

# Designing for a Changing World: The Role of Data & Artificial Intelligence



# Introducing Arup

We are a global collective of designers, experts and consultants dedicated to sustainable development. We use technology, imagination and rigor to shape a better world.





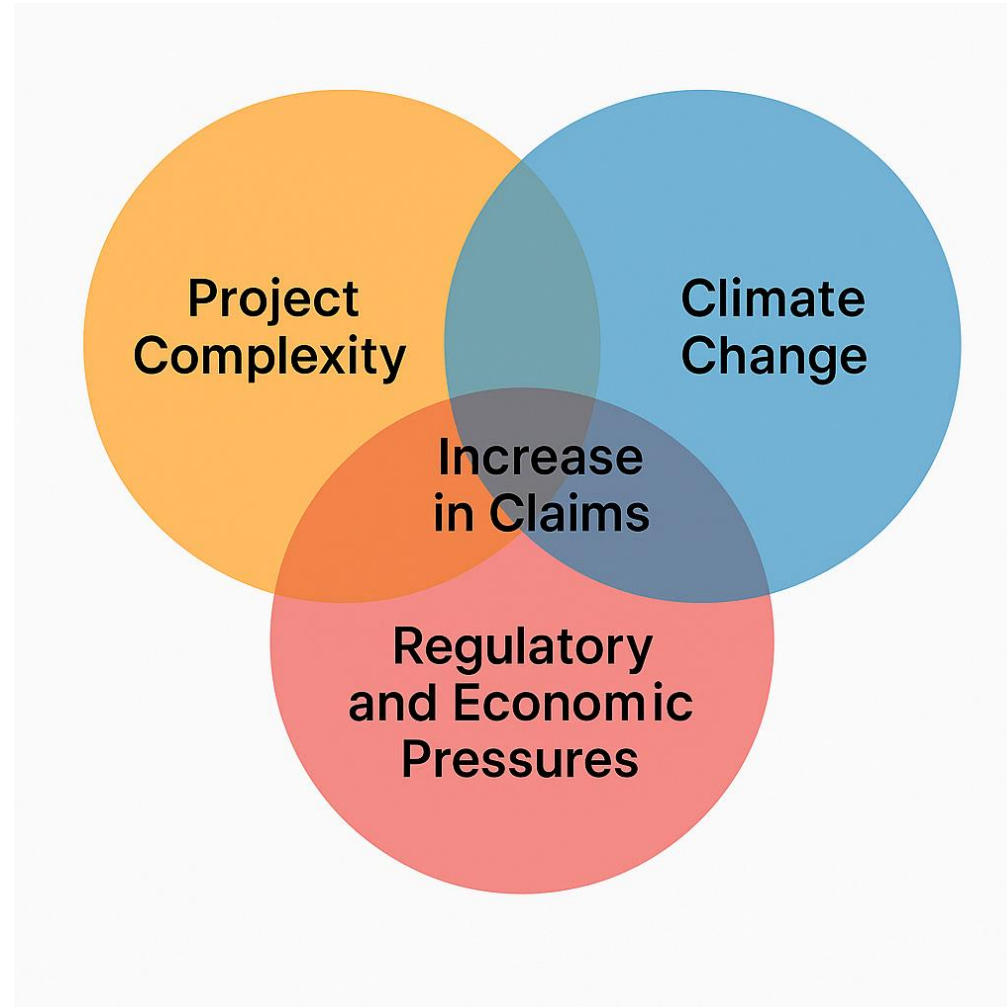
# Insurance Claims Around the World<sup>1</sup>

- Frequency of natural disasters has increased builders' risk claims by **14%**
- **Design errors** are the most frequent cause of professional liability claims, accounting for **62% of all claims** filed by construction firms in 2023
- Claims related to **new green building projects** have risen by **7%** in 2023, as more **complex environmental standards lead to frequent** disputes over project quality and timelines



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# AEC Insurance Claims: Major Contributing Factors



# Tacoma Narrows Bridge Catastrophic Failure (1940)

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Failure Cause: Aeroelastic flutter underestimated in design



