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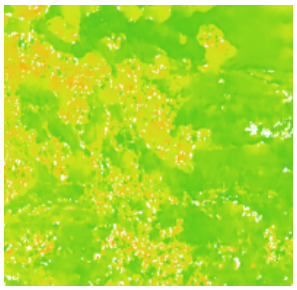
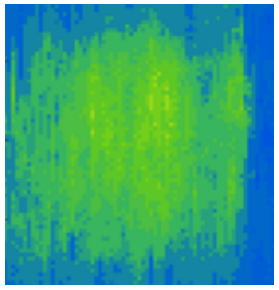
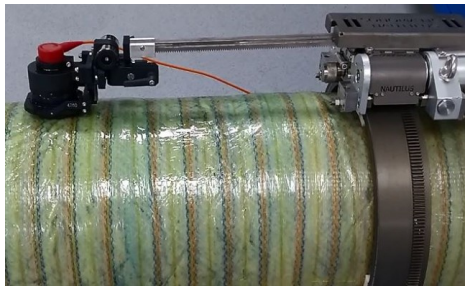
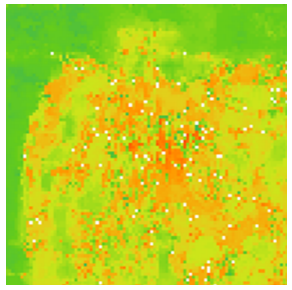
# CFRP/GFRP Repair Integrity Verification and Substrate Corrosion Mapping using a DRS Technique

January 2020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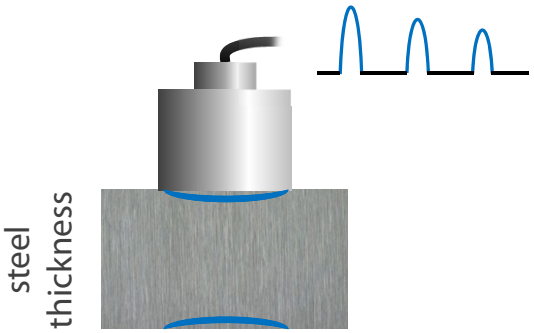
# Conventional UT

Accurate measurements of steel thickness are based on reflections using

- High frequencies (5 – 10 MHz)
- Speed, distance, time calculations

However, many coatings attenuate high frequency signals

→ *Conventional UT often not possible*

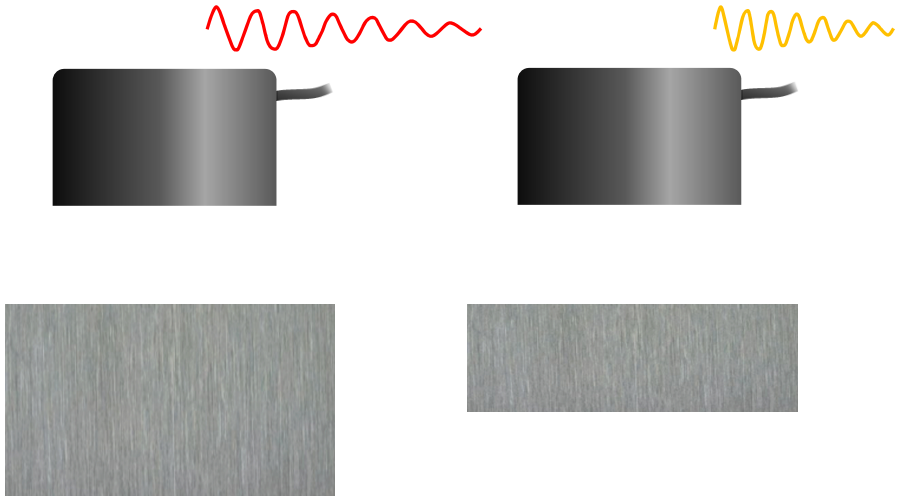



Time-based WT measurements

# The DRS Technique

Uses lower frequency ultrasound to make accurate measurements of steel WT

- Low frequencies penetrate coatings more easily
- Low frequencies cause steel to vibrate at its natural frequencies (usually < 1 MHz)
- Vibration frequencies are used to calculate steel WT



Frequency-based WT measurements



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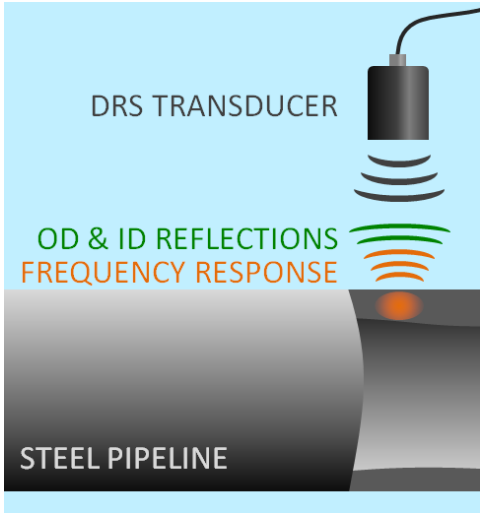
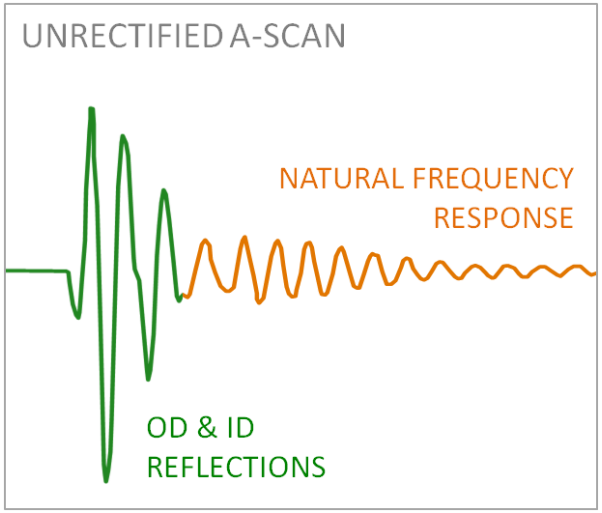
# The DRS Technique

