Non-Destructive Testing Challenges in the Net Zero World

HOIS
Advancing NDT

Dr Patricia Conder, Dr Helen Peramatzis, Dr Mark Jones, Dr Martin Wall

ESR Technology on behalf of HOIS JIP

ESR Technology

HOIS – Who are we? What do we do?

HOIS Advancing NDT

HOIS is a joint industry project

- Started in 1982
- Managed by ESR Technology
  - Programme Manager Dr Helen Peramatzis
- Annual budget ~ £750k, subscription income boosted by additional funding from the Net Zero Technology

HOIS Vision:

- **To be the best forum for the energy industry to improve the effectiveness of in-service non-destructive testing**
- Originally oil and gas focussed
- Now expanding to all energy application and other sectors

Program

- Chosen entirely by membership

2022 deliverables:

- 9 detailed confidential technical reports
- 6 papers at industry events

HOIS Members

14 Asset operator/owners

24 Inspection service, equipment vendors and notified/ appointed bodies

Recent and Ongoing HOIS Projects

Active blind trial programmes:
- Inspection of socket weld fittings
- Inspection for weld root corrosion in small bore pipework
- External corrosion scabs inspection
- Effective inspection of heat exchanger tubing
- Inspection for corrosion under pipe supports (CUPS)
- NII at elevated temperatures
- Remote internal inspection
- Small bore pipework inspection
- Stress corrosion cracking

Active review programmes:
- Pipework Analytics and inspection optimisation
- Acceptance of machine learning for use in NDT
- Digitalisation of NDT
- Low carbon and Emission Reduction
- Subsea and FPSO
- Human Factors

Net Zero – Where does NDT fit?

The road to Net Zero is paved with engineering and materials advances.

The role of inspection is to predict maintenance requirements and reduce the risk of failure.

Multiple sectors all accelerating – wind, hydrogen, carbon capture and storage, wave, solar….

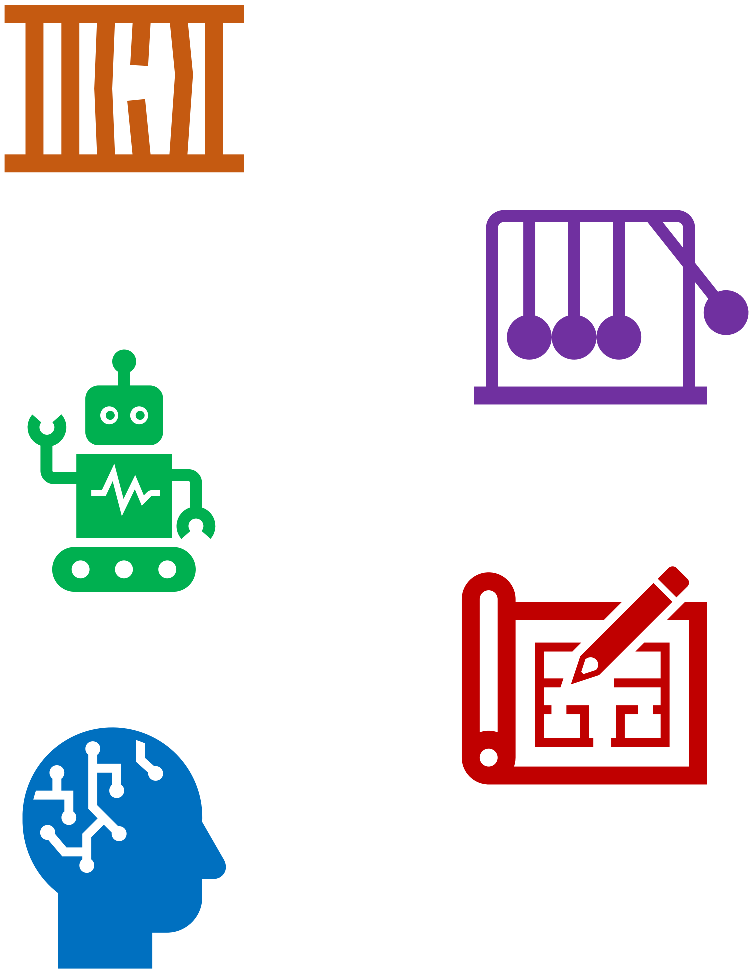
Will the equipment and materials give rise to new inspection challenges?

Can existing non-destructive testing techniques and equipment evaluate all the predicted degradation mechanisms? Or is innovation required here too?

HOIS has been posing these questions…

Five Facets of NDT

- Degradation
  - What are you actually looking for?
- Physics of Inspection
  - How can you find it?
- Inspection Deployment
  - How to access chosen locations?
- Planning
  - Where, how much and when?
- Data Analytics
  - What does it all mean?

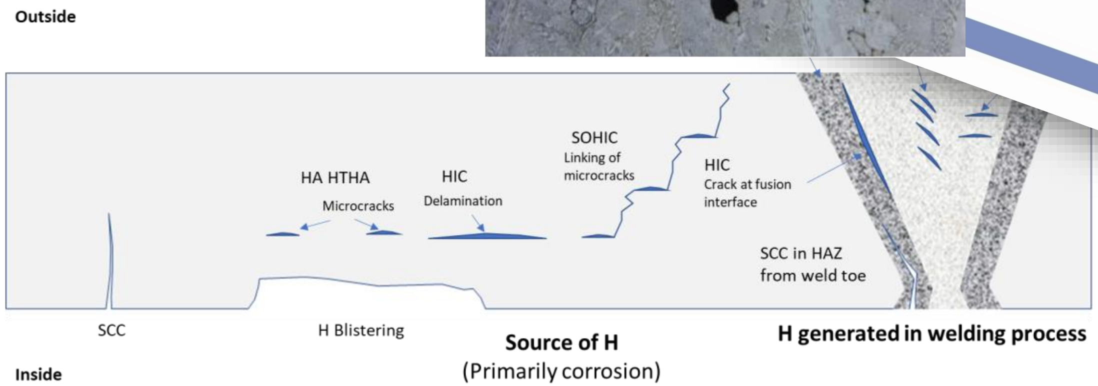


Degradation

- What forms of degradation are you actually looking for?
- Each NDT technique including visual inspection is limited to a range of different degradation morphologies
  - e.g. Near surface wall loss, far surface wall loss, near surface cracking, far surface cracking, delamination etc.
- Limited by current knowledge
  - Always potential for new failure mechanisms using new materials or new applications
- Lagging indicator
- Different materials
  - Composites
    - E.g. Delamination
- Different manufacturing route
  - Additive Manufacture
    - E.g. Porosity
- Different applications
  - Repurposing pipelines
    - E.g. hydrogen embrittlement

