



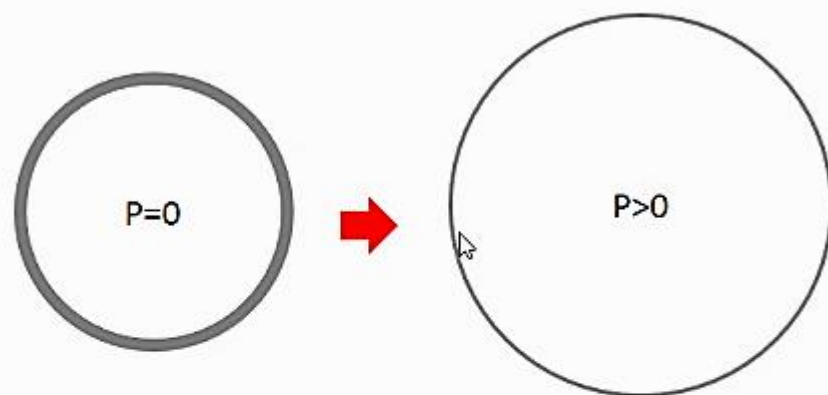
Stress Concentration Tomography

Developments in SCT Inspection of carbon steel pipelines.

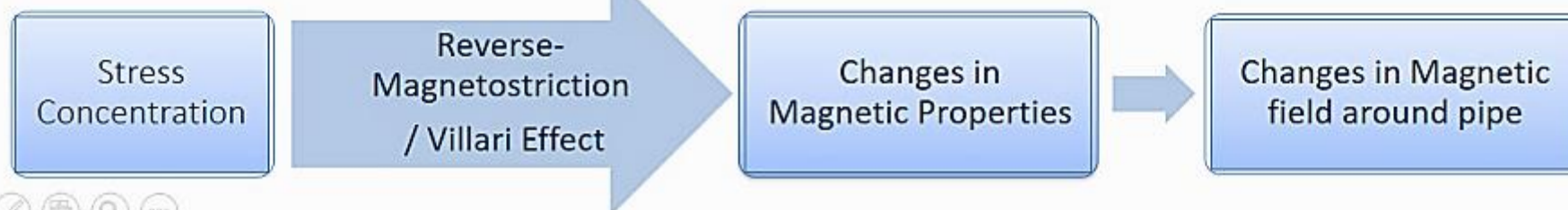
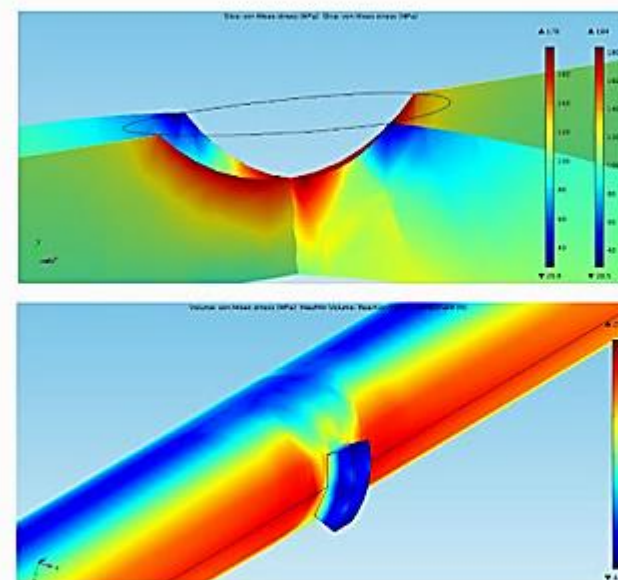
Hamed Habibi – Speir Hunter Limited



How SCT works?

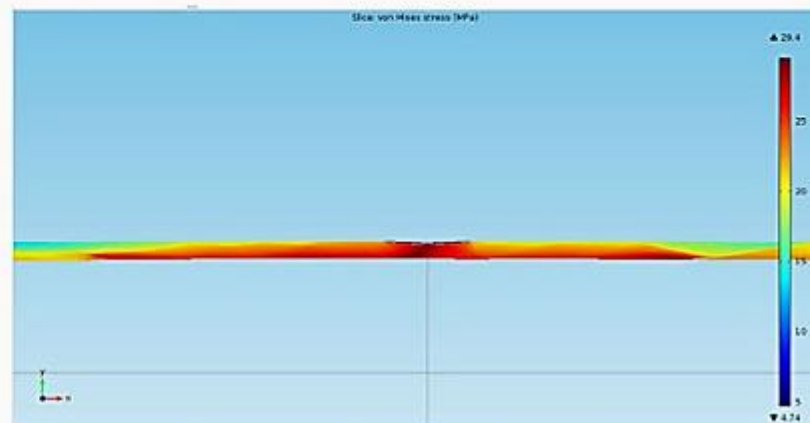
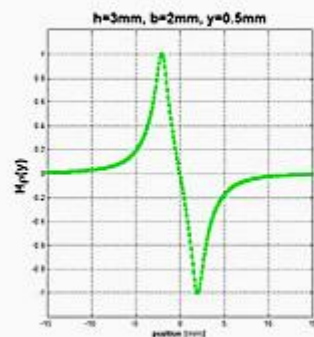
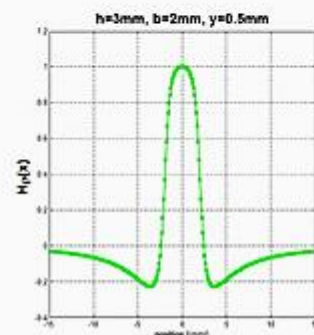


