

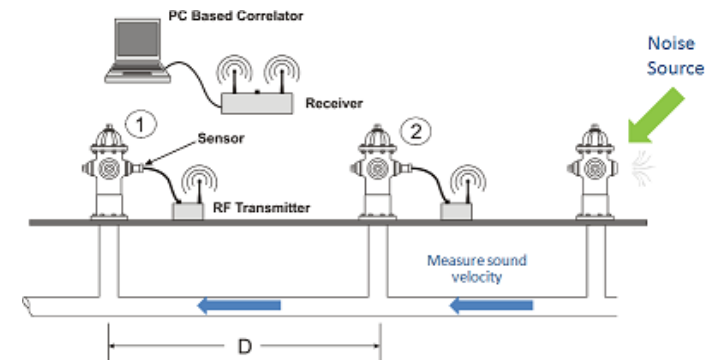
# **Activity 4d: Enhanced Reliability of Emerging Technologies**

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 – Mar'16)

# Presentation Outline

1. Summary Current State of Affairs
2. Summary Latest Progress
3. Understanding the Technologies:
  - DS pCAT
  - PCA-Echologics ePulse
  - Evaluation Challenges
4. In-Between 'Big Picture' Example:
  - Exploiting pCAT 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. 2nd trial of p-CAT (Detection Services) technology was planned and undertaken on July 2015 on SW test-bed but was again unsuccessful
  - DS found excessive acoustic signal degradation apparently caused by dissolved oxygen in water
  - Planning and feasibility of carrying out a p-CAT trial on another (SW, other utility?) live main is under discussion
2. An inspections with PCA-Echologics Mainscan technology was also carried out as part of Trial 6
3. Incorporating the information provided by pCAT 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

# 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~~  
~~Detection Services - p-CAT~~

Trial Done (September 2014), report received  
Detailed technical discussion are ongoing  
1<sup>st</sup> Trial (Apr'15) unsuccessful  
2<sup>nd</sup> Trial (July'15) unsuccessful  
Next trial on a live main under discussion

~~Breivoll - Pipescanner~~  
~~JD7 - Pipescan ++~~  
~~JD7 - Pipescan +~~

Issues with cement lining  
Company undergoing changes, tool availability issues  
Issues with large dimensional pipes

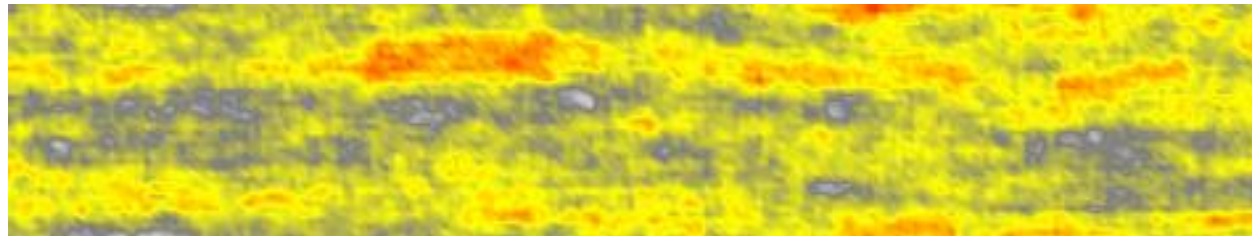
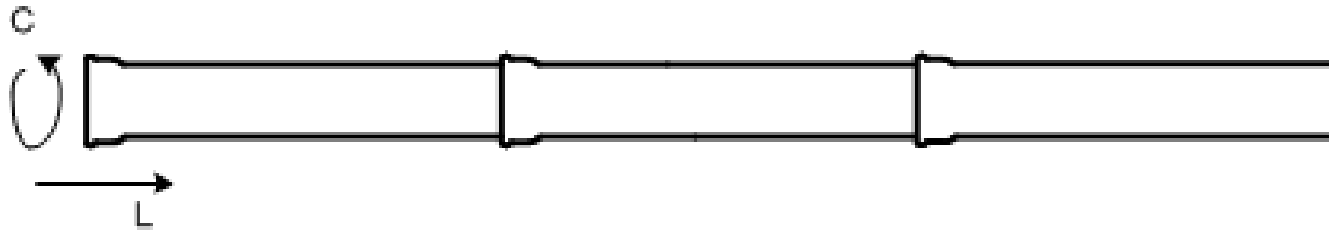
~~Transkor - SKIF~~  
~~SpeirHunter ?~~

