



## Bridge Owners Forum No. 61

### Making Assets Smart Digitally Enabled Asset Management on The Forth Road Bridges

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ameyconsulting



# Why do we need smart infrastructure?





# Importance of the Forth Road Bridges



## For Vehicles

- **4 Million** vehicles in 1964
- **25 Million** vehicles in 2017
- **860 Million** vehicles since opening
- **70 Million** HGVs since opening

## For People

- **100,000** people a day use bridges to get to work or to go about their business
- **1.2 Billion** people used bridges since opening
- **Resilience** from 2 Bridge Strategy

## For the Economy

- **£1 Million** a day contributed to the Scottish Economy
- **Over £10 Billion** since opening

**A Critical Piece of National Infrastructure**



# A Large and Complex Group of Assets

## Scale & Complexity

- 30,000+ elements to look after and keep track of
- Many elements highly complex and critical
- Queensferry Crossing - new
- Forth Road Bridge - ageing & hard working



## Functions

- Inspect
- Monitor
- Report
- Respond
- Repair
- Assess
- Enhance
- Renew



## Bridges

- Open
- Safe
- Resilient
- Long Service Life





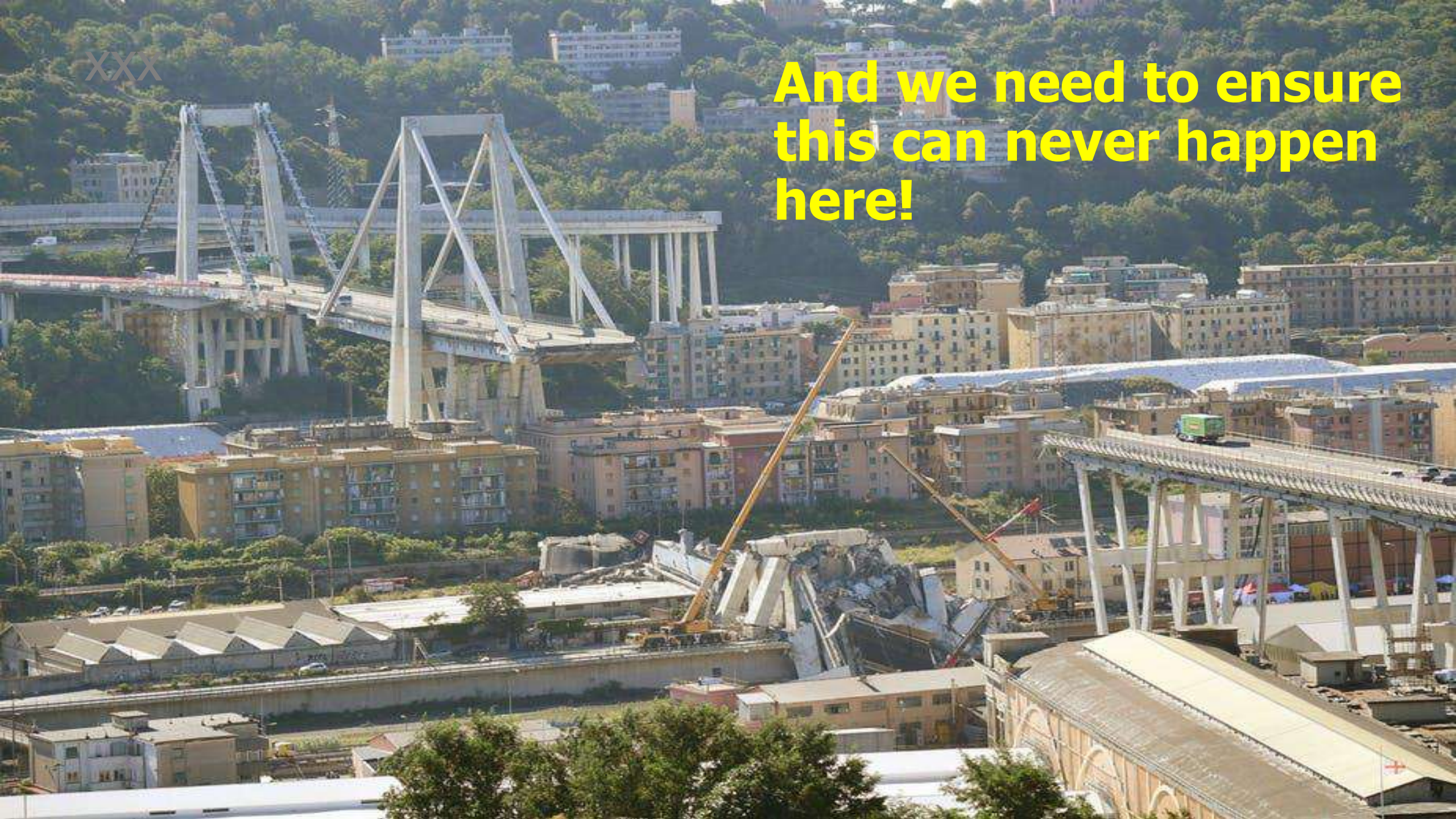
**We don't want this  
happening**





XXX

**And we need to ensure  
this can never happen  
here!**





# The Solution

Digitally Enabled  
Smart Asset Management





# Digitally Enabled Smart Asset Management

## Collect Data

- Collect appropriate data via multiple streams
- Automatic collection by remote sensors
- Effects on bridge – wind, vehicles, temperature etc
- Response of bridge
- Bridge condition – inspectors with digital capability

## Build Understanding

- Ingest & Analyse multiple big data sets
- Harness full power of cloud computing
- Integrate, analyse, visualise
- Investigate correlations
- Evaluate historic patterns, trends, events
- Understand relationships & behaviours

## Monitor & Predict

- Real time monitoring
- Harness power of Machine learning
- Prediction of future behaviour
- Automated predict, review, feedback, refine – build body of learning
- Automated alerts
- Trigger levels/alarms defined, refined, “learned”
- Automated reports

## Decide

- Confirm safety
- Respond to alerts
- Defect repair & prioritisation
- Budget definition



# Implementation

In-House Bespoke Integrated  
Systems



# Integrated Systems on FRB and QC



**Mercury**  
Data Analytics  
Platform

**Pearl**  
Information &  
Condition  
Database



# Integrated Systems on FRB and QC

## Data Analytics Platform – “Mercury”

- SHM IoT sensor data
- Condition data
- Structural effects & capacities

- Cloud based SENSOR AGNOSTIC analytics platform which ingests and compiles remote sensor and maintenance record DATA from MULTIPLE SOURCES
- Uses machine learning algorithms to understand bridge behavior and actively monitors and reports on sensor and condition data
- Interprets data to provide rich custom visualisations of bridge behavior, intelligent alerts and lifecycle records
- Intelligent alarms are specified (or even “learnt” from the data) to send SMS and email alerts, or notifications to other systems
- Other data sources, such as analysis and modelling outputs can be included to provide a rich, integrated picture of the bridge

- Automated monitoring & reporting
- On demand analytics & visualisation
- Intelligent alerts



# Integrated Systems on FRB and QC

## Bridge Information & Condition Database – “Pearl”

- Historic records
- Project records
- Live entry of inspection data from Mobile App

- Cloud storage of all records and data relating to each of 30,000 elements. Batch upload of records based on Metadata
- Management of inspection programmes, Outlook calendar style scheduling
- Recording of type and severity of all identified element defects
- Automatic inspection report generation including online approvals
- Automated update of bridge condition indices from inspection findings
- Document management module for storage of archive files & project records
- Full description of the structure and key components, including maintenance/project history

- Automated inspection reporting
- Bridge condition reporting
- Maintenance budgeting