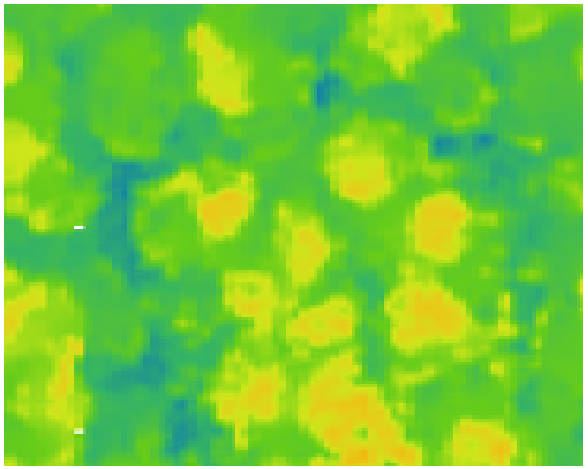
Probe excites steel with a broad range of low ultrasonic frequencies




Steel responds, vibrating at natural frequencies related to the WT




Probe rasters over area collecting response signals



Advanced signal processing algorithms extract the vibration frequencies and map the WT profile



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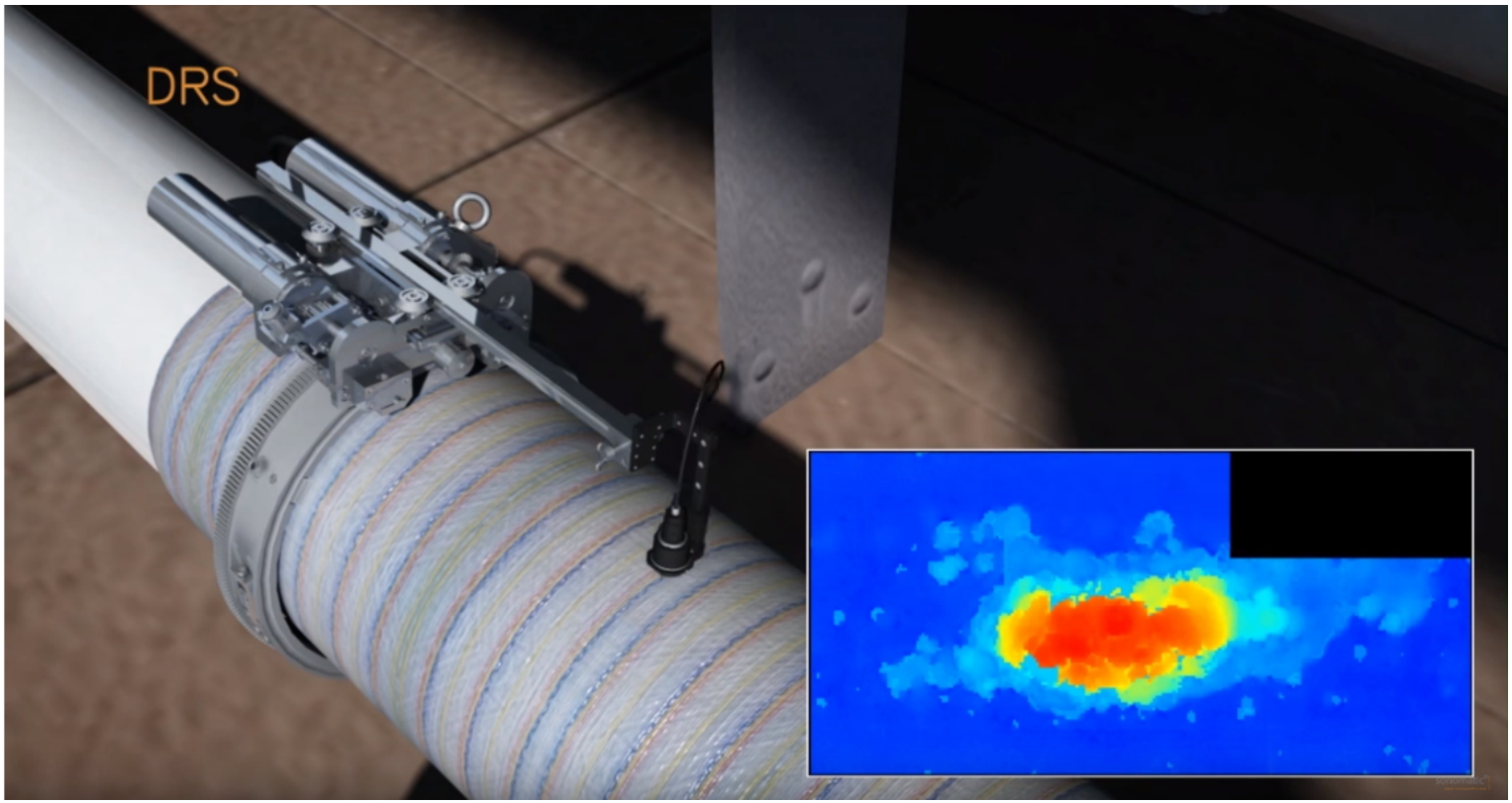
# DRS Inspection of Ex-Service Composite Repair Sample




https://youtu.be/nkj0nvEfE0g



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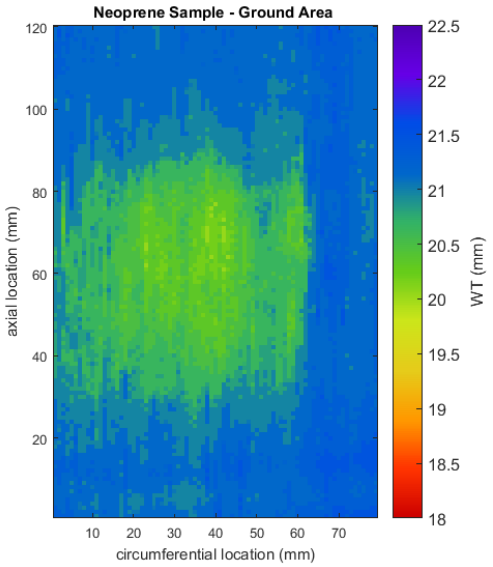
# The DRS Technique – Advantages & Limitations