Redirected to 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



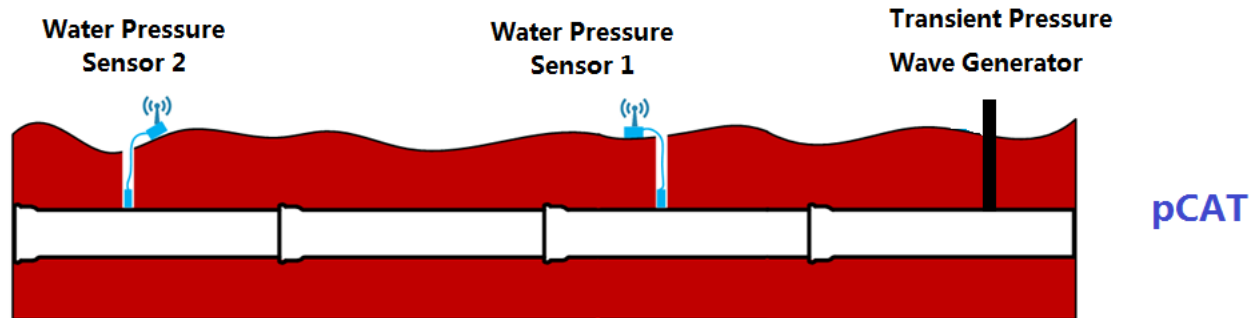
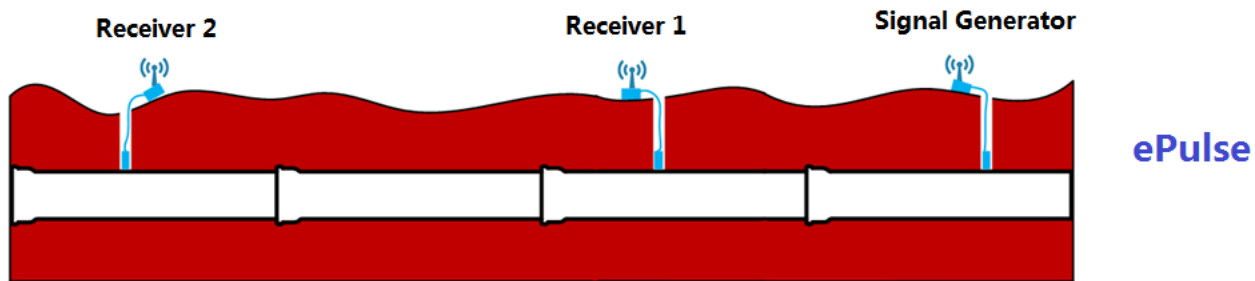
e.g. 10 Meters (joint excluded)

1. Dense Remaining Wall Thickness Map [at different resolutions]  
(e.g. **BEM**, **MFL**, **Mainscan**) -> structural analysis?
2. Average Remaining Wall Thickness (e.g. **pCAT**)
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**)



Note: A common misconception is that higher  $T_{avg}$  = higher global  $T_{min}$ . Yet based on currently available data correlation between  $T_{avg}$  and  $T_{min}$  is 0.6 (out of 1 = fully correlated)

# Reminder: Understanding the Technology



ePulse: Access the external pipe wall  
ePulse: Average minimum wall thickness  
ePulse: No sub-section information  
ePulse: Smallest reliable coverage is 25 m

pCAT: Access the water  
pCAT: Average wall thickness  
pCAT: Sub-section information available  
pCAT: Smallest reliable coverage is 10 m

