

# Recent experience of “real-time” monitoring on tunnelling projects in London

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Geotechnical bservationS



## Why do we monitor?

- 👁️ Curiosity.
- 👁️ Insurance.
- 👁️ Assurance.
- 👁️ Control risk.

“Geotechnical instrumentation can reduce the undesirable consequences from construction surprises.” (A. Marr 2007)

Increasingly, however geotechnical instrumentation is becoming important in helping to reduce the cost of construction.

What do we mean by “real-time” monitoring?

- 👁 Is it related to how fast we can retrieve our data or how we recover our data?

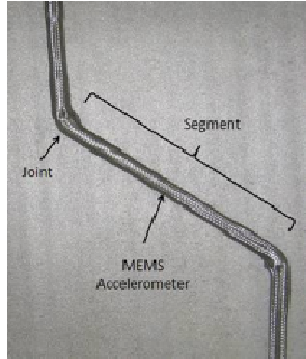
For example:

- 👁 We use a datalogger to read the instrument, where the data is stored until we collect it using a telemetric connection at the end of the day.
- 👁 We send a technician to read the instrument and bring the data back to the office before the end of the day.

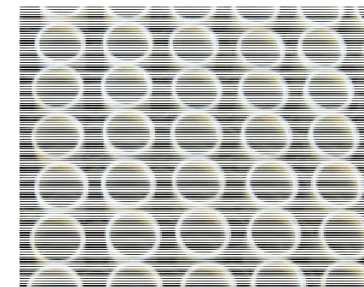
Do either of these constitute “real-time” monitoring?

- 👁 To be “real-time” the data must be available for analysis immediately.
- 👁 In reality this is difficult (practically impossible) to achieve.
- 👁 Even if we could guarantee immediate delivery of the data would anyone be looking at it?! Remember Heathrow?
- 👁 These days we set up systems that collect the data and immediately compare it to thresholds defined by the designer (“trigger values”). If a threshold is crossed the system sends a message (SMS or email) to the responsible person.

# Shape Accel Array (SAA) “Real-time” Displacement Monitoring System



- Continuous string of MEMS tilt sensors.
- Delivered on a drum for easy installation.
- Joints can move in any direction but do not twist.
- Rigid segments (200mm, 305mm or 500mm long).
- 25mm diameter
- Small diameter access casing, with no grooves.





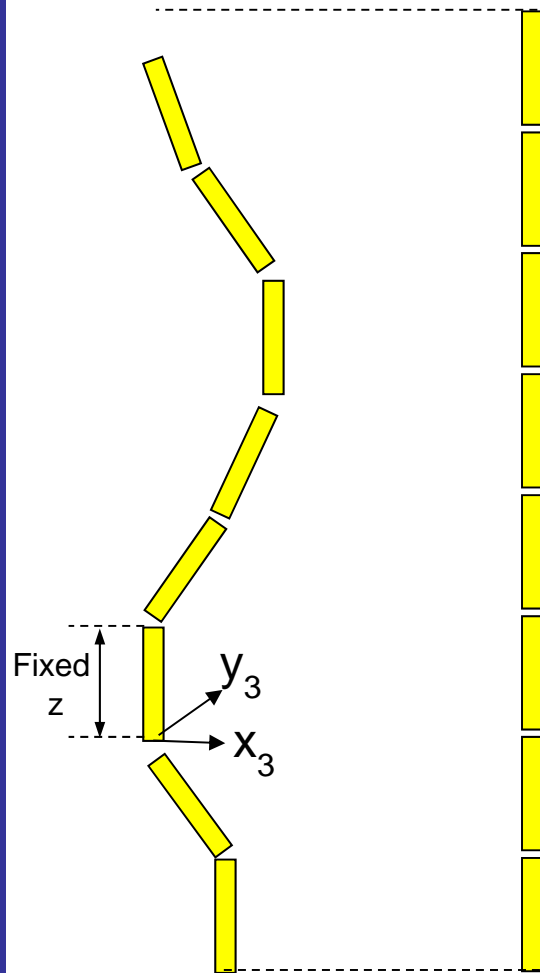
Datalogger for up to 5 SAA



SAA Field Unit for manual readings  
(includes Bluetooth and Android App)

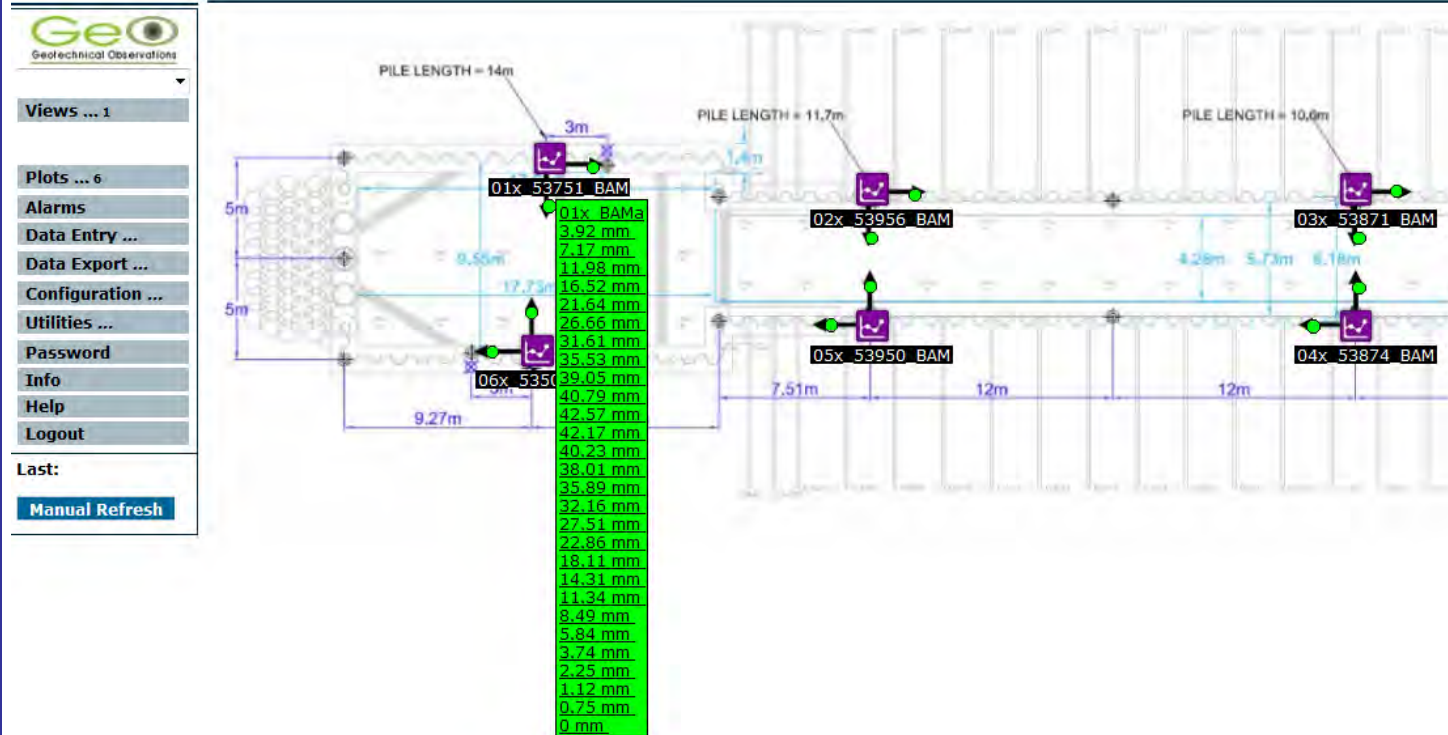


Single wire output for connection to a datalogger, a laptop or an Android device.