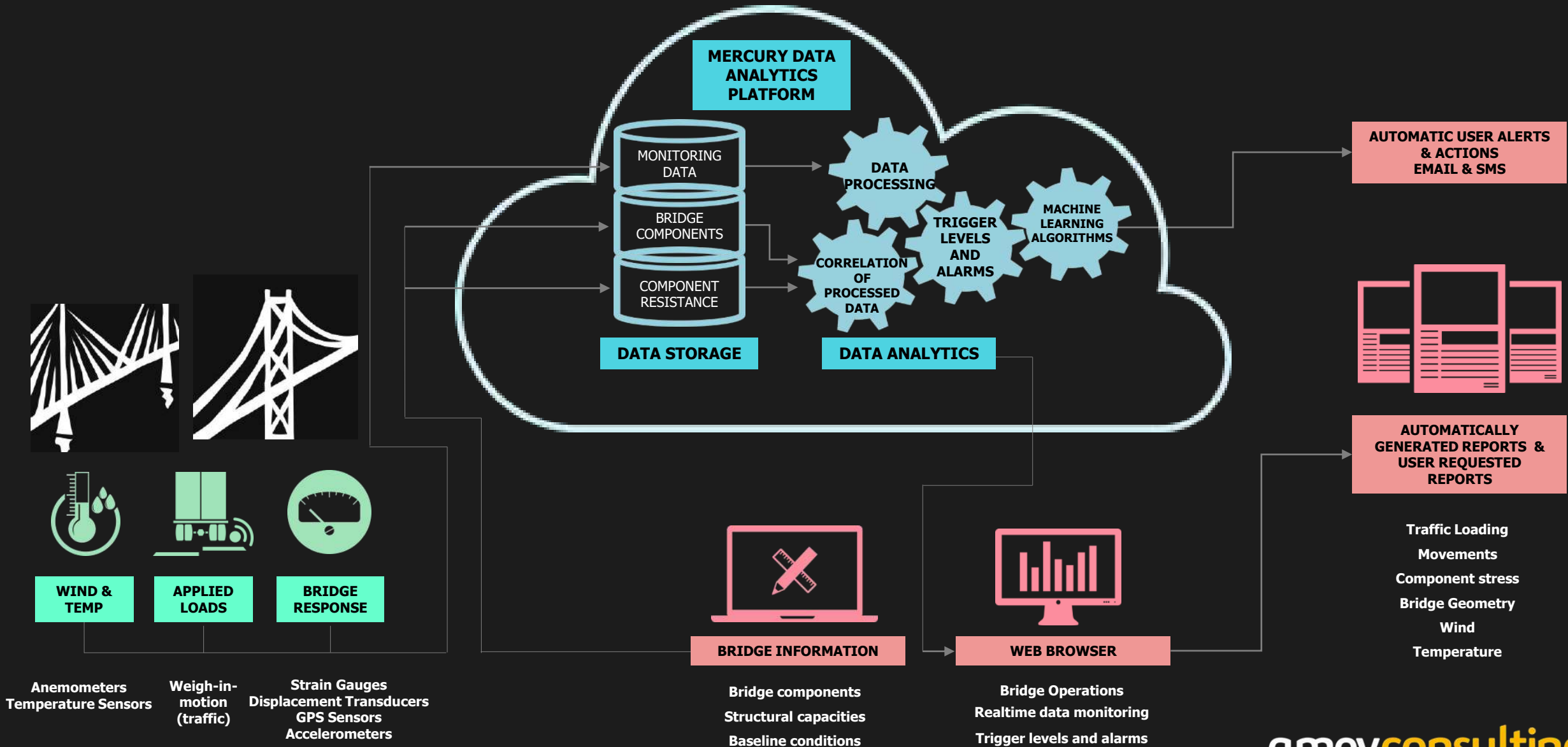


# SHM/Mercury System Overview

FRB and QC

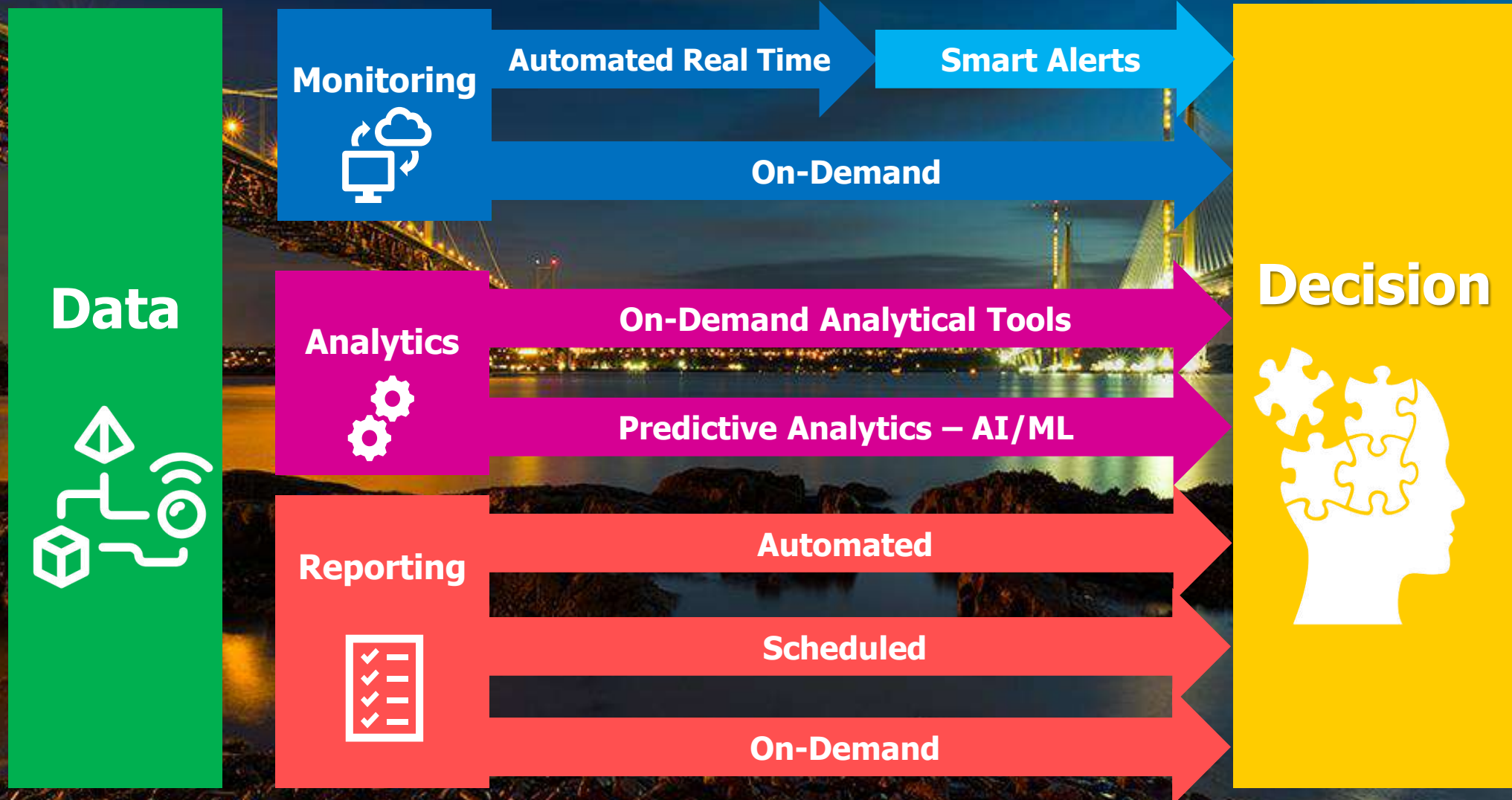


# Forth Road Bridges Smart System





# Forth Road Bridges Smart System

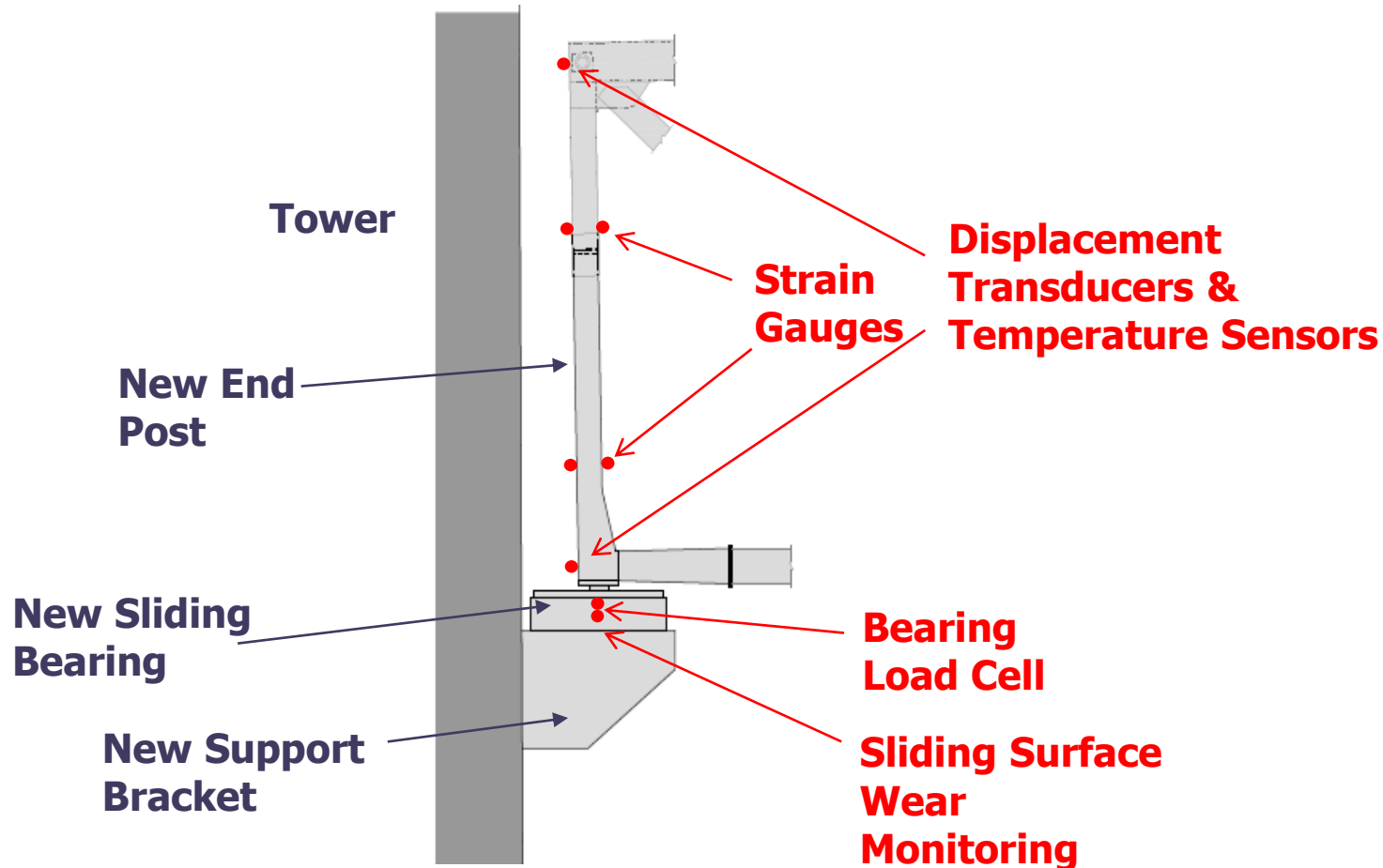
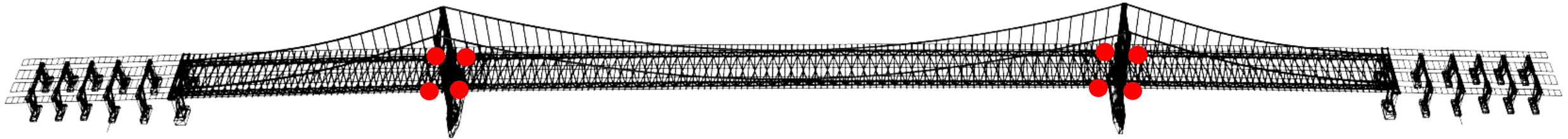




# IoT Sensor Arrangements



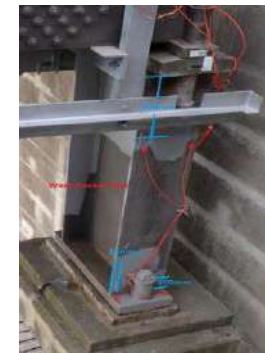
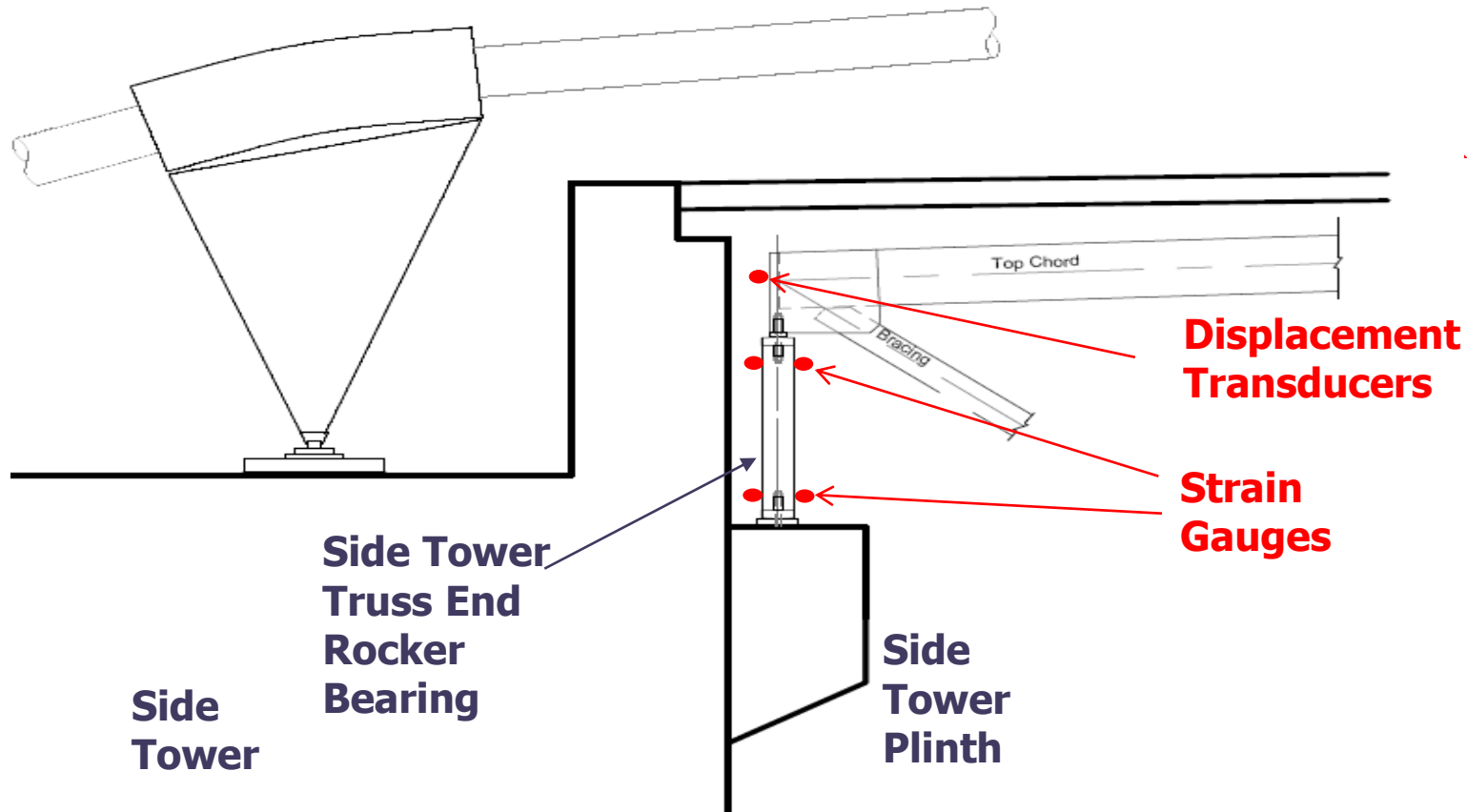
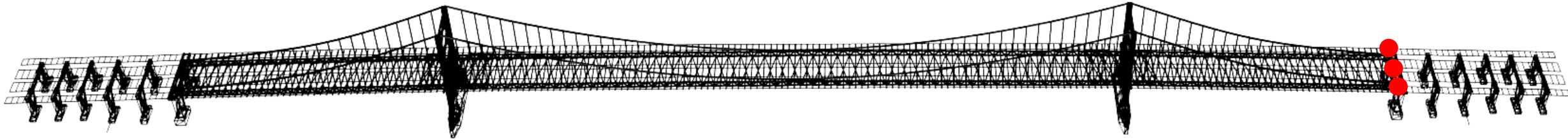
# Forth Road Bridge SHM – Arrangement at New Truss Ends



- End post stress
- Bearing load
- Bearing wear
- Truss end movement



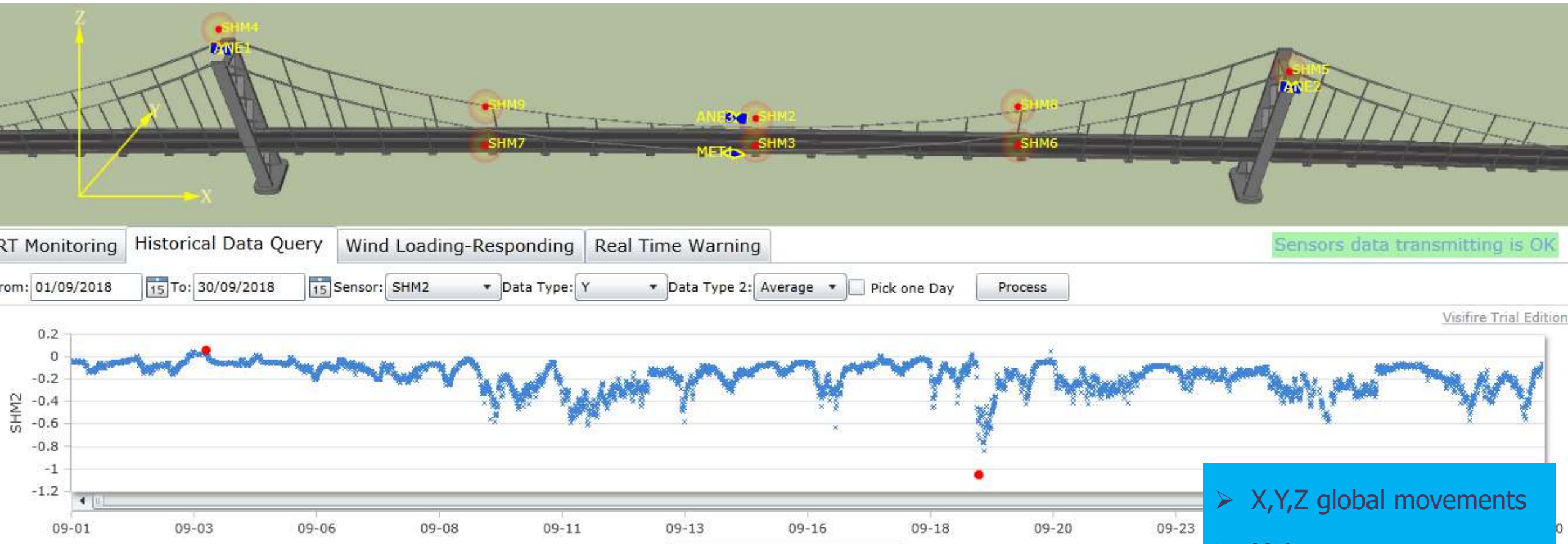
# Forth Road Bridge SHM – Arrangement at Side Towers



- Rocker rotation
- Rocker stress
- Truss end movement
- Stress in Laterals



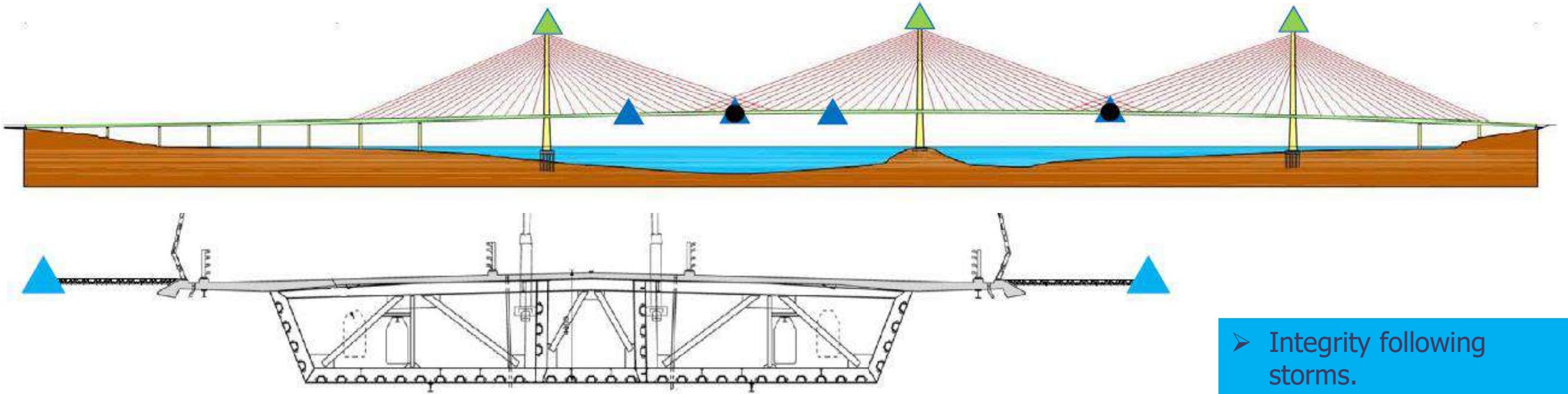
# FRB Road Bridge SHM – GPS Displacements & Wind



- X,Y,Z global movements
- Main span
- Tower tops
- Wind speed & direction



# Queensferry Crossing SHM – Wind and Weather Sensors



Installation of Anemometer



Barometer

Key



Anemometers (1 no)



Anemometers (2no)

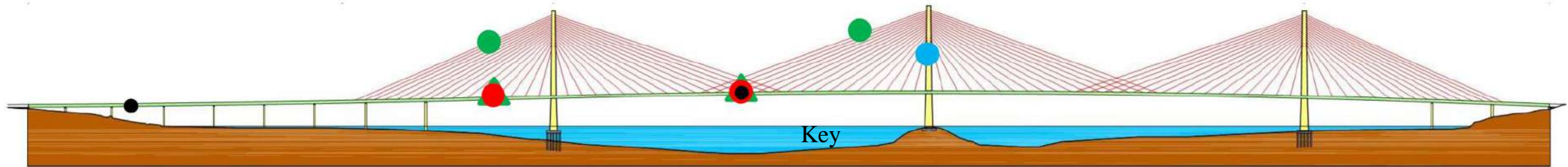


Rainfall gauge and  
barometer

- Integrity following storms.
- Wind buffeting & wind / structure interaction.
- High wind vehicle management
- Impact of climate change



# Queensferry Crossing SHM – Temperature Sensors



Asphalt TMU

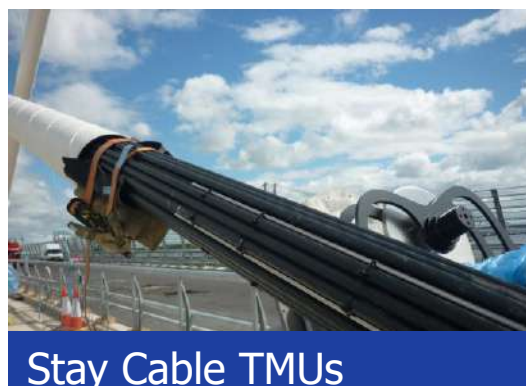


Concrete TMUs

●	Deck section
▲	Transverse Bracing
●	Towers (concrete and air temp/humidity)
●	Asphalt
●	Stay Cables



Steel TMUs



Stay Cable TMUs

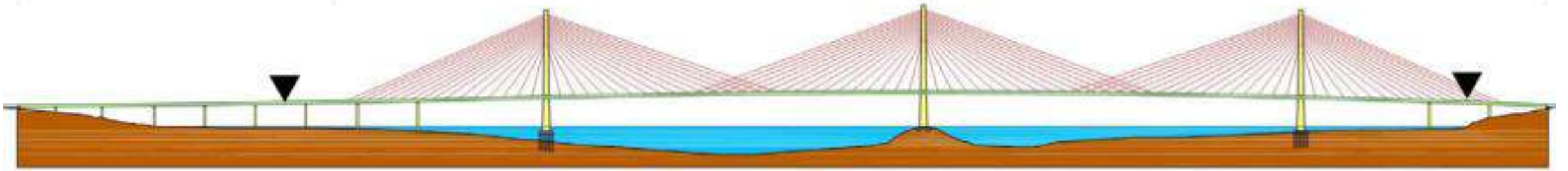


External Air TMUs

- Bridge Articulation and Geometry.
- Temperature Compensation of Strains.
- Temperature Distribution and Induced Stresses.