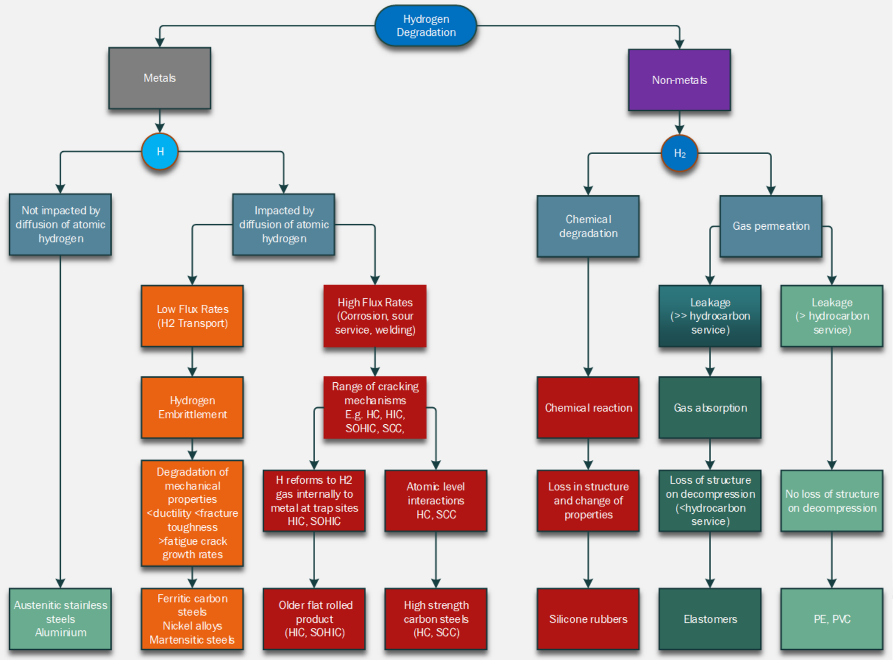

Vat Polymerisation
Powder Bed Fusion
Sheet Lamination
Material Jetting
Binder Jetting
Material Extrusion
Direct Energy Deposition

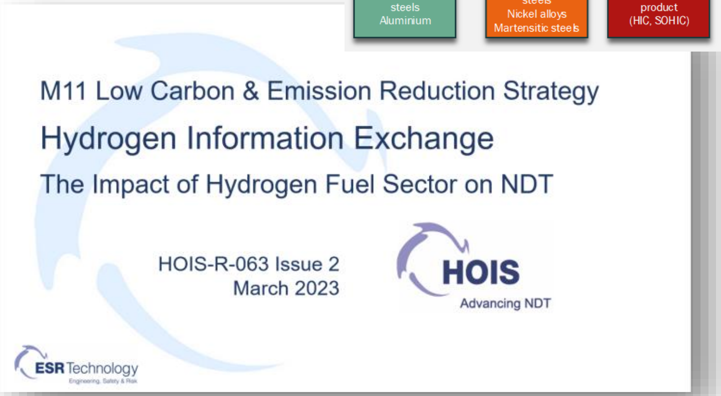
Additive Manufacturing in the Energy Sector
HOIS-R-048 1
Helen Peramatzis and Julia Nojek
November 2021
ESR Technology



Low Carbon and Emission Reduction

- Keeping watching brief on NDT related issues
  - Hydrogen
  - CCUS
  - To provide members with a one-stop starting point to build understanding of the NDT issues related to the use of hydrogen in the fuel sector and CCUS
  - Sign posting to best information sources not assimilating information
  - Issues
    - Fatigue crack growth rate
    - Critical flaw size
    - CO_2 Impurities





M11 Low Carbon & Emission Reduction Strategy

Hydrogen Information Exchange

The Impact of Hydrogen Fuel Sector on NDT

HOIS-R-063 Issue 2
March 2023

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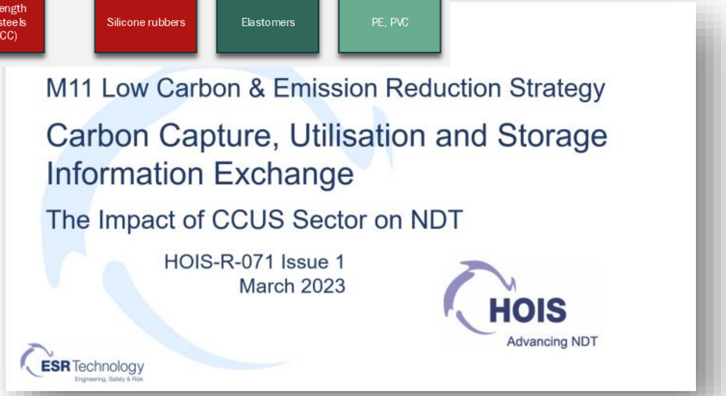