Steel WT measurement accuracy is typically ±0.5 mm (80% tolerance)

WT variations of <1 mm can be measured

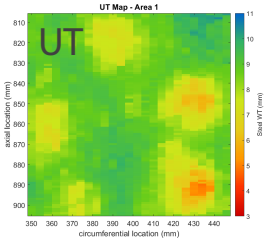
Pits smaller than 10 mm in diameter are not detected

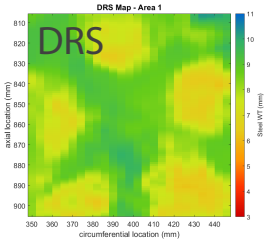
- Weak response from very small features masked by stronger response from neighboring features

Max steel WT = 22 mm (currently)

Min measurable steel WT = 3 mm (coating dependent)

- Thin steel has high frequency response which is attenuated in coatings
- Steel WTs reported as 'below detection limit'



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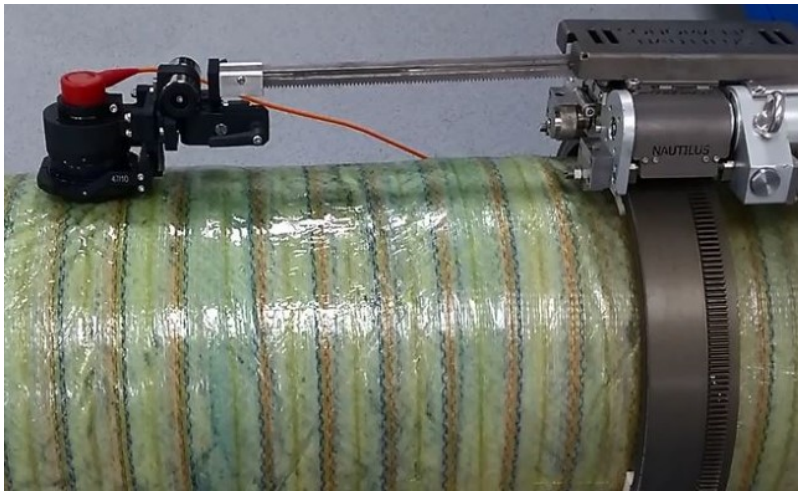
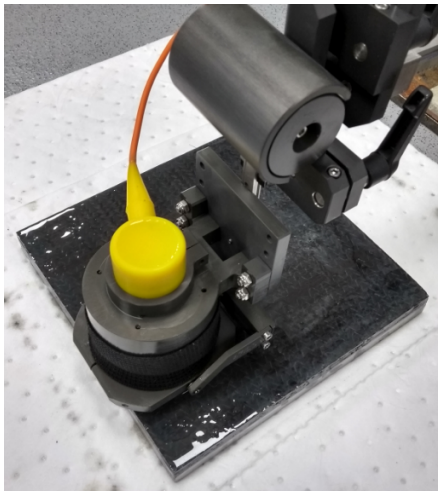
# Composite Repairs





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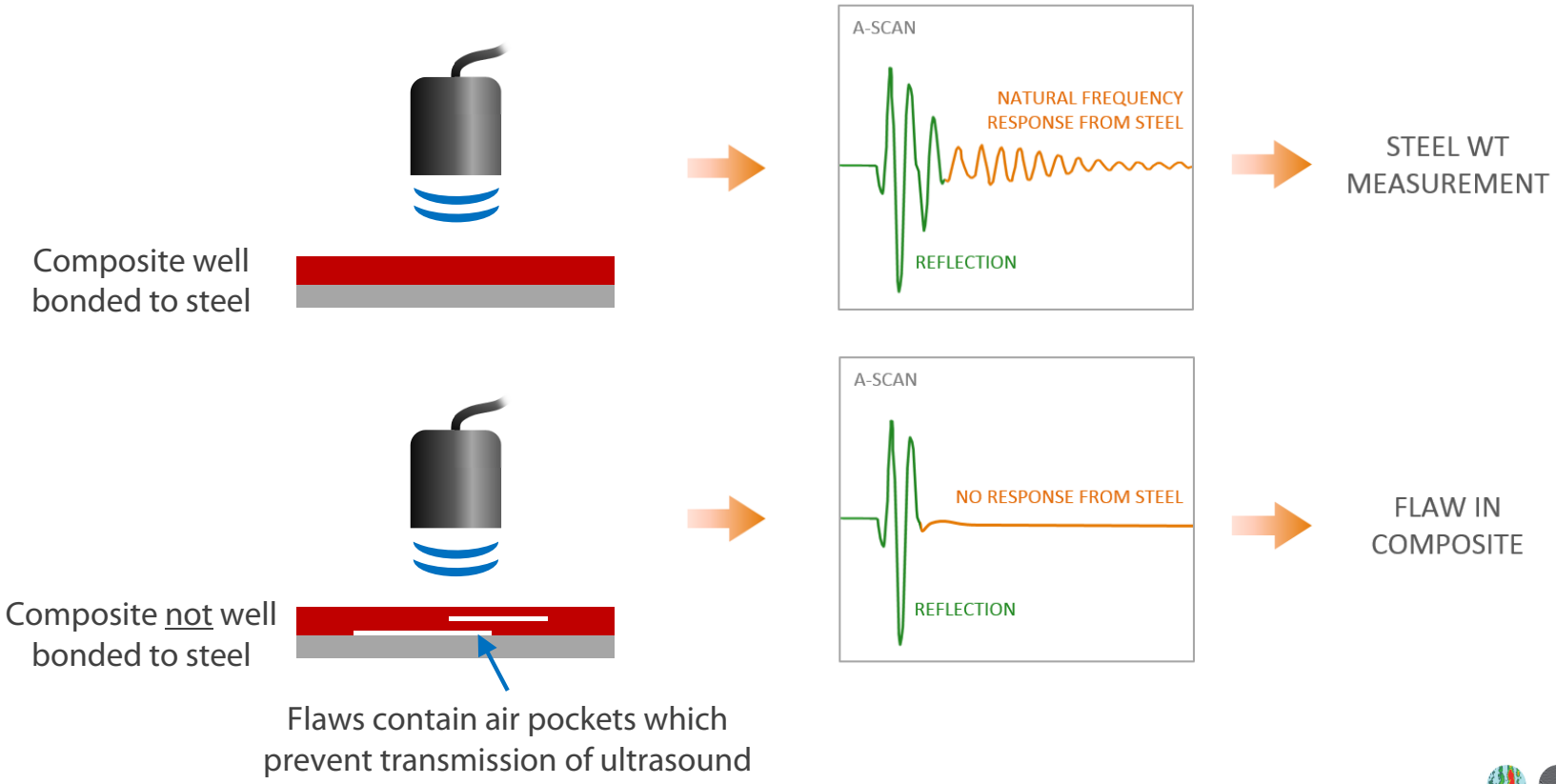
# Composite Repair Flaw Detection With DRS