- Measures tilt in X and Y directions over a fixed length Z. Transforms measurements into shape and change of shape.
- Output is in engineering units (e.g. millimetres).
- Calculations can be referenced to either end and can be changed at any time during the monitoring programme.

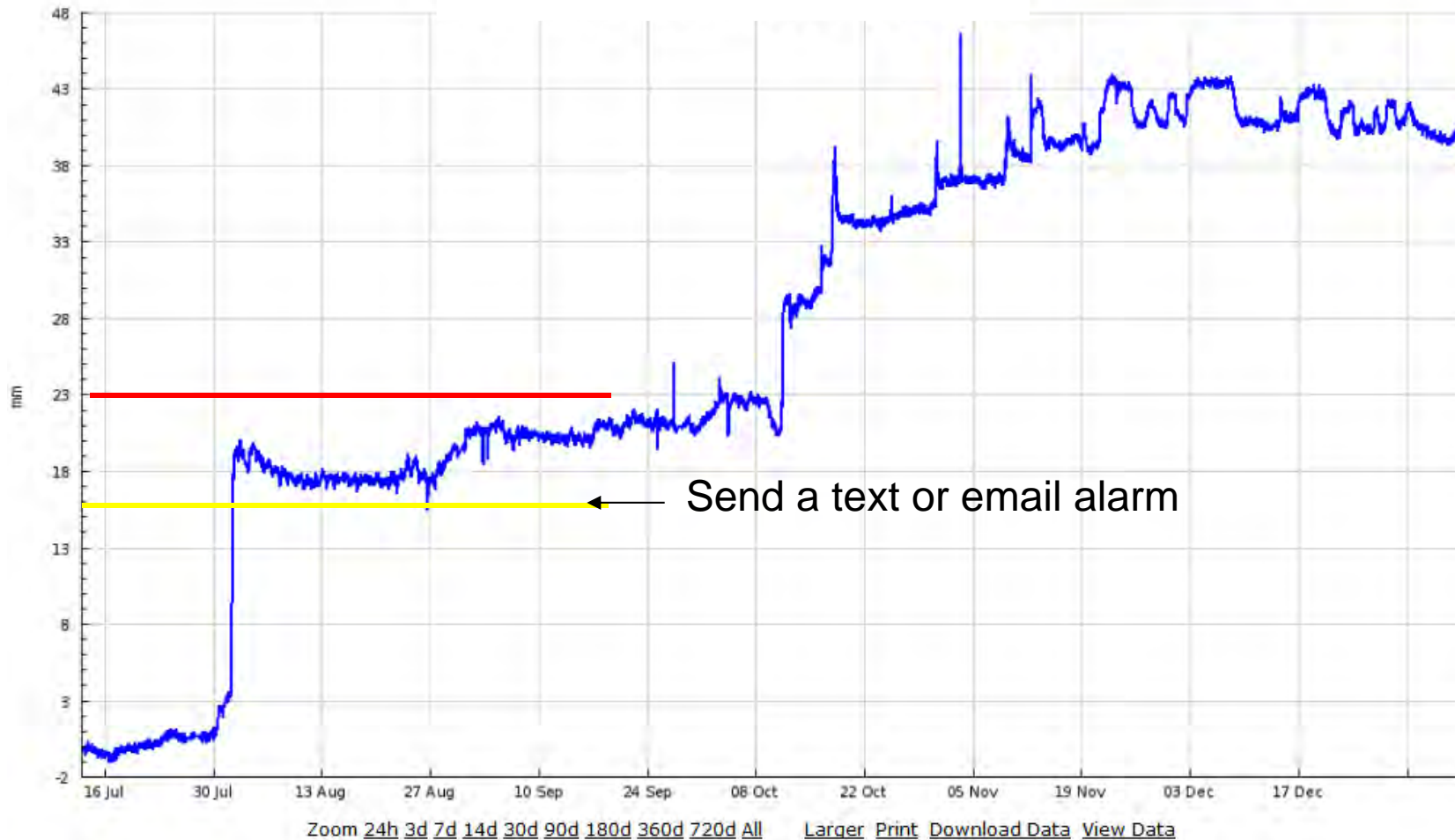
## ShapeAccelArray (SAA) located in the (vertical) wall of an excavation



- 👁 Data is transmitted to the internet for worldwide viewing and assessment.