M11 Low Carbon & Emission Reduction Strategy

Carbon Capture, Utilisation and Storage Information Exchange

The Impact of CCUS Sector on NDT

HOIS-R-071 Issue 1
March 2023

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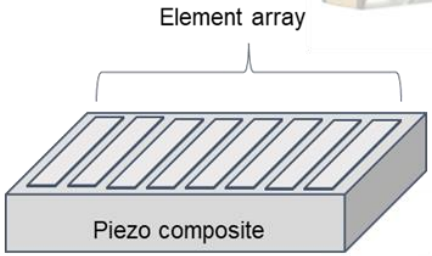
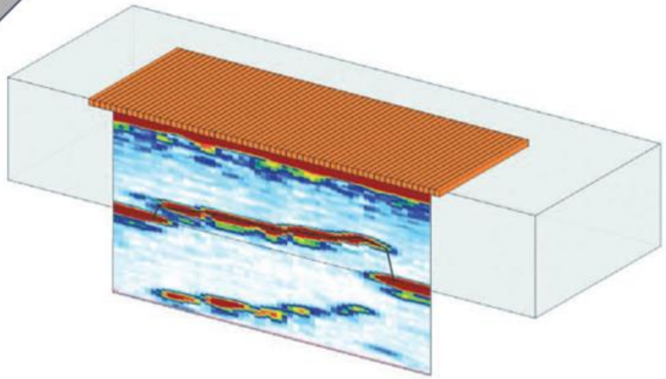
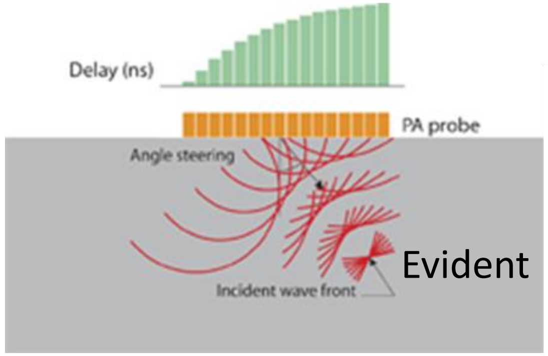
Physics of Inspection

- How can you find it?
- Range of different techniques all have limitations
  - Ultrasonics, eddy current, electromagnetic, visual, etc.
  - One technique **cannot** find all degradation types in all materials
- Material and geometry dependant
- New equipment poses new challenges (and some old ones)
  - Different materials
    - Metallic alloys
    - Composites
    - Additive Manufacture
    - Anti-corrosion/ anti-degradation coatings
    - Joints and welds
  - Different geometry
    - Is the degradation directly accessible?







Physics of Inspection

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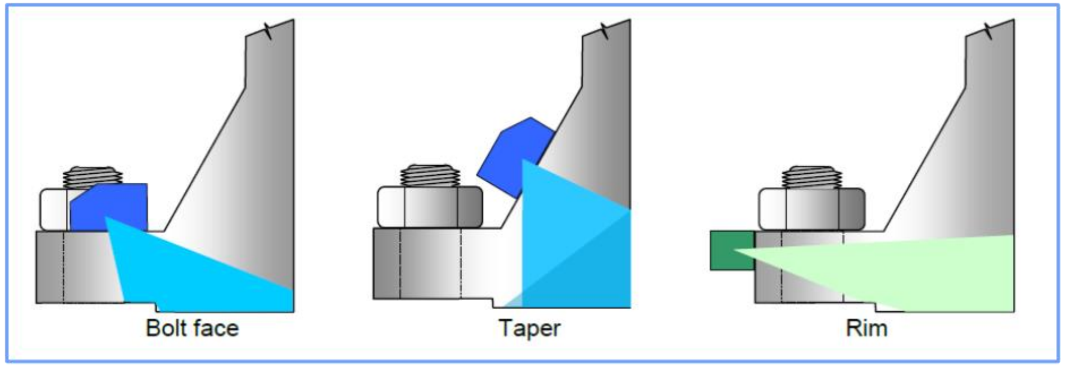
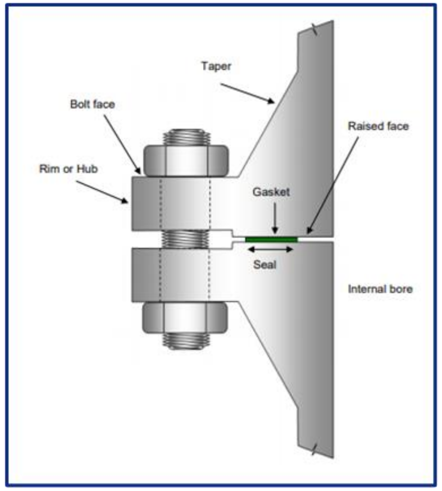
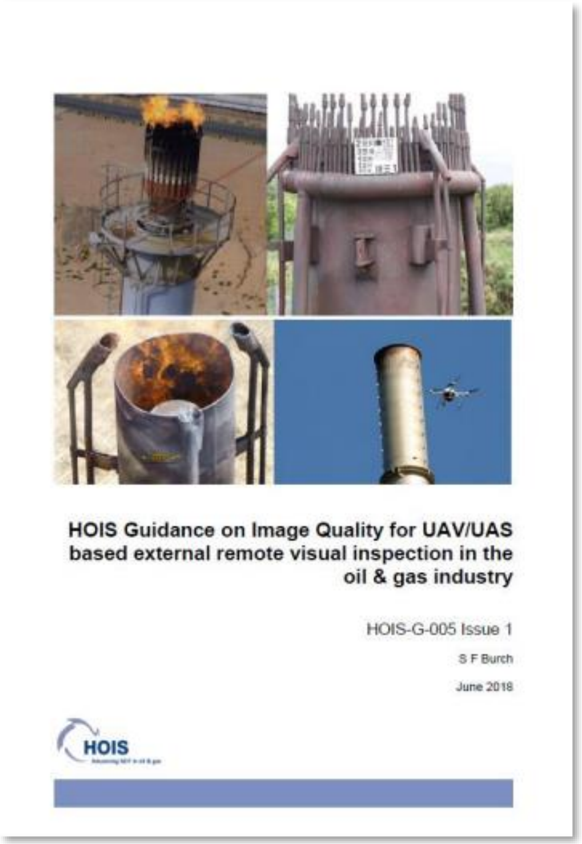
  - Different materials
    - Metallic alloys
    - Composites
    - Additive Manufacture
    - Anti-corrosion/ anti-degradation coatings
  - Different geometry
    - Is the degradation directly accessible?
    - Weld geometry and grain structure





