UNIVERSITY OF TECHNOLOGY SYDNEY

Activity 4d: Enhanced Reliability of Emerging Technologies

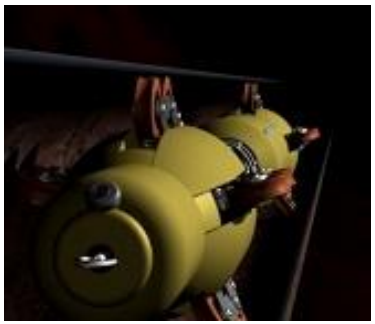
Activity Co-leaders: A/Prof. Jaime Valls Miro, Prof. Gamini Dissanayake
UTS

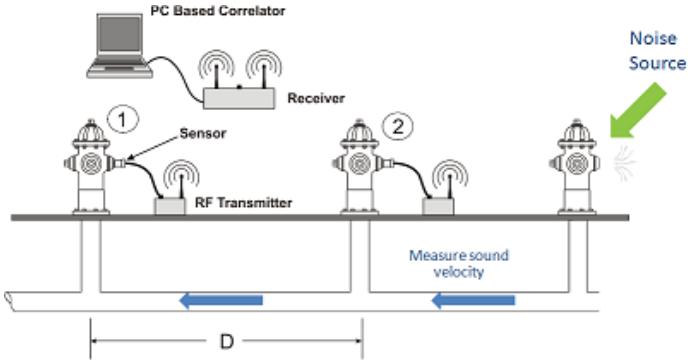
Scope Activities 4d:
Consideration of Upcoming Technologies

Key Expected Outcomes:

1. Study the merits of upcoming technologies

2. Asses their value for in-between interpretation





Activity 4 – UTS Team

Academics (x5):

- Prof Gamini Dissanayake (Co-activity leader)
- A/Prof Jaime Valls Miro (Co-activity leader)
- A/Prof Sarath Kodagoda (Sensor modelling, MFL)
- Dr Alen Alempijevic (Sensor modelling, BEM)
- Dr Teresa Vidal Calleja (Data interpretation, machine learning, estimation theory)

Fully dedicated (funded from project) personnel (x3):

- Dr Lei Shi (Leo)
  - In-between, Upcoming Technologies, LPR ML
- Ms Liye Sun (PhD candidate)
  - Multimodal Information Fusion for Advance Condition Assessment of Ageing Infrastructure
- David Hunt (Technical Assistant, Sept'15 – Dec'16)

Presentation Outline

1. Summary Current State of Affairs
2. Summary Latest Progress
3. Understanding the Technologies
   - PWA EM and SpeirHunter
   - DS pCAT
   - PCA-Echologics ePulse
   - Evaluation Challenges
4. A Ready-to-Use Development
   - Exploiting p-CAT for Improved Statistical Analysis

Summary Current State of Affairs

Aims:

- Exploring emerging technologies which have not yet been incorporated into the current research project in anticipation of the benefits they may bring

Background:

- What are the possible benefits of introducing these techniques in an in-between predictive framework?

Challenges:

- Understanding the technologies
- Validating data (particularly continuous screening techniques)
- Integration and evaluation

Latest Progress

1. After two unsuccessful p-CAT (Detection Services) trials on SW test-bed due to "excessive acoustic signal degradation apparently caused by dissolved oxygen in water – DS", planning and feasibility of carrying out a p-CAT trial on another live main is under discussion with WaterCorp and SW to validate both p-CAT and the in-between framework (4a).

2. PCA-Echologics Mainscan inspection was carried out in the test-bed in Aug'15, results have not yet been shared with us.