Cross-section of pipe wall

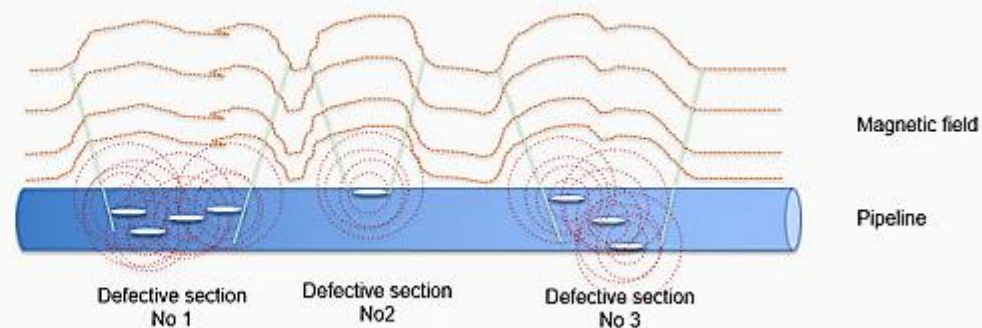




How Sensitive Is It?



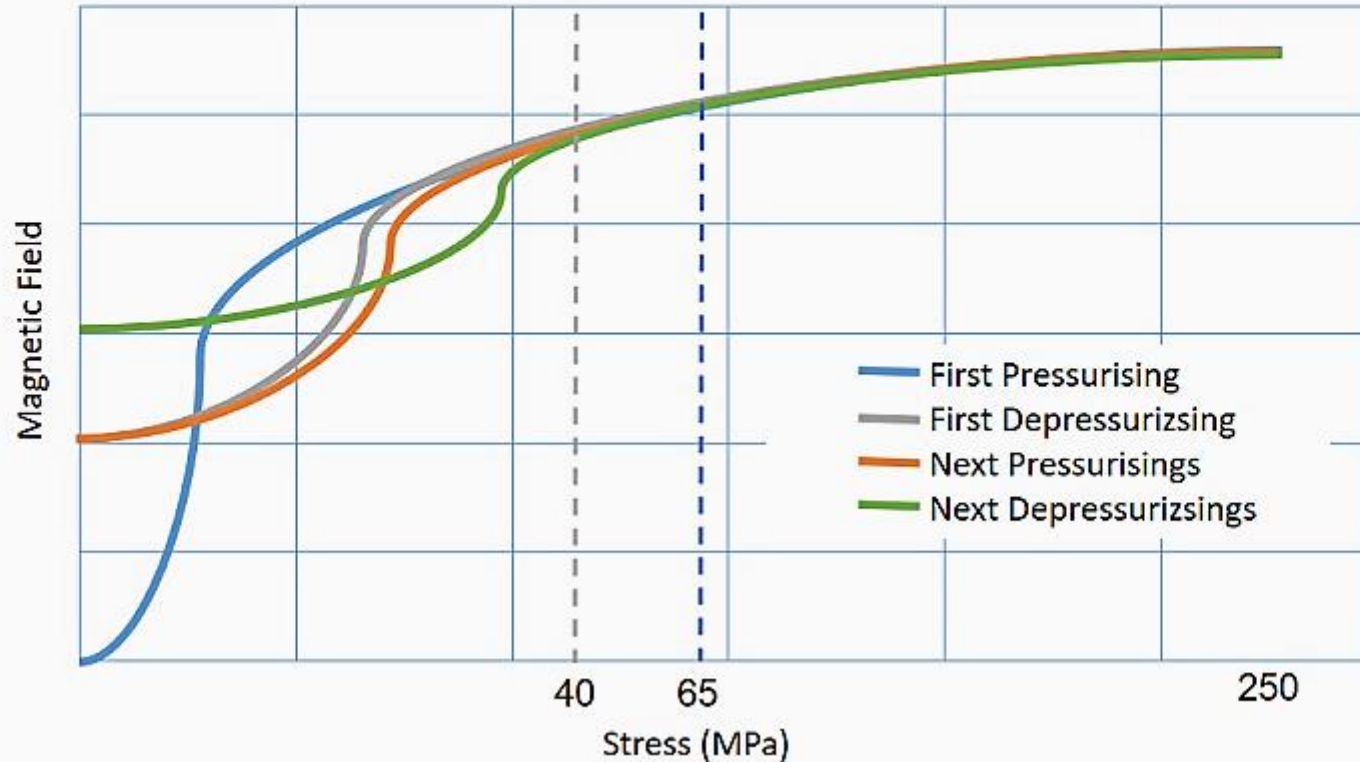
FEA simulation - 12" – 20% wt – 30mm





Stress-Magnetization Relationship

Reverse-Magnetostriction Curve





Field Performance

- More than 1000km of field surveys since 2016.
- 78 verifications by direct assessment (excavation)
- 47 verifications by comparison against available ILI data.
- Verified on:
 - Metal Loss
 - Stress Corrosion Cracking , Micro Cracks
 - Manufacturing Defects such as Weld Mismatch
 - Wrinkle Bends, Frost Heaves, Geo-hazards