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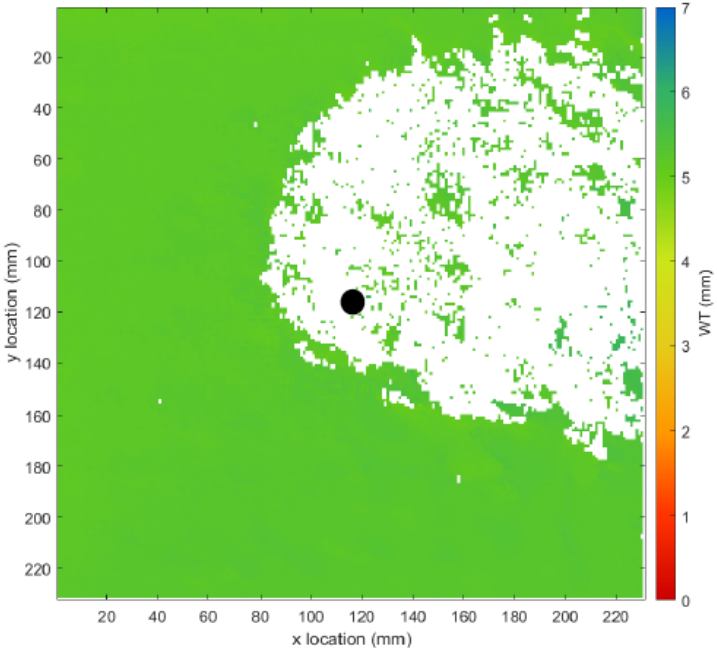
# Composite Repair Flaw Detection With DRS – Delaminated Test Plate

Composite repair on a flat plate


Pressure applied through back of plate to delaminate the composite




DRS map shows delamination in white



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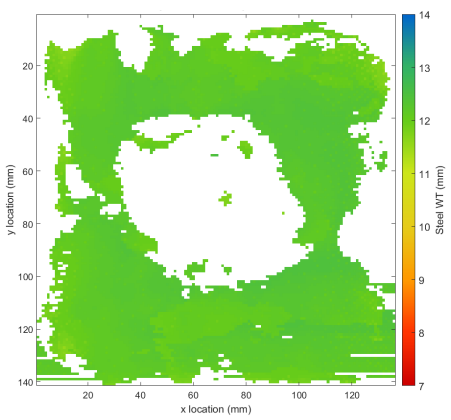
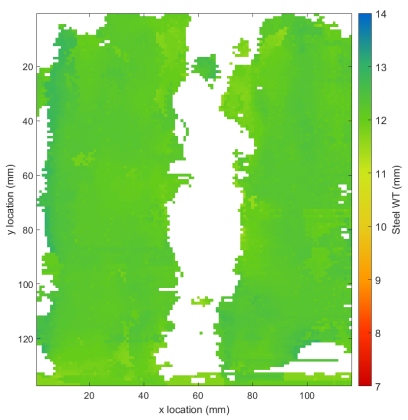
# Composite Repair Flaw Detection With DRS – Flaw Test Plates

Flaws typically contain small air pockets which ultrasound cannot penetrate

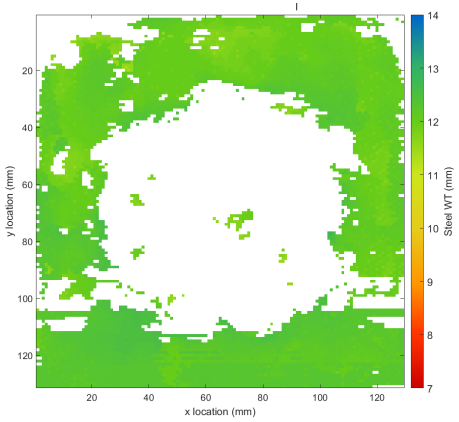
Air Bubble



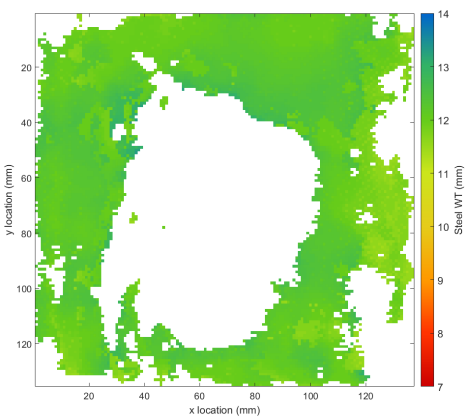

Wrinkle




Poor Saturation




Sand




DRS detects flaws and measures their extent but does not identify the type of flaw