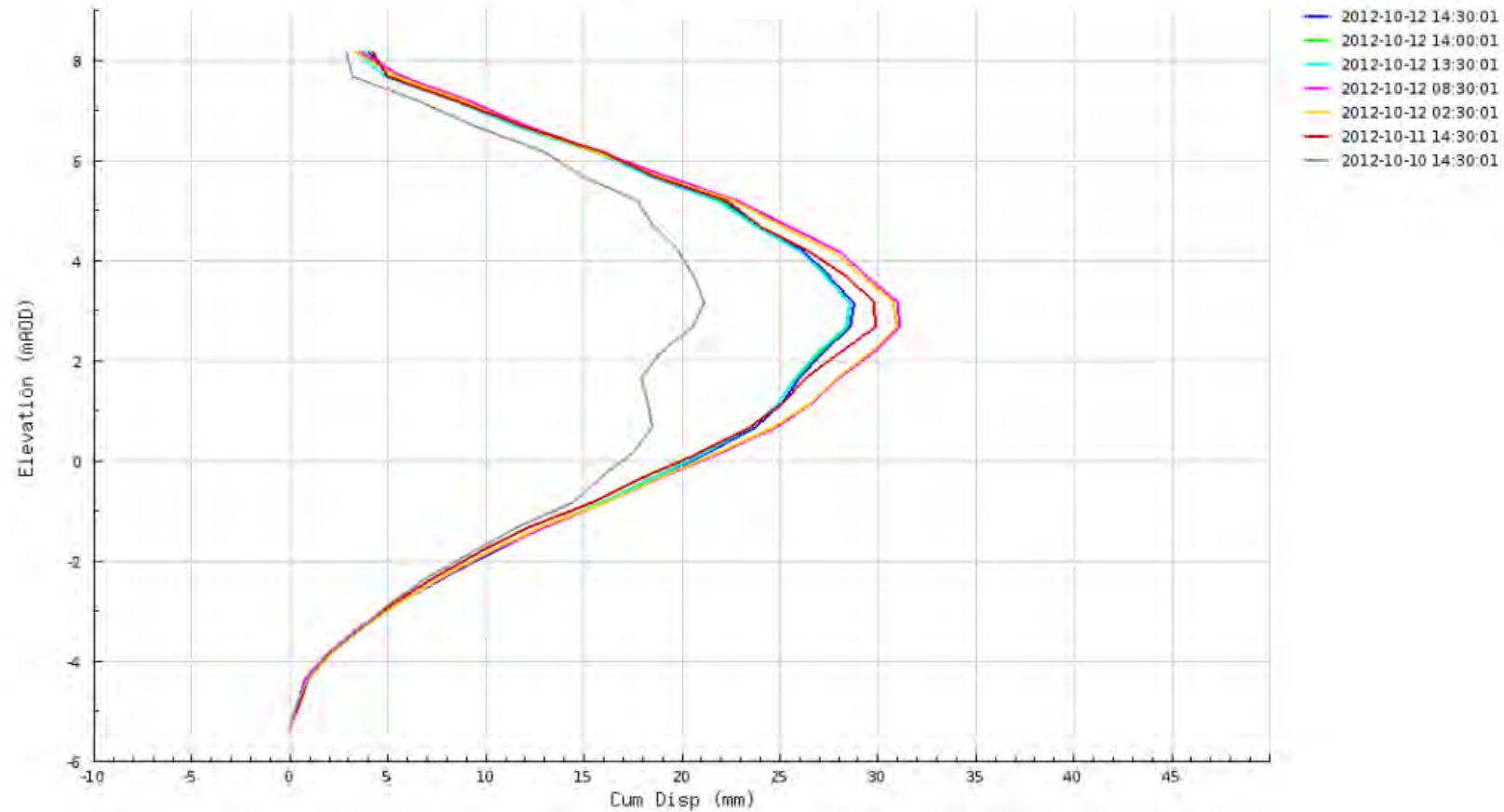


## ShapeAccelArray (SAA) located in the (vertical) wall of an excavation



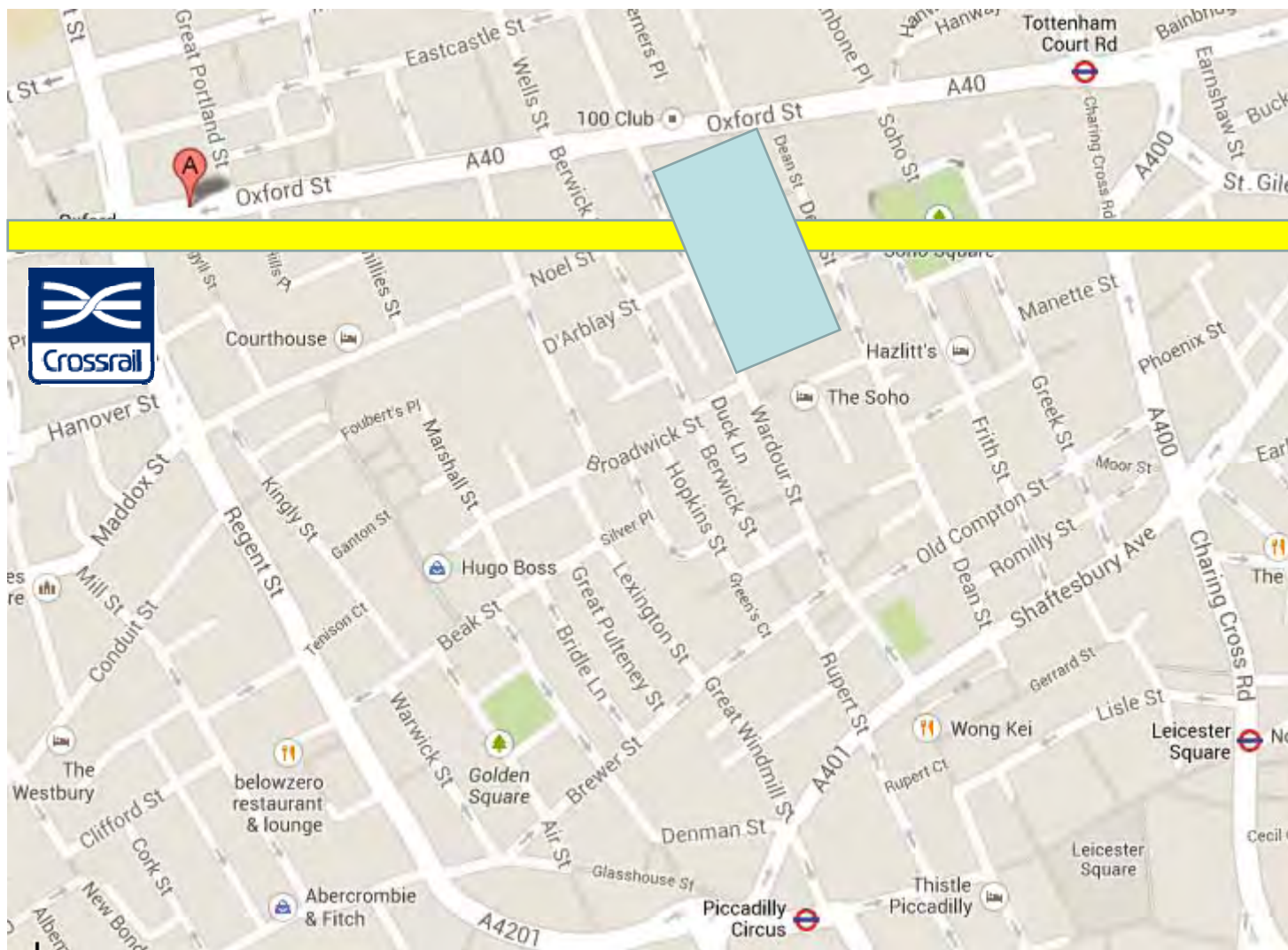
👁 Trend Plots used to check against thresholds.

## ShapeAccelArray (SAA) located in the (vertical) wall of an excavation



- 👁 Profile plots can be used to compare performance against design.