# Queensferry Crossing SHM – Weigh in Motion

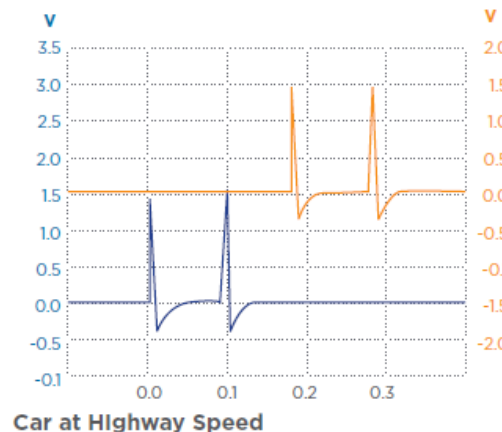


Installation of Piezoelectric Transducer Weigh-in-Motion System.

Key



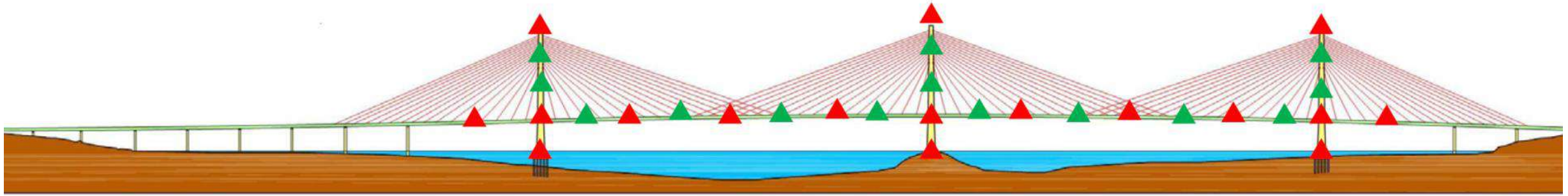
Dynamic Weigh in Motion  
(Bending Plate)



- Traffic modelling and congestion.
- Trends in HGV loading.
- Two bridge managed strategy



# Queensferry Crossing SHM – Accelerometers



Key



Permanent accelerometer



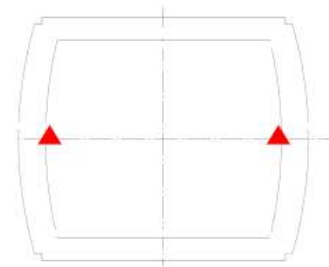
Accelerometer Housing  
(in addition each stay cable  
to fitted with an acceleration  
housing)



Accelerometer (Tower)



Housing (Tower)

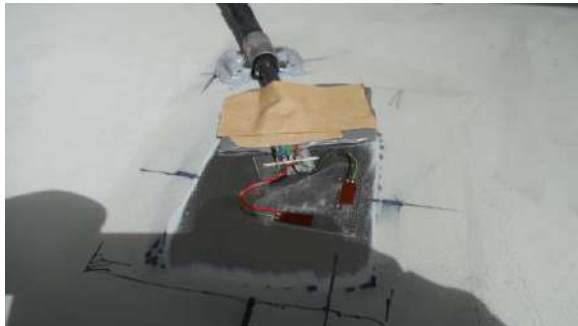
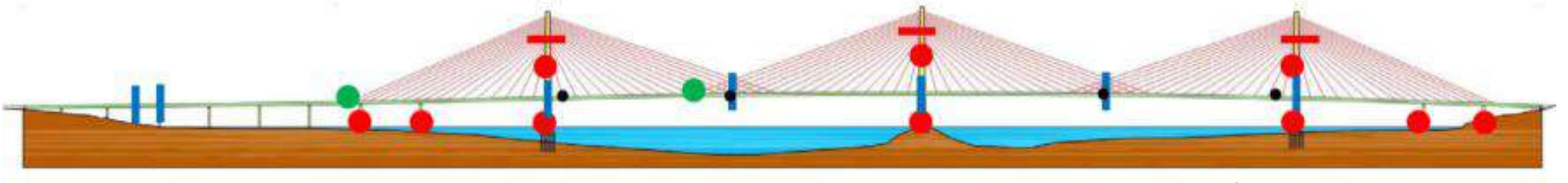


Accelerometer arrangement in towers

- Dynamic behaviour of deck, towers and cables.
- Ship impact.
- Changes in dynamic characteristics



# Queensferry Crossing SHM – Strain Gauges



Dynamic Strain Gauge



Static Strain Gauge



Deck Section (bottom plate)

Key

- Static strain gauges (tower)
- Dynamic strain gauges (tower anchorage)
- Strain gauges deck anchorages
- ▮ Deck section
- Transverse bracing

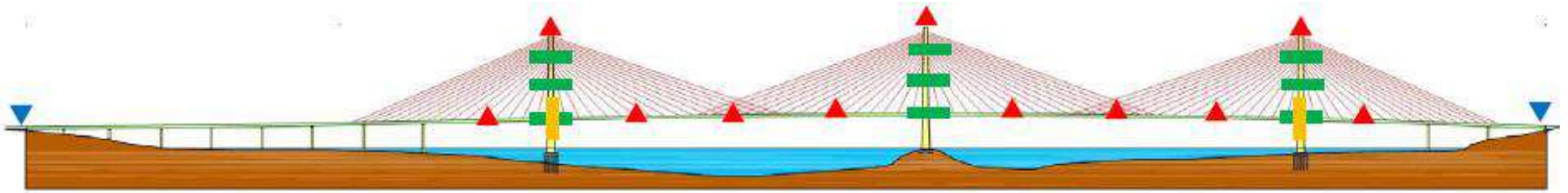


Internal Bracing

- Derivation of stresses and global effects (forces & bending moments).
- Correlation of extreme events with predicted design values.
- Calibration of fatigue models



# Queensferry Crossing SHM – GPS & Displacement Sensors







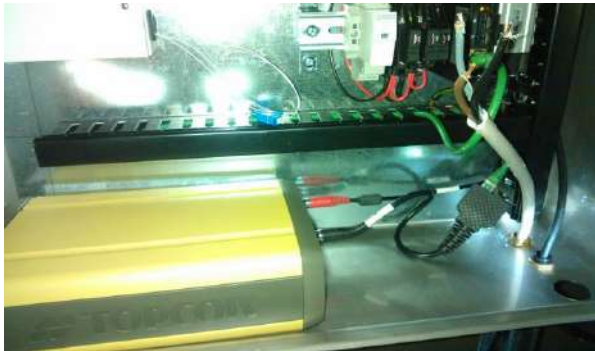
GPS Antenna



Antenna & Anti-Snow Dome

Key

-  GPS receiver
-  2D Tiltmeter
-  Bearing gauge
-  Displacement transducer



GPS Data Acquisition Unit



Tiltmeter



Ultrasonic Displacement Sensor

- Bridge articulation.
- Bridge geometry and navigational clearances.
- Bridge response applied loads and extreme events.

# Data Monitoring

## Trigger Levels Alarms and Automation



# FRB Data Analytics – Mercury – Entry Screen

Select a system to view:

FRB



QFC



# FRB Data Analytics – Mercury – Entry Screen

mercury

FRB

Summary

Locations

Asset Types

Assets

Reports

Analytics


Home

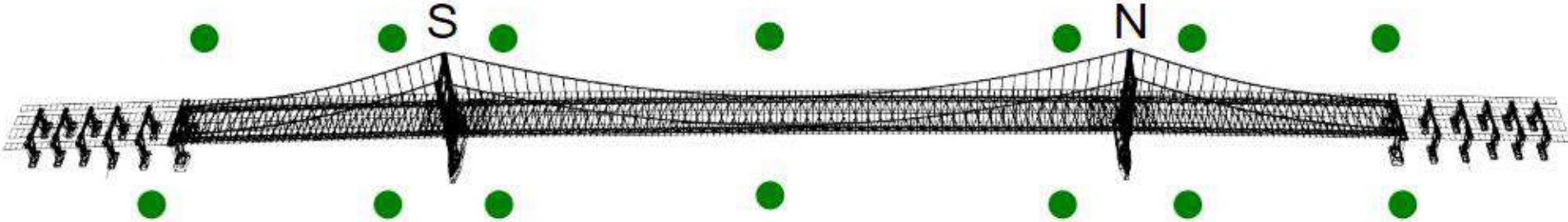
3D

TRANSPORT SCOTLAND

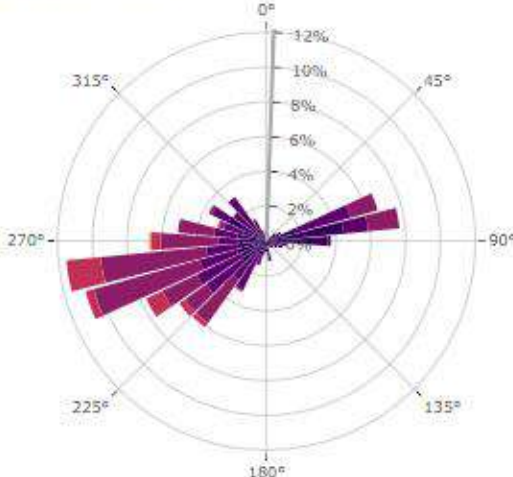
Forth Road Bridge

amey

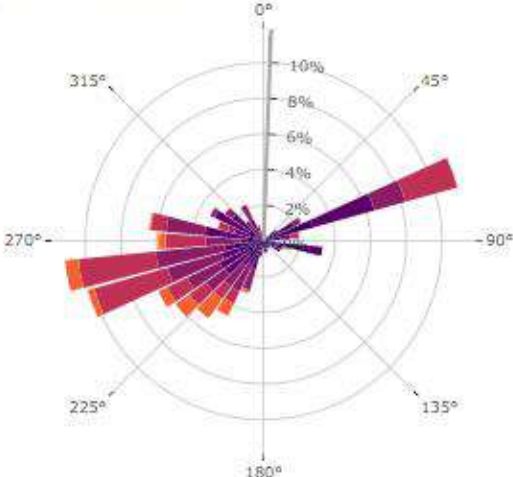




Wind Speed - last week



Wind Gusts - last week



Showing information for all locations

Alerts

Location	Asset	Sensor	Triggered At	Message	Alert Level	Details	Actions
EXTERNAL	EXTERNAL North West	Vaisala Wind Gust Speed	08/03/2019 21:49	Threshold passed. Reading: 46.08 mph Threshold: 45.0 mph	High	Acknowledged by Ewan Angus on 10/03/2019 18:15	<input checked="" type="checkbox"/> <input type="checkbox"/>
EXTERNAL	EXTERNAL North West	Vaisala Wind Gust Speed	08/03/2019 20:19	Threshold passed. Reading: 52.34 mph Threshold: 50.0 mph	High	Acknowledged by Ewan Angus on 10/03/2019 18:15	<input checked="" type="checkbox"/> <input type="checkbox"/>
NEST	Eastern Rocker	virt_ERL_stress_3478_7	08/03/2019 20:08	Threshold passed. Reading: 177.74 N/mm² Threshold: 150.0 N/mm²	High	Acknowledged by Ewan Angus on 10/03/2019 18:15	<input checked="" type="checkbox"/> <input type="checkbox"/>

Showing 1 to 3 of 3 rows



# FRB Data Analytics – Mercury – 3D Entry Screen Option

mercury

FRB ▾

Locations ▾

Asset Types ▾

Assets ▾

Reports ▾

Analytics ▾

Home

3D

Ewan Angus

Main view

NEMS (Open)

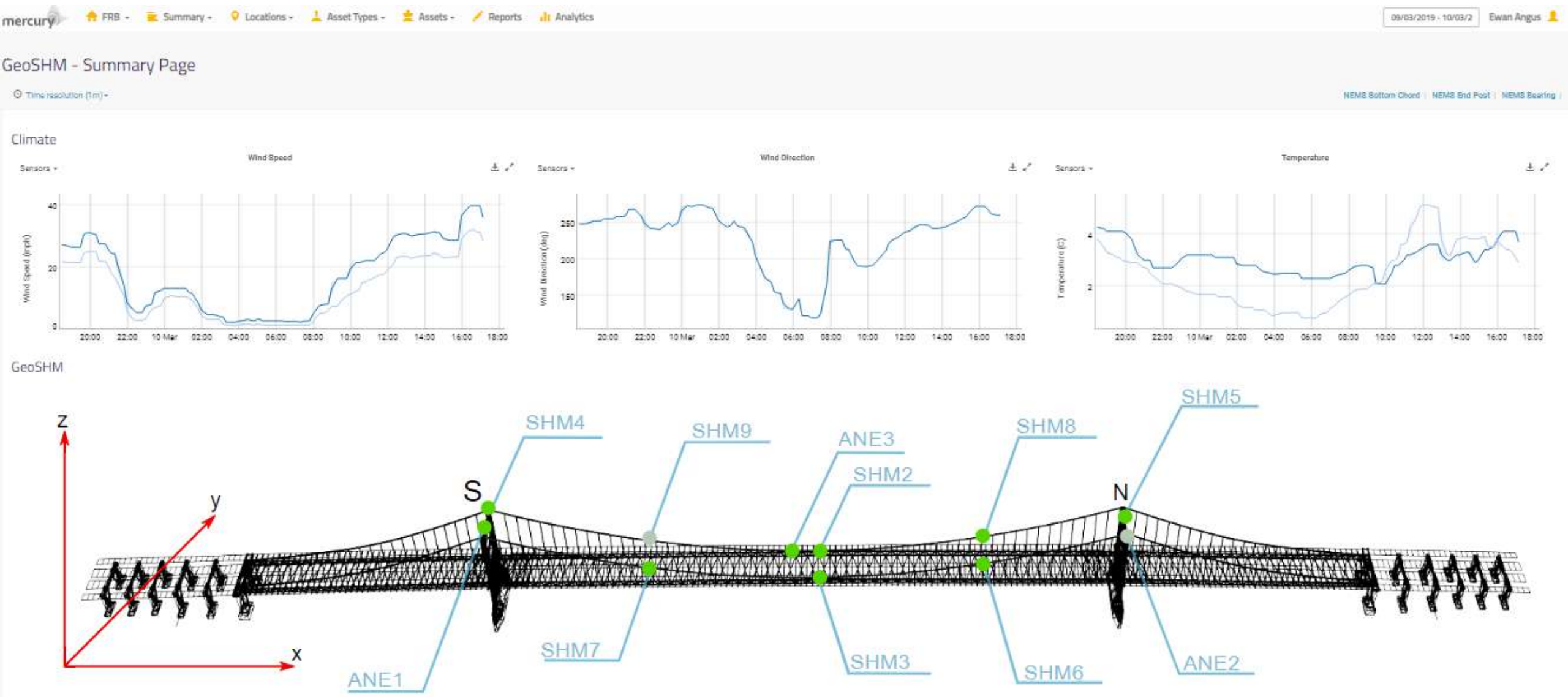
Asset	View
NEMS Chord	Open
NEMS Bearing	Open
NEMS End Post	Open
NEMS Inner Link	Open
NEMS Outer Link	Open
NEMS Truss End Post	Open