3. Incorporating the information provided by p-CAT and ePulse within the proposed framework for in-between prediction is straightforward
   - Simulation-based study have been carried out
   - This should be amenable to measurements from potentially any other screening tools that may be available in the market

4. Validation remains a difficulty. A plan has been developed for validation of 4a and 4d (see point 1 above).

5. Advances on desktop study of ePulse, p-CAT and PWA EM/SpeirHunter

(Reminder) Technology Screening

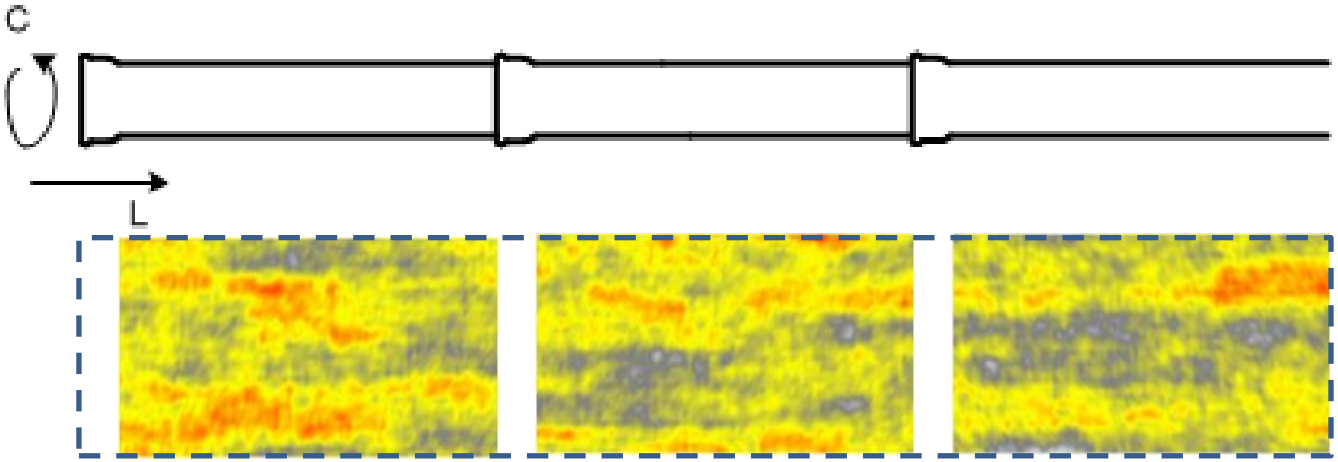
The research started with a desktop screening to review additional commercially available condition assessment technologies to narrow down possible options

Echologics - ePULSE **Detection Services - p-CAT**	Group 1: Acoustics, non-dug-up
Breivoll - Pipescanner **JD7 - Pipescan ++** **JD7 - Pipescan +**	Group 2: Ultrasonics, in-pipe
Transkor - SKIF **SpeirHunter**	Group 3: Passive electromagnetics, non-excavation
Elorane - tesTAU **Elorane - (soil)** **Zensor - (soil)**	Group 4: Environmental analysis, non-excavation

(Reminder) Technology Screening

Echologics - ePULSE	Trial Done (September 2014), report received Detailed technical discussion are ongoing
Detection Services - p-CAT	1st Trial (Apr'15) unsuccessful 2nd Trial (July'15) unsuccessful Next trial on a live main under discussion
~~**Breivoll - Pipescanner**~~	Issues with cement lining
~~**JD7 - Pipescan ++**~~	Company undergoing changes, tool availability issues
~~**JD7 – Pipescan +**~~	Issues with large dimensional pipes
~~**Transkor - SKIF**~~	Redirected to SpeirHunter
SpeirHunter ?	Lack of experience with cast iron pipe, lack of available validation too
~~**Elorane - tesTAU**~~ ~~**Elorane - (soil)**~~ ~~**Zensor - (soil)**~~	No apparent information gain given similar currently engaged alternatives

(Reminder) Understanding the Technology



e.g. 10 Meters (joint excluded)

1. Dense Remaining Wall Thickness Map [at different resolutions]
   (e.g. **BEM**, **MFL**, **Mainscan**) -> structural analysis?
2. Average Remaining Wall Thickness (e.g. **p-CAT**)
3. Maximum Pitting Rate ➡ Maximum External Pitting ➡
   Minimum Remaining Wall Thickness (e.g. **LPR**) -> time to penetration?
4. Average Minimum Remaining Wall Thickness (e.g. **ePulse**)
5. Stress concentration (e.g. **PWA EM, SpeirHunter**) -> various factors, hard to validate