# Tottenham Court Road Western Ticket Hall

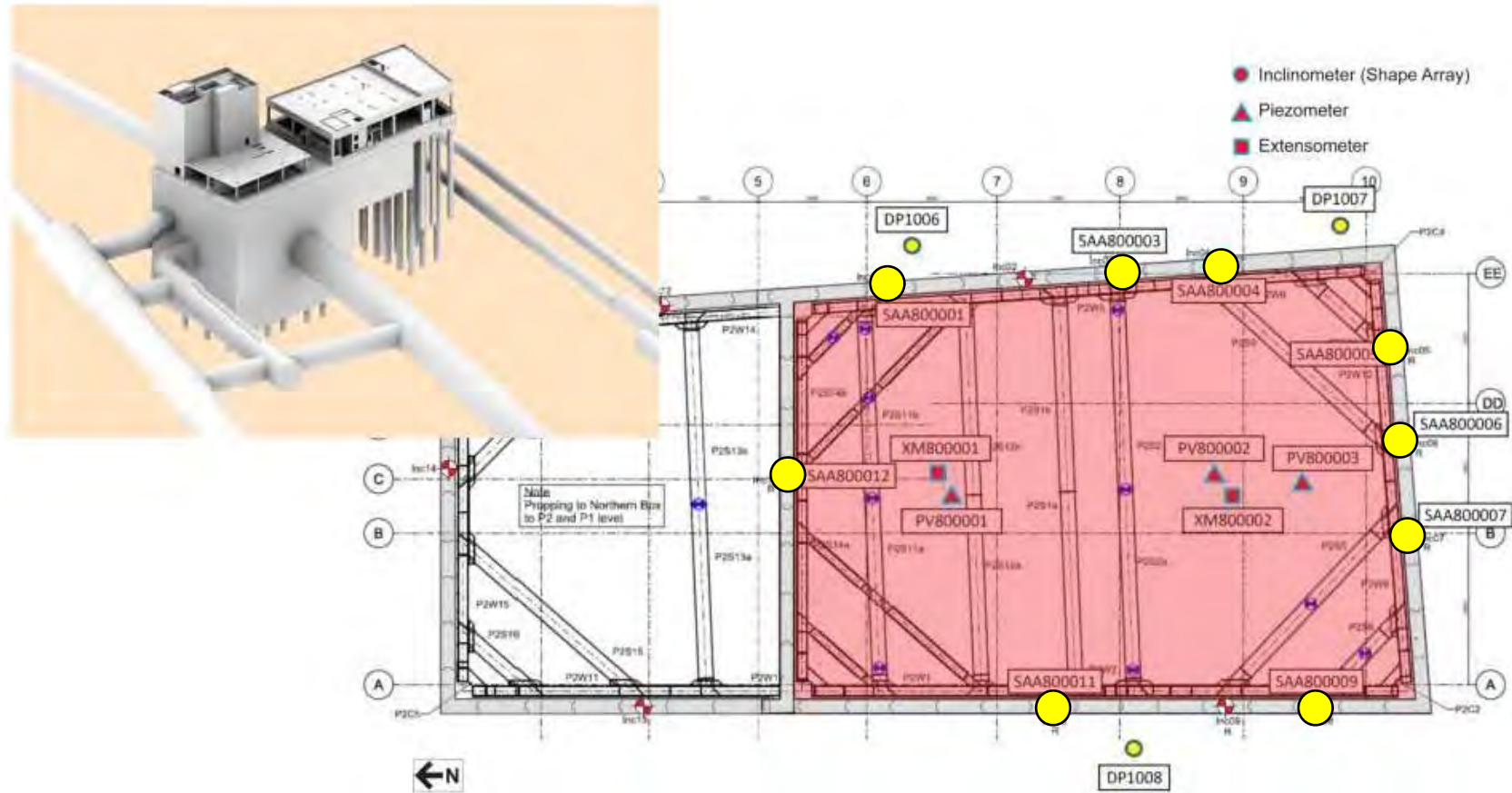




# Tottenham Court Road Western Ticket Hall



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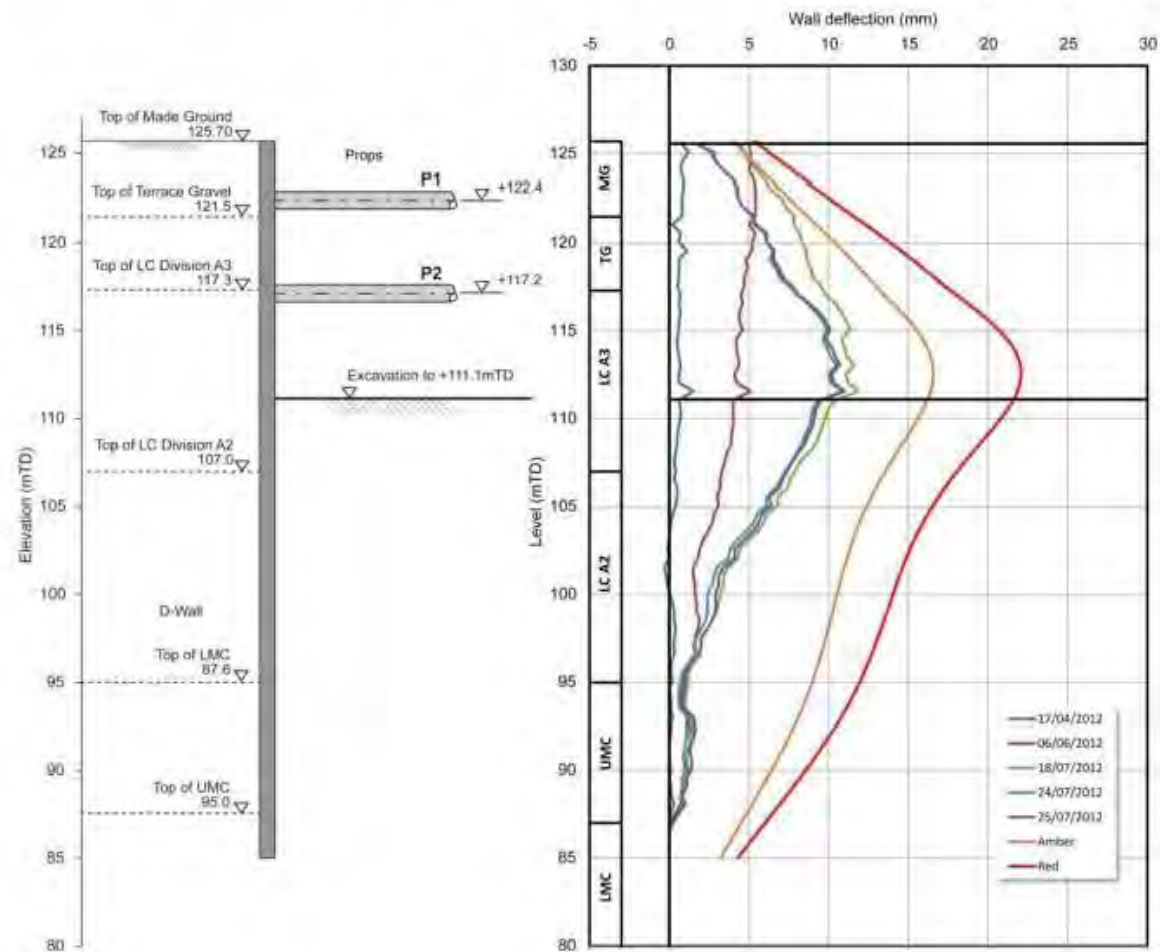


9 displacement monitoring systems - SAAs

# Tottenham Court Road Western Ticket Hall

Results courtesy of Duncan Nicholson (Arup)

- **Excavation to install P3**
- **Measured deflection <50% computed**
- **Proposed to omit P5 prop using Observational Method**