HOIS G-005 Guidance on Image Quality for use of UAVs for RVI

- Use of Unmanned Aerial Vehicles (UAV) for remote visual inspection (RVI).
- Aim to develop guidance on minimum quality of UAV imagery needed for different applications to equate to close visual inspection (CVI).
    - *Can a camera deliver the same or better than on-site in-person inspection?*
- Key aspects
    - Camera specification i.e. lens and pixel size
    - In field application i.e. lighting, distance, demonstrable resolution
    - Validated by HOIS member trials using airborne UAVs to image USAF 1951 charts at different distances.
- Since 2018 publication:
    - ASME V Article 9 revised to include reference to resolution charts (e.g. USAF 1951).
    - HOIS guidance being referenced in industry tenders
    - Publicly available
    - https://www.bindt.org/shopbindt/hois-documents/

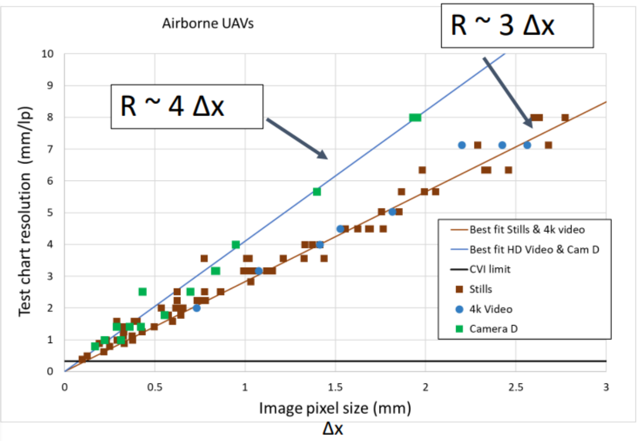

HOIS Guidance on Image Quality for UAV/UAS based external remote visual inspection in the oil & gas industry

HOIS-G-005 Issue 1

S F Burch

June 2018

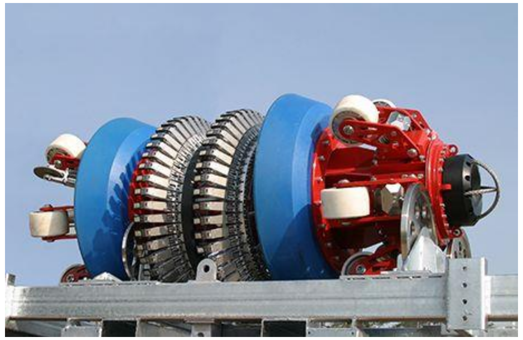
HOIS



Inspection Deployment

- How to access chosen locations?
- Rate and extent of coverage?
- Deployment (largely) controls rate of data acquisition and therefore costs
- Fixed monitor
- Robotics
  - Autonomous
    - Unmanned Aerial Vehicles
    - Stand-off robots
    - Contact robots
    - In-line inspection tools (intelligent pigs)
  - Non-autonomous
    - Scanners
    - Unmanned Aerial Vehicles
    - Contact robots
- Manual

Stock

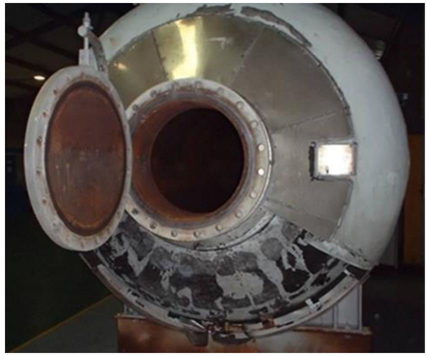


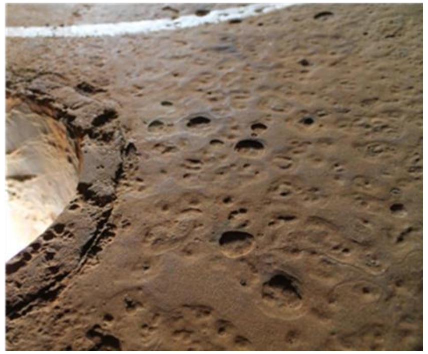
ROSEN

Trials of inspection of offshore wind foundations using mini-ROV at ORE Catapult

Remote Internal Inspection (RII)

- Example of transferrable approach
- HOIS Recommended Practice for Remote Internal Inspection of Pressure Vessels June 2022
  - Same structure as HOIS Recommended Practice HOIS-RP-103 for Non-Intrusive Inspection for Pressure Vessels
- RII can play a major role in effective minimum intervention strategies, as a supplement or sometimes alternative to IVI
- Over the past decade there have been major advances in technology for the remote internal inspection of pressure equipment:
  - Remote Digital Visual Inspection (RDVI)
  - Light based techniques such as laser
  - Robotic deployment capabilities
  - Deployability of techniques
  - Reporting and visualisation of results
- Barriers to adoption include
  - Insufficient understanding of available technologies and capabilities.
  - Variability of experience, [lack of] standards and training
  - Lack of framework





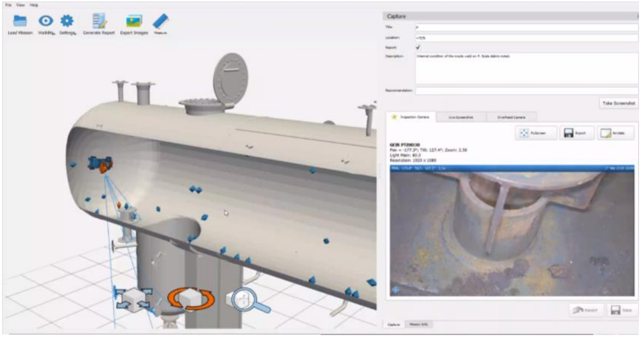
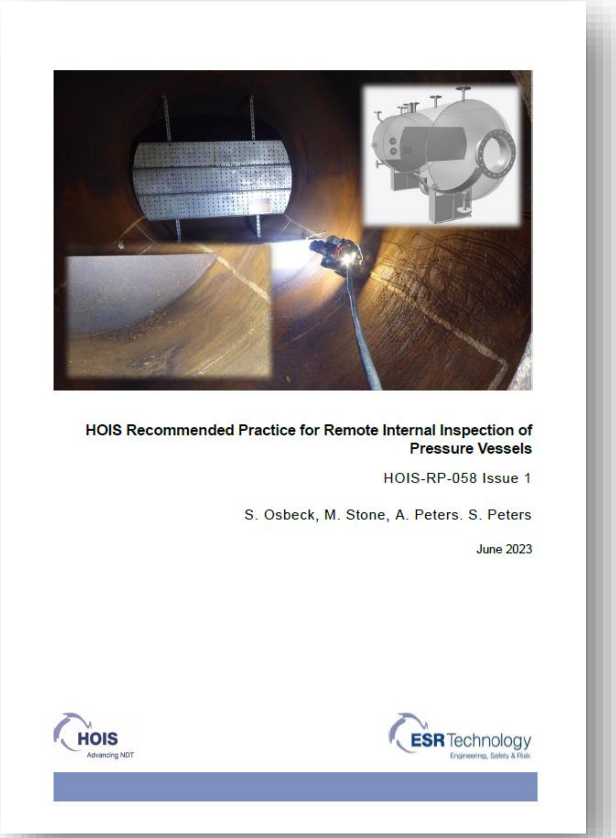


