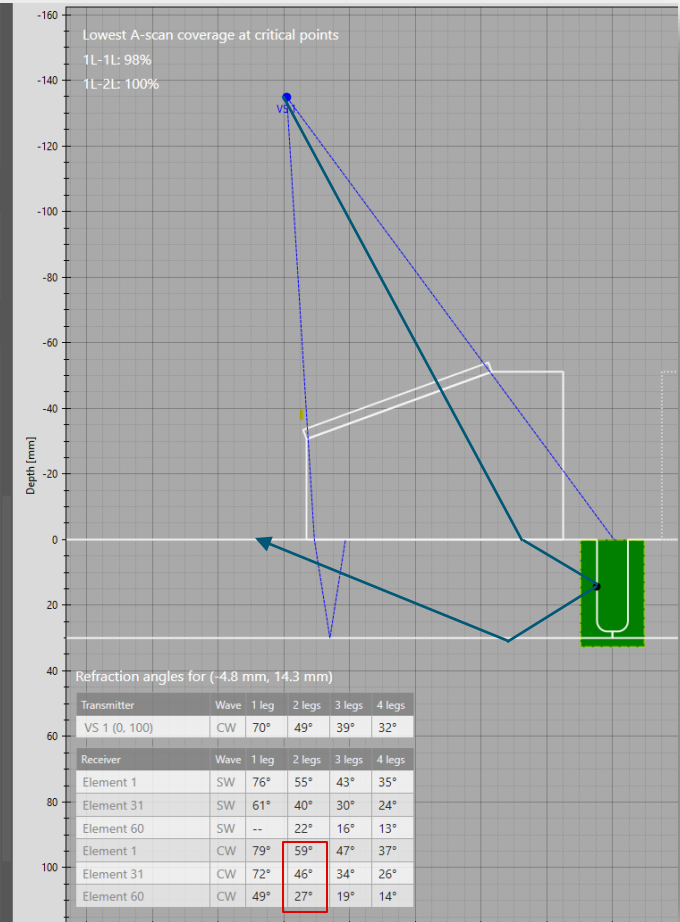
21

Aperture size

20

Allowed couplant drop (dB)

12



Probe

Number of elements

60

Pitch size (mm)

1.00

Frequency (MHz)

7.50

Digital filter

Band pass 3.75-15.0 MHz

Path selection

1L-1L

1L-2L

Path:

Add as single stream

Add as TT

Scan parameters

Stand-off (mm)

12.00

Virtual sources

Add VS

Generate VS

| Name | X (mm) | Y (mm) | PE                                  | TT                                  | TX start | TX end | Wave | Display                             |
|------|--------|--------|-------------------------------------|-------------------------------------|----------|--------|------|-------------------------------------|
| VS 1 | 23.0   | 100.0  | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | 45       | 60     | CW   | <input checked="" type="checkbox"/> |

Display mode

All skips

PA acquisition

Receiver start element

1

Receiver element step

1

Sampling frequency

☐ 62.5 MHz

☒ 125 MHz

Motion

Scan speed (mm/s)

70

≤ 100

Overlap scan distance (mm)

100

Encoder resolution (ticks/mm)

100

Couplant shot and threshold

First TX element

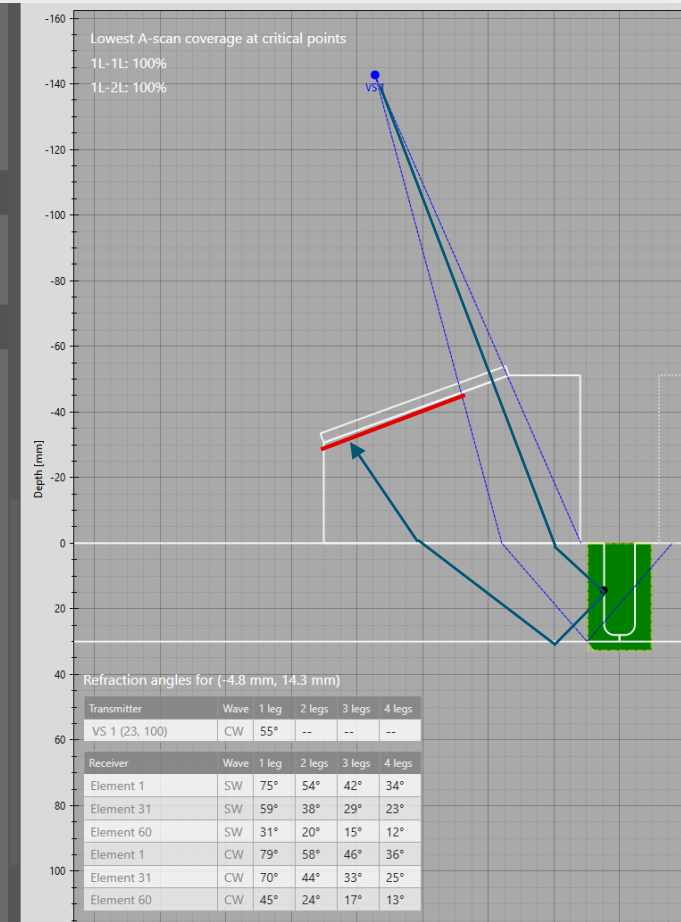
21

Aperture size

20

Allowed couplant drop (dB)

12



# Transportation of corrosive hydrocarbons

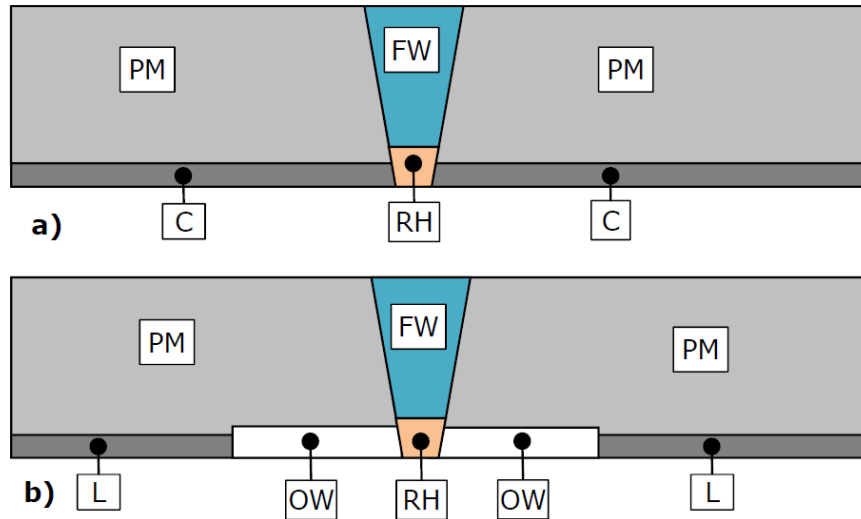
Pipelines transporting corrosive hydrocarbons are normally constructed by use of:

- C-Mn steels

corrosion allowance to compensate for corrosion, normally combined with use of inhibitors to mitigate the corrosion

- Corrosion Resistant Alloys (CRA)

- Lined or Clad pipelines

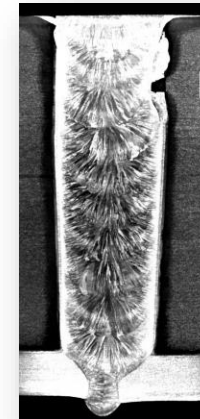


Designation of materials in clad pipeline:

- PM – Parent material
- FW – Filler weld
- C – Clad layer
- RH – Root/hot passes

Designation of materials in lined pipeline:

- PM – Parent material
- FW – Filler weld
- L – Liner pipe
- RH – Root/hot passes
- OW – Overlay weld

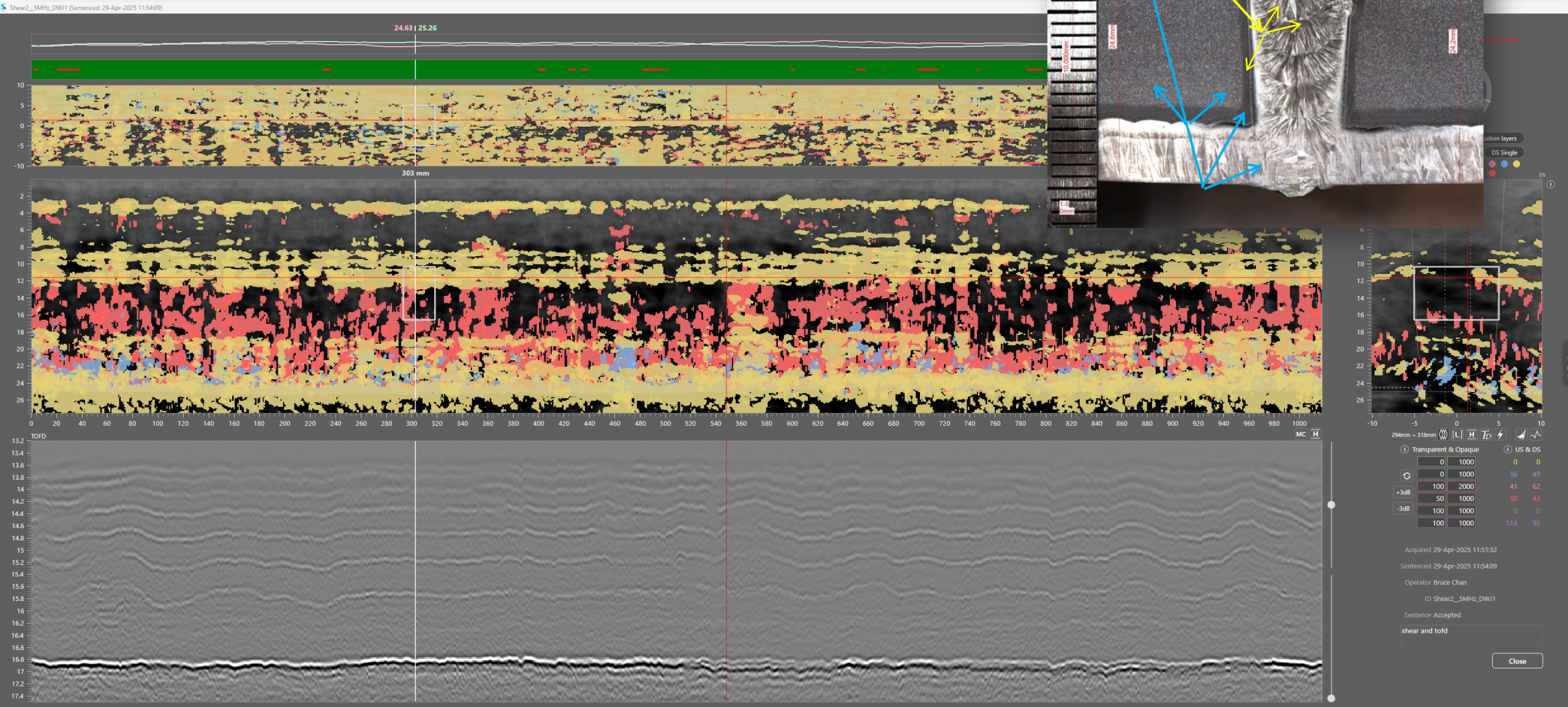




## **Extending Dolphin's capabilities for lined pipelines**

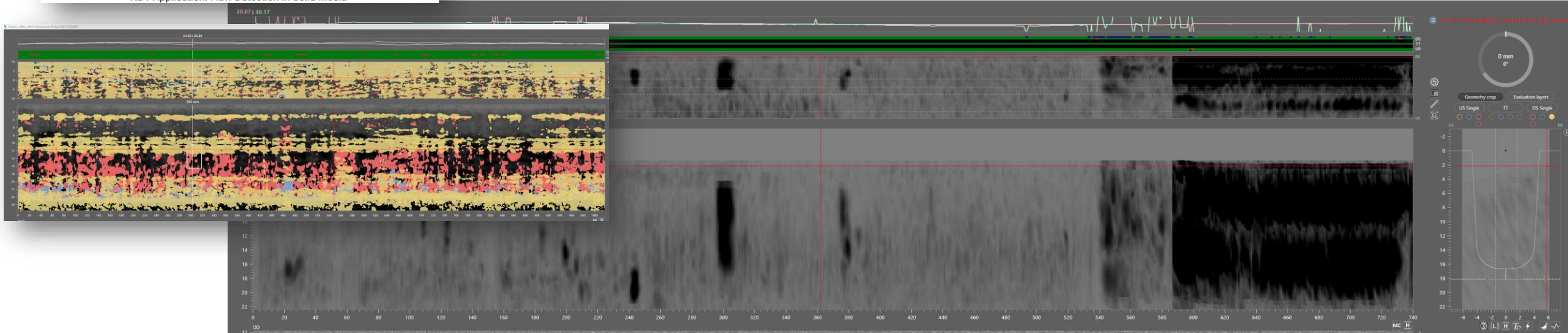
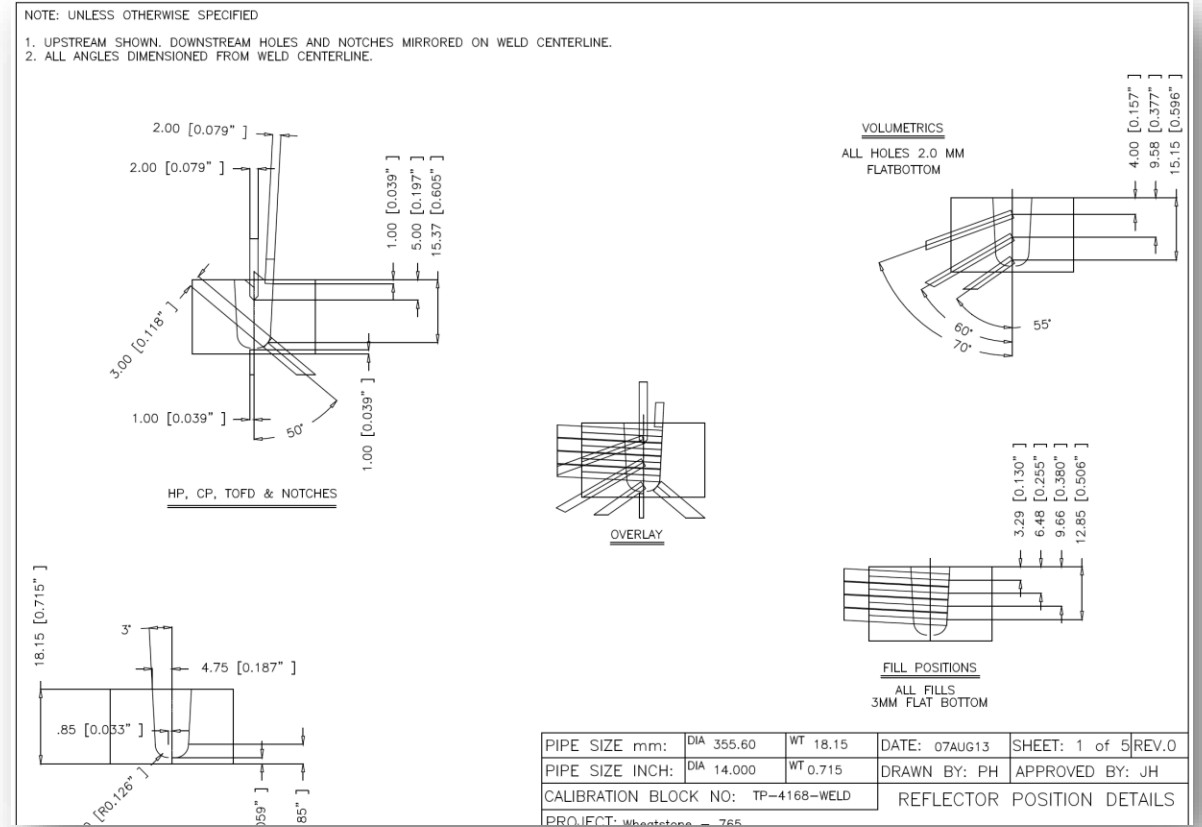
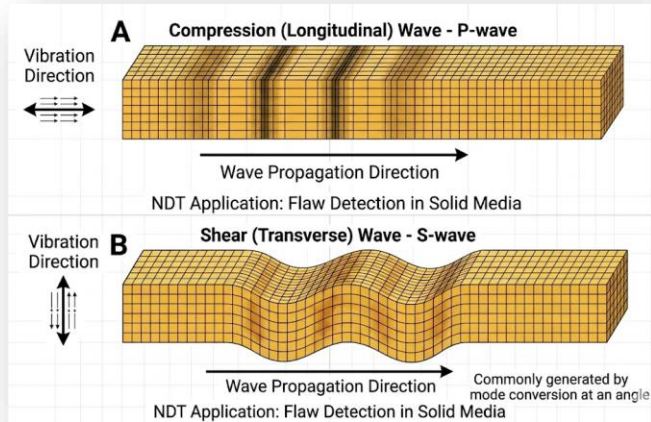
- Developed in 4 stages
  - Stage 0 - handle as Carbon Steel (CS)
  - Stage 1 - introduce compression waves
  - Stage 2 - optimize probe and wedge design
  - Stage 3 - exploit flexibility of Virtual Sources