POD

POD

POD= 88% +/- 8.6%
(95% confidence level)

POD= $\frac{\text{Number of ILI indications with at-least one SCZs next to them}}{\text{Total number of ILI indications}}$

Survey No.	Total No. of SCT Indications	Total No. of ILI Indications	Hit Rate within claimed positional accuracy	Hit Rate within double the range of claimed positional accuracy
1	69	16	81%	81%
2	40	17	65%	71%
3	77	6	100%	100%
4	34	17	82%	100%
5	77	6	100%	100%
6	59	3	100%	100%
7	50	3	67%	100%
8	58	40	100%	100%
9	61	1	100%	100%
10	21	4	100%	100%
11	43	1	100%	100%
12	30	1	100%	100%
13	21	1	100%	100%
14	31	9	100%	100%
15	30	1	100%	100%
16	32	5	100%	100%
17	50	1	100%	100%
18	45	1	100%	100%
19	91	132	84%	93%
20	65	4	75%	100%
21	46	10	90%	90%
22	292	4	50%	100%
23	231	4	25%	75%
24	175	6	83%	83%
25	75	2	100%	100%



Verification Success Rate

Definition: How often when SCT reported an SCZ is that found to be defect or evidences of an SCZ is found.

111/125=88.8% (verification based on Direct Assessment or ILI comparison)

66/78=84.6% (verification based on Direct Assessment on excavation)

45/47=95.7% (verification based on comparison to ILI data)

Verification Method	Minimum of Confidence Interval at 95% Confidence Level
Excavation	75.3%
ILI Comparison	89.5%
Both	82.7%



Using LSM in the ECDA Process

211km SCT inspections between 2016 to 2019

- 58 Excavations
 - 29 Excavation based on ECDA using LSM for prioritizing
 - 10 metal-loss (91% of all metal-loss)
 - 5 environmental features
 - 14 coating defects only
 - 29 Excavation based on only ECDA
 - 1 metal-loss (9% of all metal-loss)
 - 1 environmental features
 - 26 coating defects only (89%)



SCC



140mm long

11



Micro-Cracks

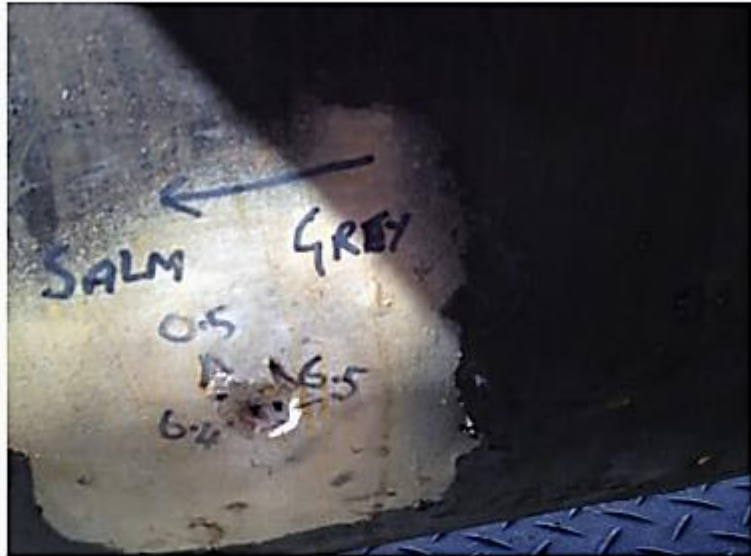


200mm x 220mm area





Metal-Loss



22% WT

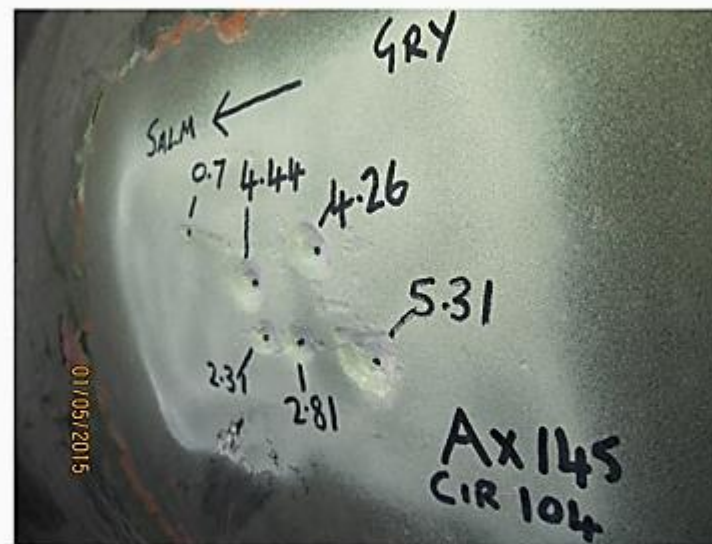
Diameter	35.4 inch
Wall thickness	0.5 inch
Pressure	59.6 Bar
SMYS	413 MPa