A Note About PWA EM and SpeirHunter

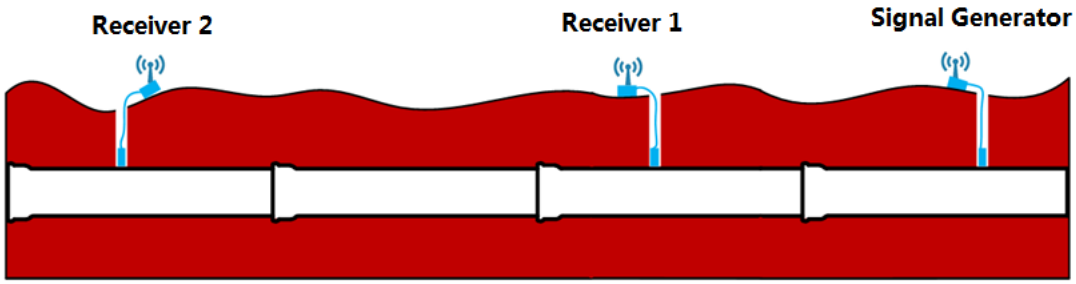
Villari Effect: mechanical stress -> magnetic susceptibility

- PWA EM -> Anomaly
- SpeirHunter -> Anomaly -> Stress

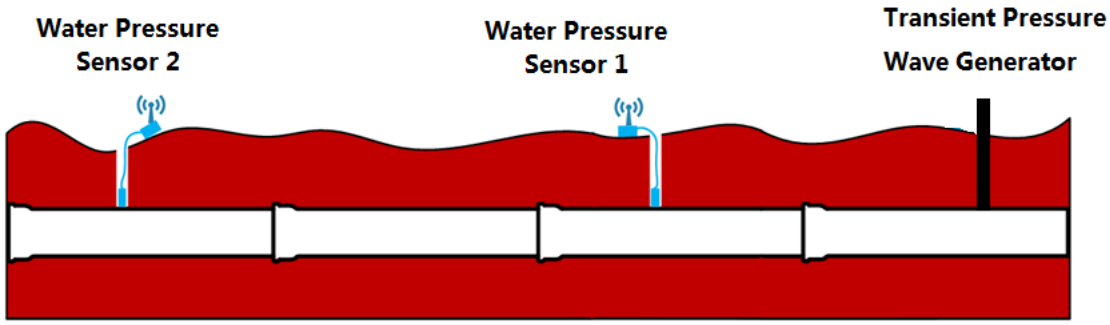
Stress-related non-geometry techniques:

- If they are quantitatively good: no further need for in-between
- If they are qualitatively good: could be used as guidance to select representative training samples (yet stress variation can be due to many reasons, not just geometry!!)
- Validation means comparing stress “ground-truth”: not feasible from UTS side