# Stage 0: Apply CS technique on lined pipelines



# Stage 1: Compression waves

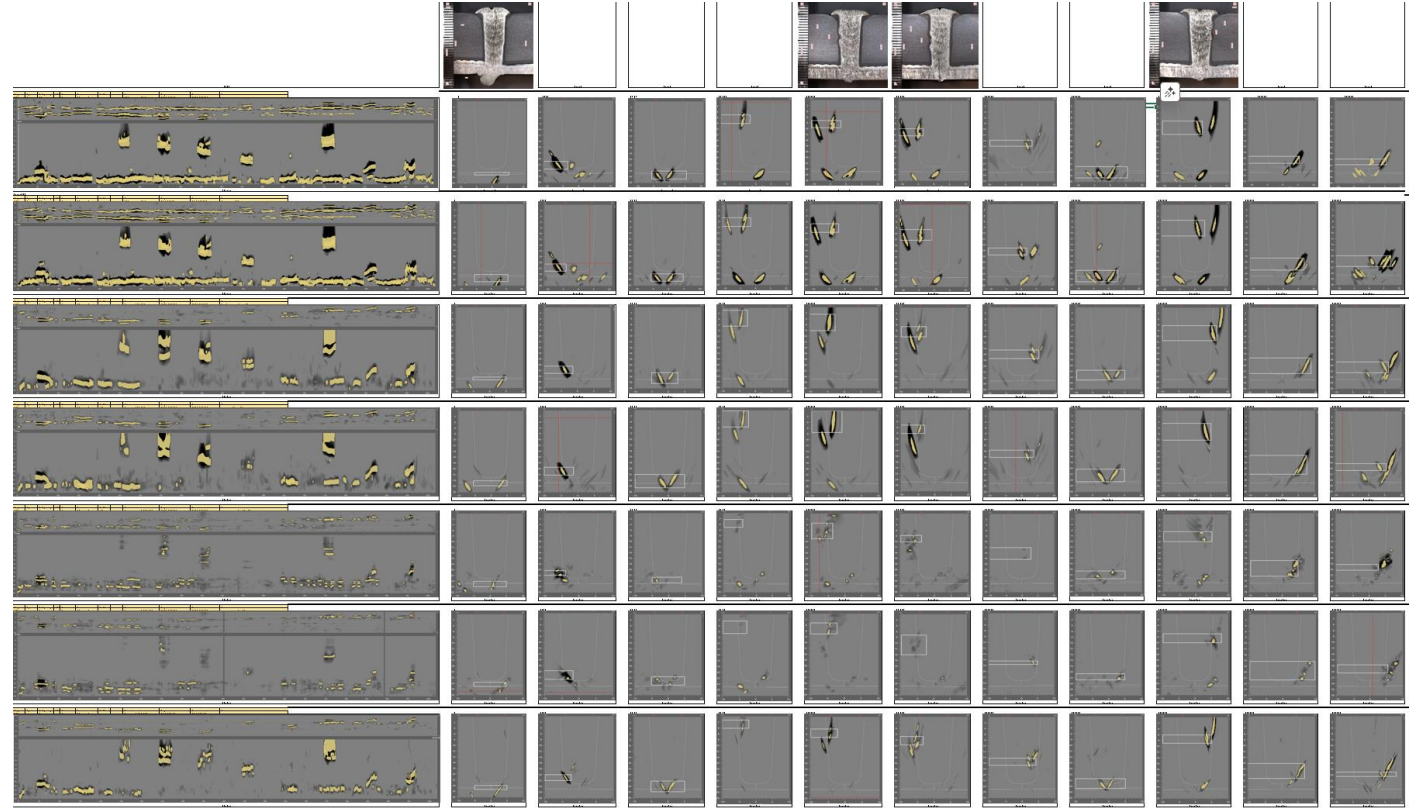
- Introduced compression waves to Dolphin
- Detection of reflectors along bevel and volumetric
- Not detected near OD/ID surfaces nor HP