Metal-Loss



ILI 1. Condition prior to repair (MFL1)



ILI 2. Condition following repair (pre MFL2)

19% WT



Frost-Heave

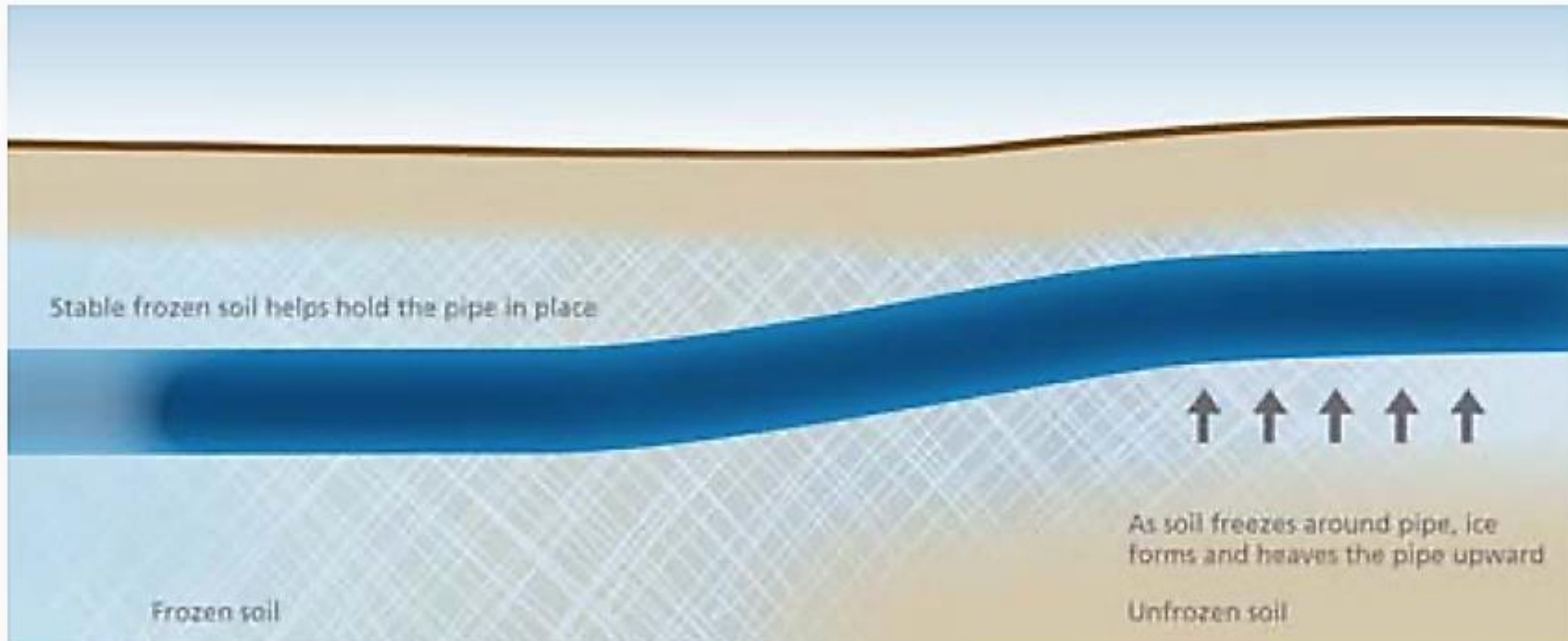
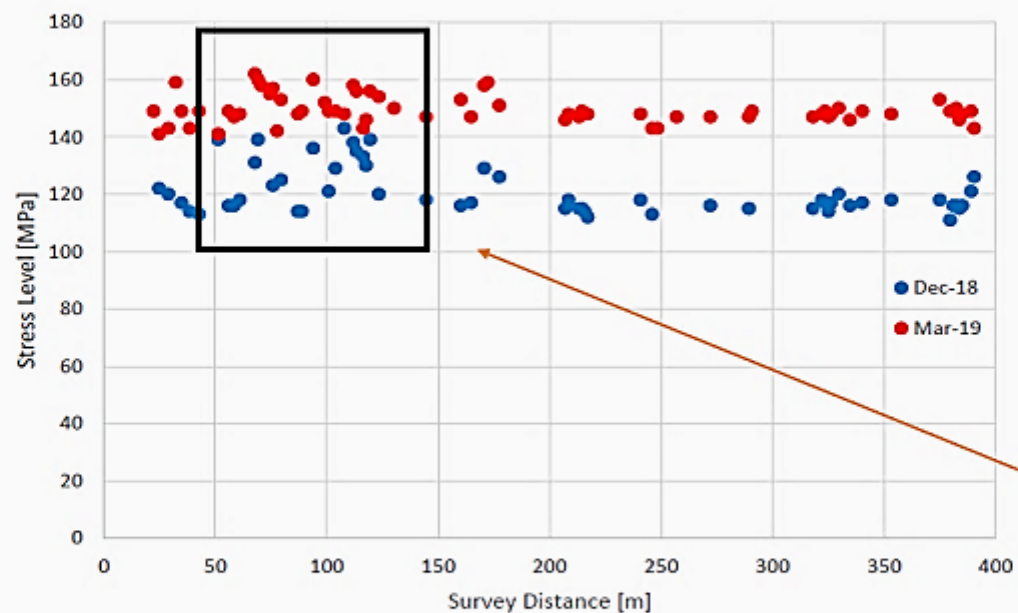