(Reminder) Understanding the Technology



ePulse



pCAT

ePulse: Access the external pipe wall

ePulse: Average minimum wall thickness

ePulse: No sub-section information

ePulse: Smallest reliable coverage is 25 m

p-CAT: Access the water

p-CAT: Average wall thickness

p-CAT: Sub-section information available

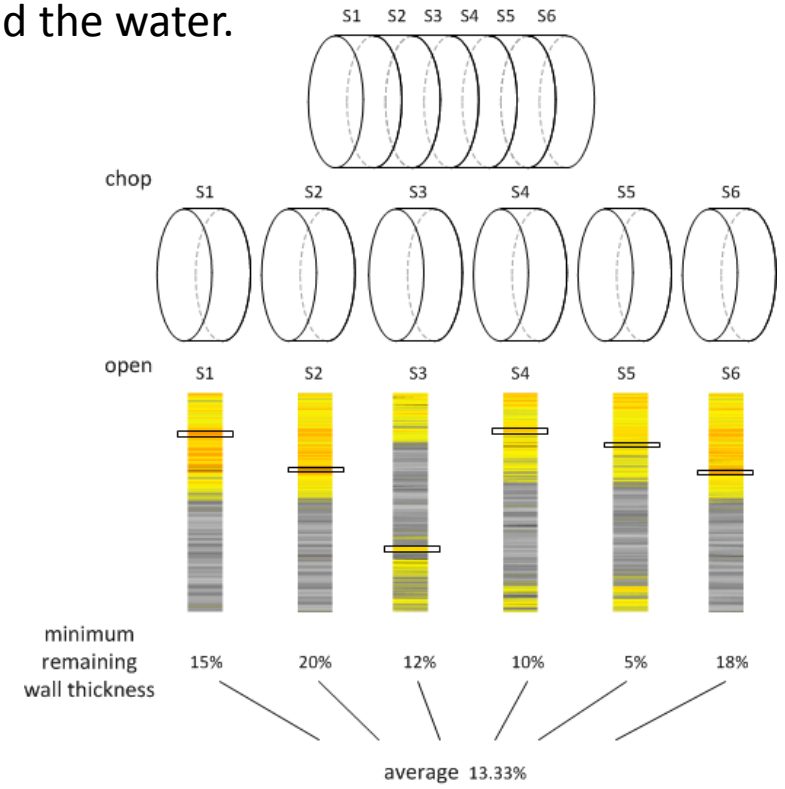
p-CAT: Smallest reliable coverage is 10 m

(Reminder) Evaluation of ePulse

First upcoming technology trial - with PCA-Echologics - was completed during September 2014. This was planned at varying access point (higher than usual) spacing to better assess the influence of spatial resolution

(Reminder) Evaluation of ePulse

- Theoretically, the measured **speed of certain acoustic wave** represents a measurement of the remaining wall thickness
- Several parameters need to be accurately fixed/known beforehand. E.g. properties of pipe material, cement lining, and the water.



(Reminder) Evaluation of ePulse

- *ePulse tests results are directly influenced by the average hoop stiffness of the pipe. The hoop stiffness at any given point along the length of the pipe is controlled primarily (but not exclusively) by the minimum thickness around the circumference – PCA-Echologics*
- Results explained as “Average minimum wall thickness” can not be readily “validated”. PCA-Echologics cannot either
- Both PCA and UTS agree that the in PCA’s interpretation of the ePulse data there is an important parameter - spatial ‘ring’ resolution - which can significantly affect the result
- PCA-Echologics has limited confidence on sensor spacing results of less that 25 meters, and does not recommend it
- ePulse results are generally affected by air pocket in the pipe, possibly also the dissolved air in water (from desktop study and experience from p-CAT)
- For measurements > 25 meters sensor spacing, ePulse test-bed trial results do not contradict the averaging results provided by Russell NDE (yet validation of the latter is still rather limited)