# Reminder: Detection Services pCAT

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

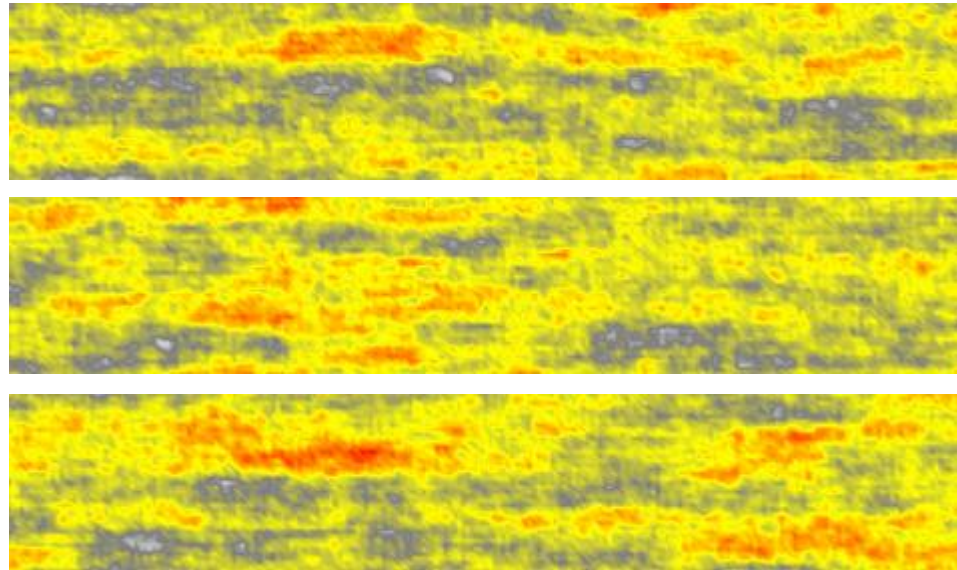
Tavg for 10m



Model



Constrained  
Samples



# 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

# 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

# Second pCAT Trial

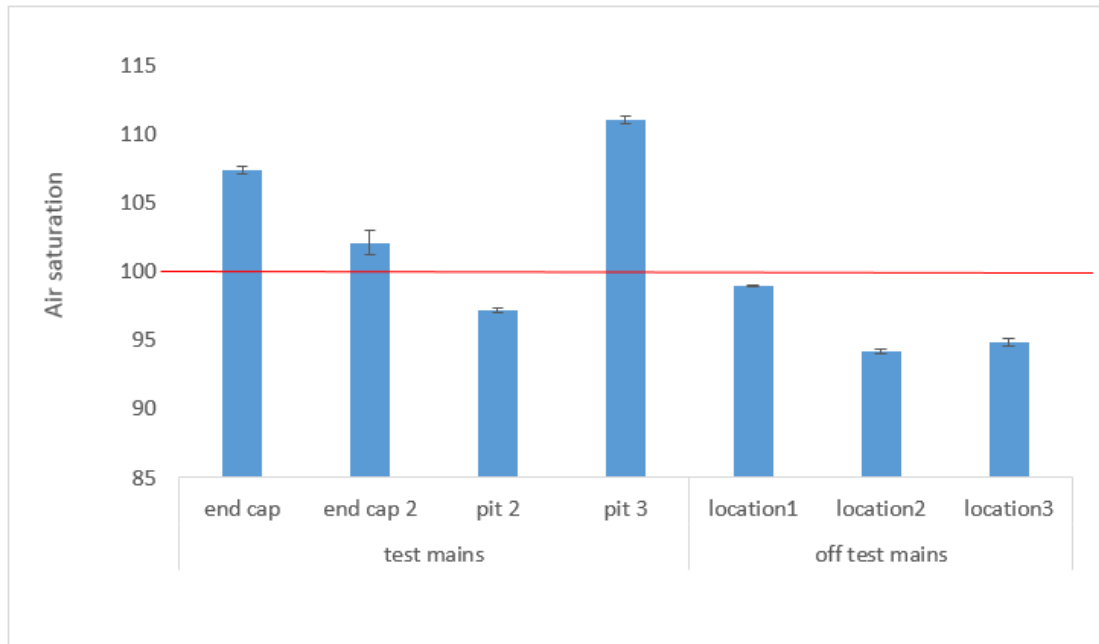


Figure 1, A comparison between the dissolve oxygen within the Sydney water test pipeline compared to mains feed by the same water.