Diagram courtesy of Canada's National Energy Board



Frost-Heave

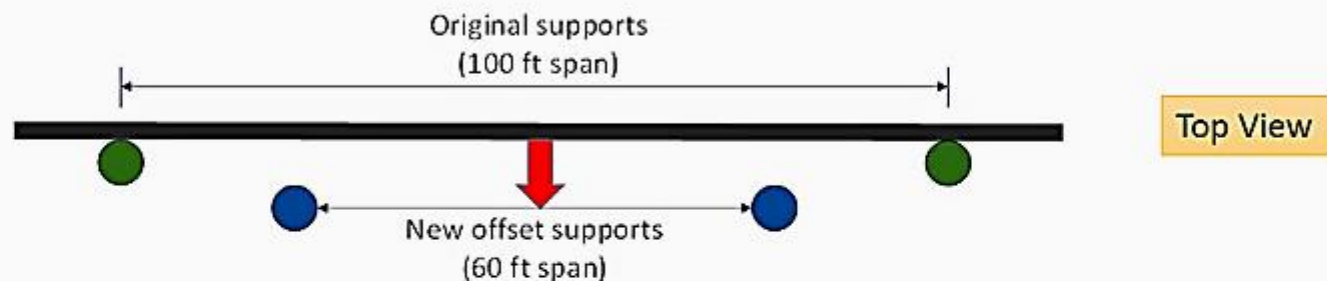


Localised Detected Stress is less dependent on operational condition suggested geo-hazard area.

Date of SCT Survey	Operating Pressure at time of inspection [bar]	Nominal Hoop Stress [% of SMYS]	Minimum Detected Localised Stress Level [% of SMYS]	Maximum Detected Localised Stress Level [% of SMYS]
19 Dec 2018	60.0	29%	25%	32%
20 Mar 2019	71.4	34%	31%	36%