(Reminder) Evaluation of ePulse

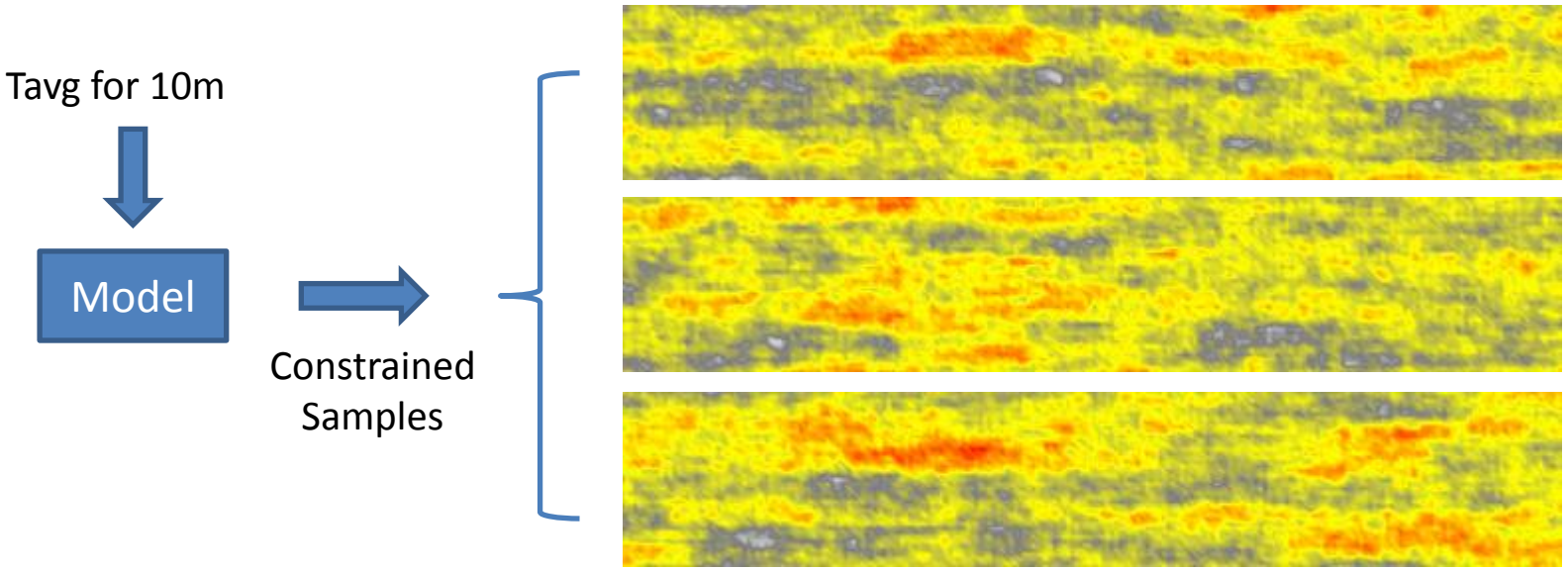
- The potential information gain by using ePulse measurements in between assessed pipe sections is theoretically straightforward within the proposed framework, but practically difficult to evaluate

- Highly detailed technical discussion are ongoing with Echologics in relation to ePulse's capabilities and virtues for in-between interpretations probabilistically.

- ePulse statistical interpretations: *"The EVA data analysis has been done for several water utilities in North America, and for one in the Netherlands. It has been commercially available since August of 2014." (Kevin Laven, Echologics Engineering)* -> UTS has received a document recently and is studying on it

(Reminder) Detection Services p-CAT

- P-CAT - acoustic technique: provides one measurement over long distances, e.g. 100 m
- It then reports average wall thickness every 10 meters (through further data analysis)
- Incorporating these measurements for in-between prediction is theoretically straightforward within the proposed framework and will add value to it - <u>if accurate</u>



(Reminder) First pCAT Trial

- April 2015
- Unsuccessful due to dissolved gas in water
- Practical validation at this stage is not feasible given the short length of GT sections available

Fill test bed pipe

Pressure Sensor

Generator

Milky Water

(Reminder) Second pCAT Trial

- July 2015
- Considerable steps taken by SW as advised to minimise oxygen in water in test-bed
- Still, again unsuccessful due to levels of dissolved gas in water. DS indicated higher than the technique can handle for reliable reporting
- Planning and feasibility of carrying out a p-CAT trial on a (SW, other utility) live main is currently under discussion
- Practical validation at this stage is not feasible given the short length of GT sections available

Dissolved Oxygen (DO) Test

Dissolved Oxygen (DO) Test

Challenge in Validation of ePulse/p-CAT

The validation of the screening technique is **INTRINSIC** to in-between validation

1. If technique goodness is proven <u>insufficient</u>
- Guidance for local inspections for model building **X**
- Constrained sampling **X**

2. If technique goodness is proven <u>sufficient in relative terms</u>
- Guidance for local inspections for model building ✓
- Constrained sampling **X**

3. If technique goodness is proven <u>in absolute terms</u>
- Guidance for local inspections for model building ✓
- Constrained sampling ✓

in-between framework prediction "with no reliable screening input"

Challenge in Validation of ePulse/p-CAT

- To validate ePulse and p-CAT, long GT sections are required to be exhumed and profiled, currently unavailable and impractical
- A proxy using BEM is being considered with practicality in mind