## Data and AI Solutions:

- ✓ Simulation tools with real-world wind data
- ✓ AI-Powered stress analysis and structural resonance prediction



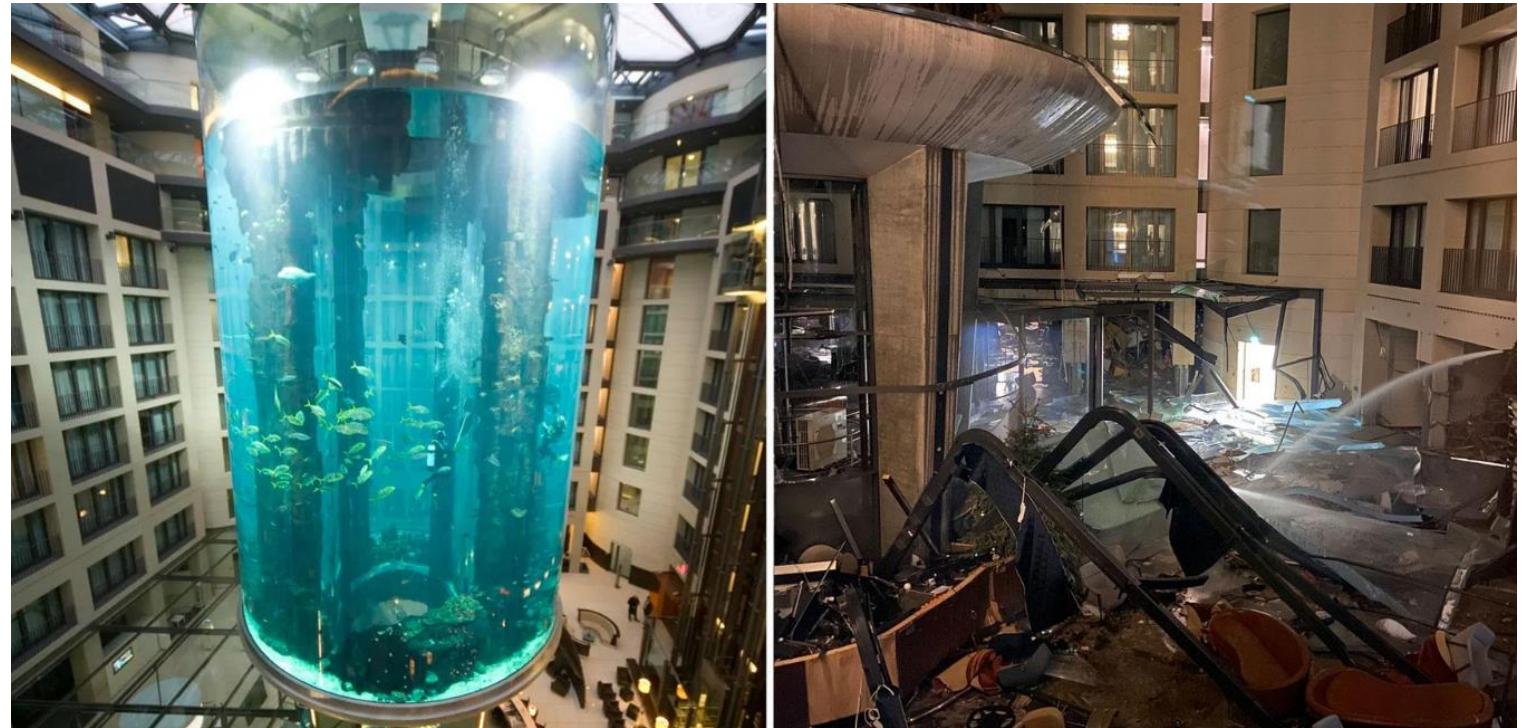
# Case Study: Berlin AquaDom (2022)

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## Failure Cause: Structural Weakness in Acrylic Cylinder