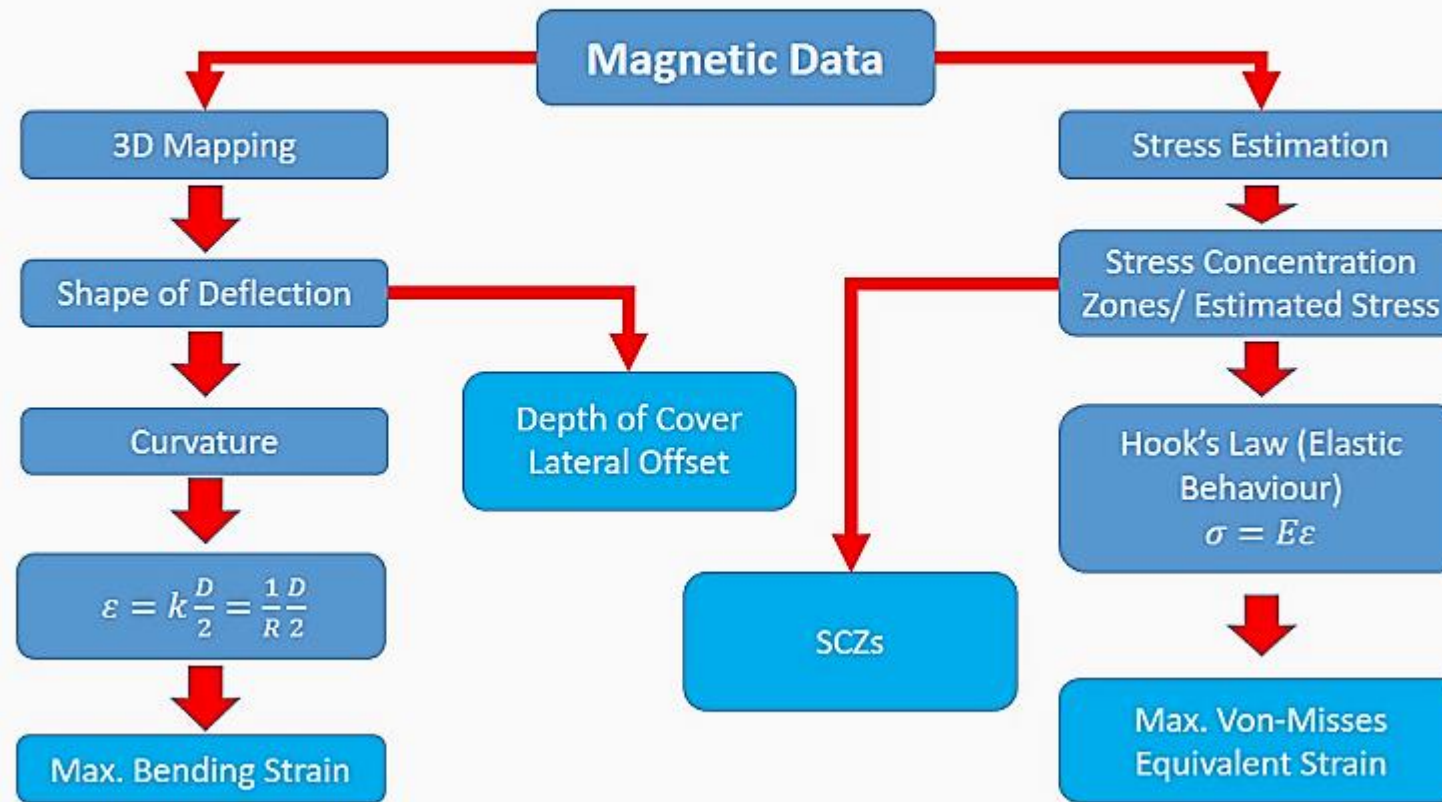
PRCI-NDE 3-4



- Capturing localised stress/strain under geo-hazard Condition
- Use SCT to identify geo-hazard threats and where to focus for mitigations. (Mission to move from qualification to quantification)
- Assess repeatability of measurements and effect of height