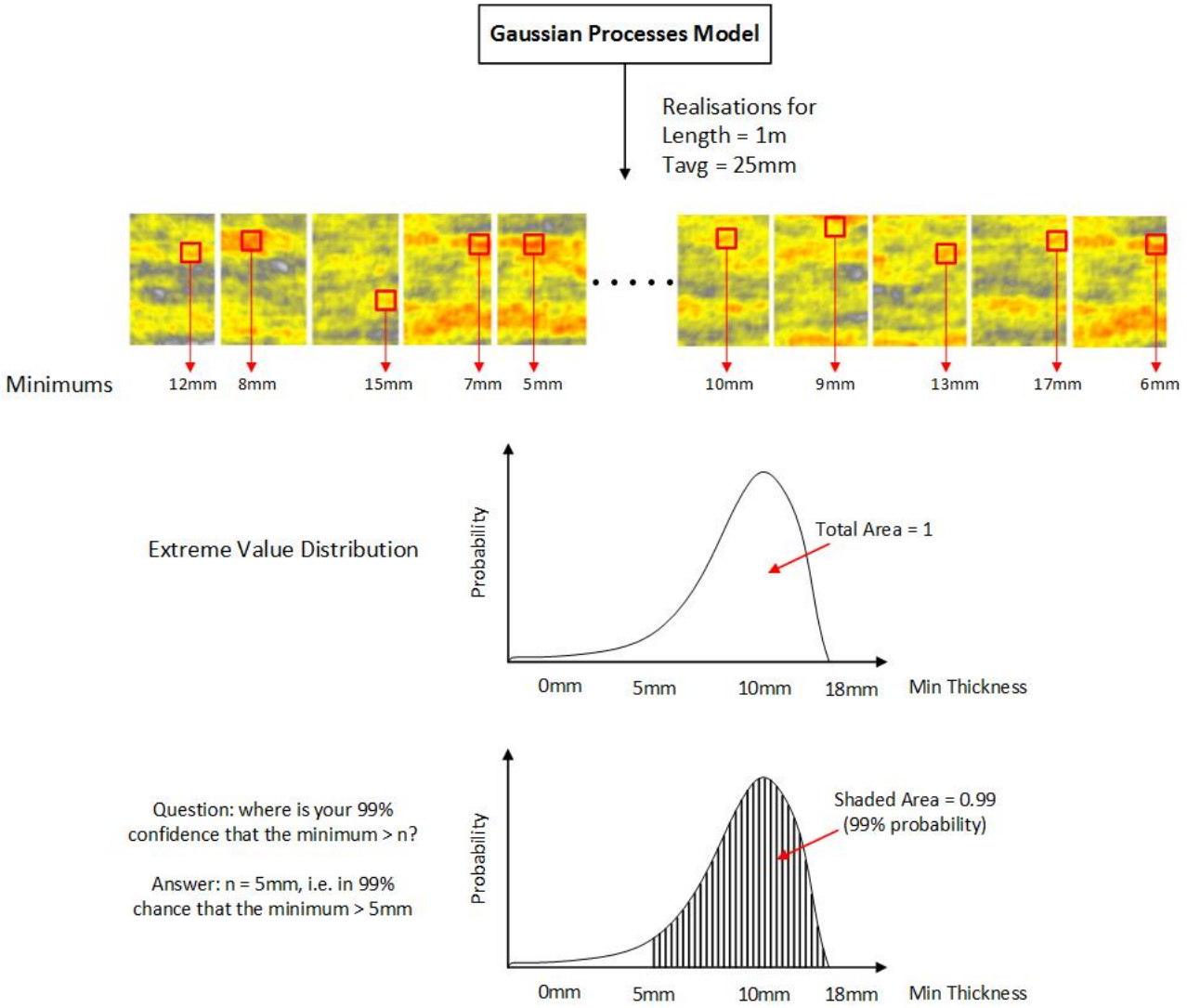
Specific to p-CAT:

- Two potential opportunities for carrying out p-CAT validation trials have been identified, one at Sydney Water and another one at Water Corporation .
- On live mains different to test-bed
- Will also facilitate evaluation of in-between framework