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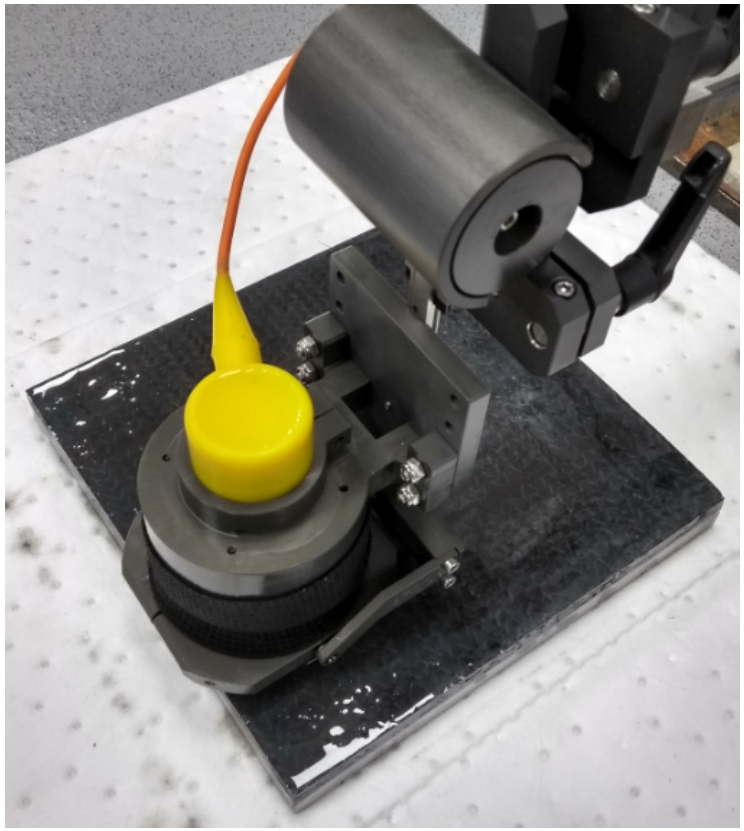
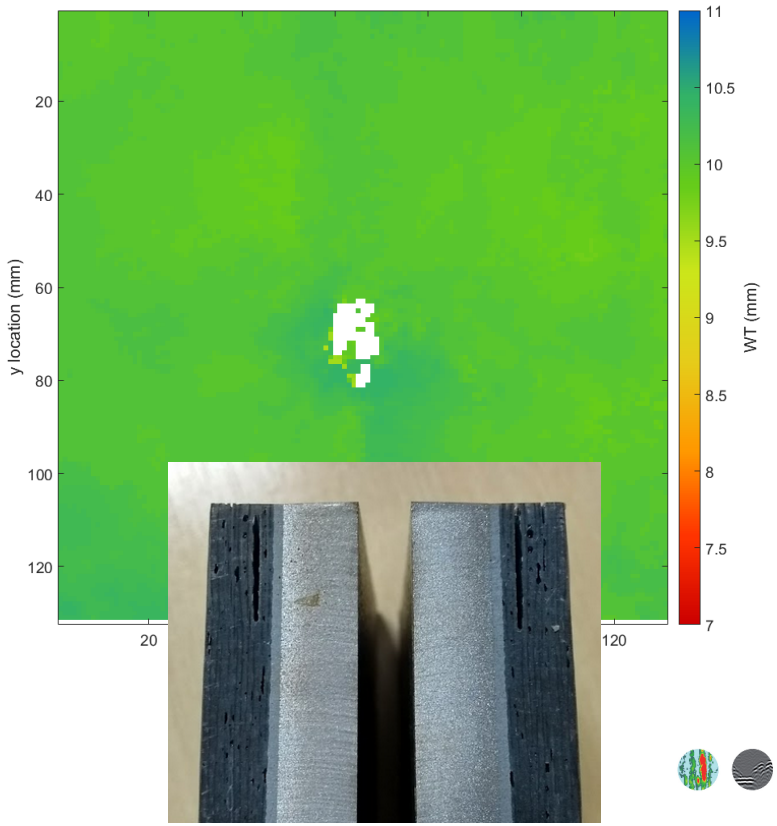
# Composite Repair Flaw Detection With DRS – A Natural Flaw



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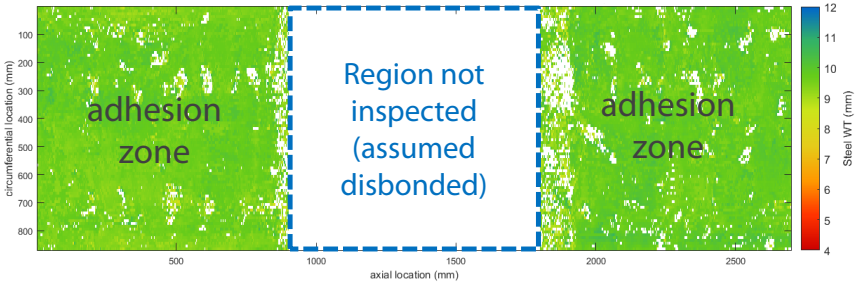
# Composite Repair Flaw Detection – DRS Validation Trial – USA

Pipe sample – 10 inch diameter

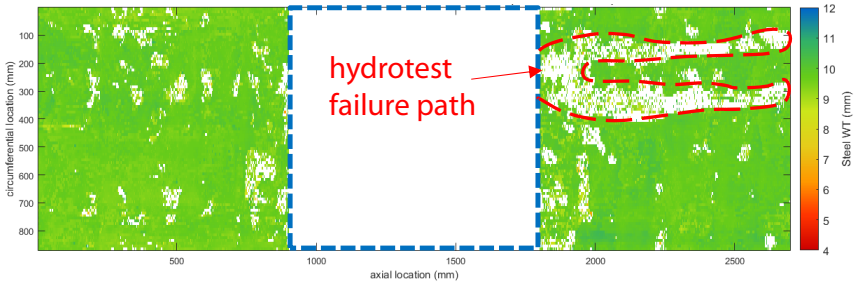

Carbon Fiber Repair

Initial inspection: some flaws evident




PRESSURE TESTED TO DESTRUCTION

Repeat inspection: same flaws plus failure path



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# Composite Repair Flaw Detection – DRS Validation Trial – USA

Definitions

Flaw: Anomaly in the composite
Defect: Flaw which affects the integrity of the composite


When is a flaw a defect?

