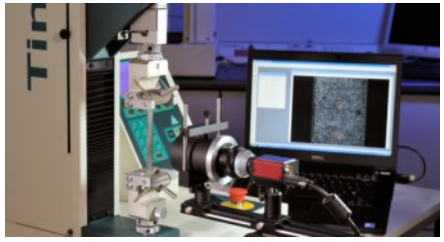
Bridge Owners Forum

27th January 2015

Dynamic Monitoring of Bridges using Video Cameras

Paul Waterfall



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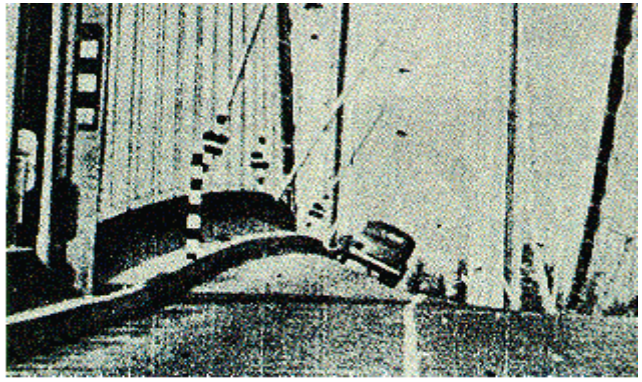
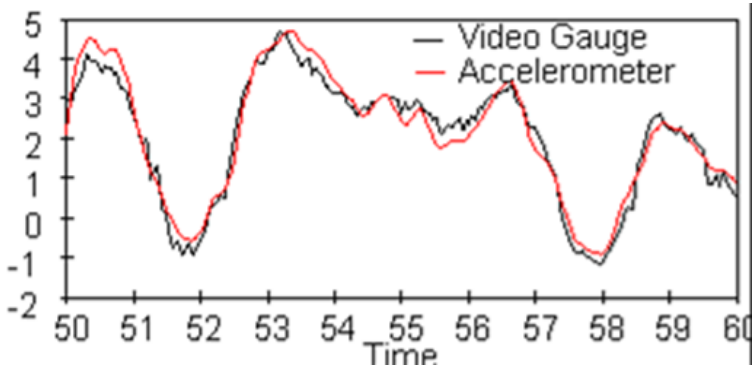
Brief History – Video Measurement

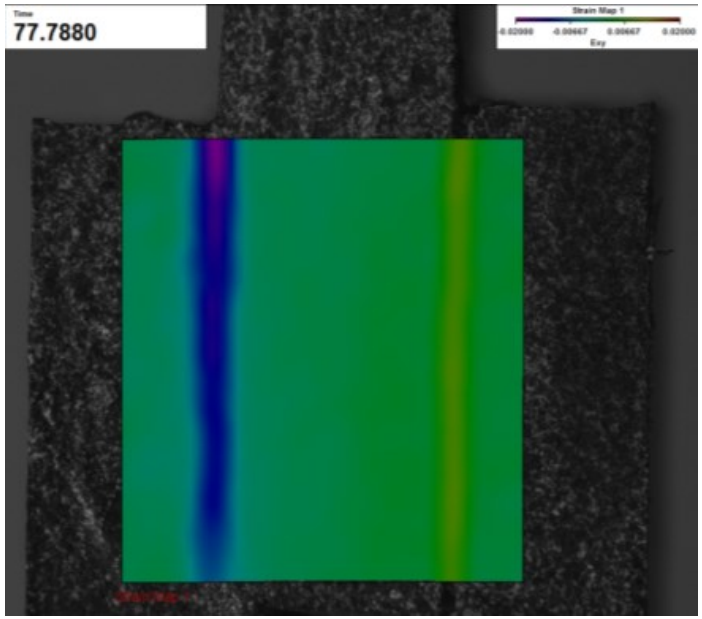
- First known example is the Tacoma Narrows Bridge, in 1940.
- Increasing use by researchers from 1980s onwards.
- Iconic use in crash testing, but principles used in motion capture, optical mice, and many optical measurement systems.
- A number of companies offering laboratory solutions.
- Imetrum is the only commercial system optimised for external use.