Image from GE Inspection Robotics

Remote Internal Inspection (RII)

- HOIS has developed a Recommended Practice for RII of pressure vessels
  - Covering planning, implementation and evaluation of RII for pressure systems.
  - Aim to build confidence in inspection methods
    - Clarifying requirements and quantifying capabilities
- Extensive work across developers and JIP's on relevant aspects of technology, processes and standards/guidance
- SPRINT Robotics active in developing guidance on deployment aspects primarily
- UK HSE Industry funded project on Remote Visual Inspection
- HOIS-SPRINT-HSE are collaborating to ensure there is no duplication of effort, outputs are complementary and aligned


HOIS Recommended Practice for Remote Internal Inspection of Pressure Vessels

HOIS-RP-058 Issue 1

S. Osbeck, M. Stone, A. Peters. S. Peters

June 2023

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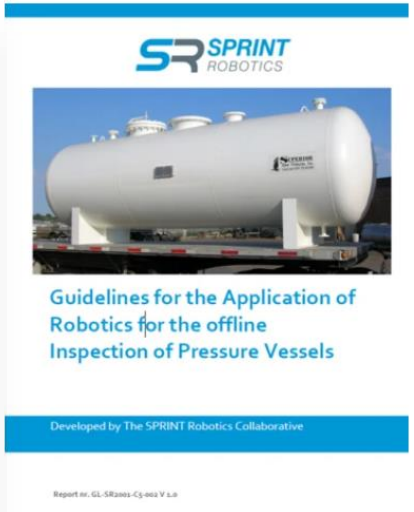
ESR Technology Engineering, Safety & Risk

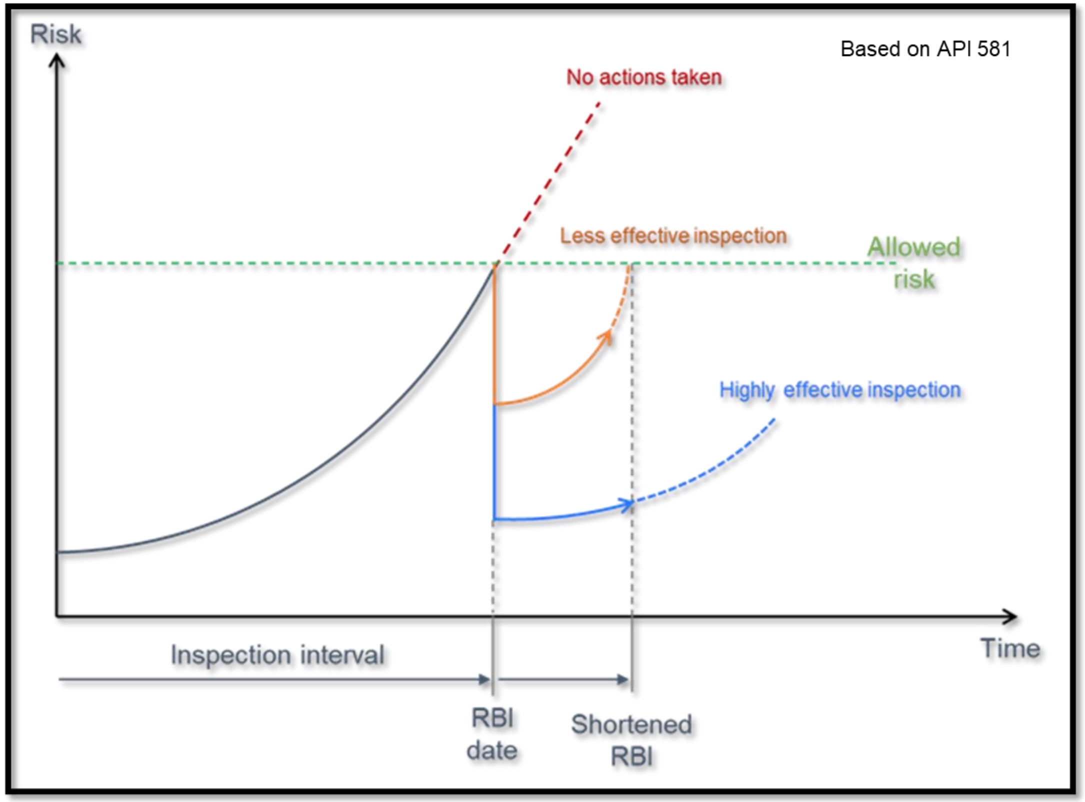

SPRINT ROBOTICS

Guidelines for the Application of Robotics for the offline Inspection of Pressure Vessels