- Close enough to the encapsulated region to interact with it
- Close enough to another defect to interact with it

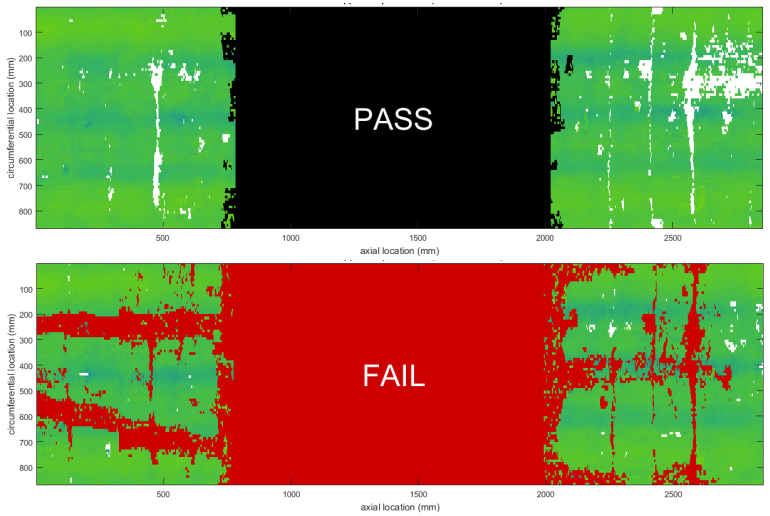
Interaction distance is determined by finite element modelling

An automated QA test can be performed

- PASS: Flaws interact over only part or none of the adhesion zone
- FAIL: Flaws interact along entire length of adhesion zone

DRS inspections and QA tests have been performed in the field

Automated QA test on pipe samples



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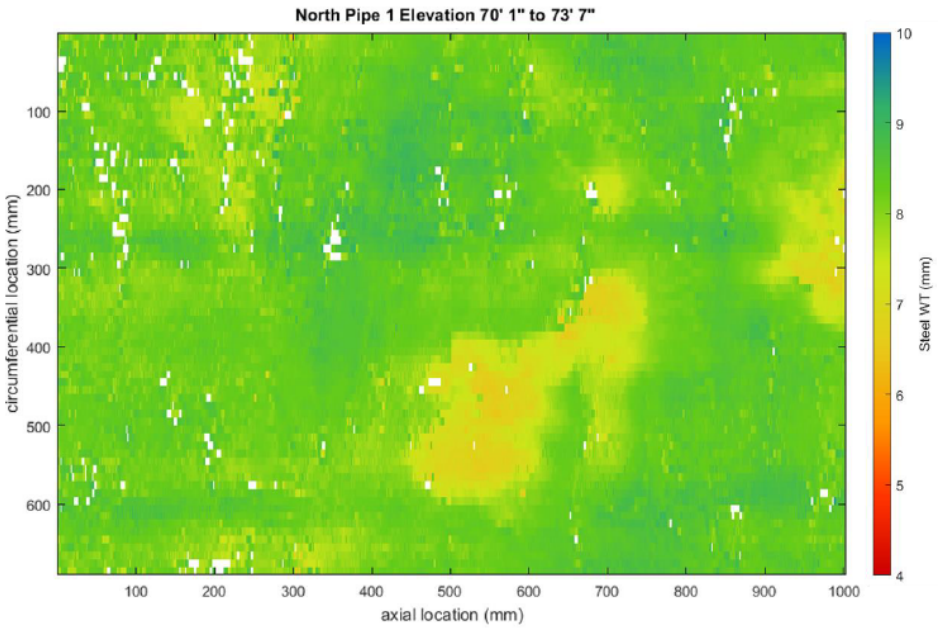
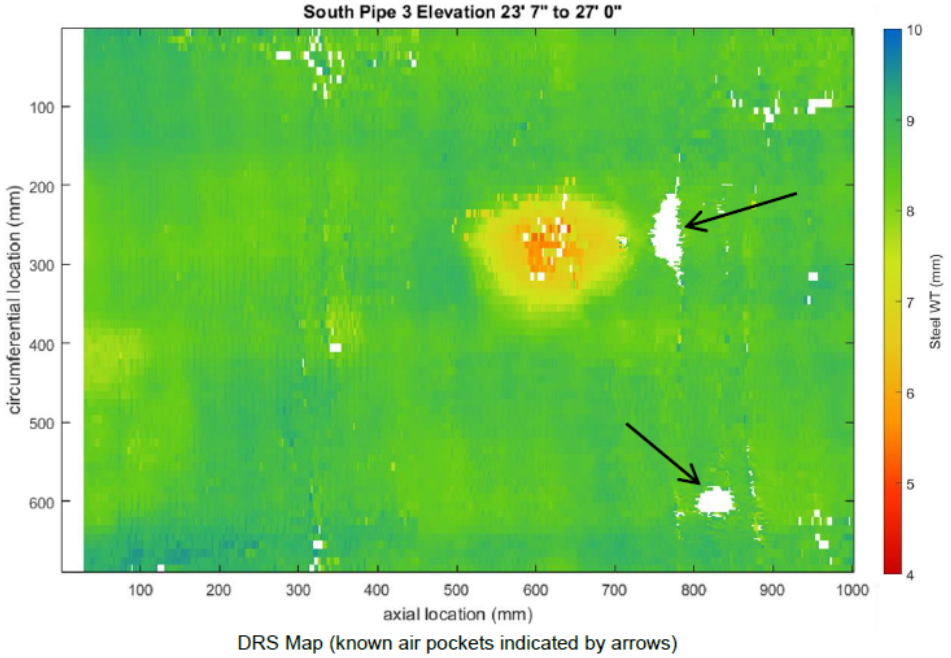
# Sample Results