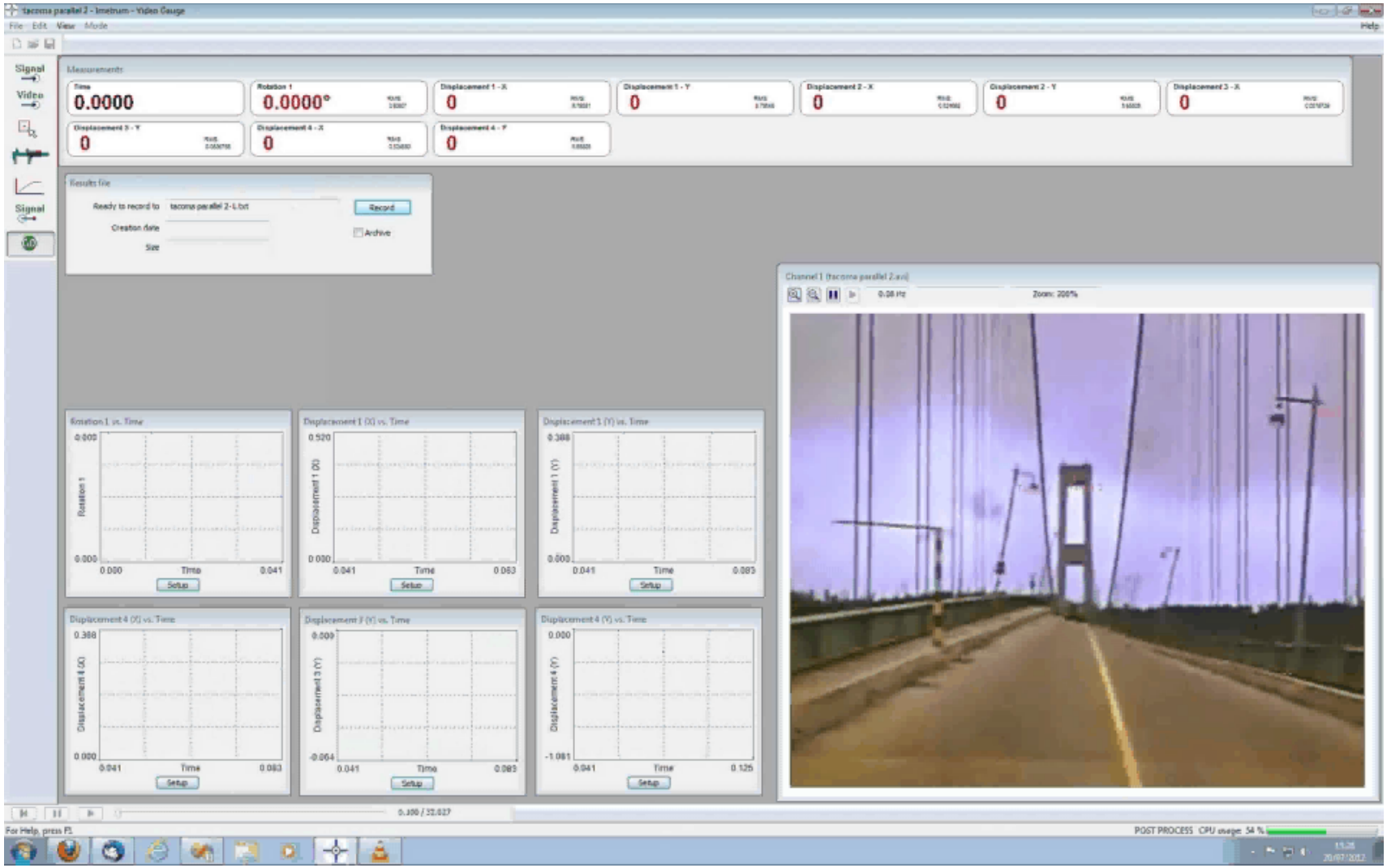
Brief History – Video Measurement

- Visual Inspection – still a mainstay of any structural survey, and the key idea behind video work.
- At Tacoma, Prof Farquharson took this further – he recorded what he saw, and then took measurements from it to help with analysis using a ruler on the screen.
- Work in Bristol University in the late 1980s & early 1990s helped to automate the ‘ruler on the screen’ – by using pattern recognition & image correlation to match a bullseye target pattern, and then calculate where that had moved to in the next image and so on.
- Simultaneous work at USC and elsewhere on applying this method to determine what was happening across a whole image (what is now commonly known as DIC).





History – Tacoma Narrows



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Rickmansworth Demonstration