## Stage 2 : Different probes and wedges



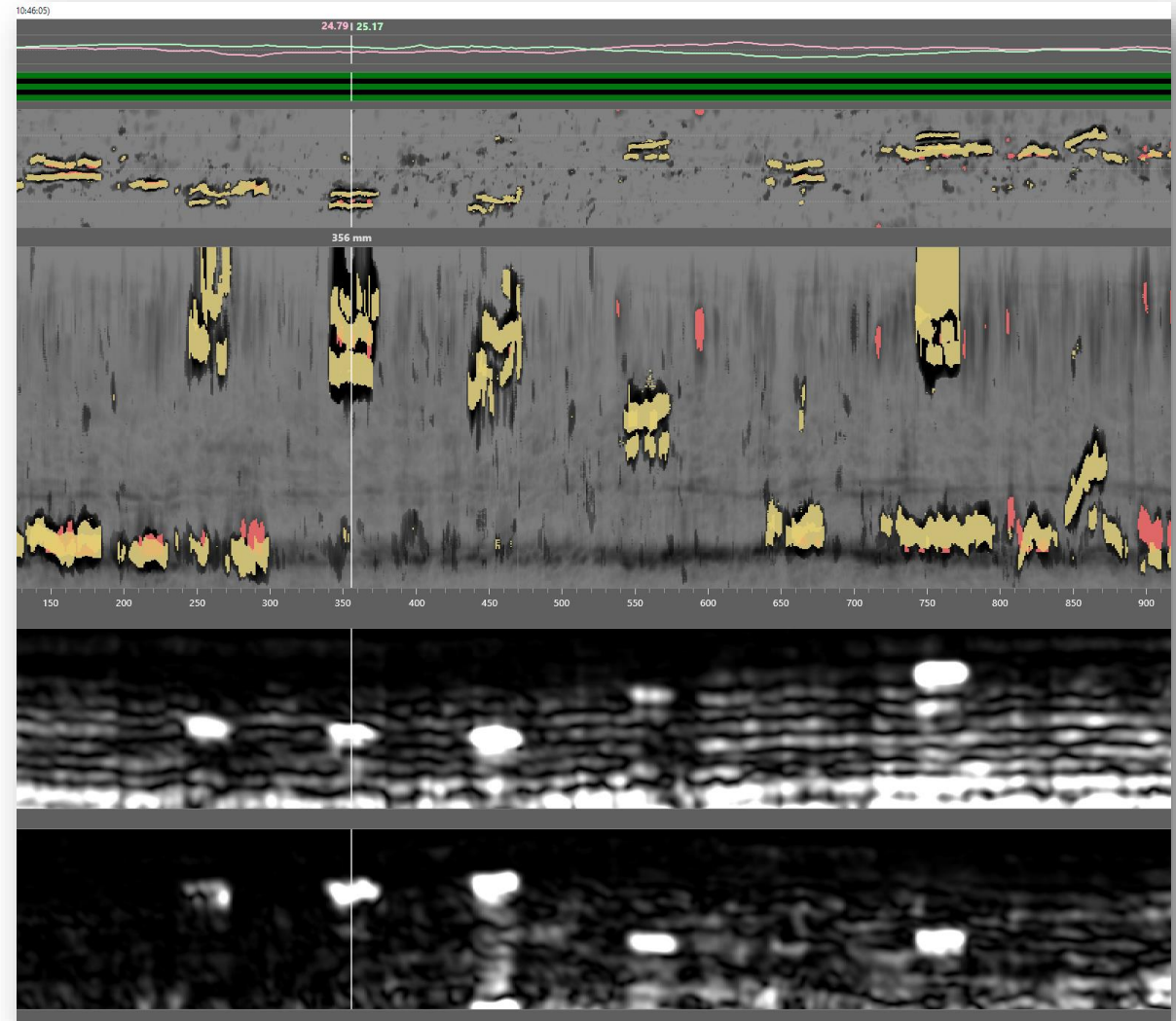
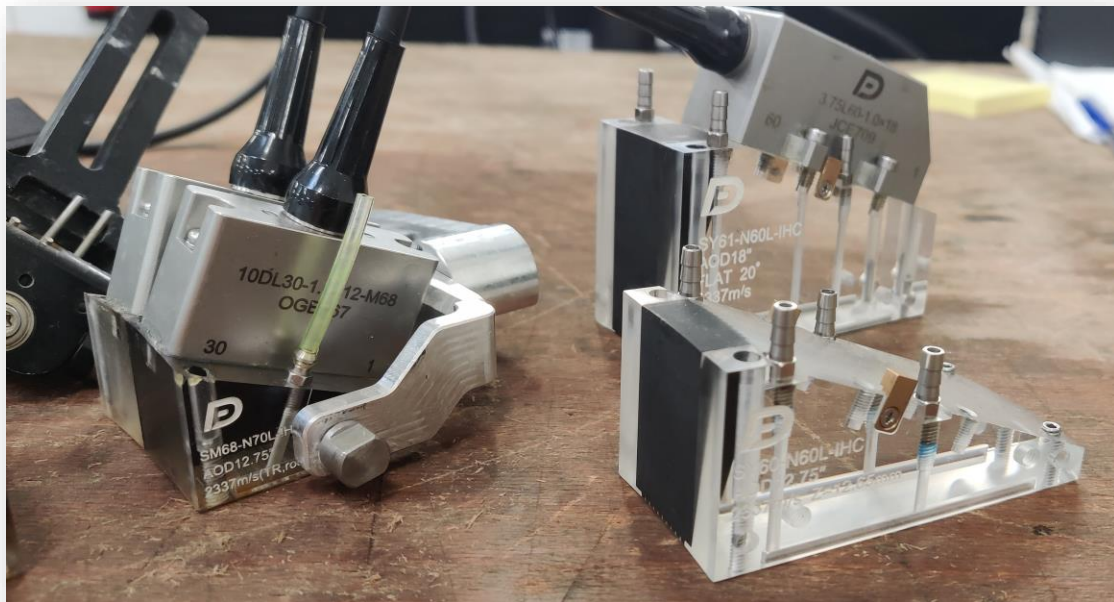
- Scanned 6 J-prep + 3 V-prep defect welds
  - Different probes & wedges:
    - PA (5MHz, 7.5MHz) , (tall, short), (20 degree)
    - DLA (5MHz), (22, 23 degree)
  - Different transmission techniques
  - Introduced creeping waves
- Evaluate their performance on
  - 100 induced flaws, 30 of them with macro sections



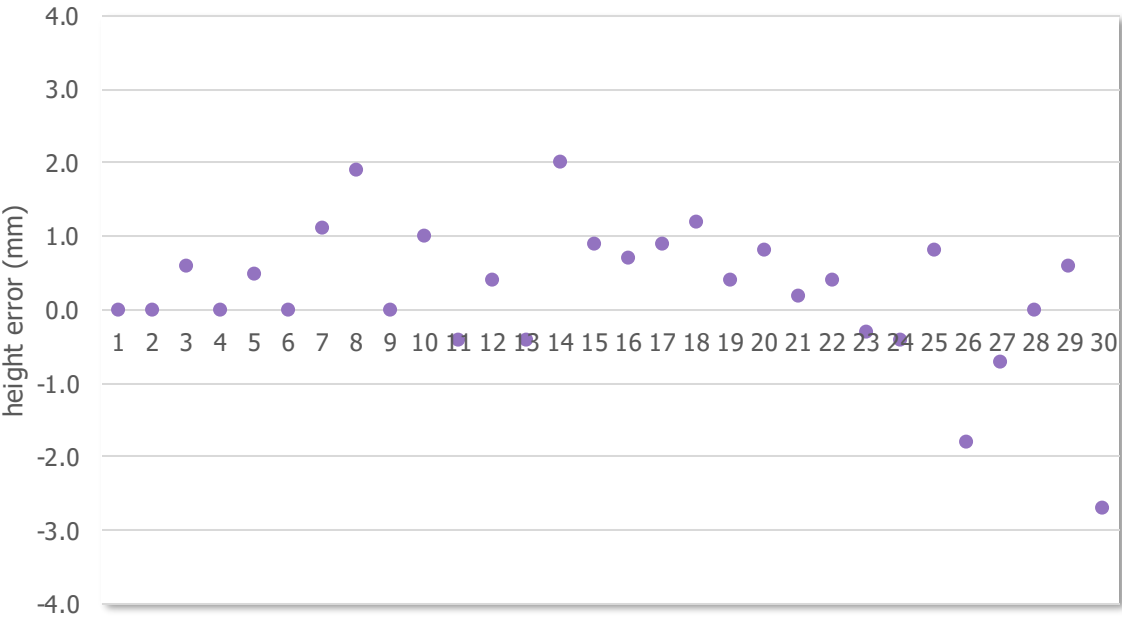
## Stage 2: Probe and wedge selection



- Detected all the intended defects with
  - 7.5MHz, 20-degree, tall wedge
- Depth accuracy is improved
- Use of creep is limited to detection