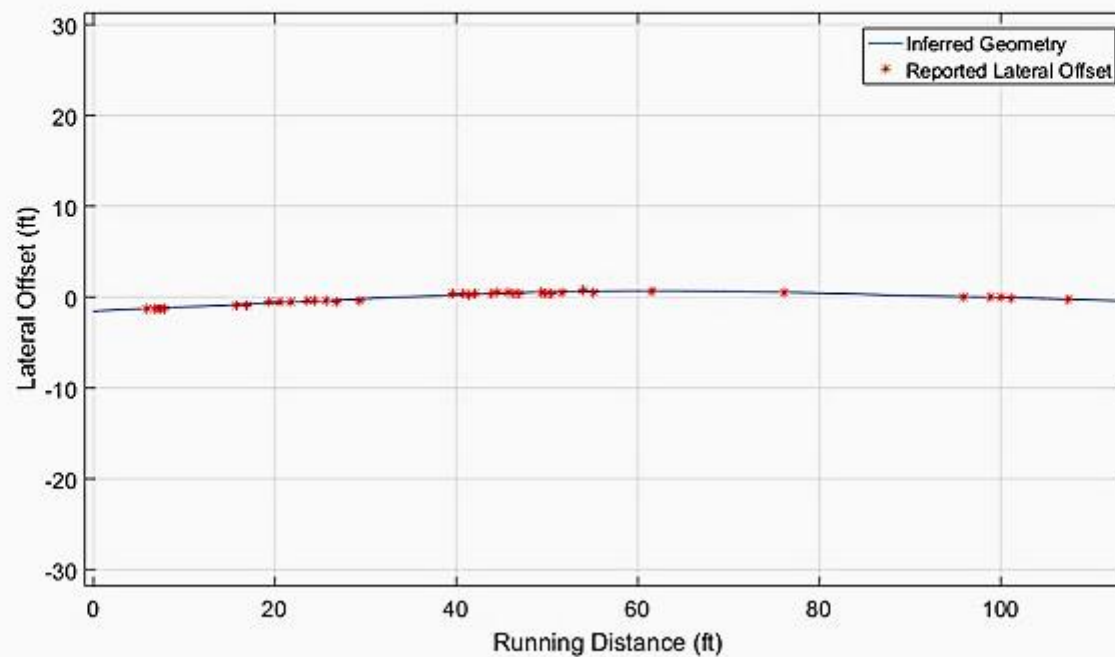
Methodology





Lateral Offset Results

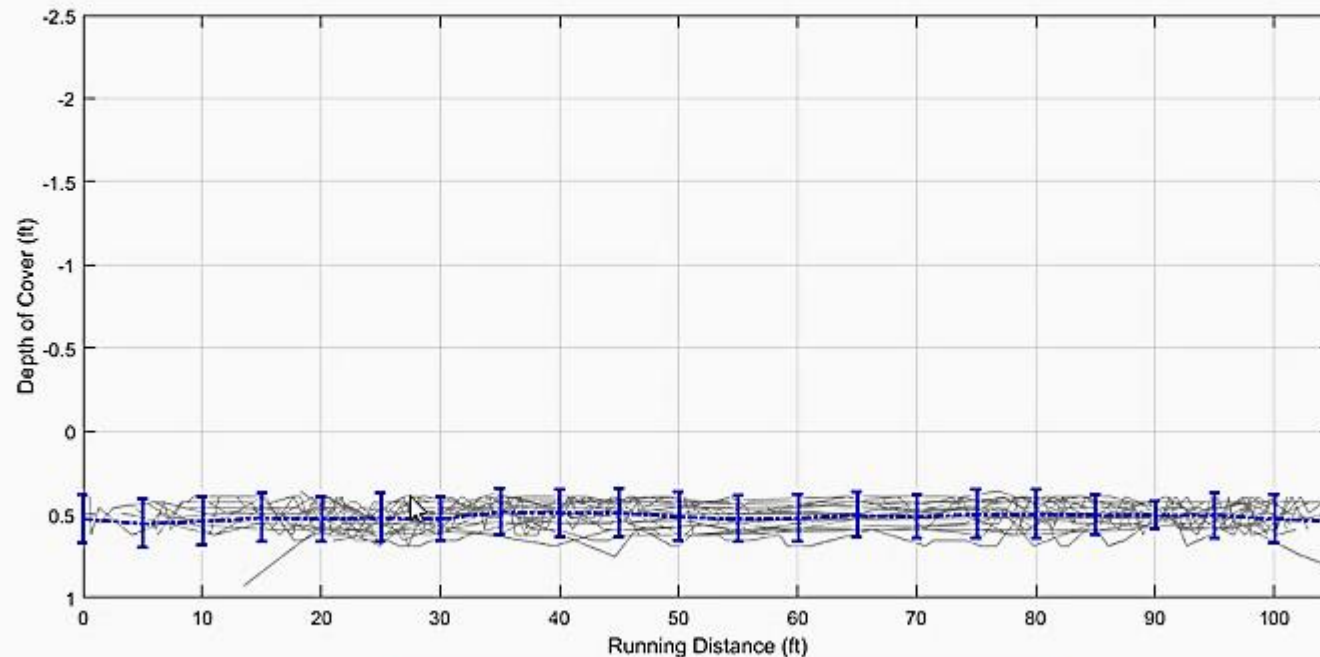
R9



R9- 12" deflection – 73" height



Results - Depth of Cover



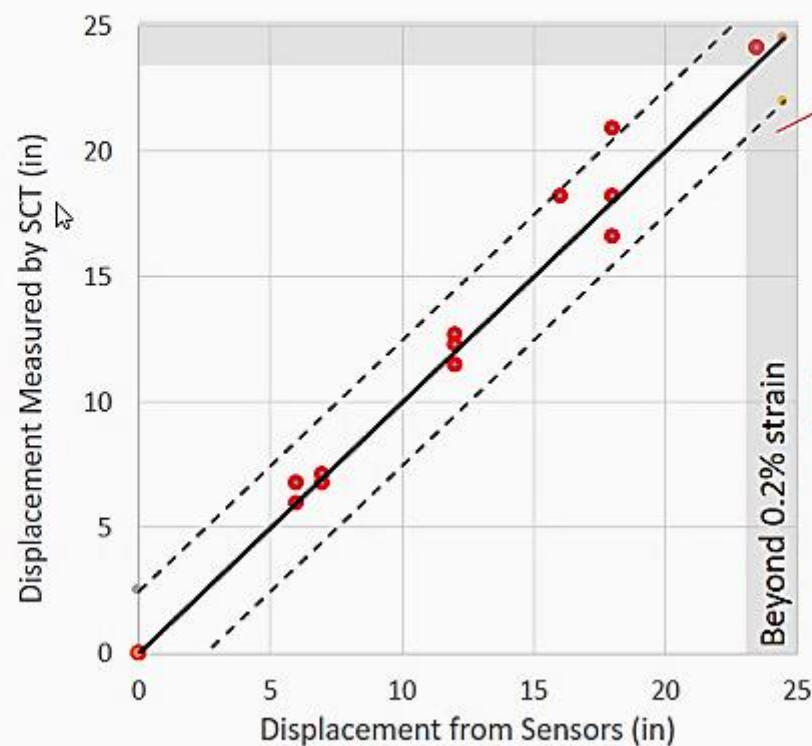
Mean error is 0.86" i.e. 2.3% of truth data





Results - Unity Plot

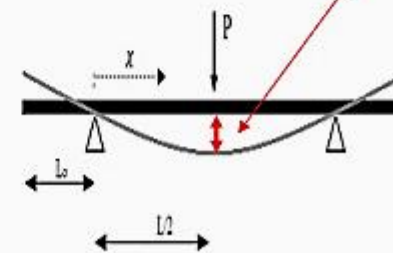
Maximum Displacement at Centre of Span



Black Margin is set at 2.5"