Developed by The SPRINT Robotics Collaborative

HSE

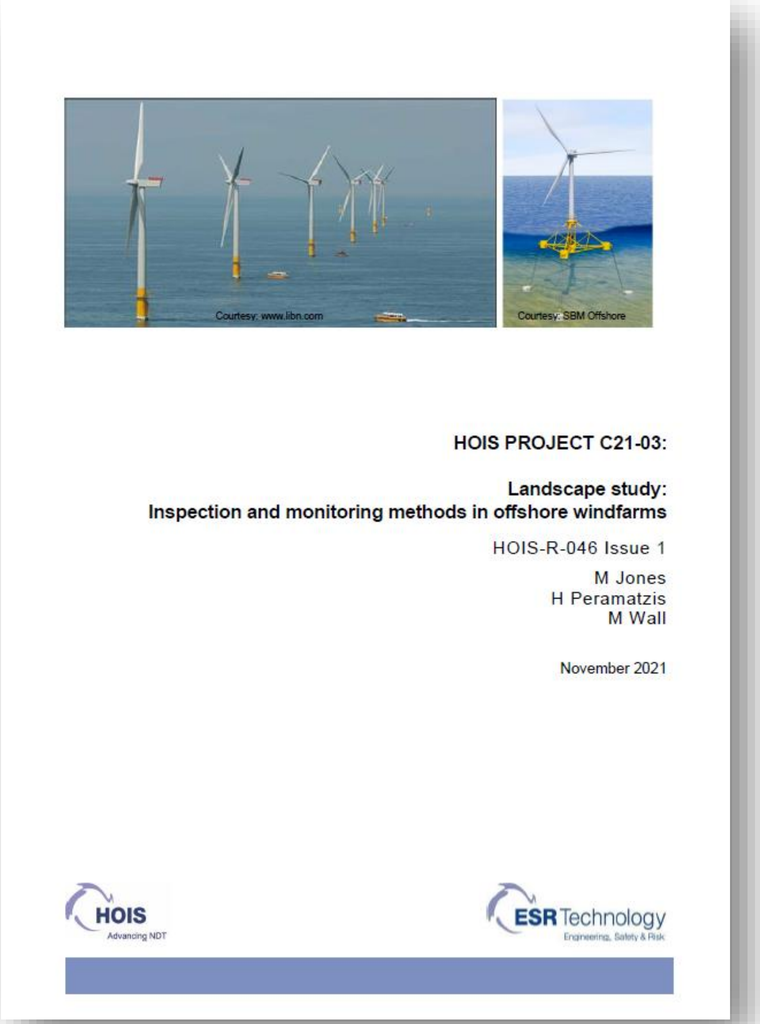
Planning



- Where, when and how much inspection?
- Is monitoring an option?
- Aim of inspection is to reduce risk of failure
- Need to understand
  - Likelihood of degradation mechanism(s) occurring
  - Progression of degradation mechanism(s)
  - Spatial distribution of degradation mechanism(s)

Landscape study: Offshore Windfarms

- Inspection and Monitoring methods in Offshore Windfarms
- Overview of offshore windfarms from the point of view of inspection requirements
- Opportunity to build in monitoring
- Drive for cost effective inspection to minimise maintenance intervention
  - Monitoring
  - Robotics
  - Remote application
- Report covered
  - Offshore installations – key components
  - Failure and damage mechanisms
  - Priorities for inspection requirements
  - Existing industry guidance
  - Relevant bodies and initiatives
  - HOIS role & opportunities


Courtesy: www.libn.com
Courtesy: SBM Offshore

HOIS PROJECT C21-03:

Landscape study:
Inspection and monitoring methods in offshore windfarms

HOIS-R-046 Issue 1

M Jones
H Peramatzis
M Wall

November 2021

Failure and damage mechanisms

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- Some mechanisms unique to or more predominant in offshore wind generation
  - Erosion e.g Leading edge corrosion
    - Several high profile cases of leading edge erosion resulting in significant repairs much earlier than at design life.
  - Lightning strikes
  - Impact damage
  - Overload
  - Corrosion fatigue
  - Fatigue cracking
  - Scouring

- Other mechanism common to marine structures
  - Microbiologically influenced corrosion (MIC)
  - Hydrogen induced cracking (HIC)
  - Stress corrosion cracking (SCC)
  - Corrosion

Monitoring for Offshore Wind

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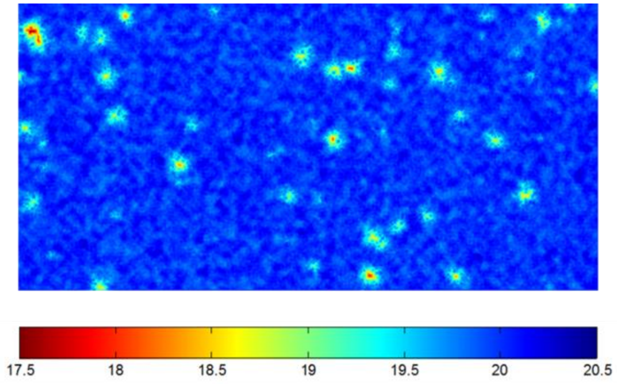
- Permanently installed monitoring is effective where;
  - Whole component assessment is possible
  - Or sampling is representative
  - Operators want to minimise the need for corrective maintenance activity.
- Monitoring examples
  - Acoustic emission
  - Vibration analysis
  - Lubrication analysis
  - Infrared thermography
  - Motor condition monitoring – tracks the current drawn by the motor to provide information about the condition of the machine the motor is driving.
- Time based analytics to link causality

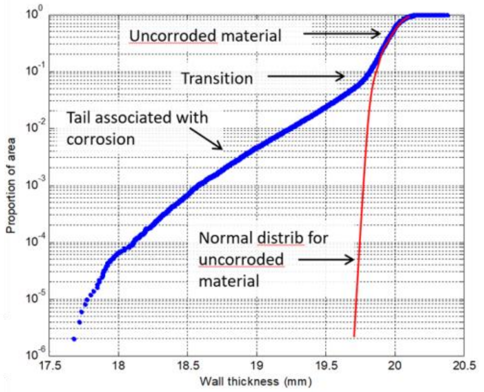
Periodic Inspection for Offshore Wind

- Periodic inspection is effective where:
- Permanent monitoring is not possible or has not been previously installed
- Sampling may or may not be representative
- **Examples**
  - **Floating substructure** – principle mechanism is corrosion in/near splash zone, fatigue due to wind/wave loadings. Subsea inspection usually performed by ROVs or ROV deployed crawlers. Splash zone more challenging.
  - **Station keeping systems -** inspection of mooring systems: GVI/CVI, dimension measurements, MPI, UT, RT, Eddy Current/ACFM
  - **Dynamic cables** (power transmission from power generation facilities to the shore).
  - Up to 70-80% of claims in insurance pay-outs are attributable to cable system damage such as:
    - Wear of outer sheath inside J-tubes.
    - Abrasion to protection sleeves at touchdown points on the seabed leading to water penetration and corrosion.
    - Abrasion and wear at transition joints.
  - Damage caused during installation is often identified as cause of in-service failure, so an as-laid baseline inspection is important to verify that the completed installation meets requirements.
  - Visual inspection by ROV is most common inspection method.