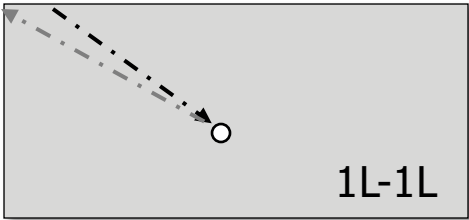


# Stage 2: Sizing results with only direct mode

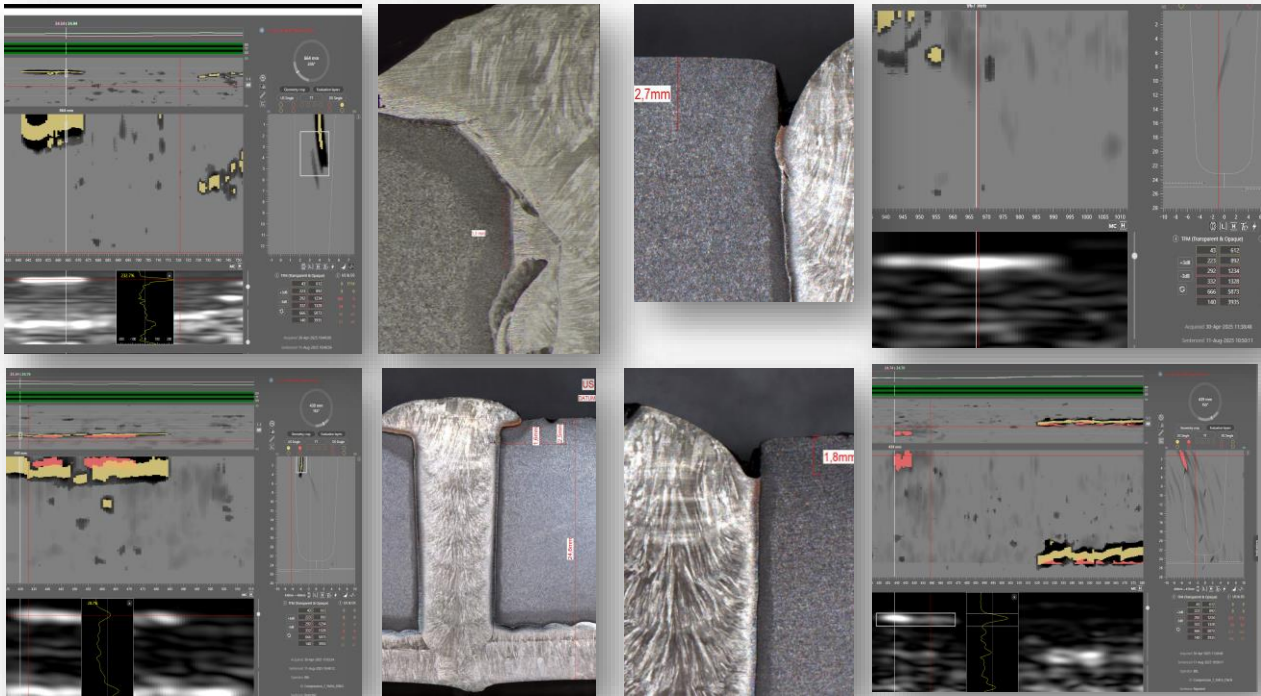
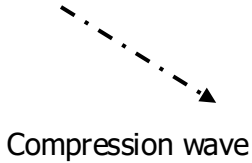


|                 | Height (mm) | Depth (mm) |
|-----------------|-------------|------------|
| Average         | 0.47        | -0.09      |
| Std dev         | 0.75        | 5.30       |
| Oversizing 95%  | 1.7         |            |
| Undersizing 95% | -0.8        |            |

\*Excludes misses



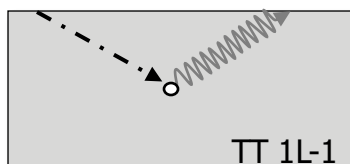
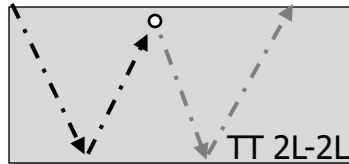
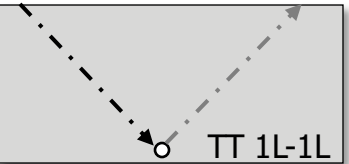
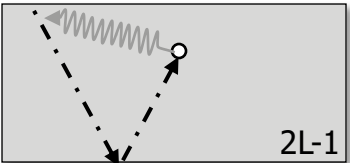
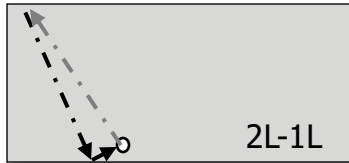
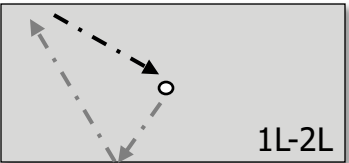
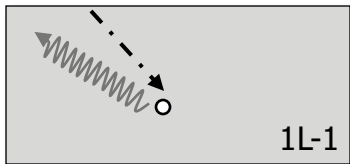
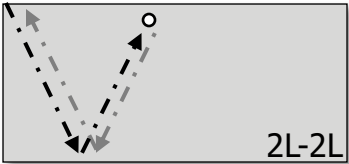
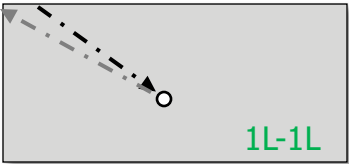
Direct mode