Open Controls

Zoomed view

Diagrams

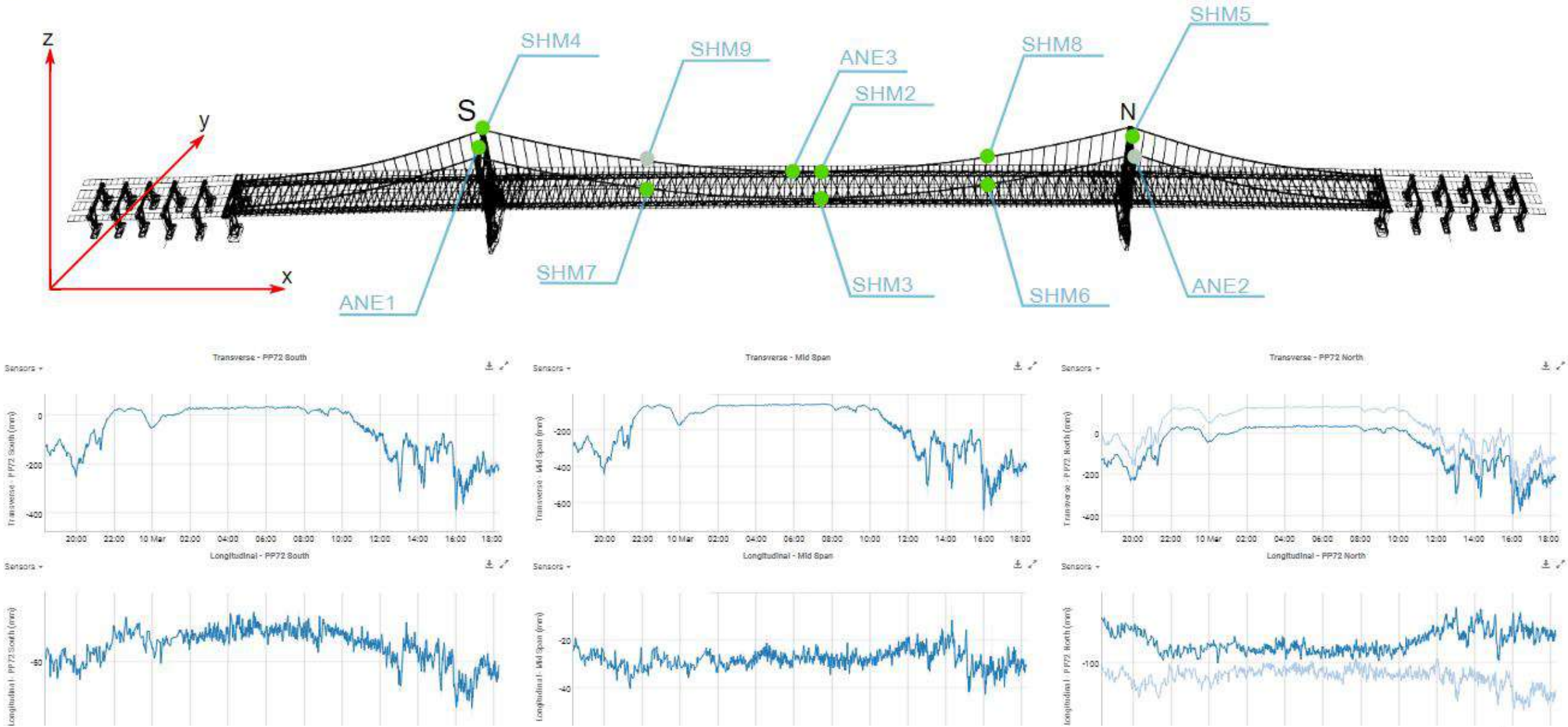
# FRB Data Analytics – Mercury – Data Monitoring



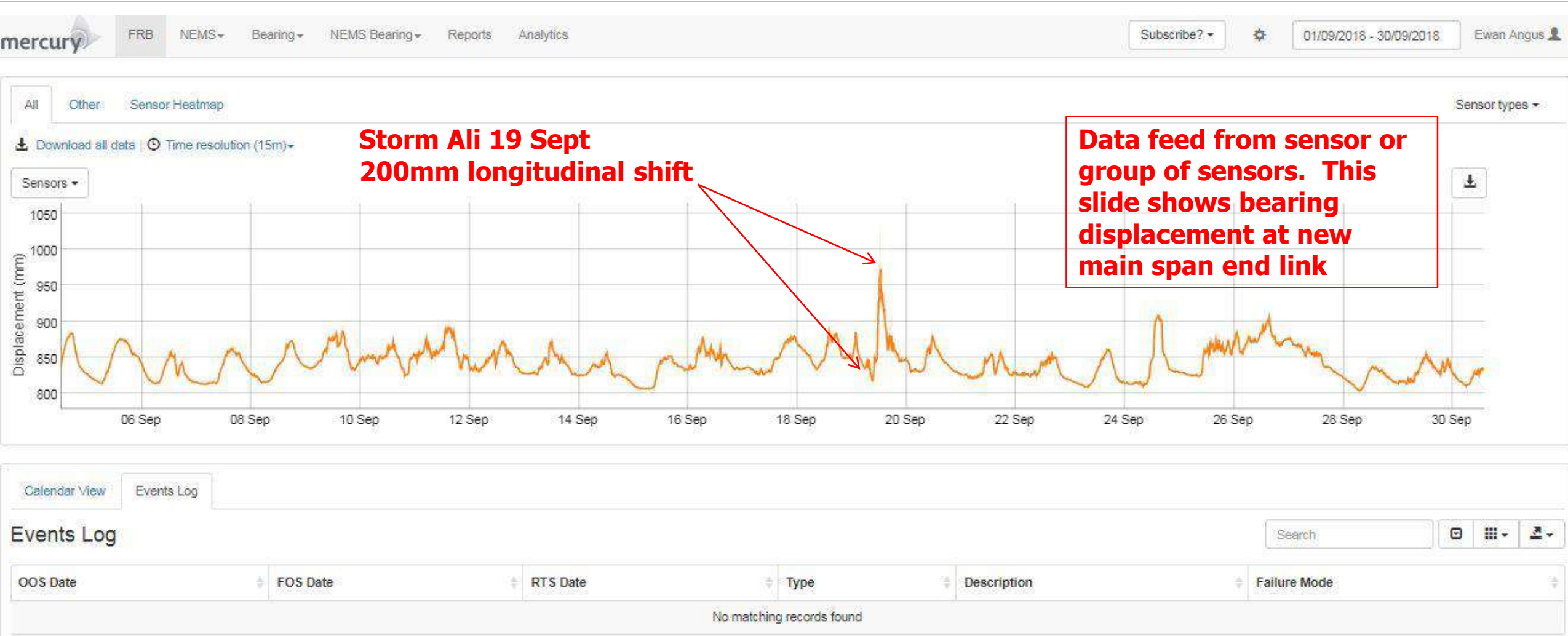


# FRB Data Analytics – Mercury – Data Monitoring

GeoSHM

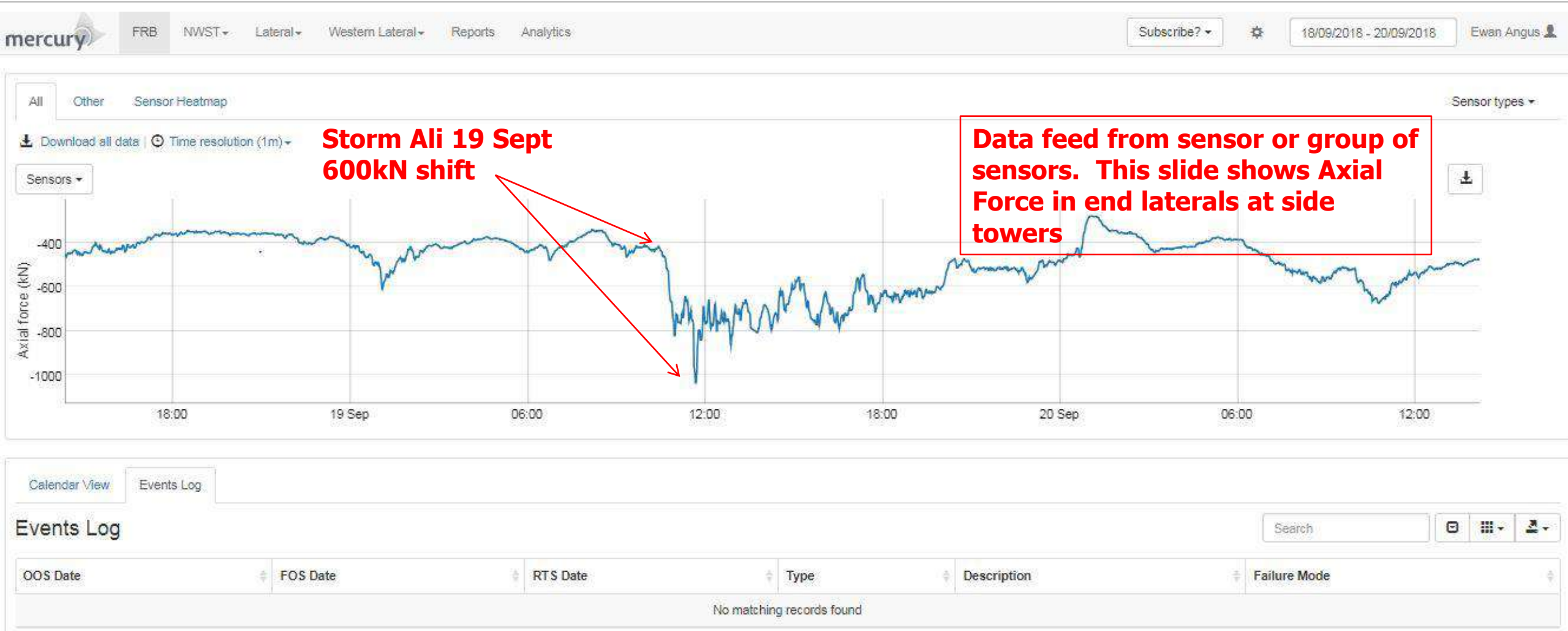


# FRB Data Analytics – Mercury – Data Monitoring

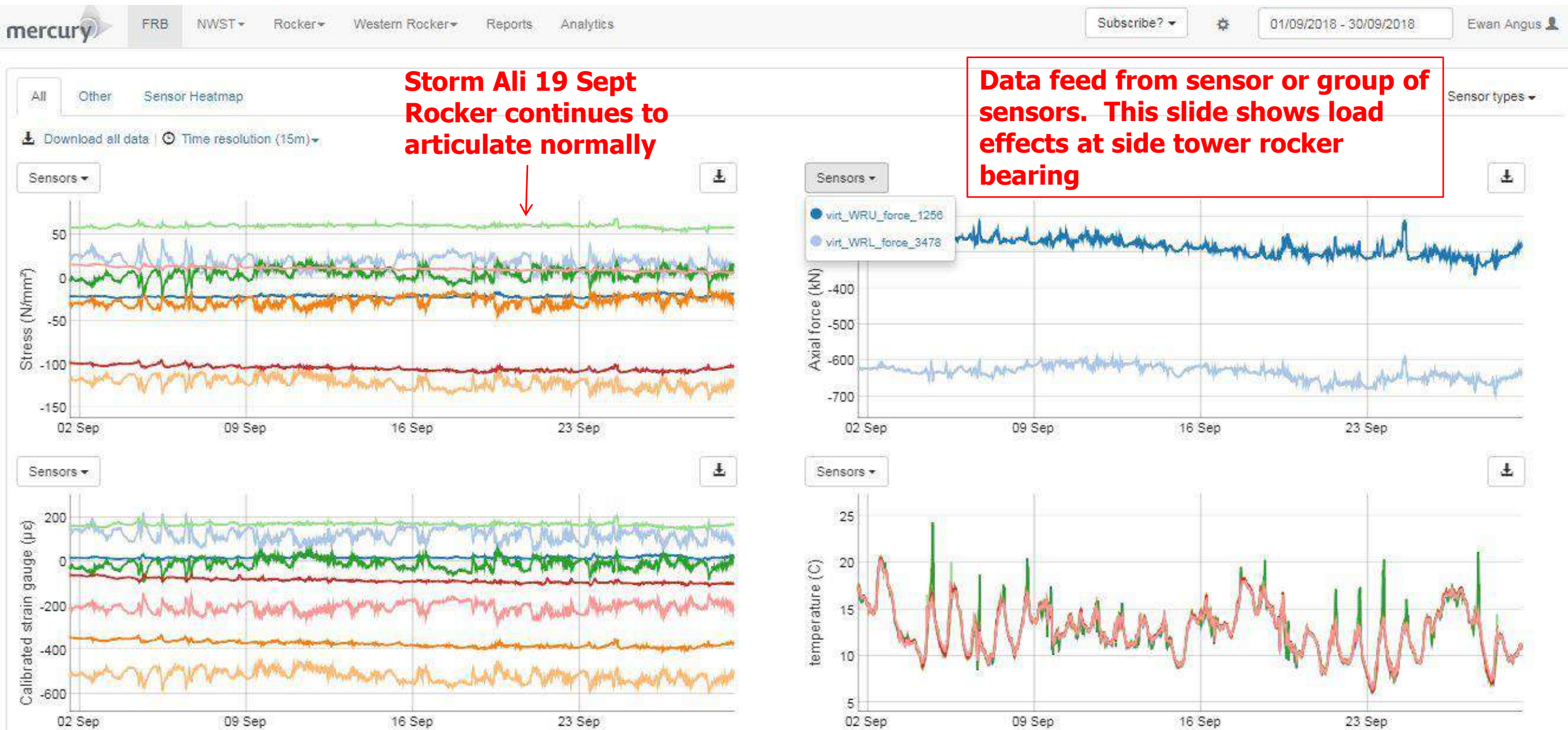




# FRB Data Analytics – Mercury – Data Monitoring



# FRB Data Analytics – Mercury – Data Monitoring





# FRB Data Monitoring – Mercury – Setting Smart Alarm Levels

mercury FRB Locations ▾ Asset Types ▾ Assets ▾ Reports Analytics Ewan Angus

## Sensors alarms configuration

stress

sensor	asset	location	sensor type	units	Threshold levels	24h change	📍	🔔	📧	alarm settings
virt_ELS_stress_3478_4	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ELT_stress_1256_2	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ELT_stress_1256_6	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ELT_stress_1256_5	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ELS_stress_3478_3	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ELS_stress_3478_7	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ELT_stress_1256_1	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ELS_stress_3478_8	Eastern Lateral	NEST	Stress	N/mm <sup>2</sup>	160 245 325		✓	✓	✓	⚙️
virt_ERL_stress_3478_4	Eastern Rocker	NEST	Stress	N/mm <sup>2</sup>	150 225 300		✓	✓	✗	⚙️
virt_ERU_stress_1256_1	Eastern Rocker	NEST	Stress	N/mm <sup>2</sup>	150 225 300		✓	✓	✗	⚙️

Showing 1 to 10 of 67 rows 10 rows per page

1 2 3 4 5 6 7

Users subscribe to status alerts

Up to 5 No. threshold levels can be set for any monitored sensor or group of sensors. Bridge automatically alerts users as needed – Email and SMS

Edit multiple sensors

# FRB Data Monitoring – Alarm Level Messages & Actions

mercury

FRB Locations ▾ Asset Types ▾ Assets ▾ Reports Analytics

Ewan Angus

## Sensors alarms configuration

sensor	asset
Vaisala Wind Gust Speed	EXTERNAL North West
Vaisala Wind Speed	EXTERNAL North West
ANE1_Velocity	geoshm_ANE1
ANE3_Velocity	geoshm_ANE3

Showing 1 to 4 of 4 rows

Edit multiple sensors

### Sensor alarm settings

Sensor: Vaisala Wind Gust Speed, Asset: EXTERNAL North West, Location: EXTERNAL

- ☒ Enable alarm
- ☒ Subscribe to assets
- ☒ Check alive

#### Threshold levels:

45	Wind gust speed 45mph. Close FRB to double decker buses
50	Wind gust speed 50mph. Close FRB to motorcycles, bicycles, pedestrians
65	Wind gust speed 65mph. Close FRB to all vehicles

levels	24h change				alarm settings
5	70	✓	✓	✓	⚙
		✗	✗	✓	⚙
		✗	✗	✗	⚙
		✗	✗	✗	⚙

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**Threshold levels set together with appropriate action which appears in automated alerts sent by bridge to users**



# FRB Data Monitoring – Email & SMS Alarms and Alerts

File

Message

Tell me what you want to do

Ignore

Junk

Delete

Archive

Reply

Reply All

Forward

More

Meeting

Pearl and Merc...