Figure courtesy of  
Detection Services

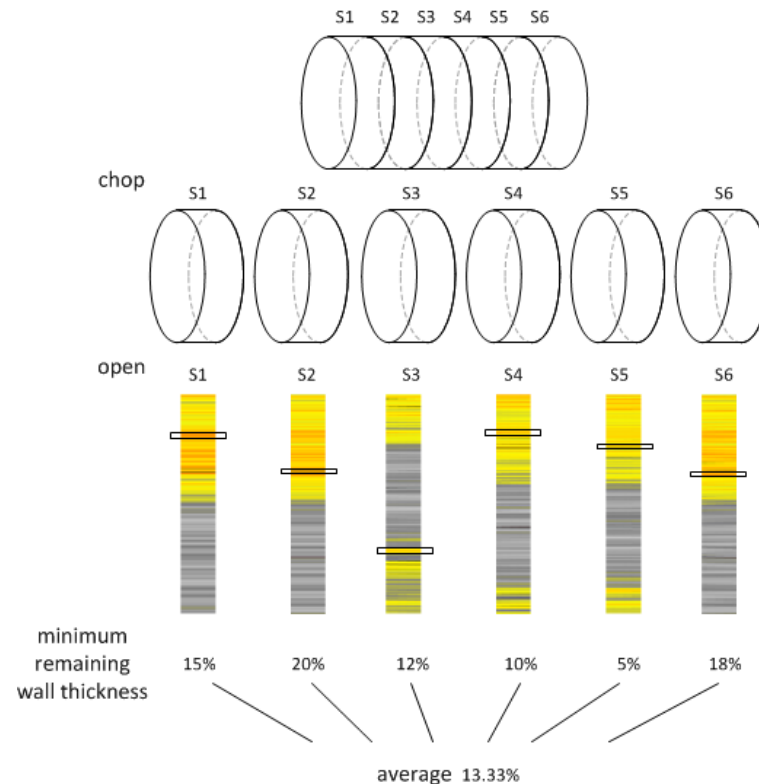
# Reminder: Evaluation of ePulse

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
- Many parameters need to be accurately fixed/known beforehand



# 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.” (Kevin Laven, Vice President, Technical Services Echologics Engineering, 24 Aug 2015)*
- 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 than 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 pCAT)
- 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)

# Evaluation of ePulse

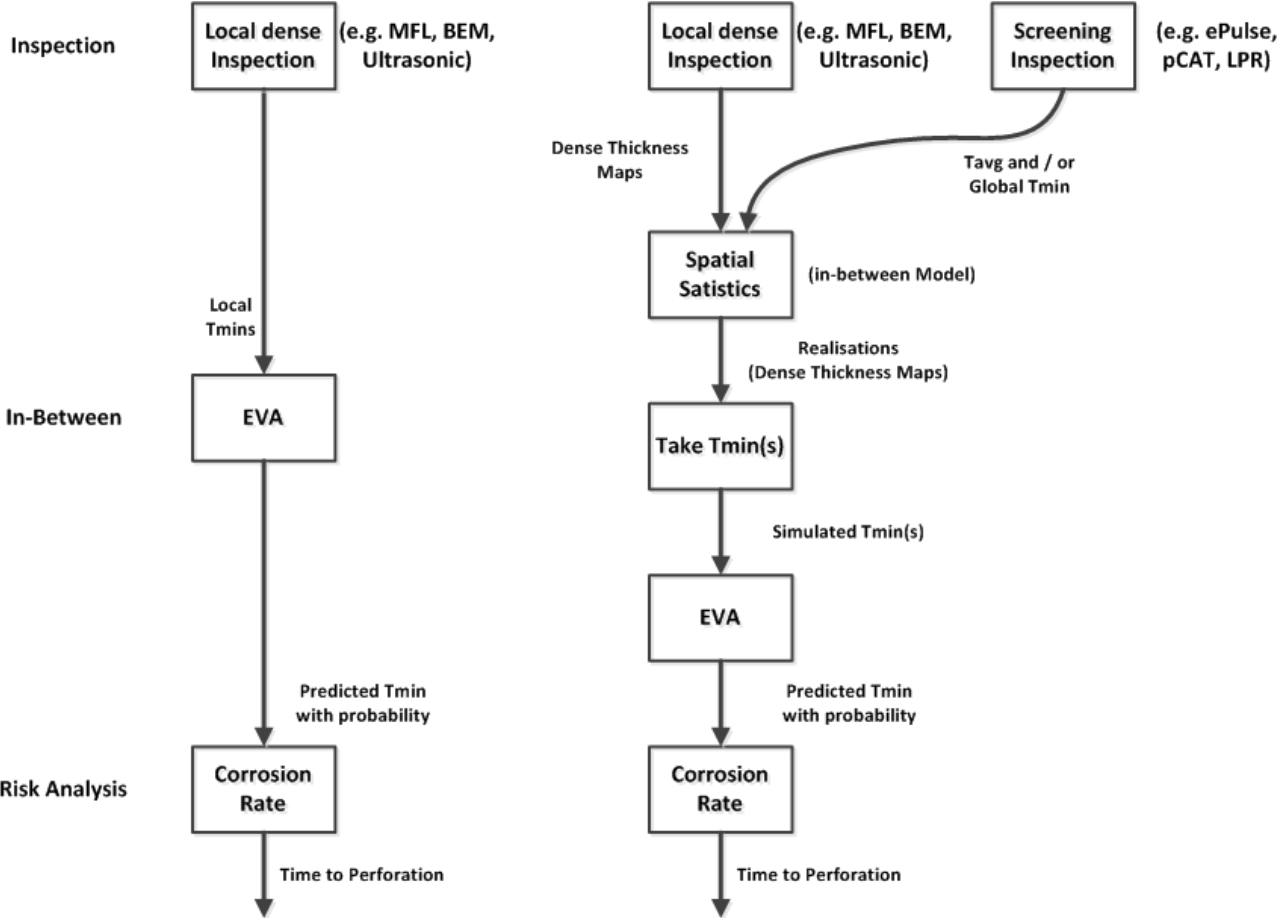
- The potential information gain by using ePulse measurements in between assessed pipe sections is theoretically straightforward within the proposed framework, but practically difficult to evaluate
- Highly detailed technical discussions are ongoing with Echologics Engineering's Vice President in relation to ePulse's capabilities and virtues for in-between interpretations probabilistically in terms of minimum remaining wall thickness. As part of these, p-CAT's virtual evaluation through simulation continues and results are available as part of these discussions.
- 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 is currently trying to assess this.