# Stage 3: Exploiting limits of VSs



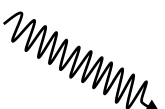
Dolphin CRA compression wave



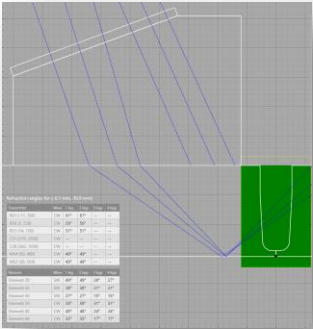
Compression wave



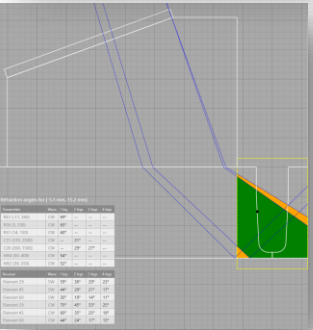
Shear wave



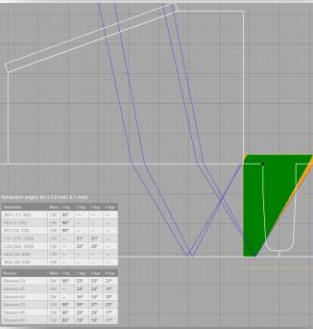
Dolphin CRA mode converted



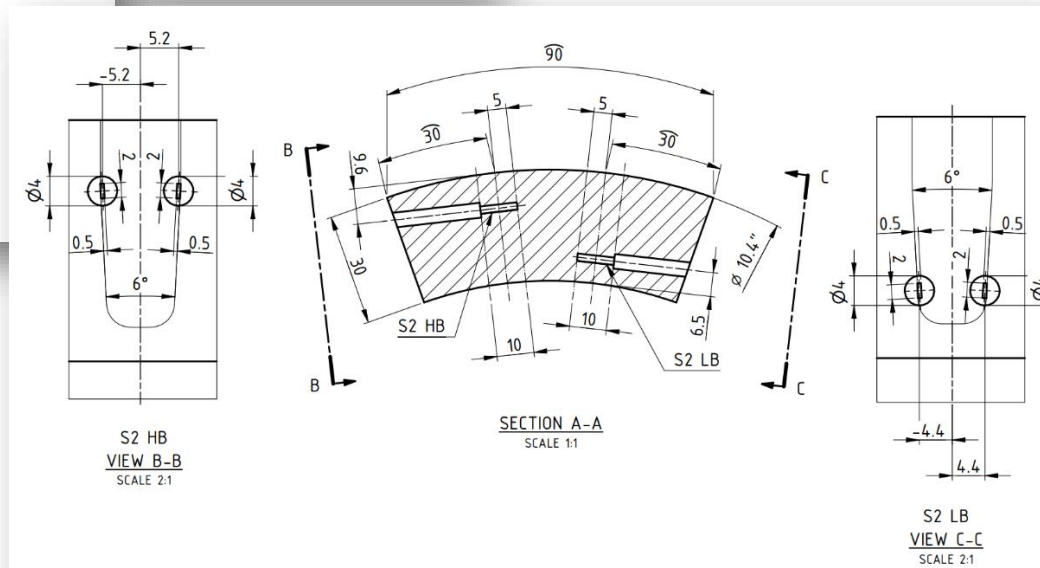
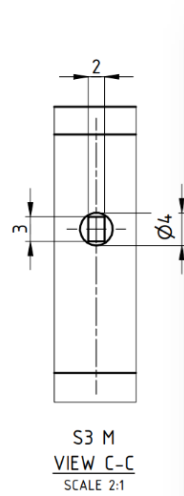
1L-1L  
1L-1  
1L-2L  
TT 1L-1L  
TT 1L-1