Team Email

Reply & Delete

To Manager

Done

Create New

Move

Rules

OneNote

Actions

Assign Policy

Mark Unread

Categorize

Follow Up

Translate

Find

Related

Select

Zoom

Zoom

ME

Tue 09/10/2018 09:33

mercury1=amey.co.uk@assetstate.com on behalf of mercury1@amey.co.uk

alert on (FRB: EXTERNAL Weather) at Tuesday, 09 October 2018 09:19AM

To Angus, Ewan; Madden, Patrick; Danovich, Mark

If there are problems with how this message is displayed, click here to view it in a web browser.

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the sender and know the content is safe.

**Fault on Asset (FRB: EXTERNAL Weather) at Tuesday, 09 October 2018 09**

Triggered by sensor: **Vaisala-NW-11273-1\_Wind gust speed**

Threshold passed. Reading: 53.24 mph Threshold: 50.0 mph

Alarm Level: 2

Message: Wind gust speed 50mph. Close FRB to motorcycles, bicycles, pedestrians

more info at [\(FRB: EXTERNAL Weather\)](#)

You are receiving this email as you are subscribed to email notifications of asset alerts on the Mercury system.

Mercury

DELETE

message: Threshold passed. Reading: -150.5 N/mm² Threshold: 150.0 N/mm², Alarm Level: 1, Alarm level message:

12:05

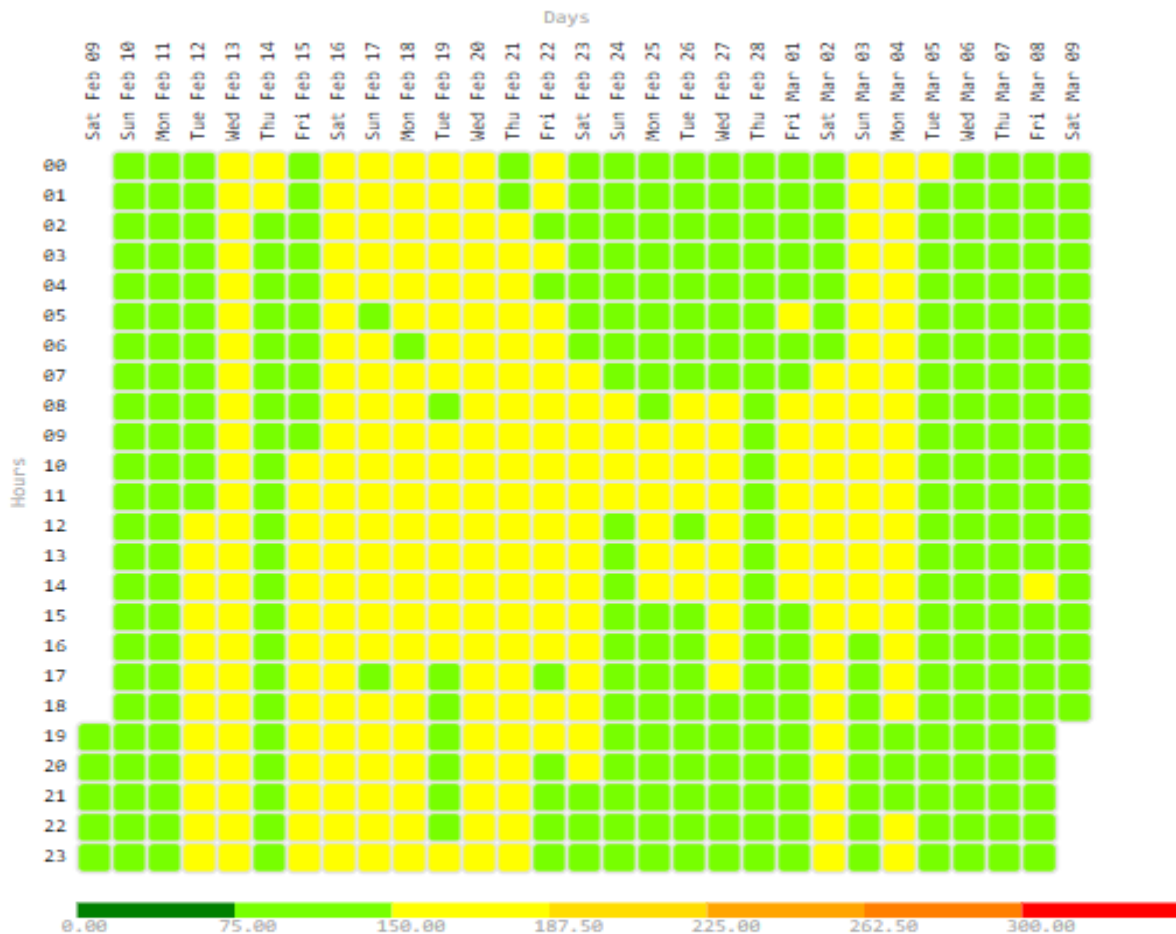
Monday, 4 February 2019

Alert on (FRB: EXTERNAL, EXTERNAL North West, Weather), sensor Vaisala Wind Gust Speed at Monday, 04 February 2019 07:39AM, message: Threshold passed. Reading: 45.41 mph Threshold: 45.0 mph, Alarm Level: 1, Alarm level message: Wind gust speed 45mph. Close FRB to double decker buses

07:50

Alert on (FRB: NWST, Western Rocker,

# FRB Data Monitoring – Sensor Heatmaps



**Sensor Heatmaps used to visualise recorded value compared to threshold values each hour of each day of user selected period.**

Thresholds (N/mm<sup>2</sup>)

150

225

300

Update colormap

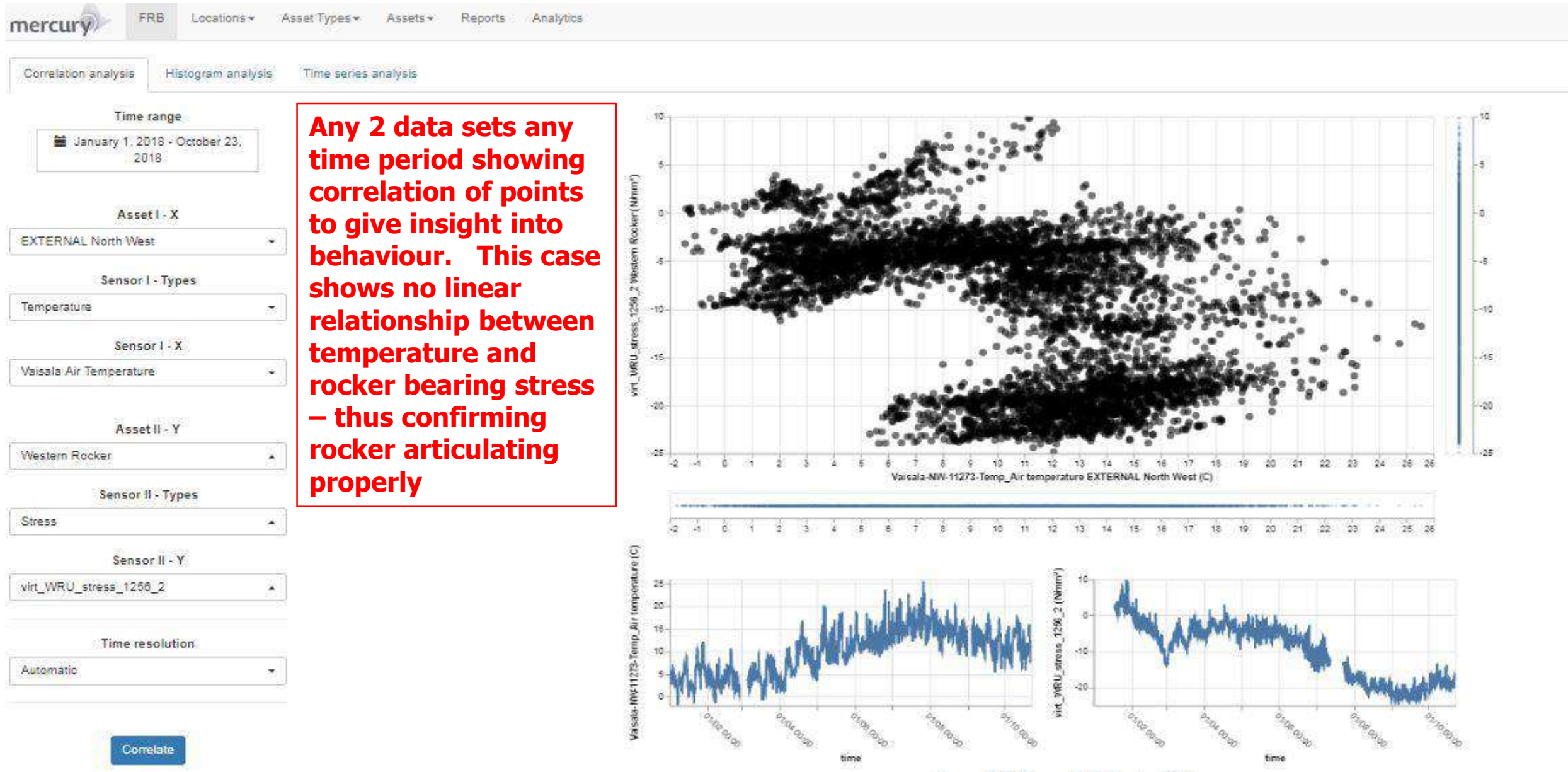
Reset colormap



# Analytical Tools

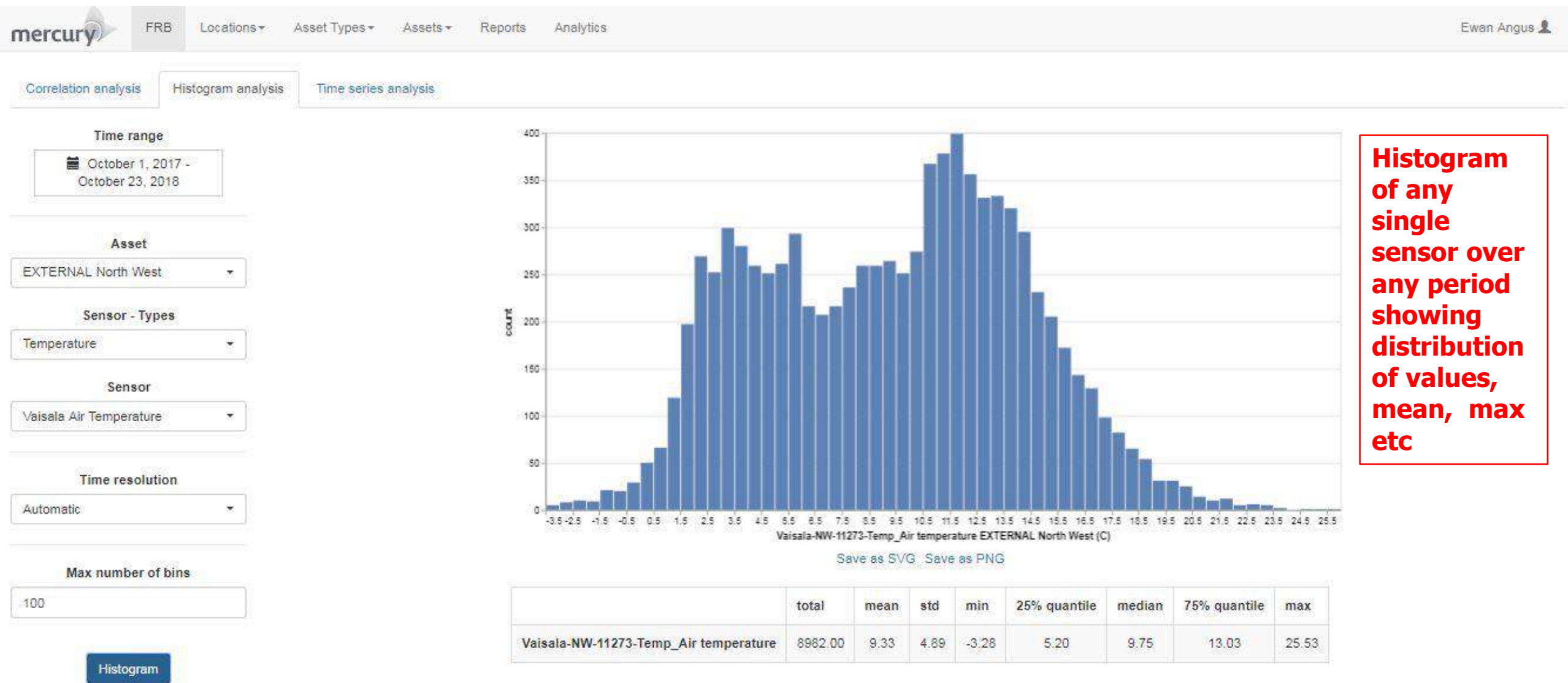
Data Visualisation to enhance understanding and provide perspective and insight

# FRB Data Analytics – Correlation of Data Sets





# FRB Data Analytics – Histogram of Sensor Data



# FRB Data Analytics – Time Series Data Set Analysis

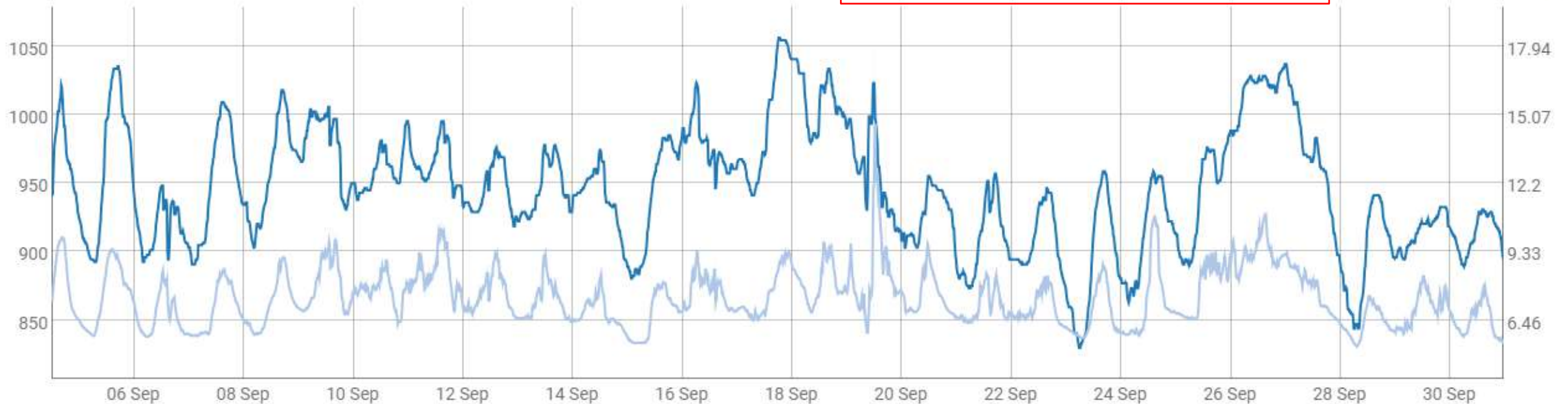
**Visualisation of any sets of in any time period. In this case showing truss end displacement versus temperature and a clear relationship**