# Challenge in Validation of ePulse/pCAT

- To validate ePulse and pCAT, 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



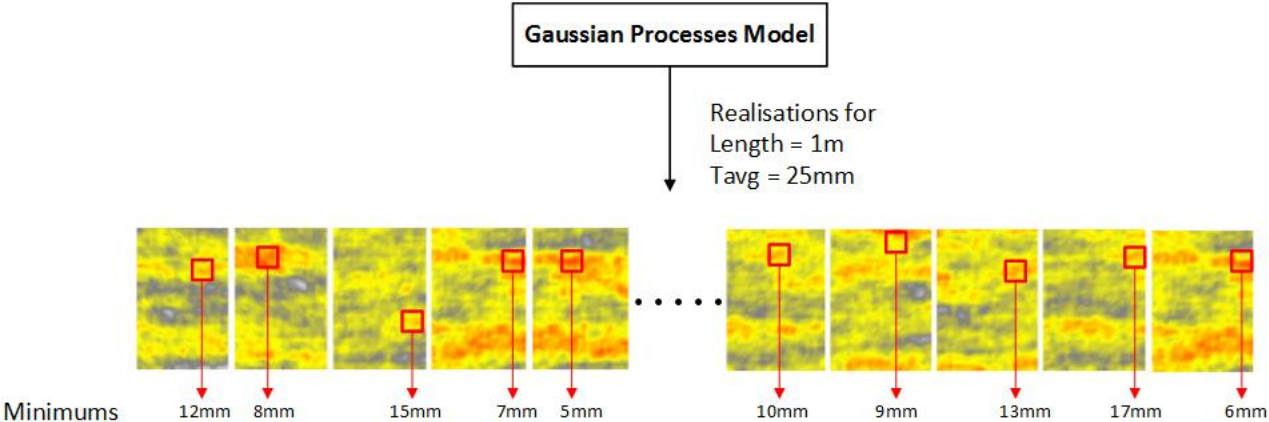
# Reminder: UTS EVA



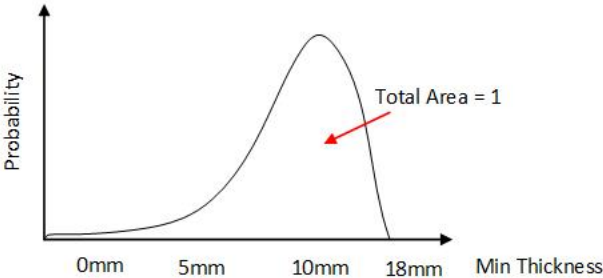
Conventional EVA

UTS EVA

# Reminder: UTS EVA

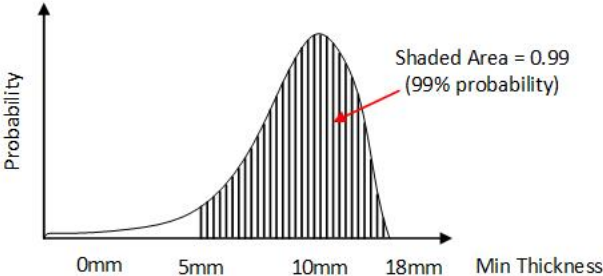


Extreme Value Distribution



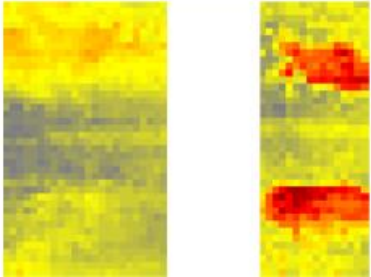
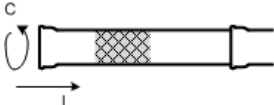
Question: where is your 99% confidence that the minimum > n?