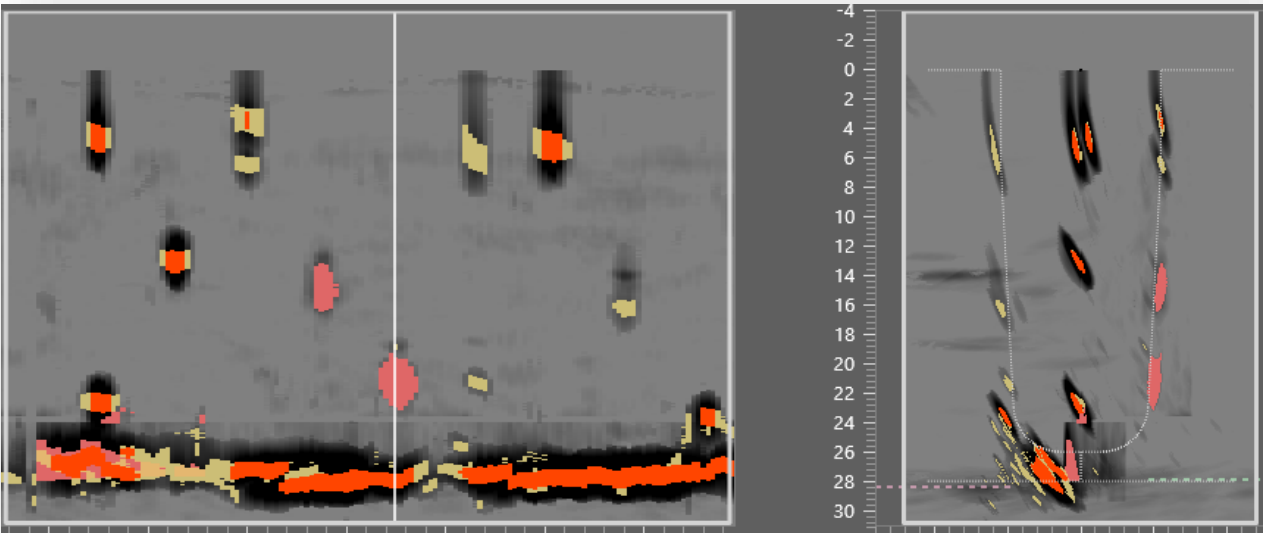
1L-2L



2L-1L  
2L-1  
2L-2L  
TT 2L-2L

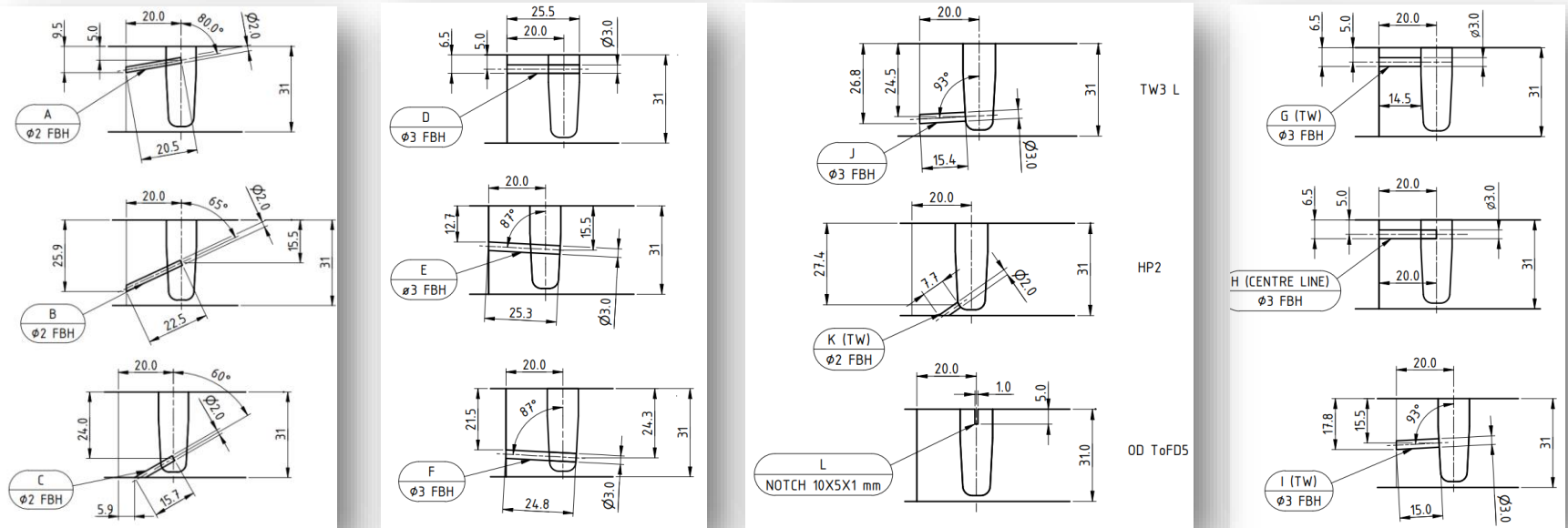


# Stage 3: Reference block with weld

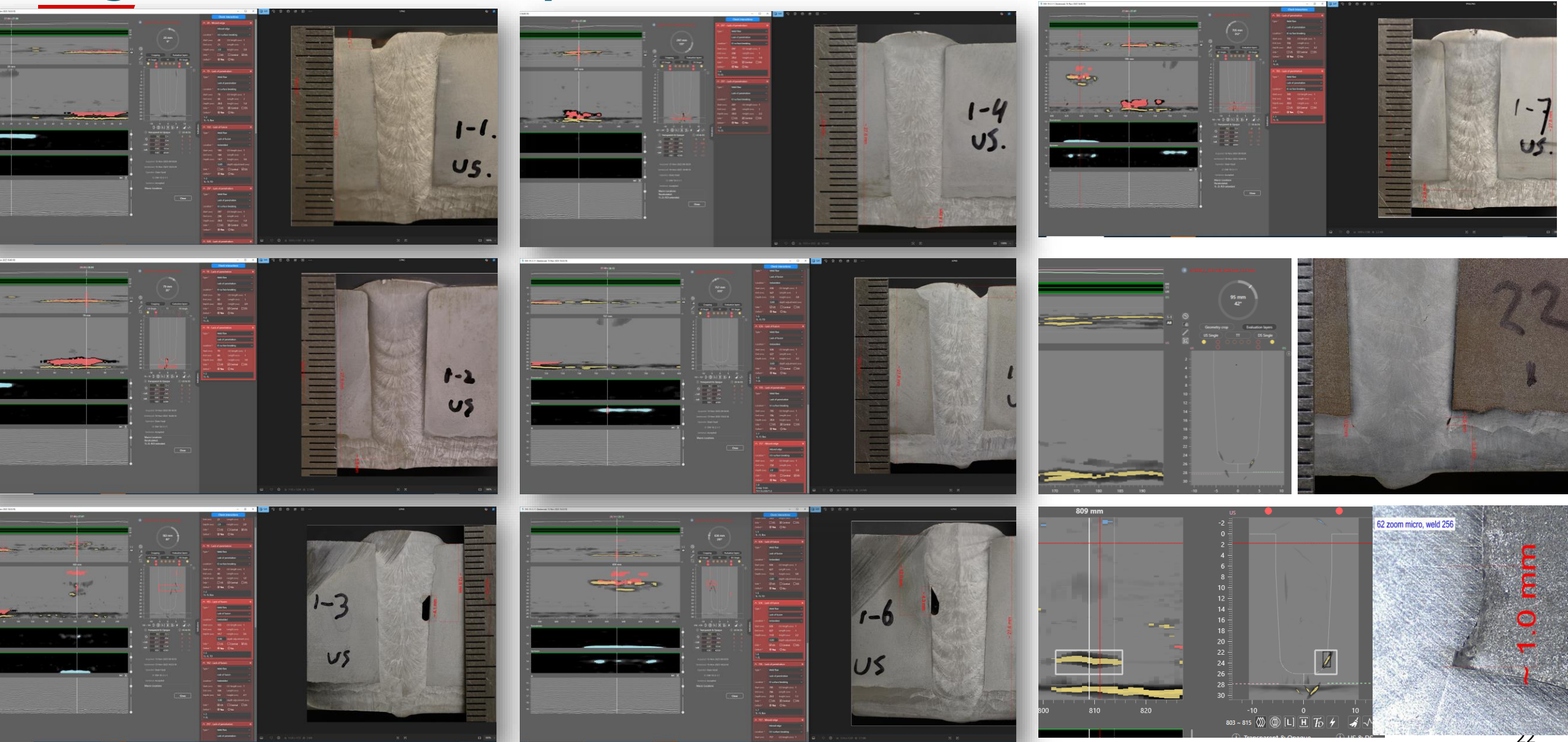


side view projection

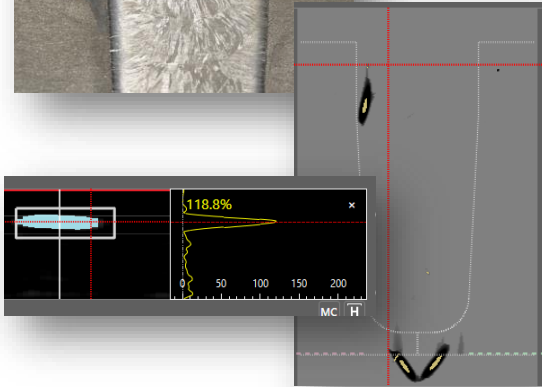
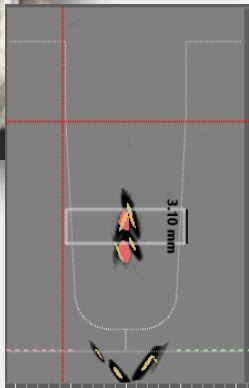
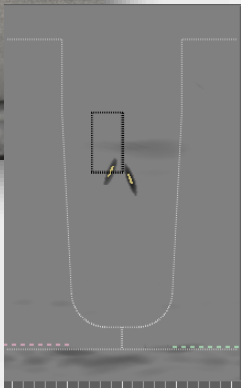
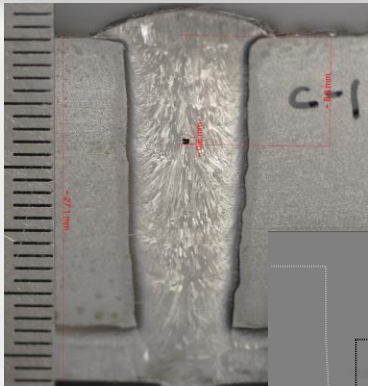
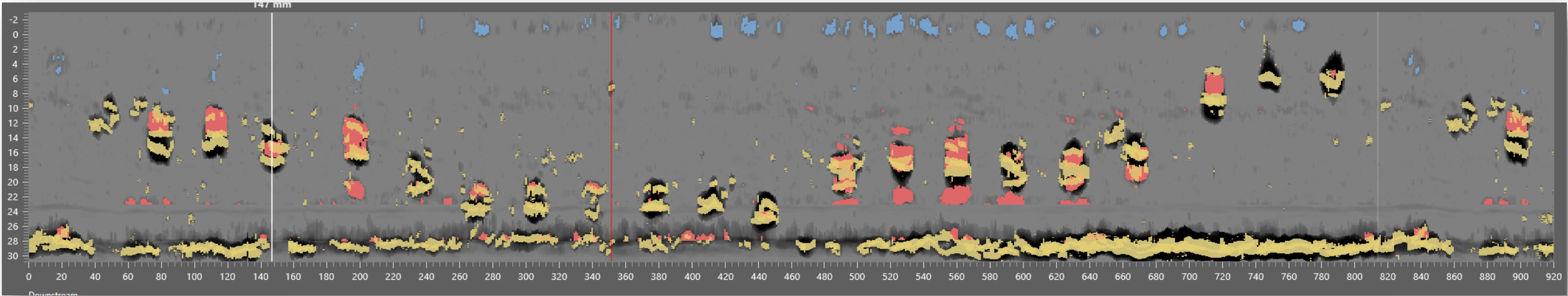
merged bevel view