Data Analytics

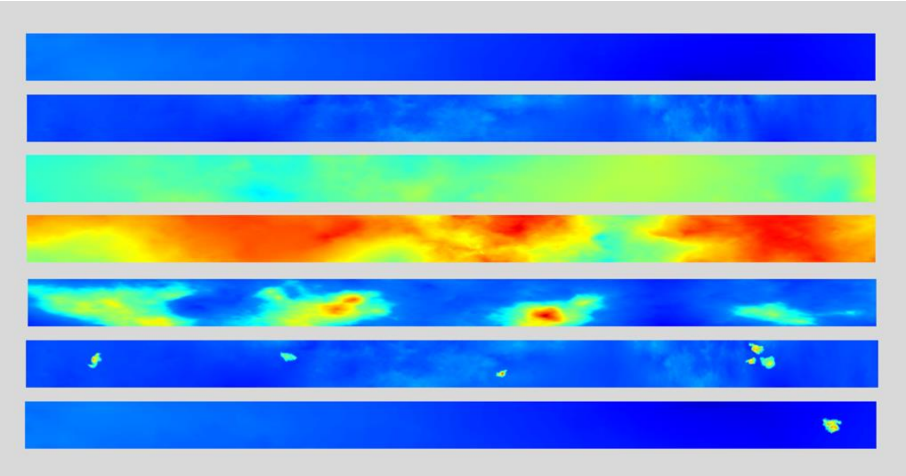
- What does it all mean?
- Historically NDT has been focussed on reporting on the area of inspection,
    - e.g. minimum overall wall thickness, highest category of scab, anomaly exceeding defined threshold
- Focus now on looking at the bigger picture and combining results or results from different techniques to better understand and predict degradation behaviour
- Building on
    - Data science and statistics
    - Machine learning and AI

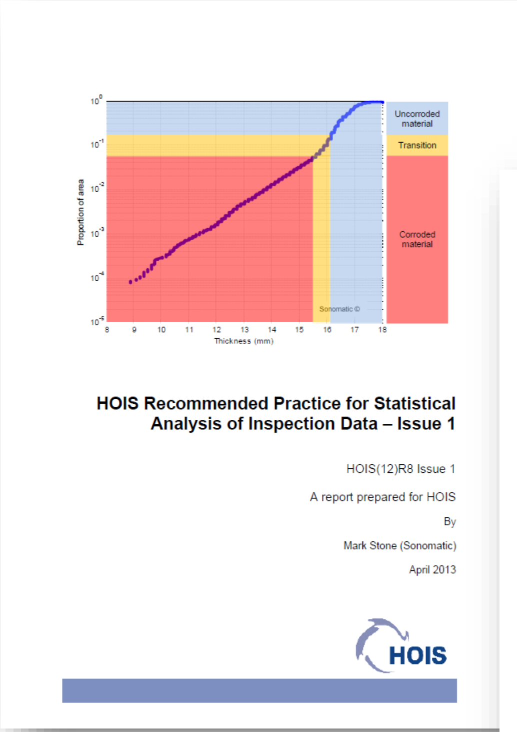




Applying Data Science

- Developing an understanding of the likelihood, progression and spatial distribution of degradation can better inform planning
- Approach can be applied to different applications
- Matching inspection to degradation
- Digitalising workflow





HOIS Recommended Practice for Statistical Analysis of Inspection Data – Issue 1

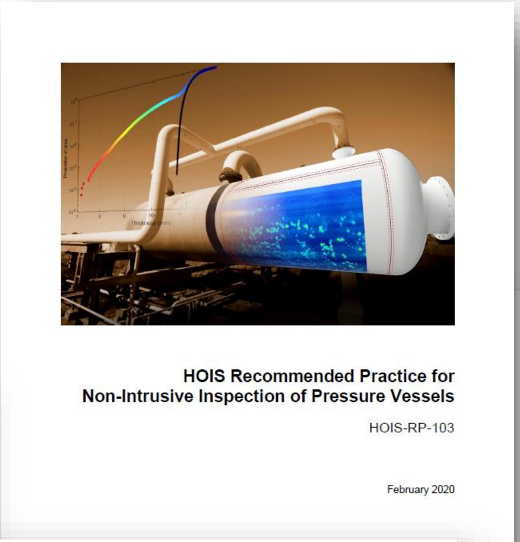
HOIS(12)R8 Issue 1

A report prepared for HOIS

By

Mark Stone (Sonomatic)