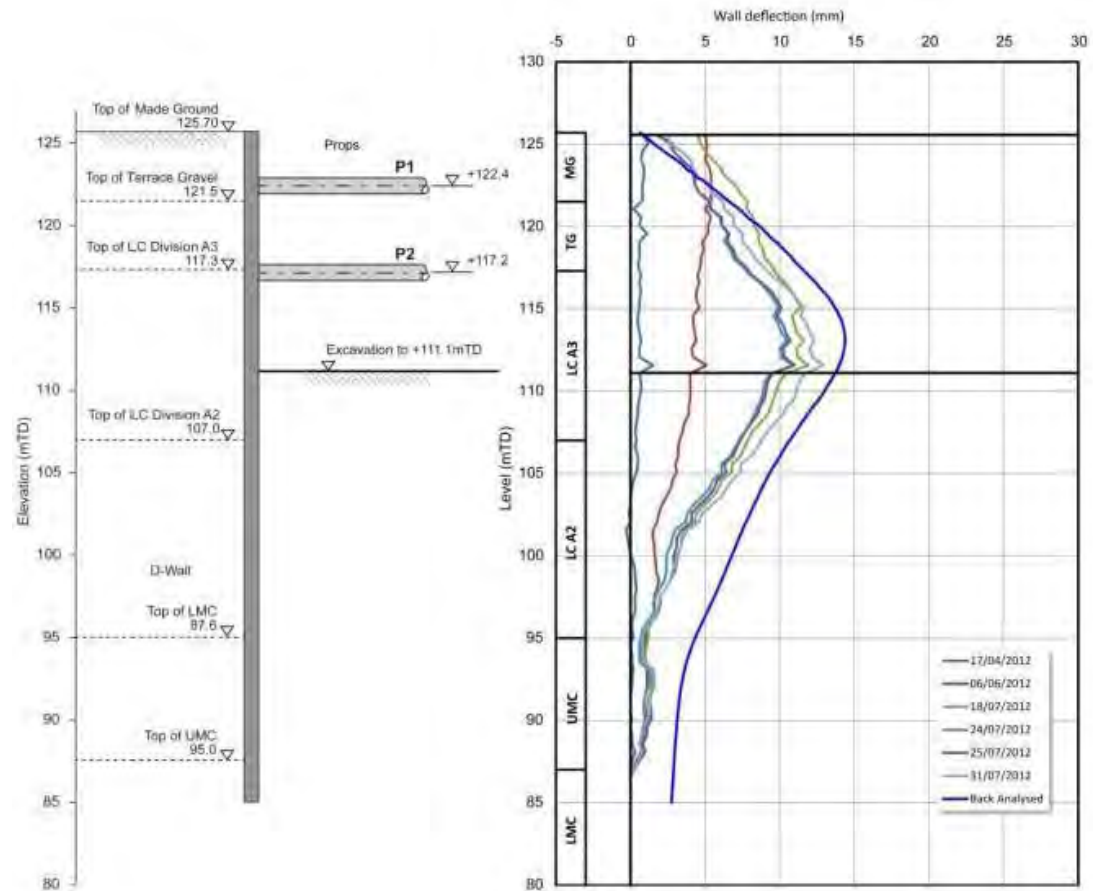




# Tottenham Court Road Western Ticket Hall

## Results courtesy of Duncan Nicholson (Arup)

Back analysis  
to refine design  
in line with  
measurements



# Tottenham Court Road Western Ticket Hall

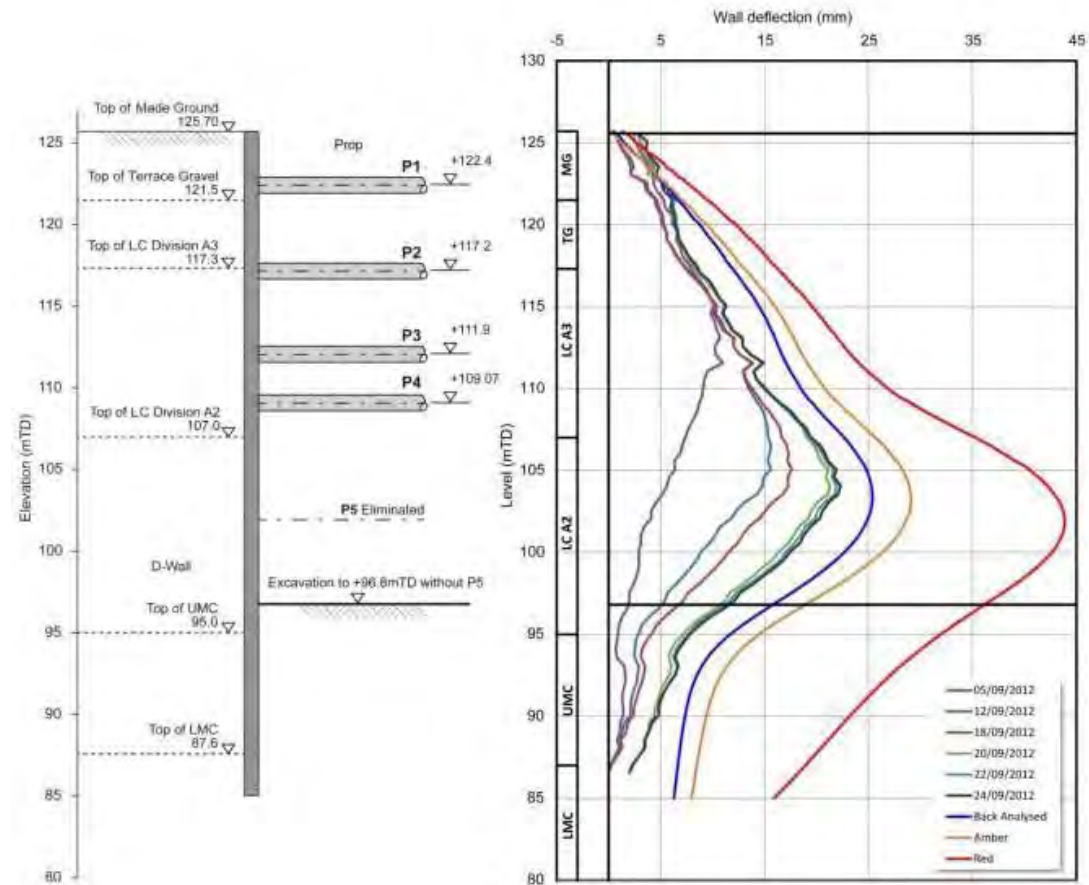
## Results courtesy of Duncan Nicholson (Arup)