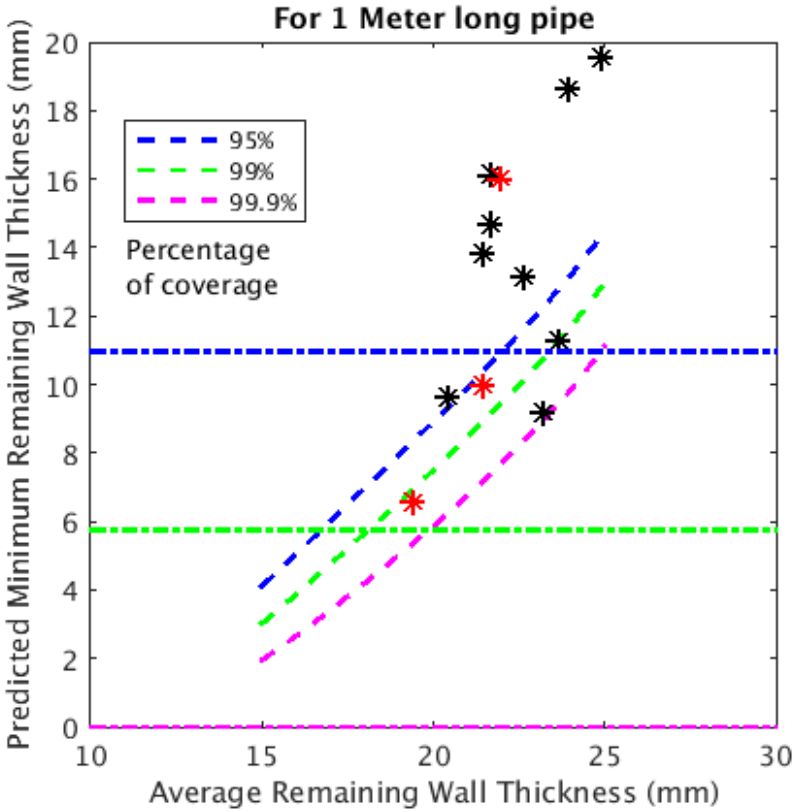
Challenge in Validation of ePulse/p-CAT (Alignment)

- A framework has been proposed and implemented to align in-pipe distance to above ground locations to facilitate validation (and other applications)

(Reminder) A tool ready to use: UTS-EVA for p-CAT

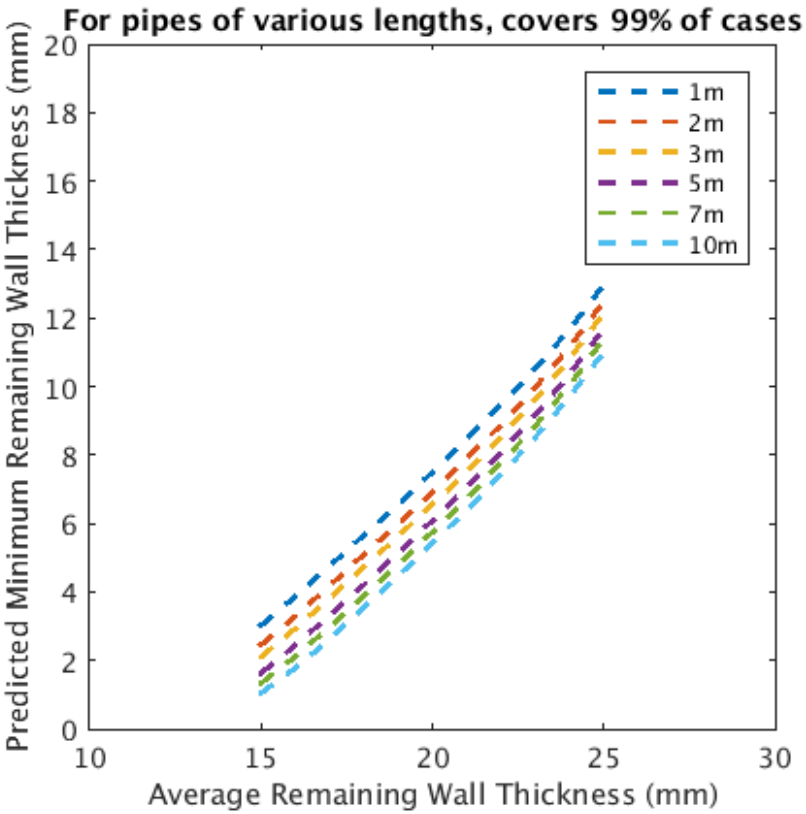


(Reminder) A tool ready to use: UTS-EVA for p-CAT



- UTS EVA considers data correlation and can incorporate constraints
- On the limited available validated data, UTS EVA improves accuracy