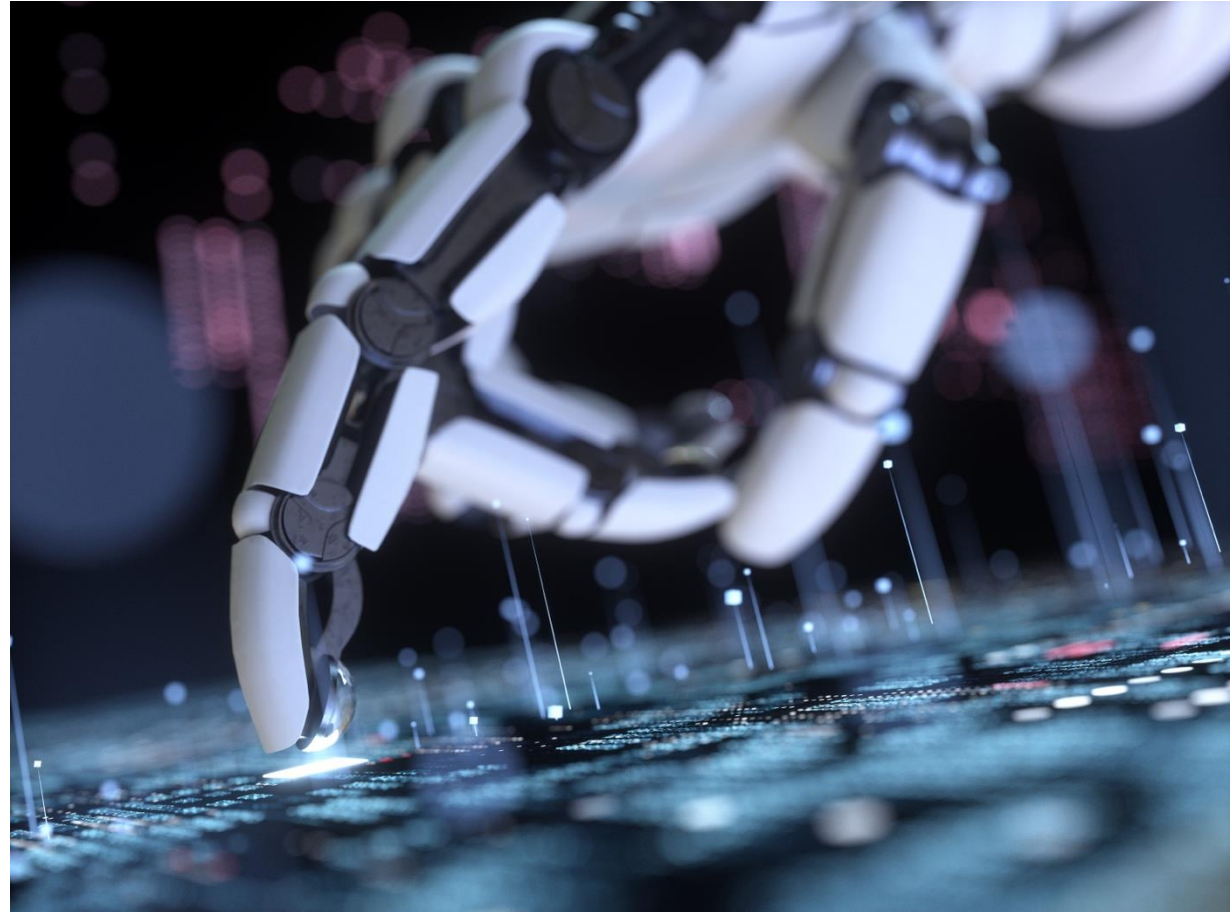
### Data and AI Solutions:

- Predicative Maintenance Using AI
- Structural Health Monitoring
- Environmental Data Correlation
- Automated Risk Assessment



# Key Technologies Driving Change

- ❑ Digital Twins
- ❑ Generative Design  
(e.g., Autodesk  
Dreamcatcher )
- ❑ Predictive  
Maintenance  
Systems
- ❑ Neural Networks for  
Pattern Recognition  
in Material Behavior



It Begins with the Data.....