- Suggested by Ashok Pamar, supervised by Jonathan Cooper.
- Vertical deflection of each beam near bearing plate.
- Before and after works to pack one of the beams that was know to have excessive deflections.
- No direct access to structure.

- Multiple steel beams – patterning of beams used as ‘targets’.
- Distances from camera to various points on structure used to scale images (and get engineering units).
- Displacement of 18 points simultaneously, at 15 Hz.

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Site Specific Setup

- 3 camera Video Gauge system, mounted on a single tripod.
- Battery powered, with test control using a tablet PC.
- Approximately 10 load events on each day (2 hours on site).

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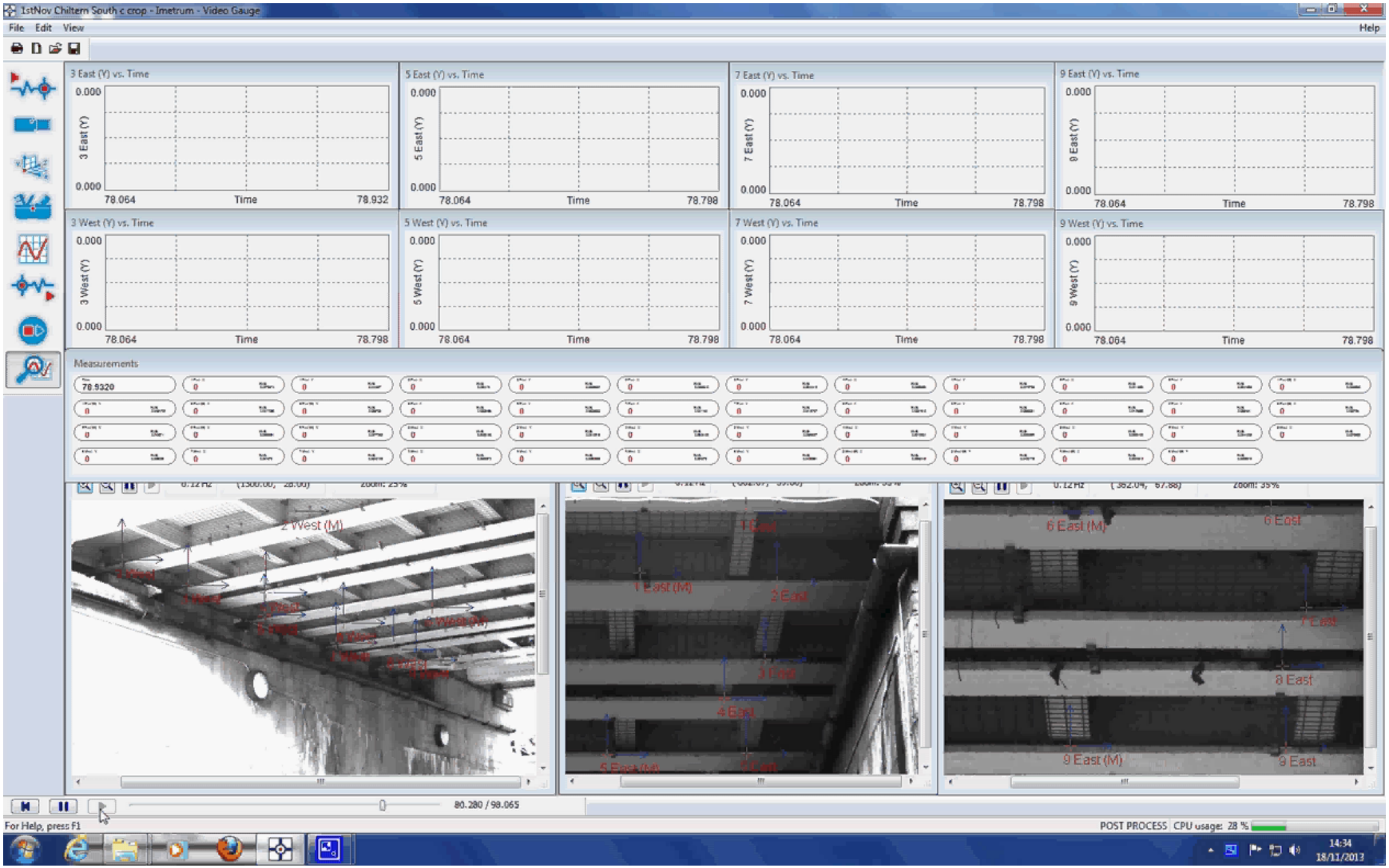
Rickmansworth Screen Capture