Good Adhesion, minor corrosion




DRS Map (known air pockets indicated by arrows)

Mostly good Adhesion, two air bubbles



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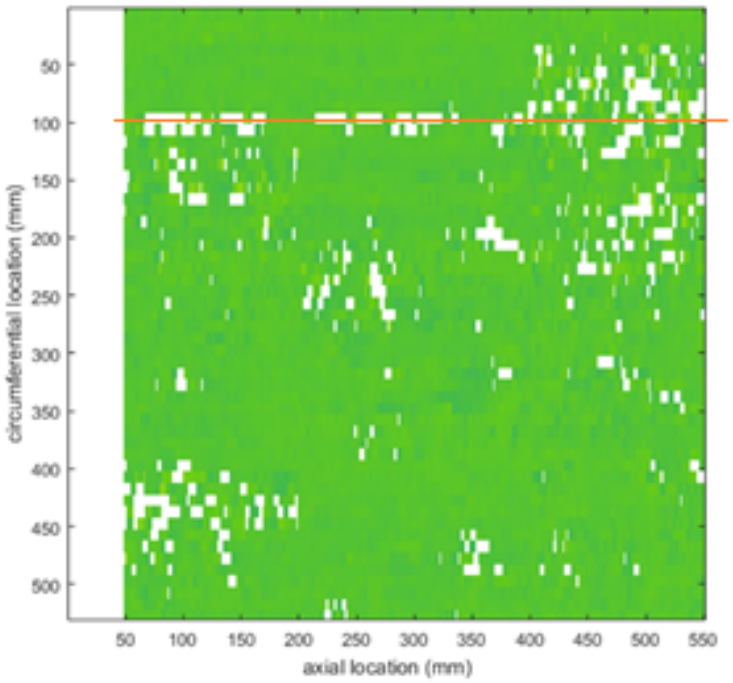
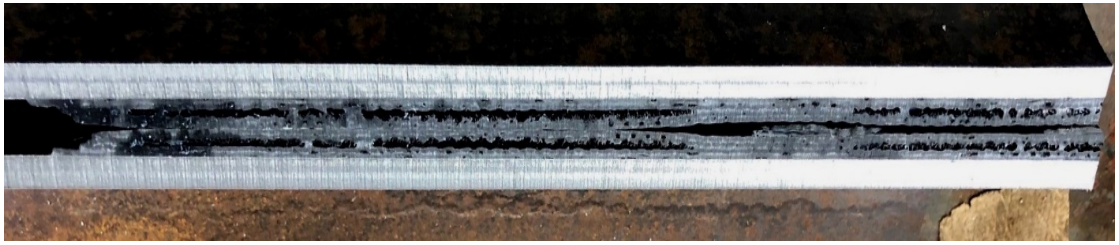
# Sample Results





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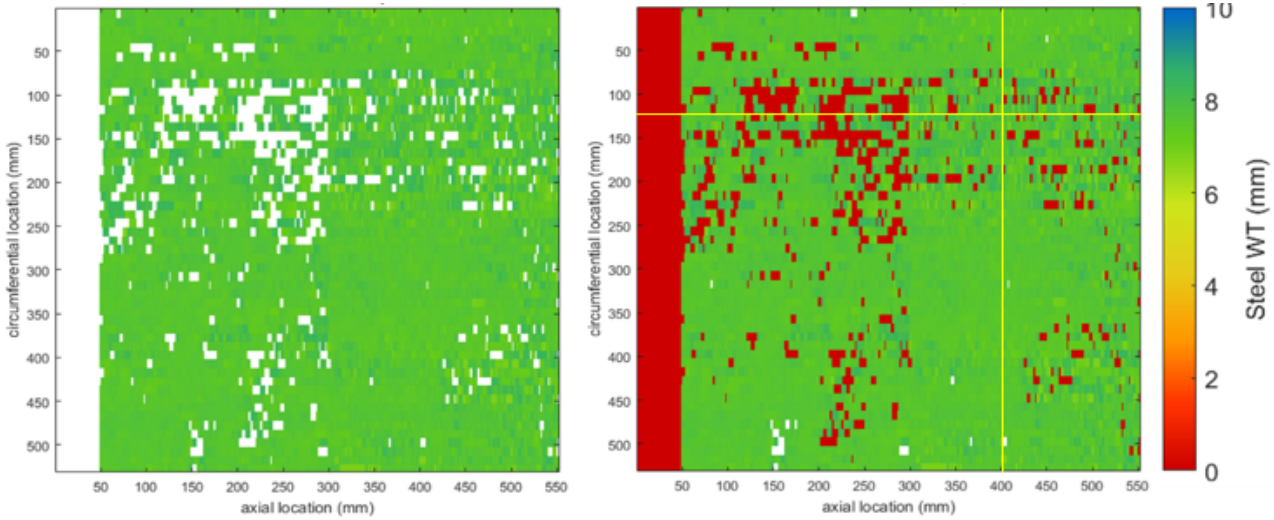
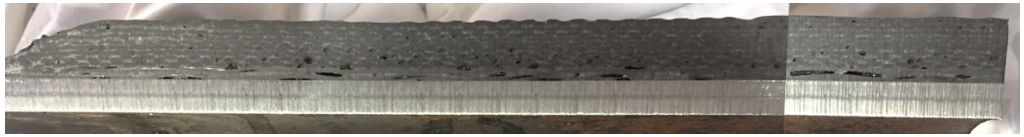
# Sample Results