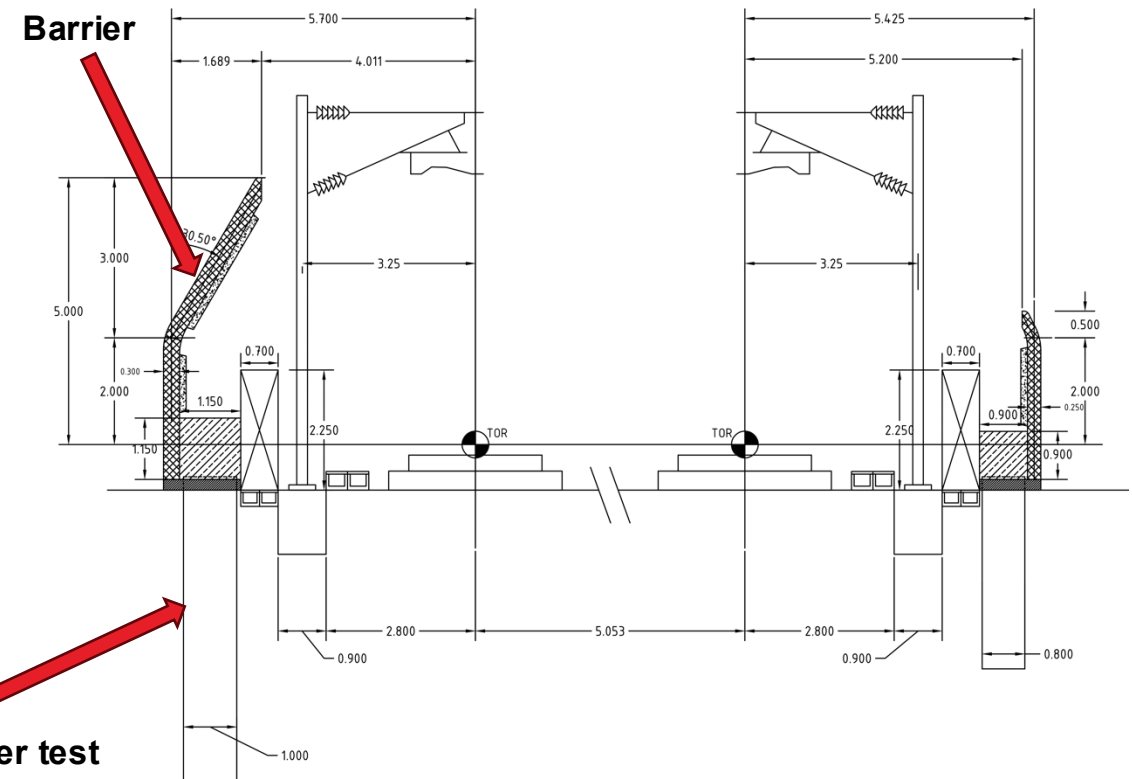
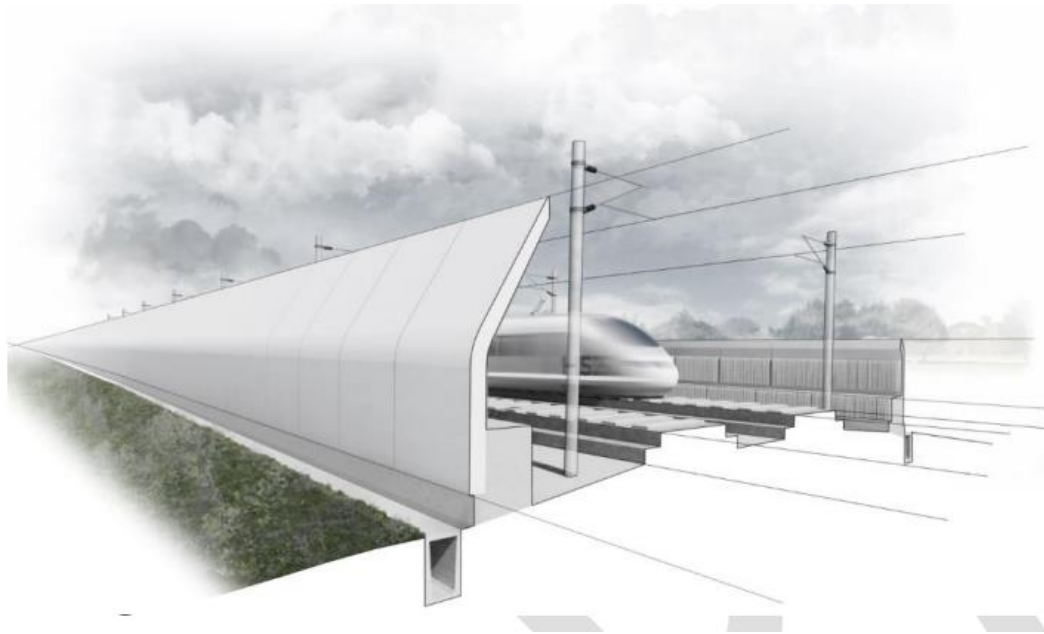
.....Start There!