P5 removed

11m headroom  
instead of 3m

Cost of inst.  
~£200k

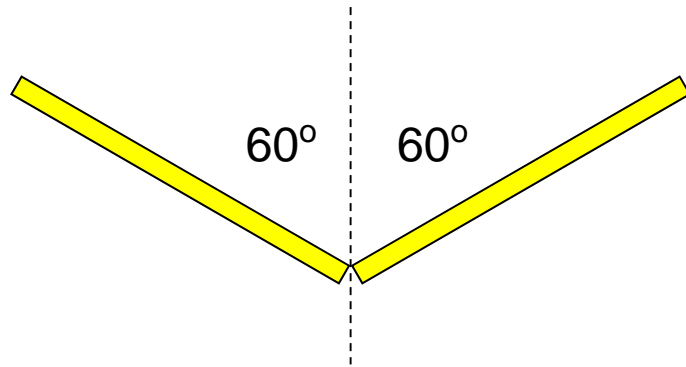
Saving ~£715k



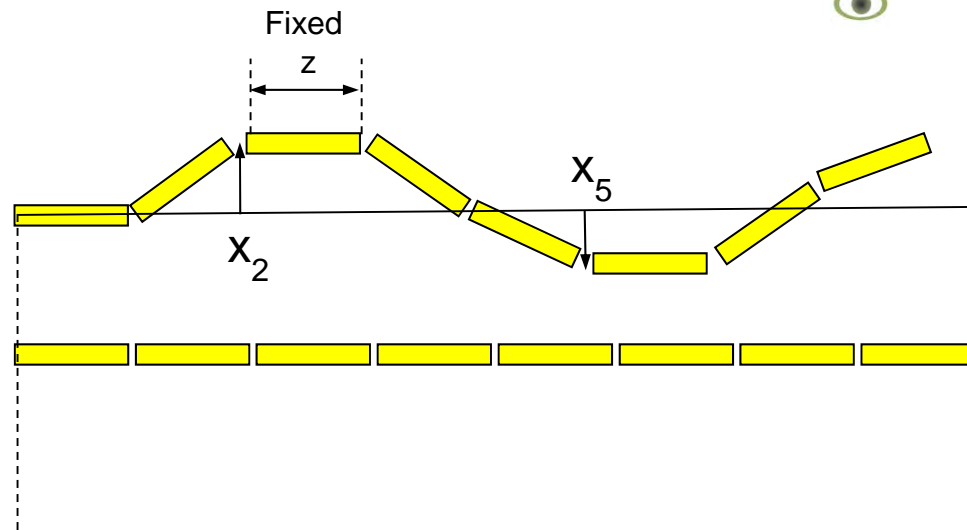




SAA works over a wide range (same sensors)

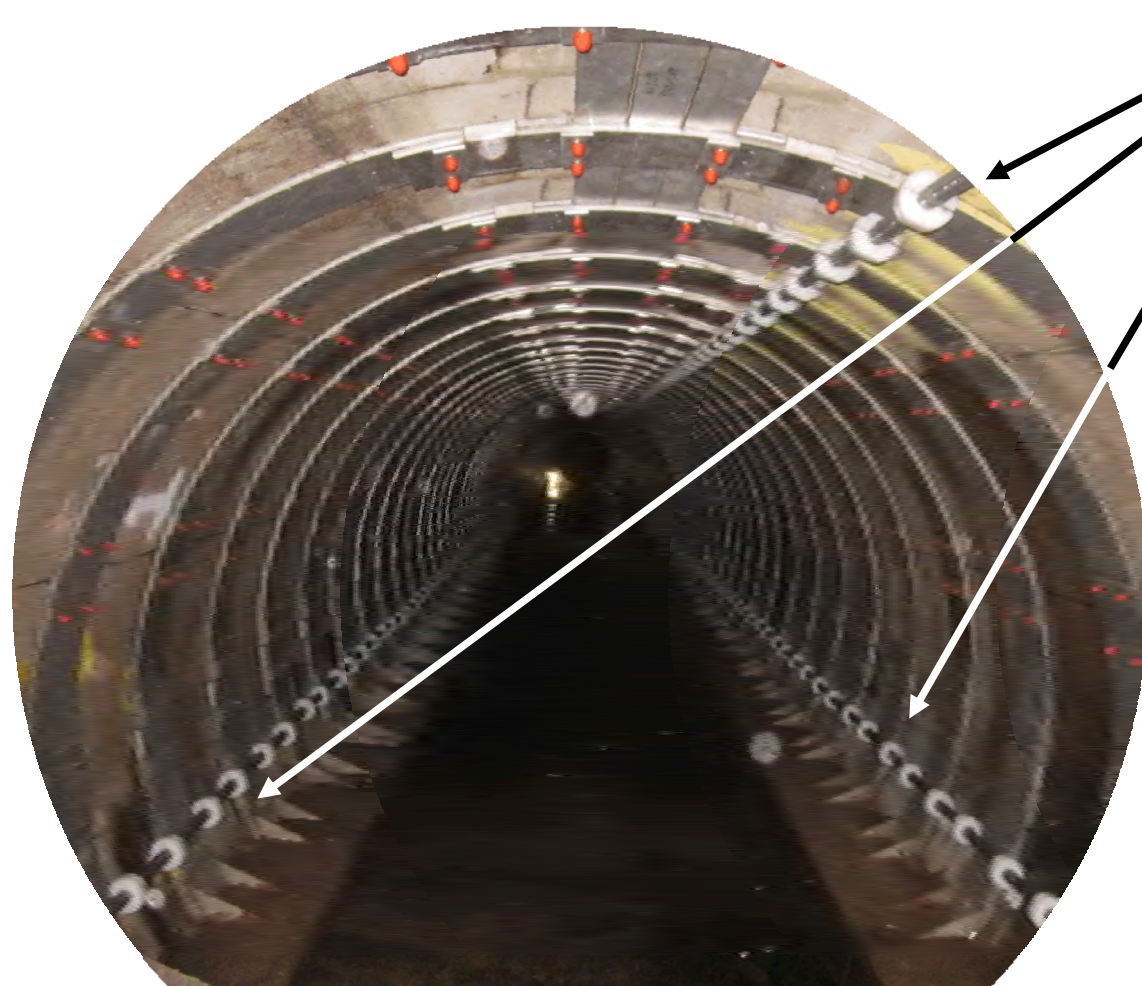


$\pm 60^\circ$  for X-Y (Z) mode.



$360^\circ$  for X (Z) mode.

ShapeAccelArray (SAA) located (horizontally) along the inside of a sewer



- 👁 Each SAA is encapsulated inside an ATEX rated Flameproof Protection System.