Correlation analysis

Histogram analysis

Time series analysis

Sensors ▾



Vaisala Air Temperature (C, right) ✕ ✎  
NEMS-EP-DSP-L (mm, left) ✕ ✎

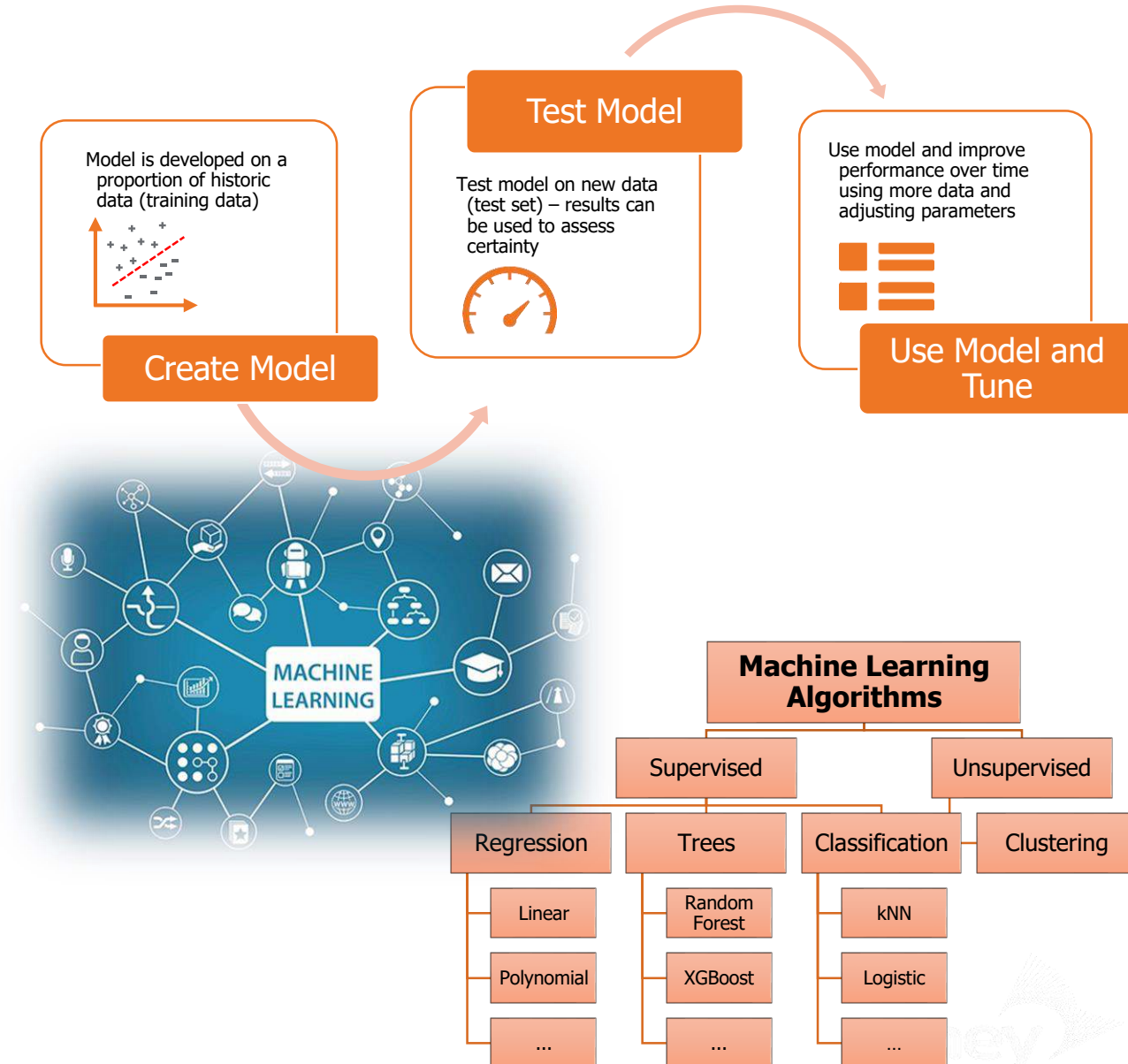


# Machine Learning

Predicting near future values  
and the learning cycle

# FRB Data Analytics – Machine Learning

- Machine Learning includes a broad set of algorithms which infer unknowns from knowns without being explicitly programmed to do so
- Useful when relationships and correlations are hidden in large quantities of multidimensional data and the required knowledge is large
- Deployed at FRB (then QC) to predict near future bridge behaviour and identify anomalies in advance
- Useful in “What-if” scenarios for differing loading or events such as storms
- Body of “Learning” constantly increases as data/learning cycle continues – even suggesting refined alert levels

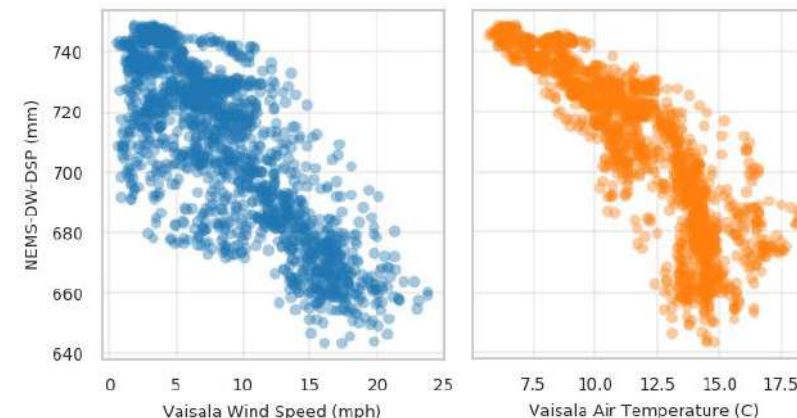




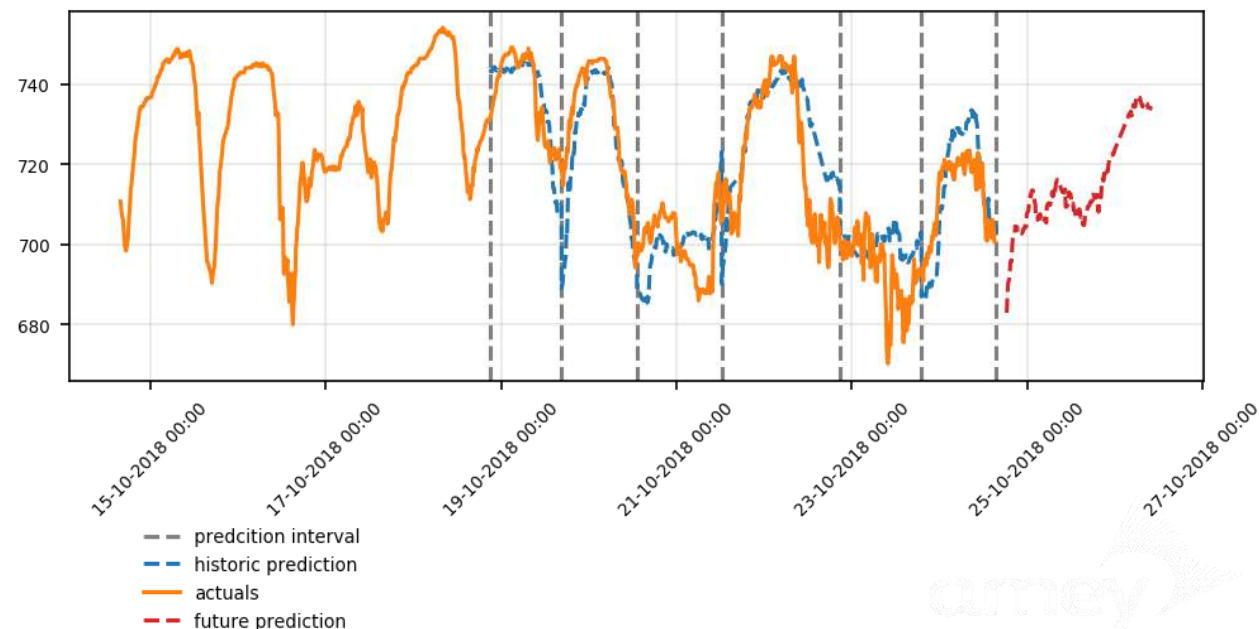
# FRB Data Analytics – Machine Learning

- In Mercury one can observe strong correlations between the response of the bridge and weather conditions (wind, temperature)
- One can thus use the weather forecast to estimate future bridge response
- To predict bearing displacements we have used a combination of historic time-series data and weather forecasts with machine learning models
- The current 24-hour prediction results for 23 October are shown as an example

NEMS-DW-DSP Correlations



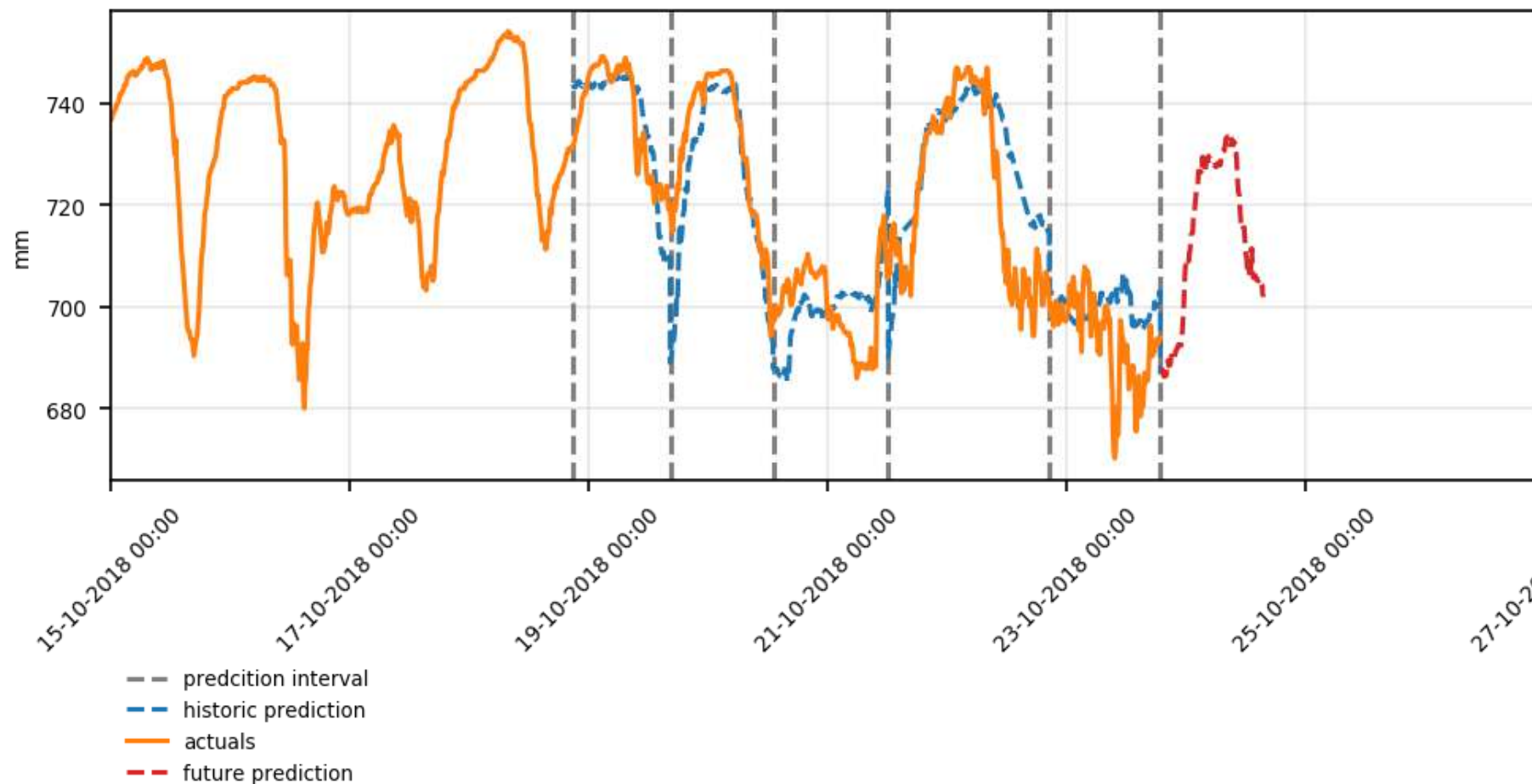
NEMS-DW-DSP Prediction



# FRB Data Analytics – Machine Learning

- Prediction at 7pm 23rd October and then refreshed at 3pm the next day

**NEMS-DW-DSP Prediction**



**At each vertical grey line, a new prediction is made based on the weather forecast at that point in time.**

**The blue line shows the results of historic predictions against actuals in orange.**

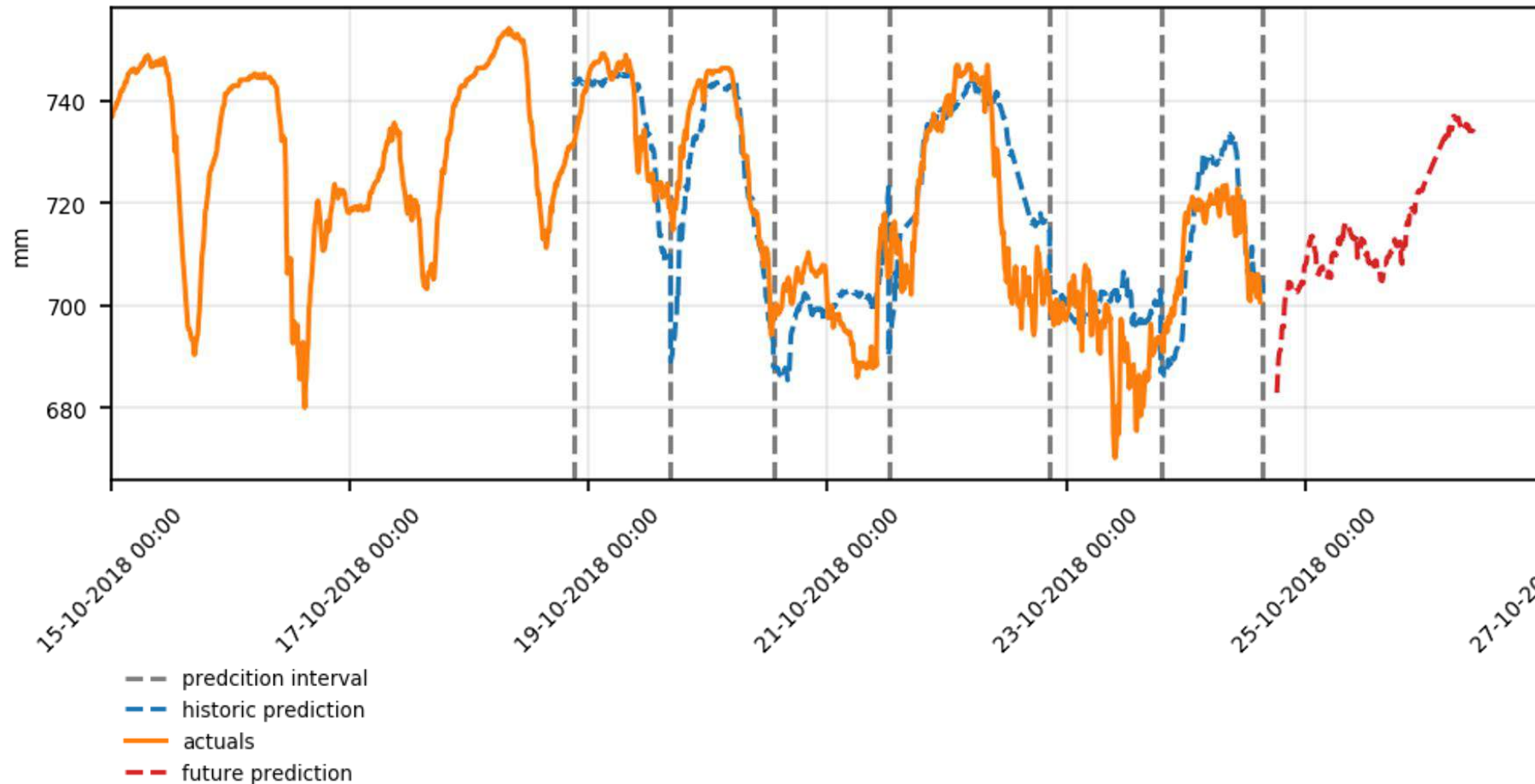
**The red line shows the current prediction which rolls forward as new data is learned**