# Arup Use Case: Project XYZ Noise Barrier Testing

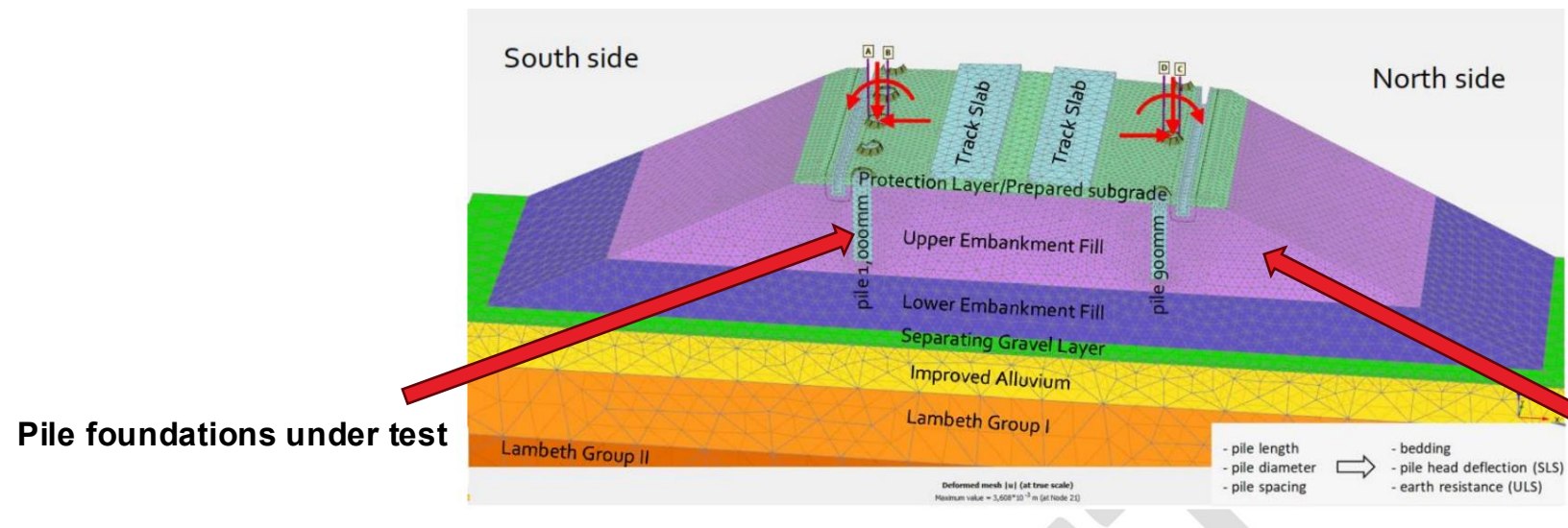
# 'Cranked' Noise Barriers in Open Urban Area