ShapeAccelArray (SAA) located (horizontally) along the inside of a TBM to monitor ground settlements during an advancing SCL tunnel

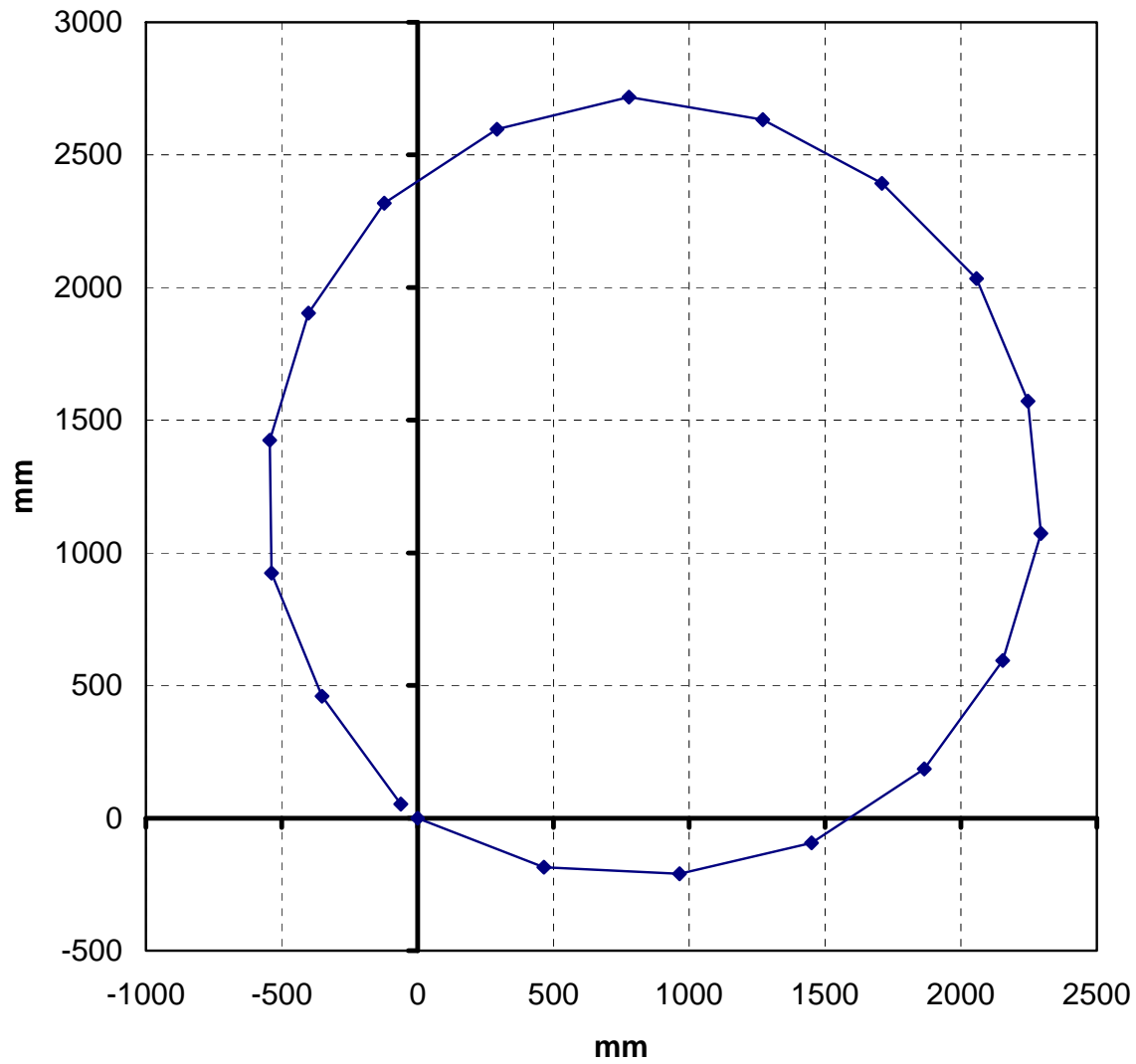




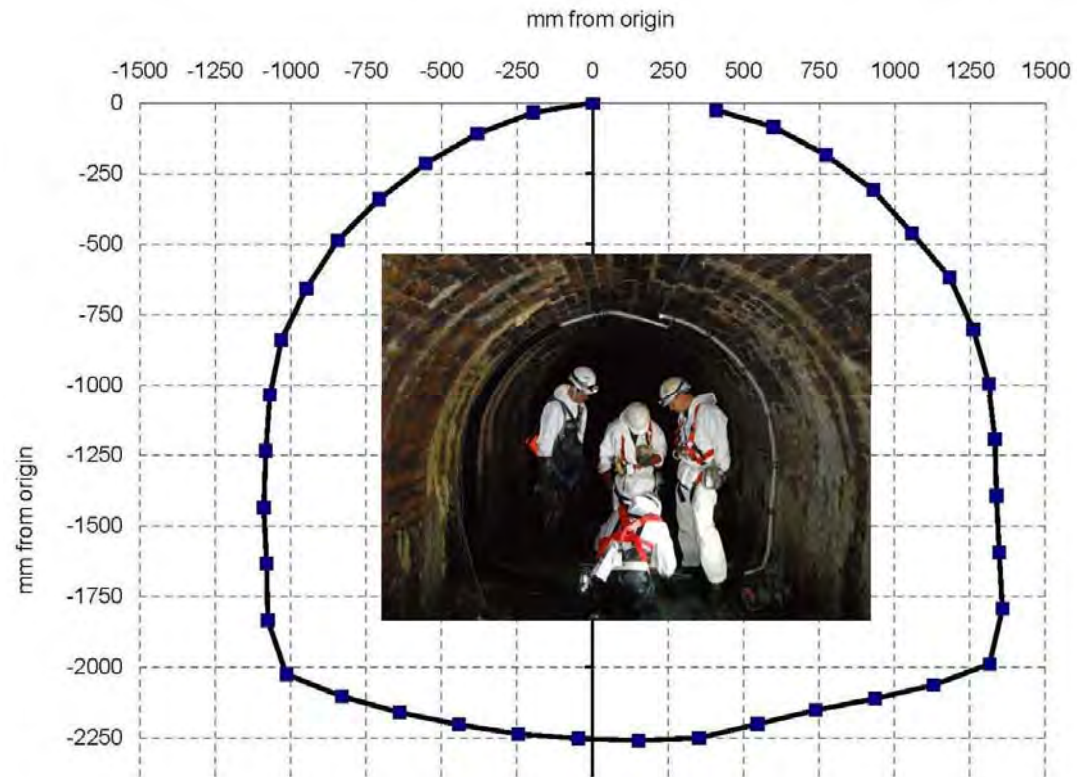
# SAA sensors work at any angle

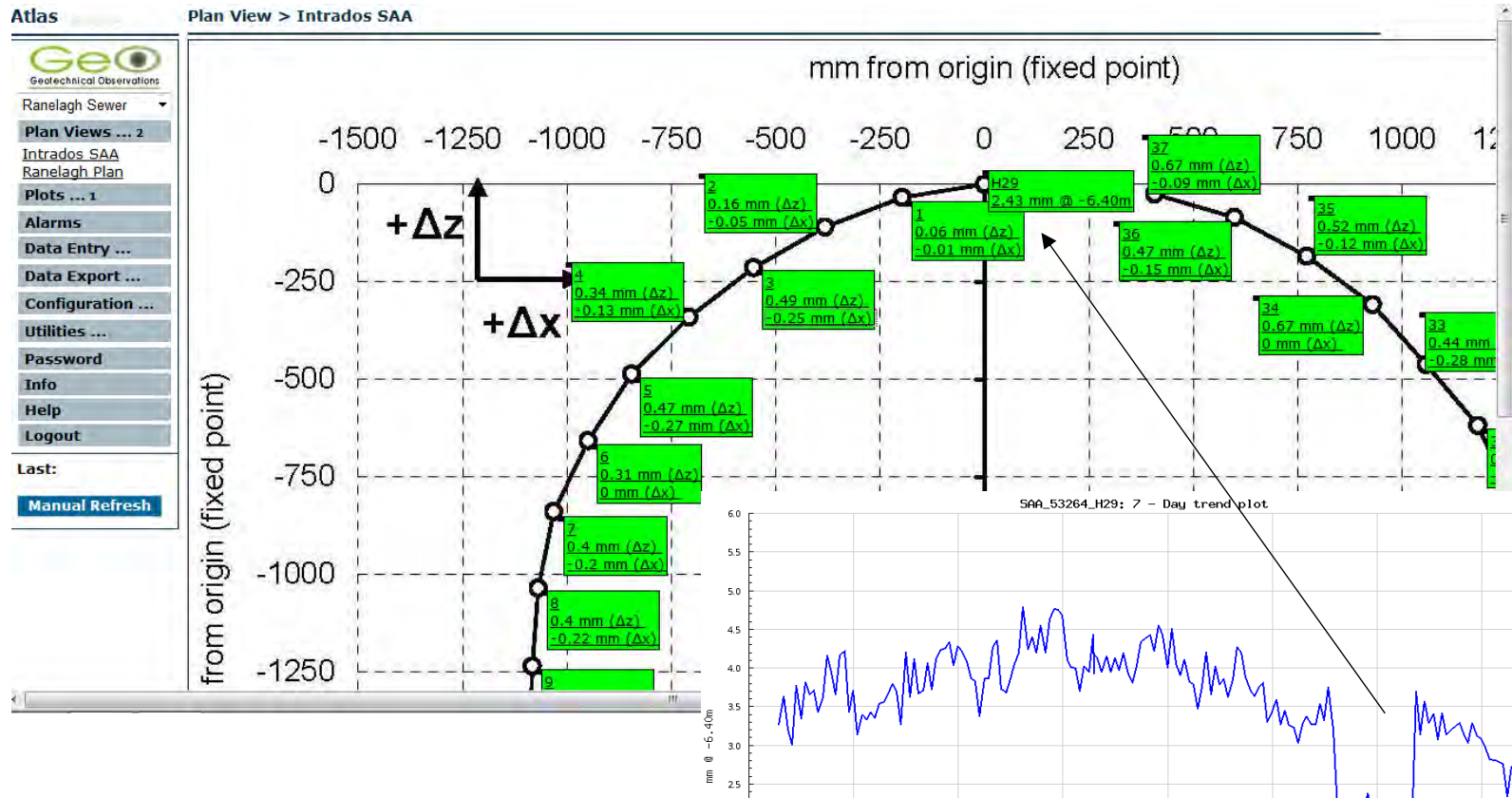


# SAA sensors work at any angle



- 👁️ Absolute shape of the sewer as measured by the intrados SAA

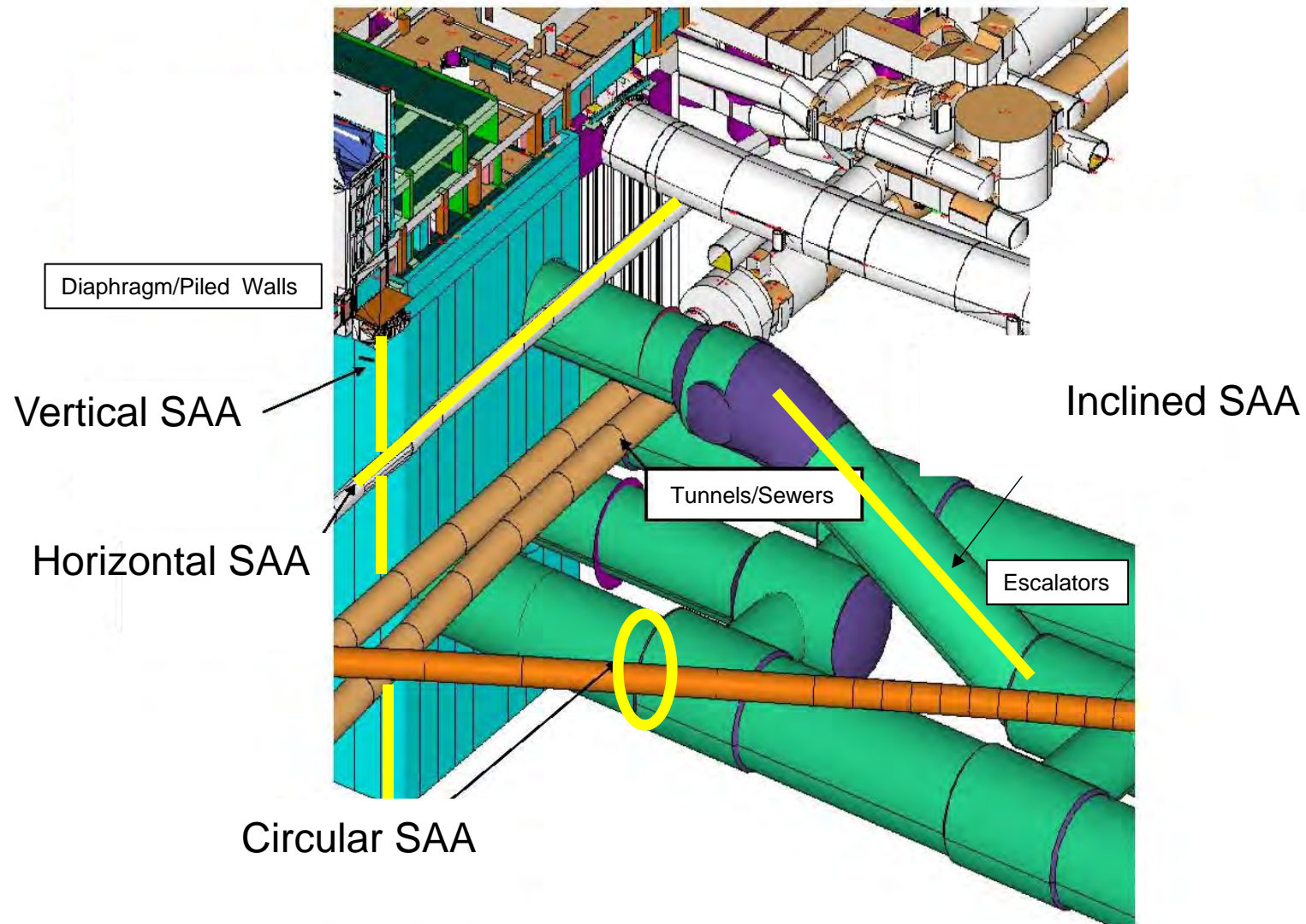




- Internet presentation of results as TBM passed under the sewer, shows short term settlement followed by heave as the tunnel shields are positioned. Minimal change in shape of the sewer (measured as change in x and z at points around the intrados).







- 👁 ShapeAccelArray – one tool to cover a wide range of monitoring problems.



Thank You

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