# FRB Data Analytics – Machine Learning

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**NEMS-DW-DSP Prediction**



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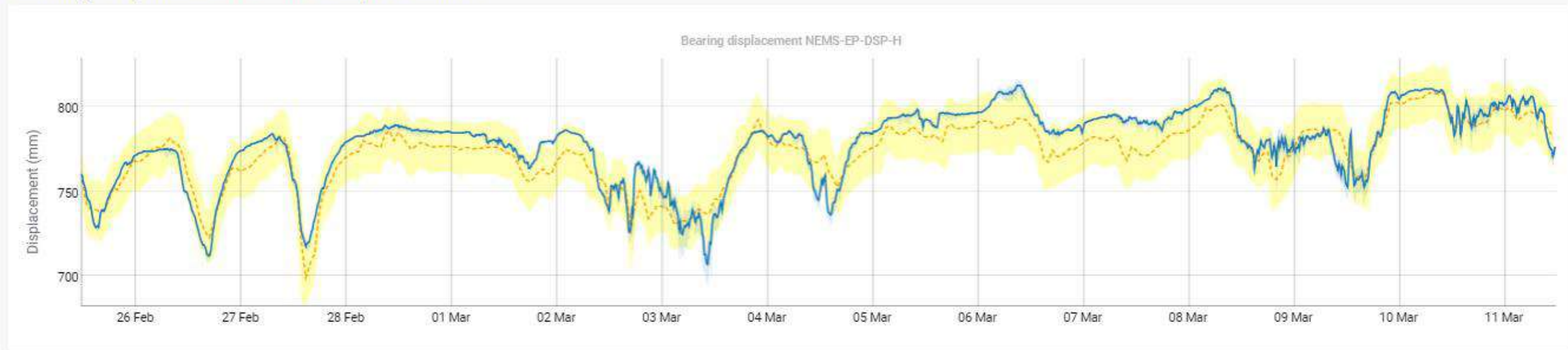
**The blue line shows the results of historic predictions against actuals in orange.**

**The red line shows the current prediction which rolls forward as new data is learned**

# FRB Data Analytics – Machine Learning

- Recent 2 weeks – model prediction versus actual

Bearing displacements - model predictions

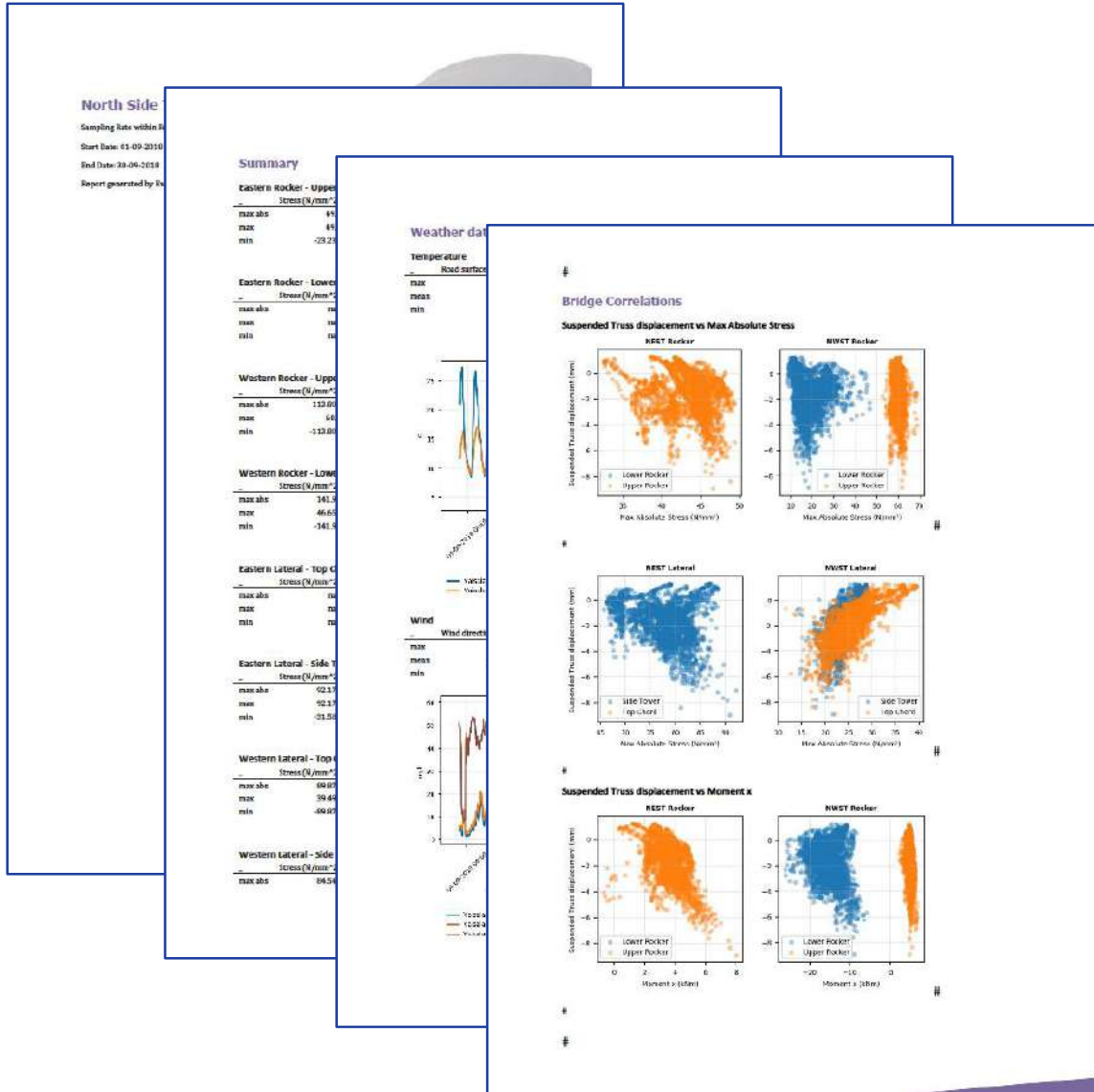




# Reporting

Automated, Scheduled & On-Demand Reports

# FRB Data Analytics – Automated and On Demand Reporting



- Data monitoring and analytics tools can be grouped and applied for any chosen period to create **automated or scheduled or on demand** reports
- Suite of reports developed for FRB, each report configured once manually then coded into system to become automated
- Suite of reports being planned for QC once fully online
- Routine reports set up for client reporting
- Special event reports for use in after storm reviews for Named Storms
- Real time, historic, or predictive



# Bridge Information & Condition Database (Pearl)

# Bridge Information & Condition Database (Pearl) FRB & QC

Home About Contact Account Manage Log Out

## Records Storage

- Cloud storage of all info and records for 30,000 elements
- Batch inputting of records using meta data (QC)

## Inspection Management

- Inspection programme management
- Outlook style calendar scheduling

## Defect Management

- Automated updating of BCIs for elements or whole bridge
- Repair & maintenance management

## Document Management

- Full bespoke online document management module
- Records by element
- Records by project

## Reporting

- Automatic generation
- Online approvals
- PI/GI
- BCI
- Defects
- C&V

## Analytics

- Deterioration analysis
- Element structural capacities
- Loading & Event scenario analysis
- Mercury interface

**Pearl**

Information & Condition Database



# Pearl – Major Bridges Entry Screen

[Home](#) [About](#) [Help](#) [Account](#) [Manage](#) [Log Out](#)

## Select Bridge



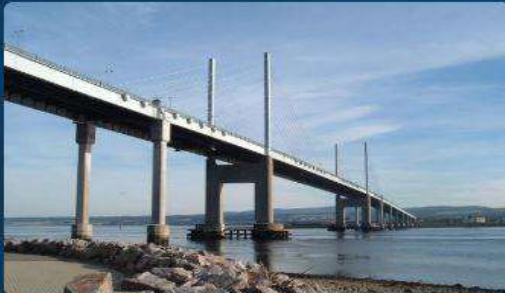
Queensferry Crossing (M90 0-1 60)



Forth Road Bridge (A9000 9)



Erskine Bridge (A989 100)



Kessock Bridge (A9 1350)



Cross-bridge Analysis and Reporting

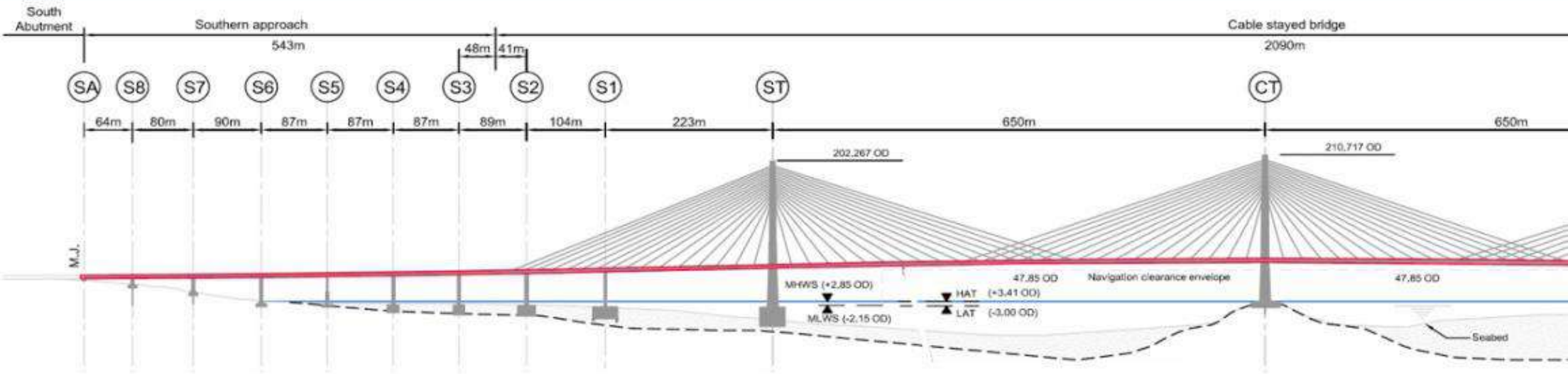
# FRB & QC Pearl – QC Overview



- OVERVIEW
- INVENTORY
- SCHEDULE
- HIERARCHY
- REPORTS
- DOCUMENTS
- LOG OUT

QUEENSFERRY CROSSING (M90 0-1 60)

## QUEENSFERRY CROSSING (M90 0-1 60)



### Overview

No Description Available.

### Agenda -7 Days

Today



07 May 2019-14 May 2019



### Agenda +7 Days

Today



14 May 2019-21 May 2019



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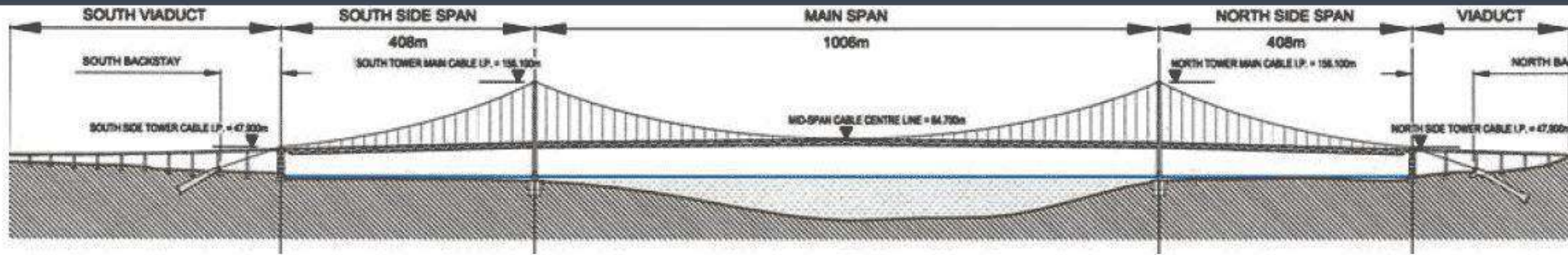


# FRB & QC Pearl – FRB Overview



FORTH ROAD BRIDGE IDRMDB

## FORTH ROAD BRIDGE IDRMDB



### Overview

The Forth Road Bridge is a long span suspension bridge which was opened in September 1964.

The bridge crosses the Firth of Forth some 15km west of Edinburgh and is a vital link in Scotland's strategic road network. The bridge deck supports a dual two lane carriageway without hard shoulders or strips. There is a separate footway / cycletrack on either side.

The historic importance of the structure to Scotland was recognised in 2001 when the bridge was classed as a Category A listed Structure.

### Bridge Information



### Favourite Documents

OVERVIEW

INVENTORY

SCHEDULE

HIERARCHY

REPORTS

DOCUMENTS

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# FRB & QC Pearl – Agenda Page



FORTH ROAD BRIDGE IDRMDB

## FORTH ROAD BRIDGE IDRMDB

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### Agenda -7 Days


Today ◀ ▶ 📅 17 October 2018-24 October 2018 ↻		
Date	Time	Event
17 Wednesday October 2018	◀ all day ▶	🔍 Main Cable Saddles PI
	all day	🔍 North Side Span, Longitudinal Truss PI
18 Thursday October 2018	◀ all day ▶	🔍 Main Cable Saddles PI

### Agenda +7 Days

Today ◀ ▶ 📅 24 October 2018-31 October 2018 ↻		
Date	Time	Event
24 Wednesday October 2018	◀ all day ▶	🔍 Main Span Longitudinal Truss, PI
25 Thursday October 2018	◀ all day ▶	🔍 Main Span Longitudinal Truss, PI
26 Friday October 2018	◀ all day ▶	🔍 Main Span Longitudinal Truss, PI
27 Saturday October 2018	◀ all day ▶	🔍 Main Span Longitudinal Truss, PI



# FRB & QC Pearl – Outlook Style Inspection Diary



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FORTH ROAD BRIDGE IDRMDB

TASK SCHEDULE

Today

◀ ▶

📅 October 2018

Export

Import

Week


Month

Agenda

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
		🔍 Cross Girder (Beam				
08	09	10	11	12	13	14
🔍 Main Cable Saddles PI						
15	16	17	18	19	20	21
🔍 Main Cable Saddles PI						
		🔍 North Side Span, Longitudinal Truss PI				
22	23	24	25	26	27	28
🔍 Main Span Longitudinal Truss, PI						
29	30	31	01	02	03	04
🔍 Main Span Longitudinal Truss, PI			🔍 South & North Main Tower (Levels 1 to 4), PI			

Amey

# FRB & QC Pearl – Document Management Module



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FORTH ROAD BRIDGE IDR MDB

DOCUMENT MANAGEMENT

Forth Road Bridge

Archive

Scheme Information

Inspections

2017-04-12 Side Tower Cycletrac

2017-05-03 Test Inspection

2017-05-18 Truss End Link (Main

2017-03-16 Top Chord PI Mar 16

2017-03-16 Top Chord PI Mar 16

2017-06-20 Test General Inspect

2017-04-12 Side Tower Cycletrac

2017-08-01 Main Tower, Top Cro

2017-07-11 Northbound & South

2017-08-04 DCP PP24-PP25 Nort

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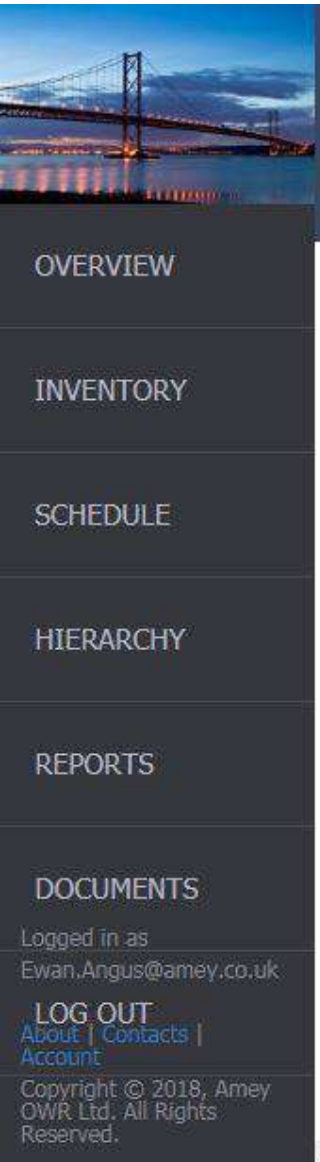
Name	Type	Version	Modified		Final
Main Tower Crossover PI Aug 2017.pdf	Report	1	22/05/2018 09:32	☆	🔒