Design life of 200-mph train every 10 minutes for 120 years



# Test site and geological context

Test to ensure design will withstand expected forces on fabricated embankment



Pile foundations under test

Built up embankment hosting foundations





# Pile test site

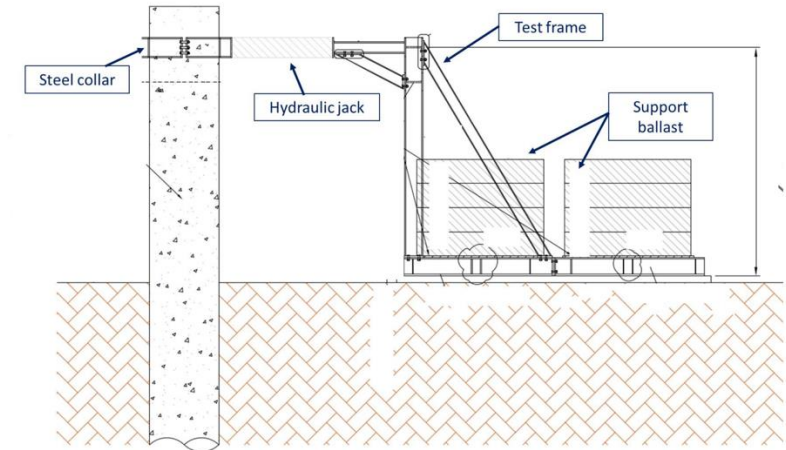
Data in its Context

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Data cabin

Pile 1

Pile 2



Reaction Frame

# Inside the pile!

## Sample construction – Pile reinforcement & strain gauge installation



- **Pile reinforcement**
  - 820 diameter cage
  - B25 diameter main bar
  - B16 links
  - 160mm steel casing for inclinometer
  - TW extension for weld lifting band
  - Band stiffeners connected to main bars with bulldog clips
- **Strain gauges**
  - Electrical strain gage - linear
  - M series 1-LM11-3-350
  - $10^7$  cycles at 2000 micrometres per metre



# Data Source Overview

## Two types of data

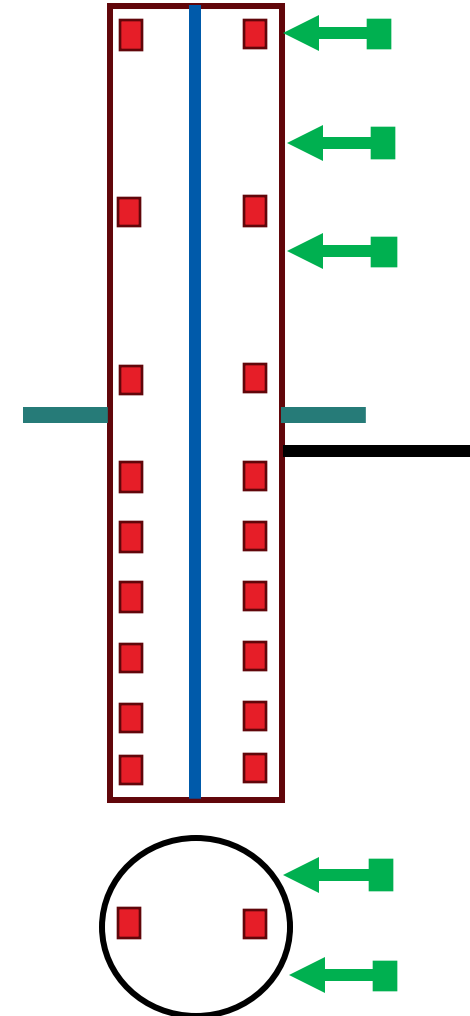
### Action

- Actuator data
- Application of force, up to 96kN, 1-second cycles



### Reaction

- Multiple sensors
- 6 Displacement (external)
- 18 Strain (internal)