Answer:  $n = 5\text{mm}$ , i.e. in 99% chance that the minimum > 5mm



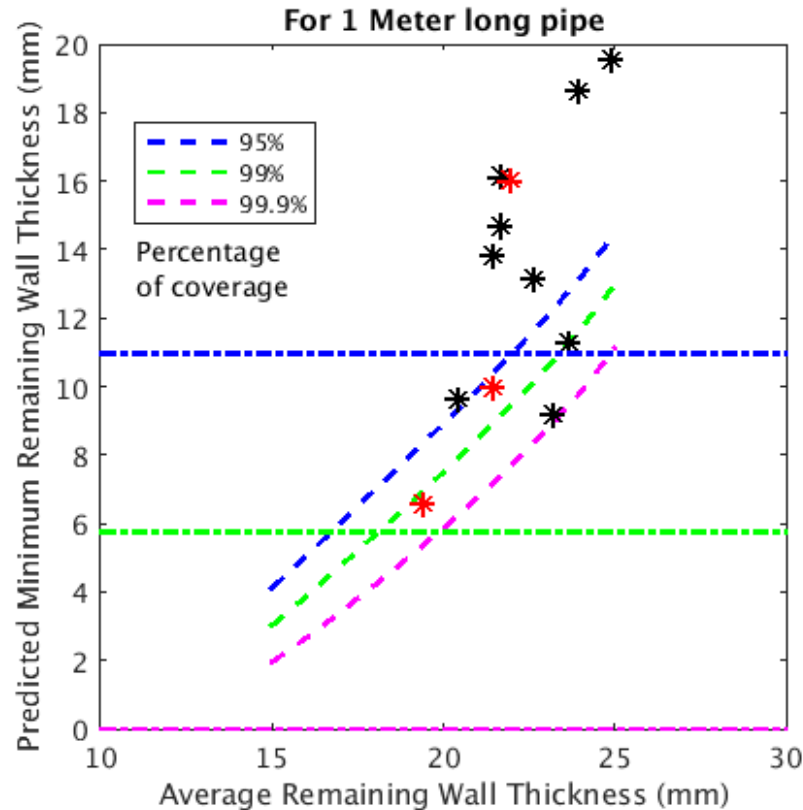
# Reminder: UTS EVA

## Training / Test Data



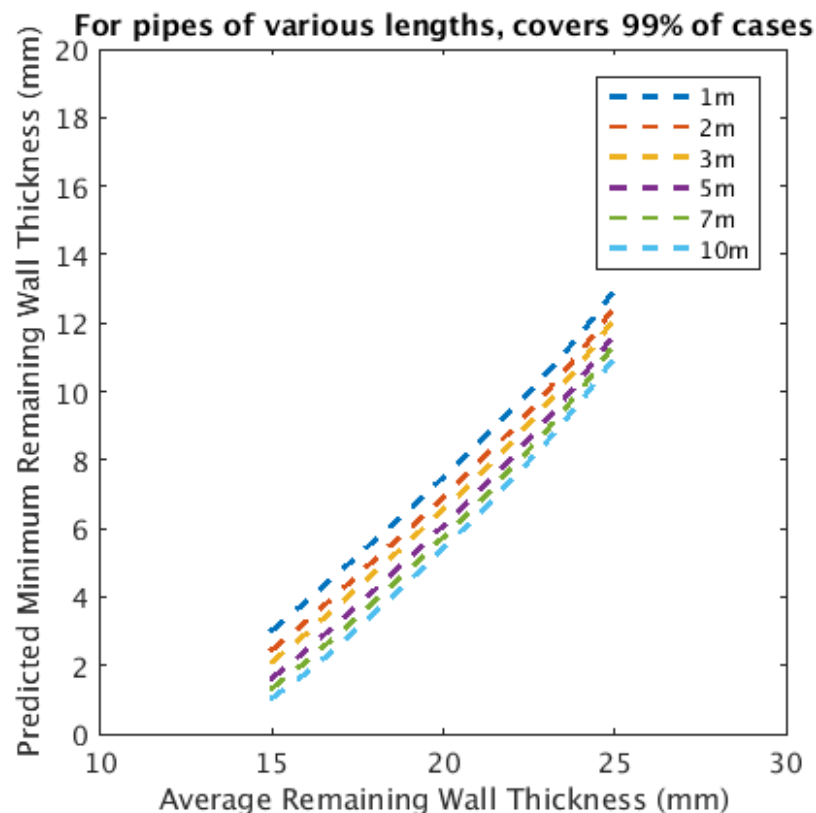
Pits labeled in **RED** are used for training

# Reminder: UTS EVA



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

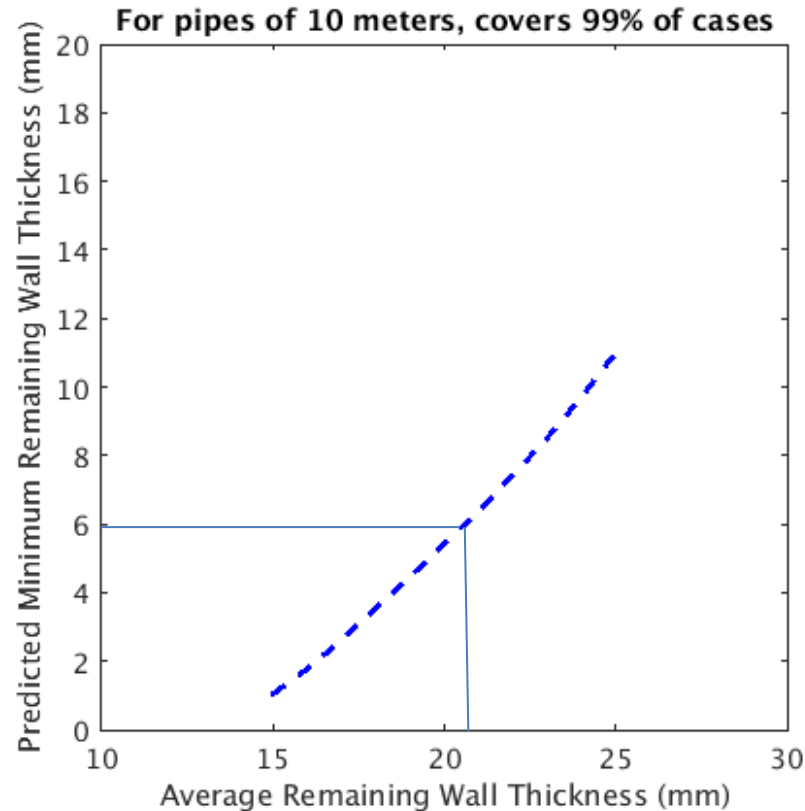
# UTS EVA - How to Use pCAT Results?



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

# UTS EVA Example - How to Use pCAT Results?



Example: if critical  $T_{min}$  is 6mm, critical  $T_{avg}$  from pCAT for 10 meters is 21mm

# 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 (50%)
Interim evaluation of potential information gain by use of measurements from novel technology with respect to ground truth	In progress (70%) (proxy from simulations)
Robust validation of potential information gain by use of measurements from novel technologies with respect to ground truth	In progress (30%) (proxy from simulations)