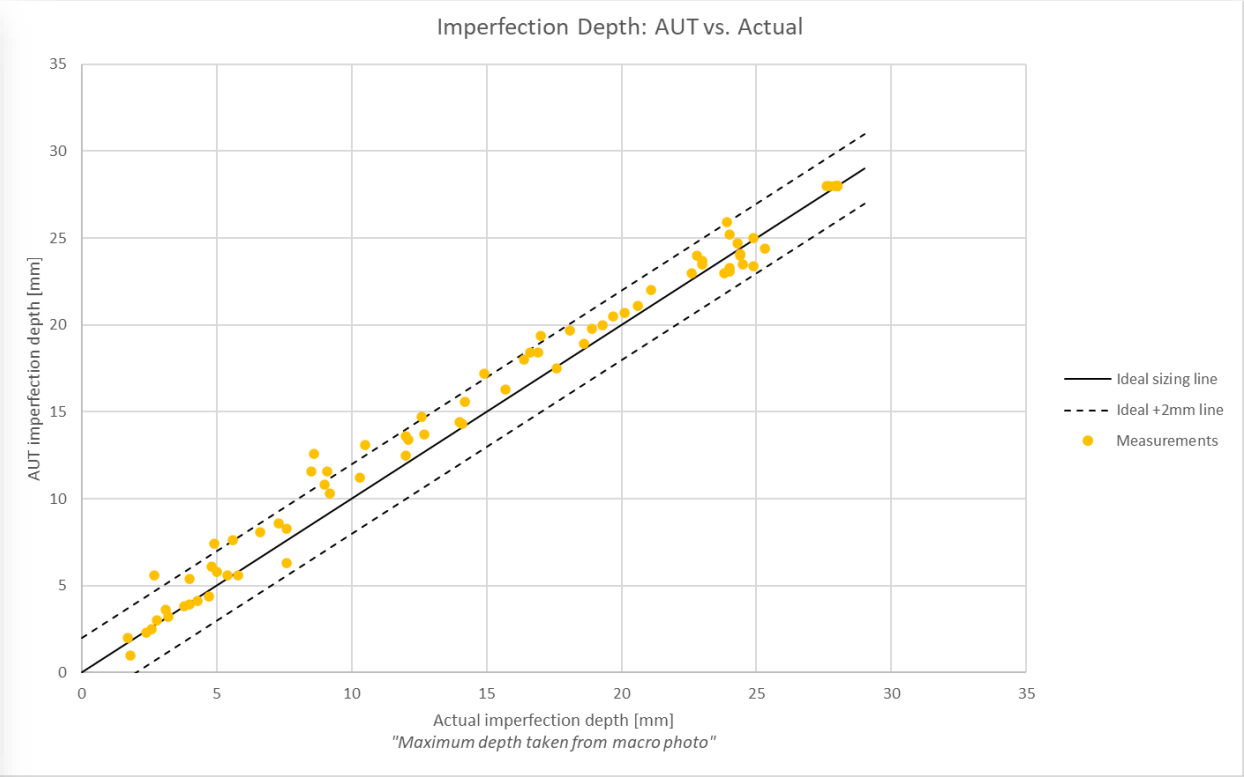
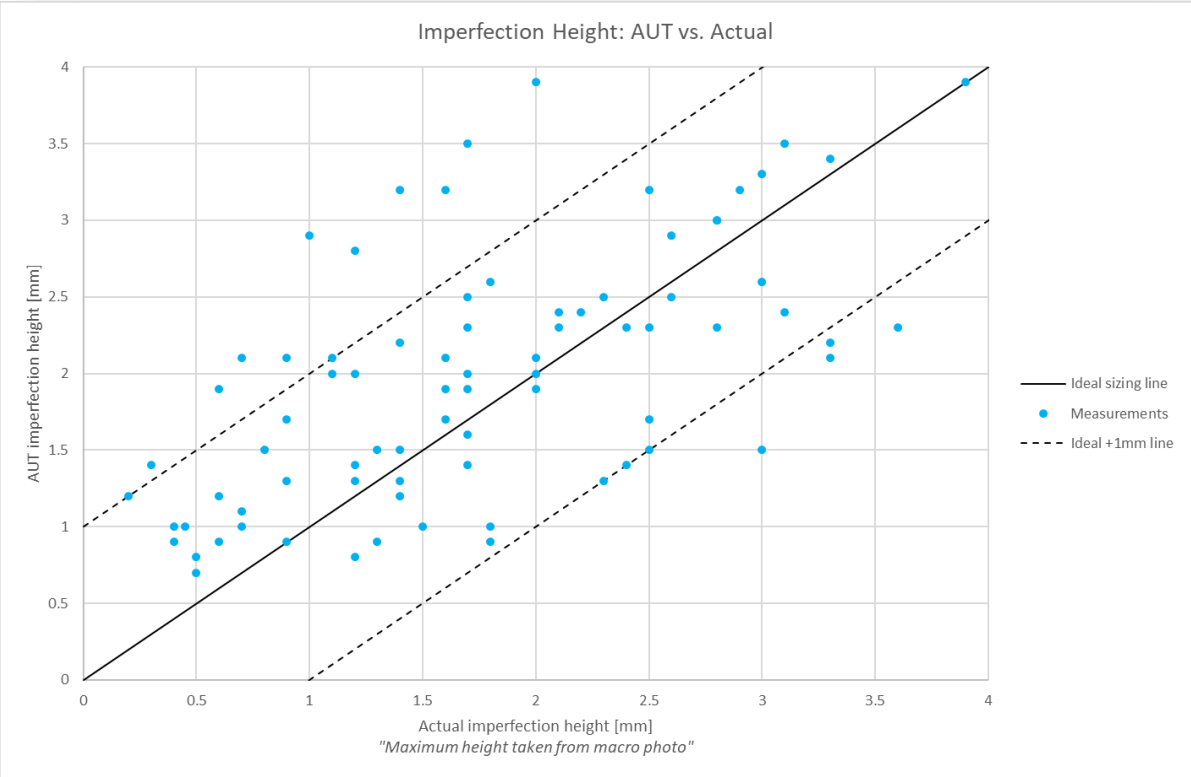
# Stage 3: Defect weld sample 1



# Stage 3: Defect weld sample 2



# Stage 3: Sizing results



## Results

|                                                |               |
|------------------------------------------------|---------------|
| Number of indications for accuracy calculation | 81            |
| Average sizing error: Height                   | 0.20mm        |
| Standard Deviation: Height                     | <b>0.77mm</b> |
| Average sizing error: Depth                    | 0.61mm        |
| Standard Deviation: Depth                      | 1.24mm        |

## Stage 3: Offshore trials



Dolphin AUT – CRA version has been tested in offshore conditions as well

## Future work

- Qualification program to enable system for commercial projects
- Streamlining setup process
- Automating system parameter tuning
- UX and speed performance improvements