# Raw Data Complexity

Significant pre-processing required before analysis

## Action data

- Non-standard CSV format
- Data in 20-second increments from 0.000, but not saying when “0” was

```
Part 1 Repeat 500 times - (100 of 500)_AcquiredData.txt
1 Source File: C:\Users\johy\Downloads\Part 1 Repeat 500 times - (100 of 500)_AcquiredData.txt
2 Actuator_1 Displacement Maximum Value = 4
3
4 [556 Minimum Value = -5.682
5 Actuator_1 Load Maximum Value = 52.555 Minimum Value = -47.916
6 Actuator_1 Command Maximum Value = 12.949 Minimum Value = -23.881
7 Time [s] Actuator_1 Displacement [mm] Actuator_1 Load [kN] Actuator_1 Command [mm]
8 0.000 4.582374 52.413848 12.934126
9 0.050 4.582374 52.413977 12.934126
10 0.100 4.582376 52.411348 12.934126
11 0.150 4.582439 52.417439 12.934126
12 0.200 4.583642 52.408893 12.934126
13 0.250 4.590131 52.408813 12.934126
14 0.300 4.516759 52.555775 12.934126
15 0.350 4.519719 52.537765 12.934126
16 0.400 4.522428 52.558972 12.934126
17 0.450 4.526764 52.566871 12.934126
18 0.500 4.528565 52.559143 12.934126
19 0.550 4.538793 52.563888 12.934126
20 0.600 4.532722 52.566908 12.934126
21 0.650 4.533616 52.560877 12.934126
22 0.700 4.534953 52.553548 12.934126
23 0.750 4.536784 52.551581 12.934126
24 0.800 4.538677 52.549525 12.934126
```