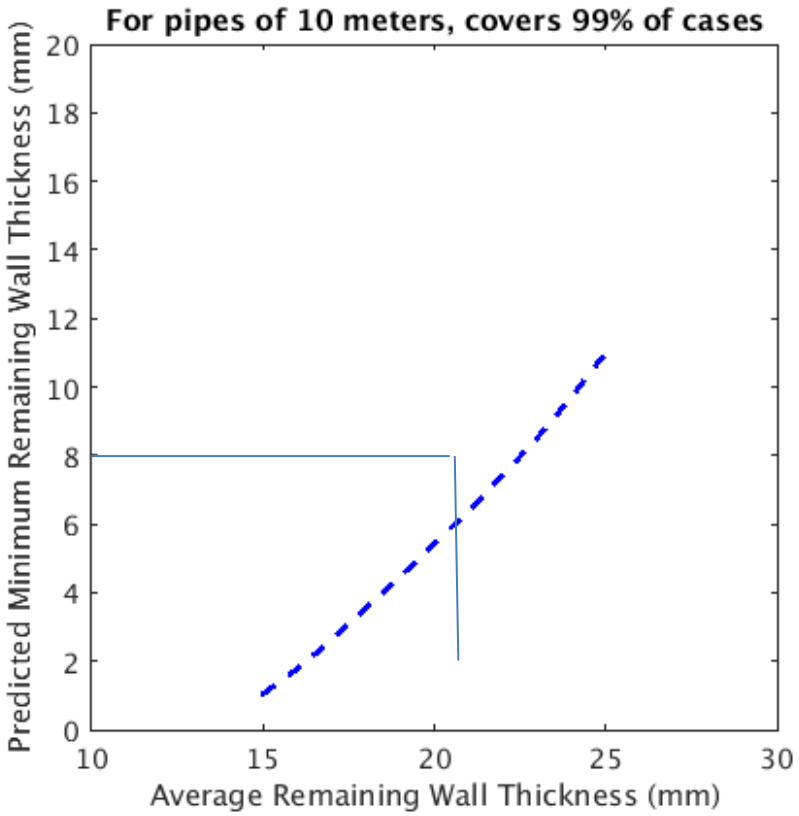
(Reminder) UTS EVA - How to Use p-CAT Results?



Simulation results (for convenience at BEM resolution) show that:

- Larger remaining wall thickness implies higher minimum wall thickness
- Targeting longer pipe sections imply lower minimum wall thickness

(Reminder) UTS EVA How to Use p-CAT Results? Example



Example: if critical Tmin is 6mm, critical Tavg from p-CAT for 10 meters is 21mm

Pending

1. DS p-CAT trial at Sydney water

2. Pure Smartball EM PWA trial at Sydney water

3. DS p-CAT survey (plus inspections with BEM) at Water Corporation - part of an exercise to validation in-between framework

4. Further validate fitness and potential information gain of using acoustics based screening technologies for in-between framework.
   - If real data is in the end not readily available we will do so only as desktop study using simulated data (FEA, analytical).

Current Progress and Future Goals

Goal	Status
Appoint personnel Selection of appropriate emerging technologies (on-going) Negotiate technology agreements (on-going)	Completed
Integration of novel techniques with proposed data-driven multi-resolution fusion network	In progress (70%)
Interim evaluation of potential information gain by use of measurements from novel technology with respect to ground truth	In progress (80%) (proxy from simulations)
Robust validation of potential information gain by use of measurements from novel technologies with respect to ground truth	In progress (50%) (proxy from simulations)