1

1 - 1 of 1 items



# FRB & QC Pearl – Document Management Module



FORTH ROAD BRIDGE IDRMDB

## DOCUMENT MANAGEMENT

### Scheme Information

#### 15/FB/1203/008 South Anchorage

Health & Safety File / PCIP / C

#### O&M Manuals

##### Volume 1 - Consultant Drawings

50034 Forth Road Bridge

##### Volume 2 - Building Fabric & Structure

Volume 3 - Mechanical Installation

Volume 4 - Electrical Installation

##### Volume 5 - McLaughlin & Harvey

Site Photographs

#### 17/FB/1203/005 Main Span Billet

Health & Safety File / PCIP / C

Site Photographs

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Name	Type	Version	Modified			Final
50034 Architectural Services - Drawing...	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-00-DR-A-1112 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-00-DR-A-1110 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-ZZ-DR-A-1141 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-ZZ-DR-A-1140 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-00-DR-A-1111 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-ZZ-DR-A-1142 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-ZZ-DR-A-1301 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-ZZ-DR-A-1300 C01.pdf	As Built	1	16/10/2018 09:00	☆		
FRBF-MCL-00-ZZ-DR-A-1161 C01.pdf	As Built	1	16/10/2018 09:00	☆		

# FRB & QC Pearl – Logging of Defects



FORTH ROAD BRIDGE IDRMDB

## LOG INSPECTION RESULTS

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General Inspection Data

**South West Main Tower, Cable Saddle**  
3 ITEMS

**South East Main Tower, Cable Saddle**  
3 ITEMS

**North West Main Tower, Cable Saddle**  
3 ITEMS

**North East Main Tower, Cable Saddle**  
3 ITEMS

▶ North Side Tower, East, Rocker Saddle	1	1.10	2	B	minor rusting of bottom bearing block		<input checked="" type="checkbox"/>		
▶ North Side Tower, East, Rocker Saddle	1	1.10	1	A	No signs of rusting or damage to the cast steel saddle		<input checked="" type="checkbox"/>		
▶ North Side Tower, East, Rocker Saddle	1	1.10	1	A	No significant signs of wear. Welds to rocker box in good condition with no signs of		<input checked="" type="checkbox"/>		
▶ North Side Tower, East, Rocker Saddle	1	1.10	2	C	Minor corrosion noted on 24 of 64 Pivot block bolts		<input checked="" type="checkbox"/>		

◀ ◁ 1 ▷ ▶ 10 items per page 1 - 8 of 8 items ↻

### UPDATE DEFECT

☐ Snag



# FRB & QC Pearl – Logging of Defects



FORTH ROAD BRIDGE IDRMDB

## LOG INSPECTION RESULTS

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General Inspection Data

South West Main Tower,  
Cable Saddle

3 ITEMS

South East Main Tower,  
Cable Saddle

3 ITEMS

North West Main Tower,  
Cable Saddle

3 ITEMS

North East Main Tower,  
Cable Saddle

3 ITEMS

### UPDATE DEFECT

☐ Snag

DEFECT TYPE:

1 - Metalwork

DEFECT CLASSIFICATION:

1.1 - Corrosion

DEFECT SEVERITY:

3 - Rusting and pitting (localised corrosion)

DEFECT EXTENT:

Select defect extent...

DEFECT POSITION:

PART REF

Bearing E

FACE

Top

CROSS FRAME

Enter Cross Frame

X START (MM)

X FINISH (MM)

Y START (MM)

Y FINISH (MM)

Z START (MM)

Z FINISH (MM)

# FRB & QC Pearl – Report Generation



## FORTH ROAD BRIDGE IDRMDB GENERATE REPORTS

USER: EWAN.ANGUS@AMEY.CO.UK

USER TYPE: ADMINISTRATOR, MANAGER, INSPECTOR,  
STAKEHOLDER, IMPORTANCE CONTROLLER, EXTERNAL REVIEW

SCHEDULE

GANTT

HIERARCHY

REPORTS

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SELECT REPORT

Inspection Reports

Compliance Report

Bridge Condition Indices

Criticality and Vulnerability Reports

Schedule and Condition Heatmaps

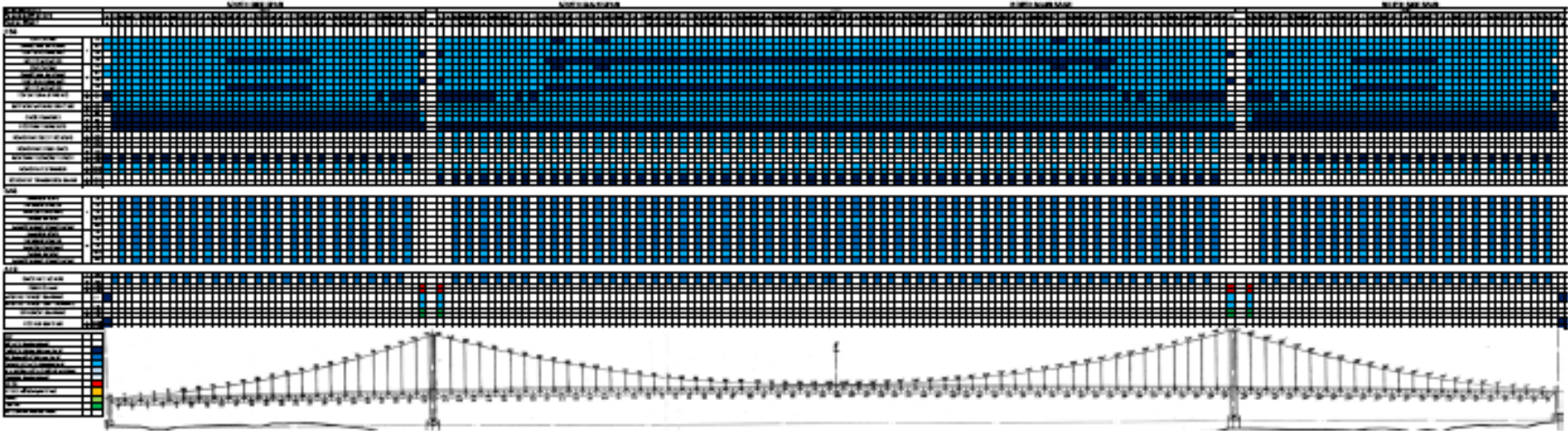
Defect Report

- Schedule

Produce a schedule based heatmap, where each cell represents the urgency of a specific component's inspection.
- BCI (average)


Produce a heatmap showing average BCI scores for each component.
- BCI (critical)

Produce a heatmap showing critical BCI scores for each component.





# FRB & QC Pearl – Automated Inspection Report Generation



**Principal**  
**Forth Road**

	Name
Inspected by	Gerry Blair
Checked by	Grasmo Shoph
Approved by	Mike Lahq

Rev: 1    Date: April 2016  
© Amey

**4. Description of Inspection**

4.1 Criticality & Vulnerability Assessment Rating

As detailed with  
Criticality Assess

4.2 Previous Insp

Component
South Viaduct
South Side Main Sp
North Side Main Sp
North Viaduct

4.3 Name of Inspection

Inspecting Engineer

Assistant(s):

4.4 Dates of this inspection

From: 01/08/20

4.5 Description of inspection

Access Equipment

First = Optical Access

Second = No access

Third = No access

Traffic Management

First = Contraflow

Second = No traffic

Third = Contraflow

**6. Reference Sketches**

Northbound Carriageway

Southbound Carriageway

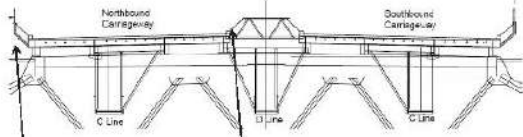
C Line


D Line


E Line

Outer Grillage

Central Reserve Grillage







A90 Forth Road Bridge

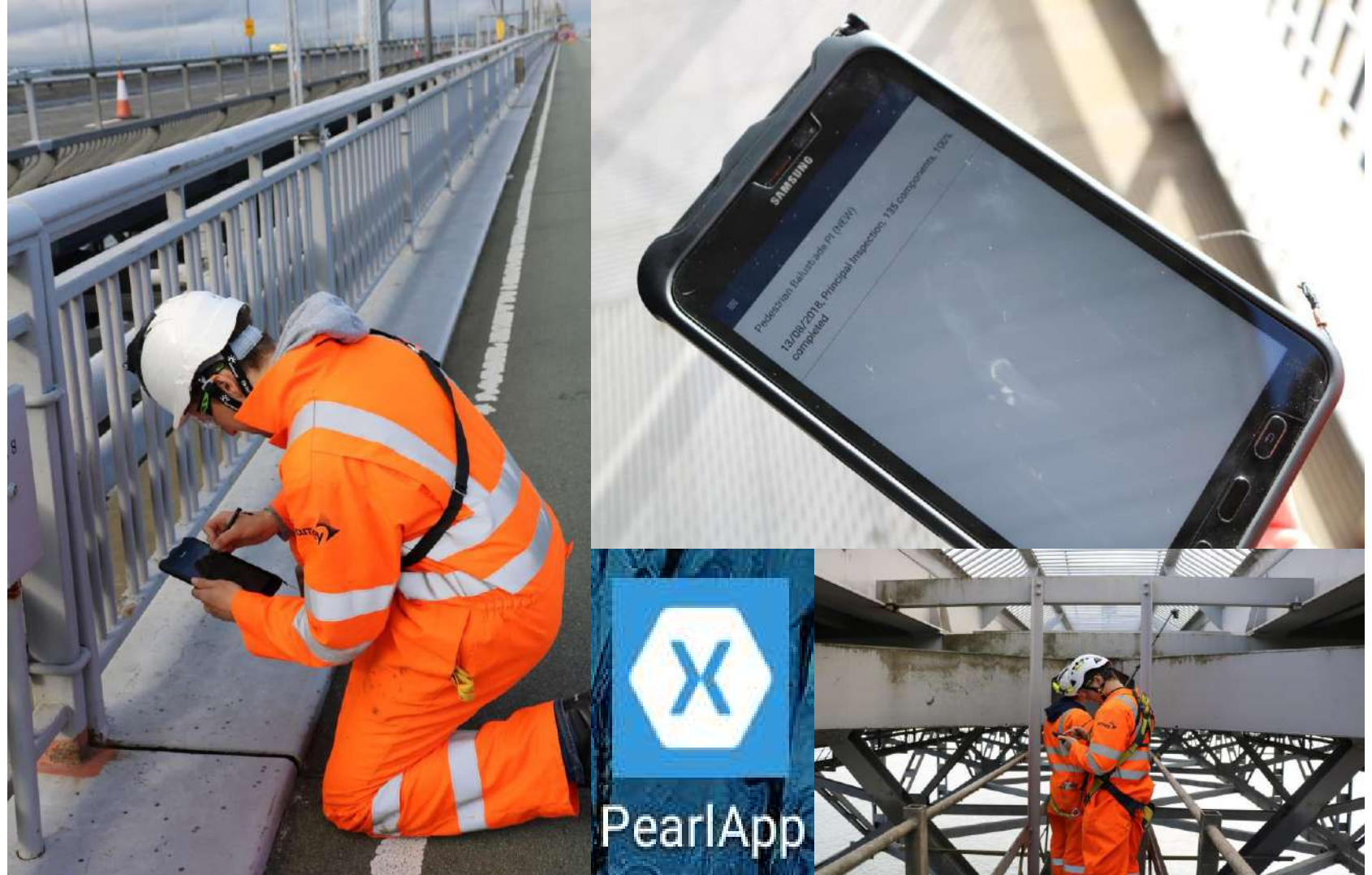
A90 Forth Road Bridge

61

- Inspection reports generated by system automatically or on-demand
- Huge increase in efficiency – report template only needs set up once by engineers then coded into system
- Automatically set up to demonstrate compliance with contract KPIs
- Client approval of reports online

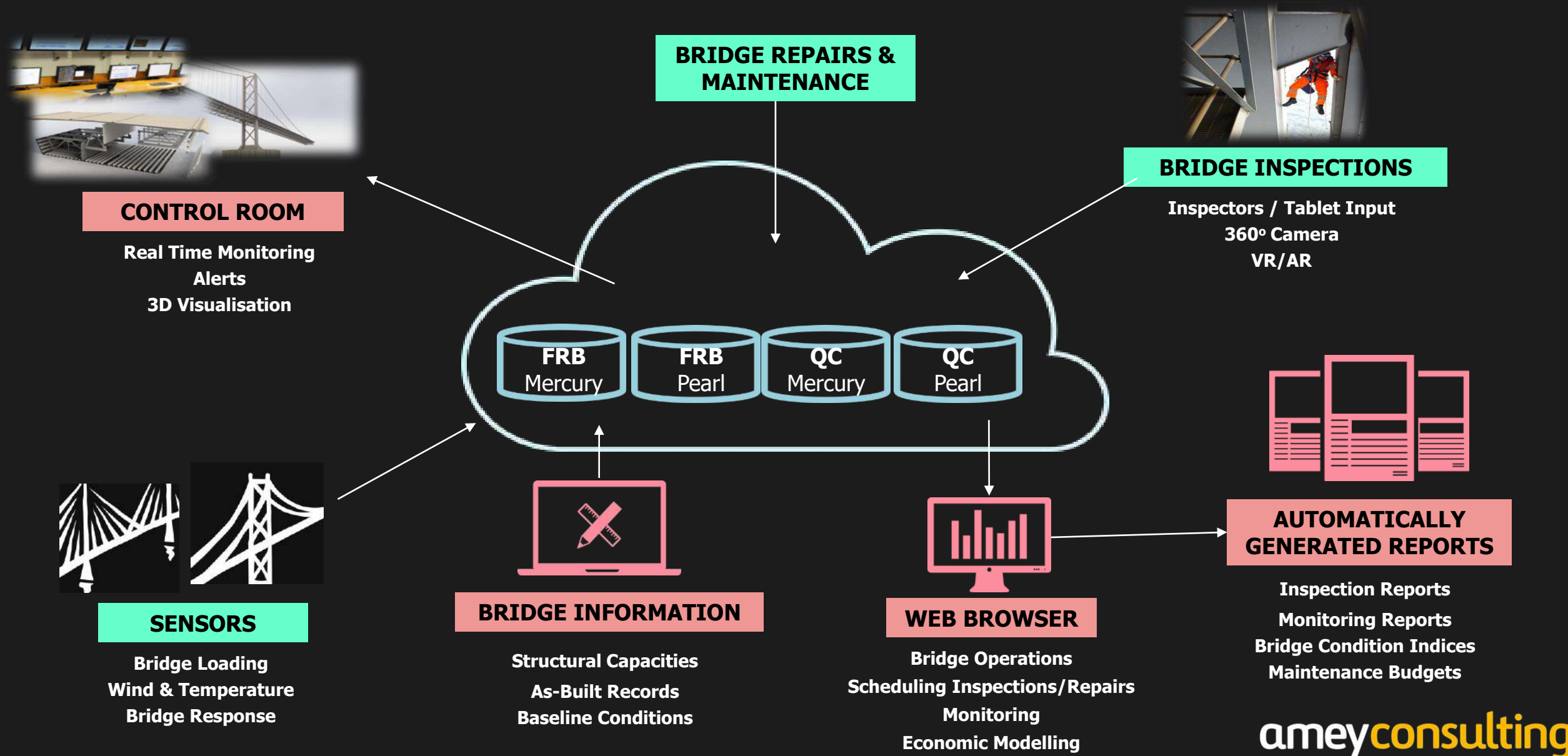
# FRB & QC Pearl – Mobile Device Input via PearlApp

- ❑ Defects recorded directly on site by inspectors using Wifi enabled Mobile App
- ❑ Element records and defect history available to inspectors
- ❑ Bridge Wifi allows Bridge Condition Indices to be automatically updated and inspection reports created automatically
- ❑ 360° camera and VR system being trialled





# Pulling It All Together



# In Conclusion

- **This is all about Data! Lots of assets generate lots of data but many don't make full use of it**
- **The systems we have developed have put these bridges in a world leading position**
- **Resilience and confidence can be increased with proper use of technology and data**
- **Owners of smart assets can make better informed decisions**
- **Integration, automation, and harnessing the full power of Data Analytics are key to success**
- **Engineering judgement will always be needed but the analytics free up time for this**



A night photograph of a large bridge spanning a body of water. The bridge features a suspension section on the left and a cable-stayed section on the right. The bridge is illuminated with lights, and its reflection is visible in the water. In the background, city lights are visible across the water. The foreground shows a rocky shoreline. The text "Live Demonstration" is overlaid in the center of the image.

# Live Demonstration