## Reaction data:

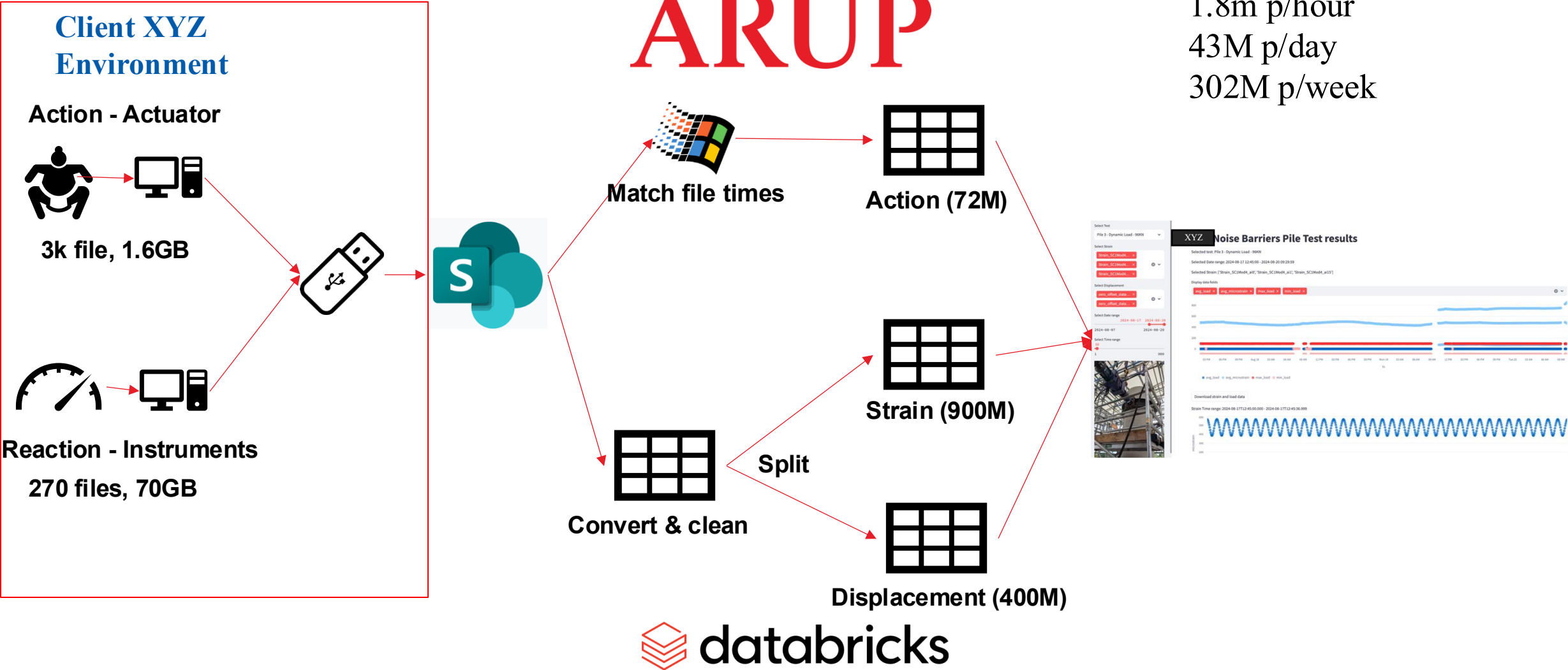
- Structure changed between tests (became more compact)
- Time is recorded as seconds since 1<sup>st</sup> Jan 1904 (in scientific format)
- ‘Wide’ data in columns – requires ‘melting’ (stacking) to compare

```
test_61.txt /Users/johy\Downloads\test_61.txt [data]
1 Time Strain - SCIMod4_a10 Time Strain - SCIMod4_a11 Time Strain - SCIMod4_a12 Time Strain - SCIMod4_a13 Time Strain
2 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.513647387184813E-4 3.80242083965885E+9 3.49226117388815E-5
3 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.568431619840981E-4 3.80242083965885E+9 1.37123768488893E-4
4 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.571718701021859E-4 3.80242083965885E+9 1.423824903241017E-4
5 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.567335926678091E-4 3.80242083965885E+9 1.422729329549689E-4
6 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.572814395312888E-4 3.80242083965885E+9 1.438398351309704E-4
7 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.575085784741048E-4 3.80242083965885E+9 1.435876232453618E-4
8 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.570623007012866E-4 3.80242083965885E+9 1.432589562921446E-4
9 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.580848423247807E-4 3.80242083965885E+9 1.435976232453618E-4
10 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.575085784741048E-4 3.80242083965885E+9 1.430398351309704E-4
11 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.570623007012866E-4 3.80242083965885E+9 1.440258542443658E-4
12 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.577197175297350E-4 3.80242083965885E+9 1.441354128646022E-4
13 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.577197175297350E-4 3.80242083965885E+9 1.445736436274898E-4
14 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.577197175297350E-4 3.80242083965885E+9 1.441354128646022E-4
15 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.570623007012866E-4 3.80242083965885E+9 1.45736436274898E-4
16 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.581579959794378E-4 3.80242083965885E+9 1.44603201588961E-4
17 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.570623007012866E-4 3.80242083965885E+9 1.431493269746465E-4
18 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.581579959794378E-4 3.80242083965885E+9 1.441354128646022E-4
19 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.581579959794378E-4 3.80242083965885E+9 1.438667386884753E-4
20 3.80242083965837E+9 1.766261832775899E-4 3.80242083965861E+9 3.570623007012866E-4 3.80242083965885E+9 1.438667386884753E-4
```

# Data Processing & Modelling

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500 rows p/second  
30k p/minute  
1.8m p/hour  
43M p/day  
302M p/week



# Project XYZ Lessons on Data and AI Integration

- ✓ All data comes from people in a context – understand the Data Generation Point
- ✓ Optimize the collection, flow and completeness of data before analysis. **Use AI to Optimize or Improve Quality of Data!**
- ✓ Automate everything you can and iterate the design
- ✓ SaaS Cloud technology enables scalable large data processing and application of Machine Learning
- ✓ **Experience feeding into Industry Research project on modernizing ‘Observational Method’**





Conclusion....

**Client Value** = Project Overhead plus **Expertise**



❑ Leveraging “Big” Data and AI for engineering and design is no longer optional. It helps to prevent catastrophic failures and enables groundbreaking designs

❑ Engineering’s Future Lies in Data-Driven Innovation





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