Mean Accuracy is 0.78"
i.e. 6% of truth data

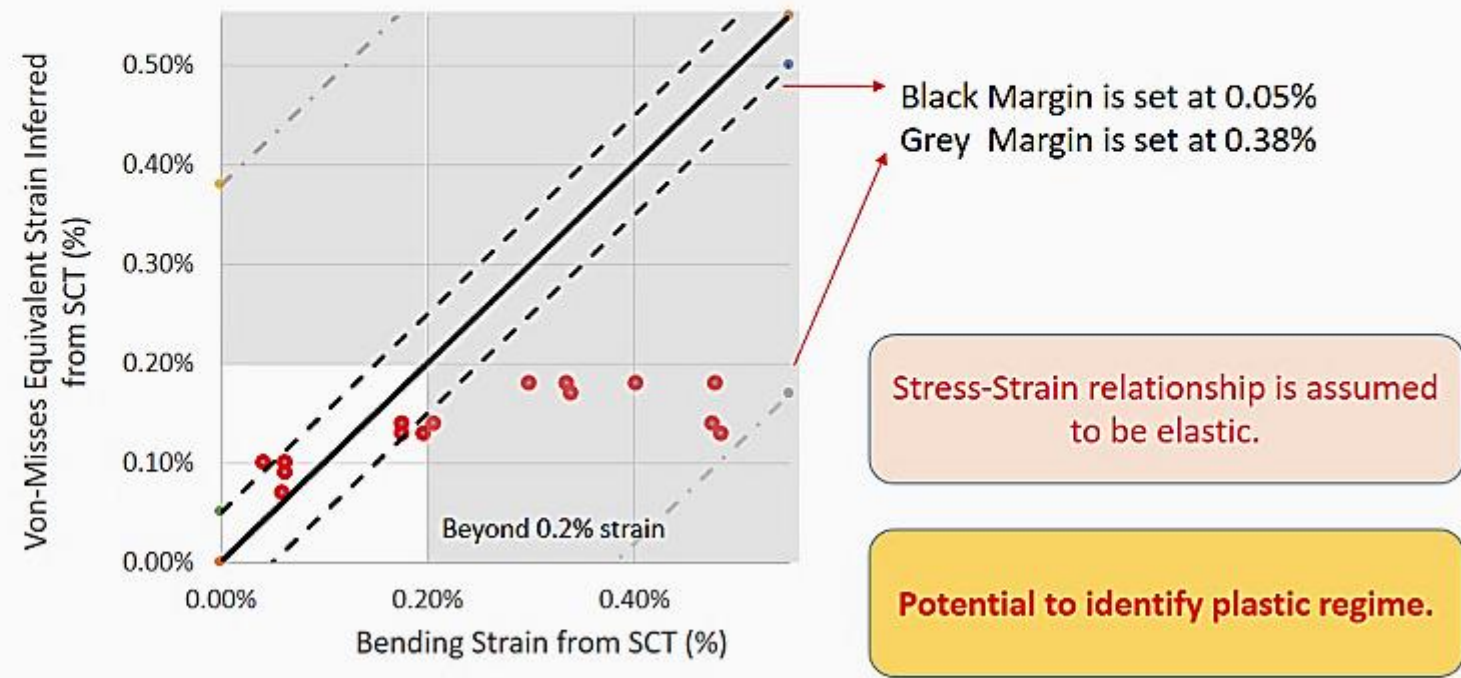
Maximum Displacement at Centre of Span





Results - Unity Plot

Max. Von Misses Equivalent Strain vs Max. Bending Strain





Recent Developments

Function



Continuous Depth of Cover

Girth Weld Detection

Bending Strain Estimation

Geo-hazards Detection

Metallic Feature Detection

Plastic Regime Detection

Field Work



Drone Carrier

ATV Carrier

Extended Operational
Ambient Temp.

Optical Positioning System

Application



Geo-Hazard Monitoring

Corrosion Under Insulation

Girth Weld Under Insulation

ECDA improvement



Future Developments

- Marinisation
- Defect Type Categorisation
 - Feasibility Assessment shows promising results in close range
- Auto-Pilot Drone Carrier
 - Lighter Scanner
 - No need for locating pipe in advance



Marinisation Feasibility Assessment

Hardware



Pressure/ Water Proofing

Sub-Sea Positioning

Remote-Controlling

Software

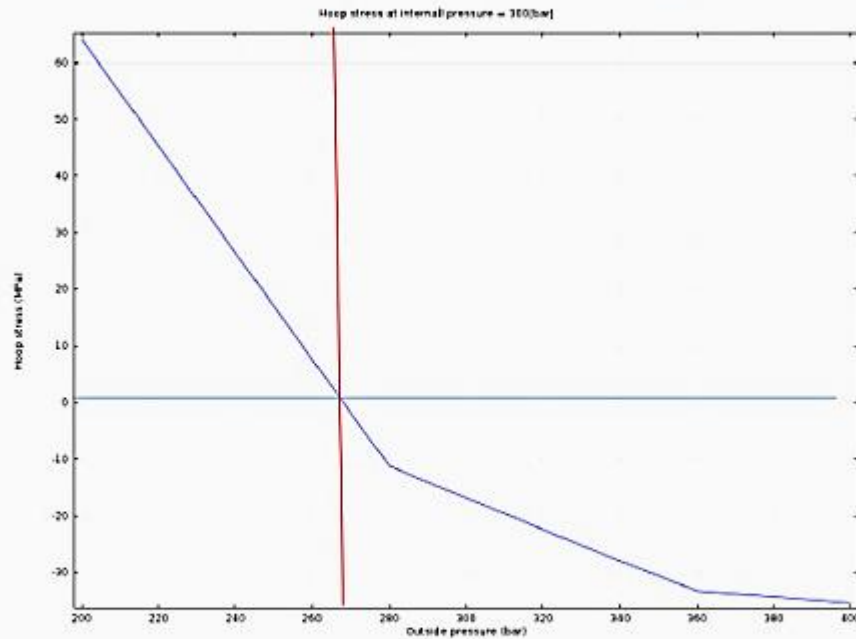


Effect of Compressional Stress

Live Data processing



Sub-Sea Stress-Magnetization



External Pressure of 270bar at ~2700m depth
Internal Pressure 300bar



Jiles-Atherton Stress Magnetisation





Hardware / Software

- Hardware
 - None magnetic enclosure
 - Use of ROV positioning and data cable
 - Sweep Scan the area to find location of the pipeline
- Software
 - Lab and Field Tests to modify algorithms for compressional stress
 - Live data processing