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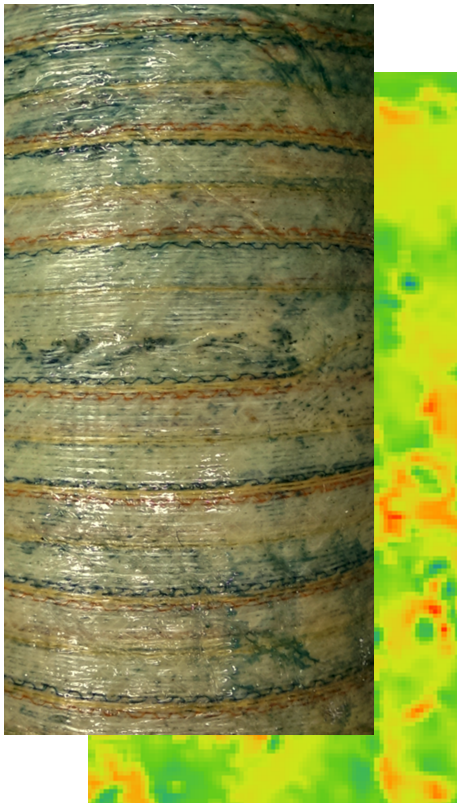
# Benefits of DRS Inspection



Identifies flaws in composite repairs

The high accuracy of DRS maps makes them suitable for

- Confirming absence of steel degradation
- Quantifying extent of steel wall loss
- Determining if corrosion growth is active
- Estimating corrosion growth rates
- Input to Fitness for Service assessment, including Level 3 using finite element analysis
- Statistical analysis of limited coverage inspections



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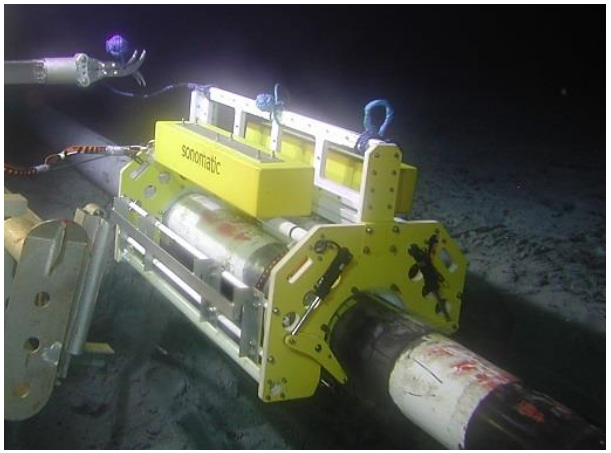
# DRS Deployment

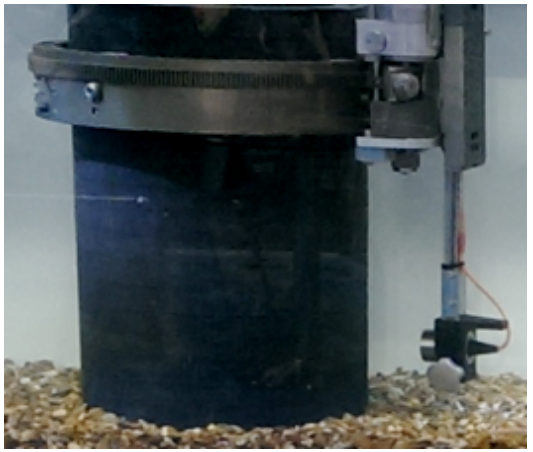
DRS system is deployed on Sonomatic's range of proven inspection tools

All tools are designed by Sonomatic and can be modified for specific project requirements

Topside Nautilus




ROV-iT



Subsea Nautilus



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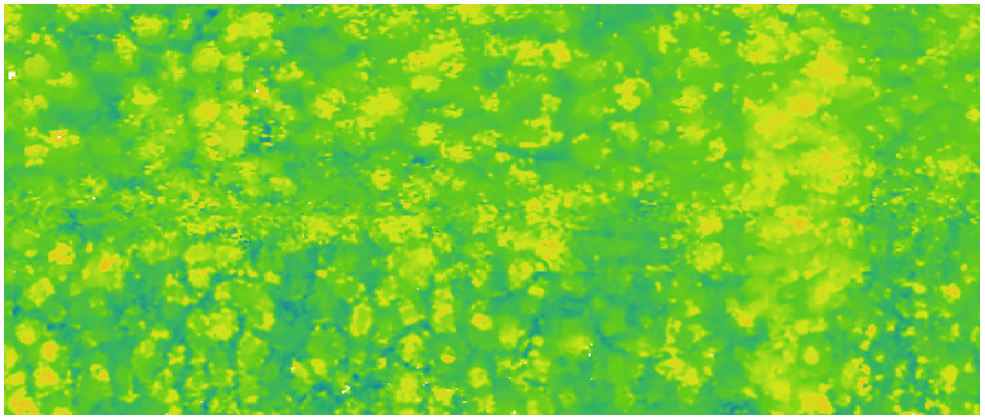
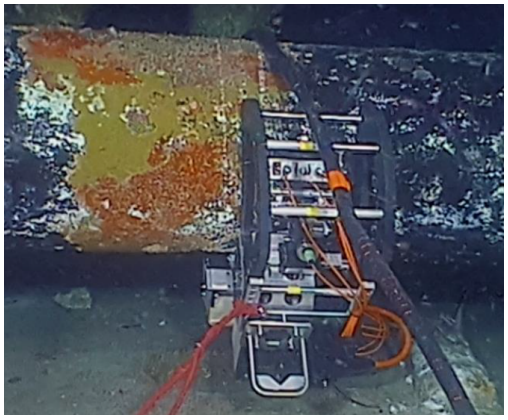
# DRS Experience

The DRS technique has been validated by Sonomatic and several clients for a range of applications

First used in the field in 2015, it has been deployed worldwide on many projects since, including:

- Onshore and offshore assets
- Topside and subsea locations
- Composite repairs, coal tar enamel, multilayer polypropylene and Neoprene coatings
- Inspections for mapping corrosion and evaluating flaws in composite repairs







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