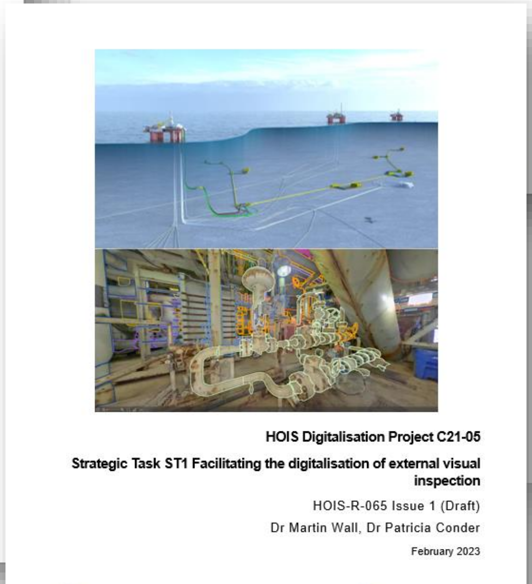
April 2013



HOIS Recommended Practice for Non-Intrusive Inspection of Pressure Vessels

HOIS-RP-103

February 2020



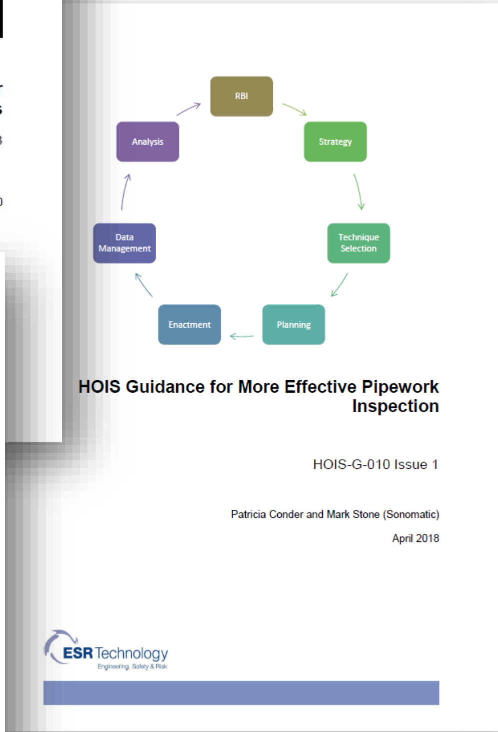
HOIS Digitalisation Project C21-05

Strategic Task ST1 Facilitating the digitalisation of external visual inspection

HOIS-R-065 Issue 1 (Draft)

Dr Martin Wall, Dr Patricia Conder

February 2023



HOIS Guidance for More Effective Pipework Inspection

HOIS-G-010 Issue 1

Patricia Conder and Mark Stone (Sonomatic)

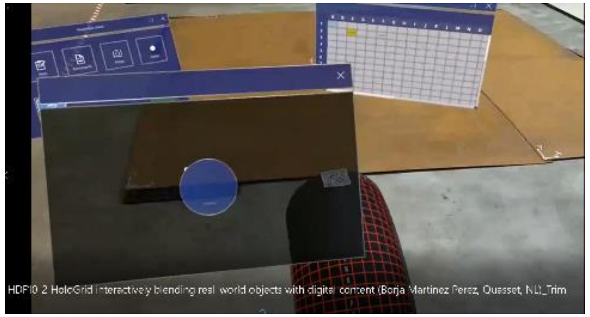
April 2018

HOIS Digitalisation Forum HDF

HOIS
Advancing NDT

www.abysssolutions.com.au

- Virtual bi-monthly forum
  - Launched in May 2020
  - Open event – not limited to HOIS members
  - 3 Speakers per event
  - International audience up to 100+.
- Covers all aspects of digitalisation of NDT throughout the workflow in the Energy sector
- "To promote engagement with NDE 4.0 and digitalisation stakeholders worldwide and across industry sectors."
- Range of topics so far include;
  - Digitalisation of inspection, Digital twins, NDE data processes, NDE 4.0, integrity management and cloud solutions
- For info, replay links or to register for future events: Email info@hois.co.uk



https://quasset.com/hologrid/

www.bam.de Courtesy Marija Bertovic

www.guided-ultrasonics.com

Inspection for Net Zero

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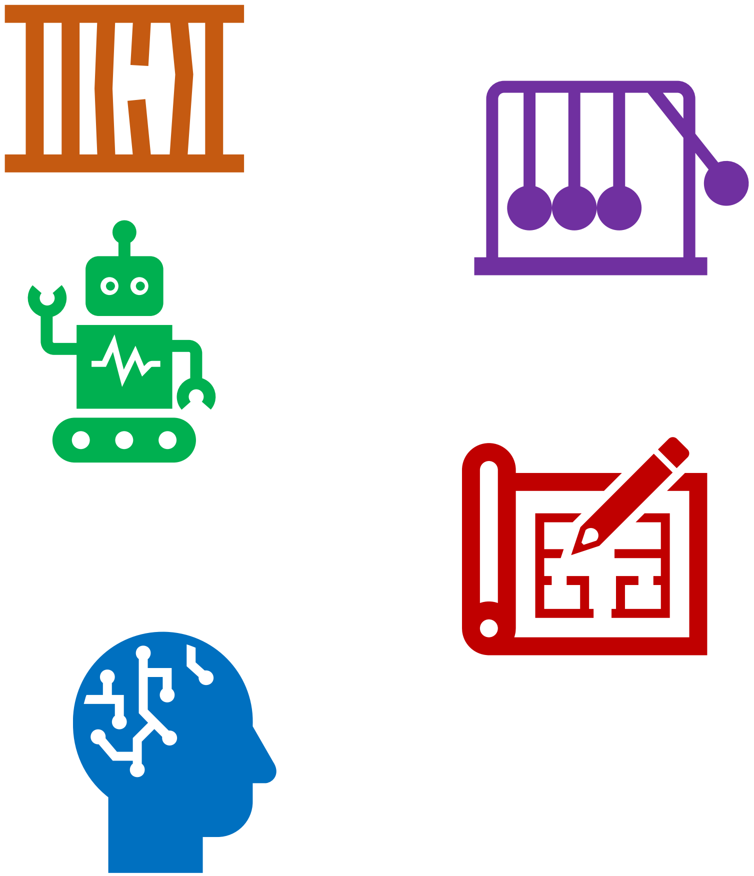
Advancing NDT

- New Applications, New Challenges - Same Basic Approach
  - What are you actually looking for?
    - Degradation
  - How can you find it?
    - Physics of Inspection
  - How to access chosen locations?
    - Inspection Deployment
  - Where, how much and when?
    - Planning
  - How can you maximise the value of your inspection?
    - Data Analytics
- NDT inspection solutions can only meet defined challenges. The better the definition of degradation challenges the better the inspection solutions.



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