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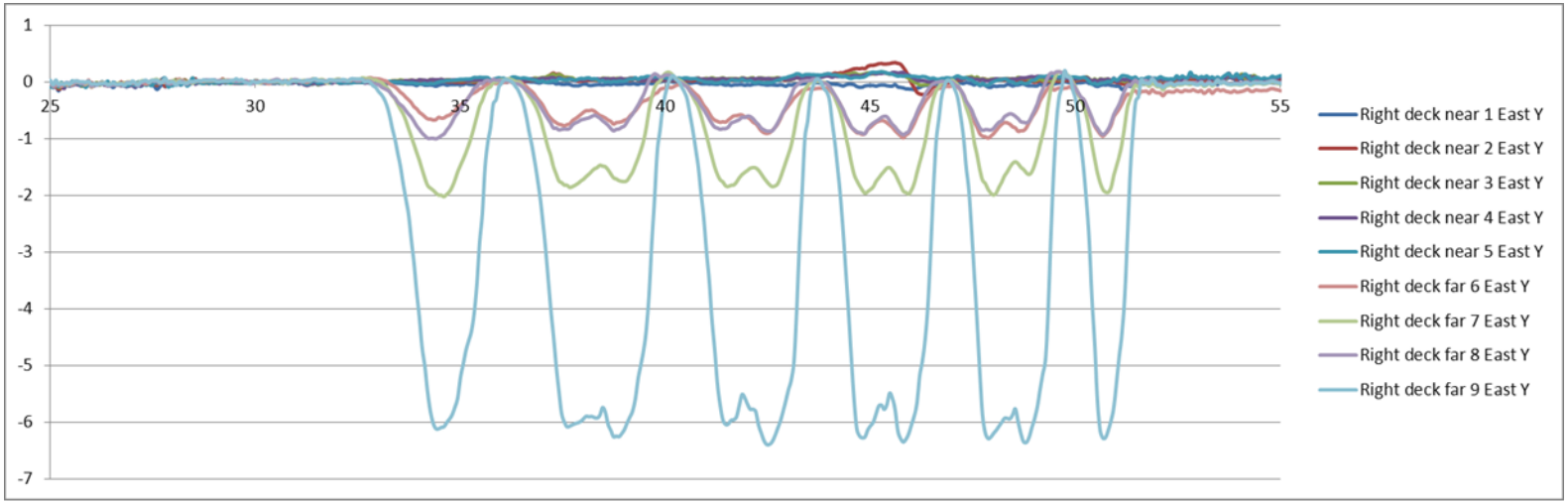
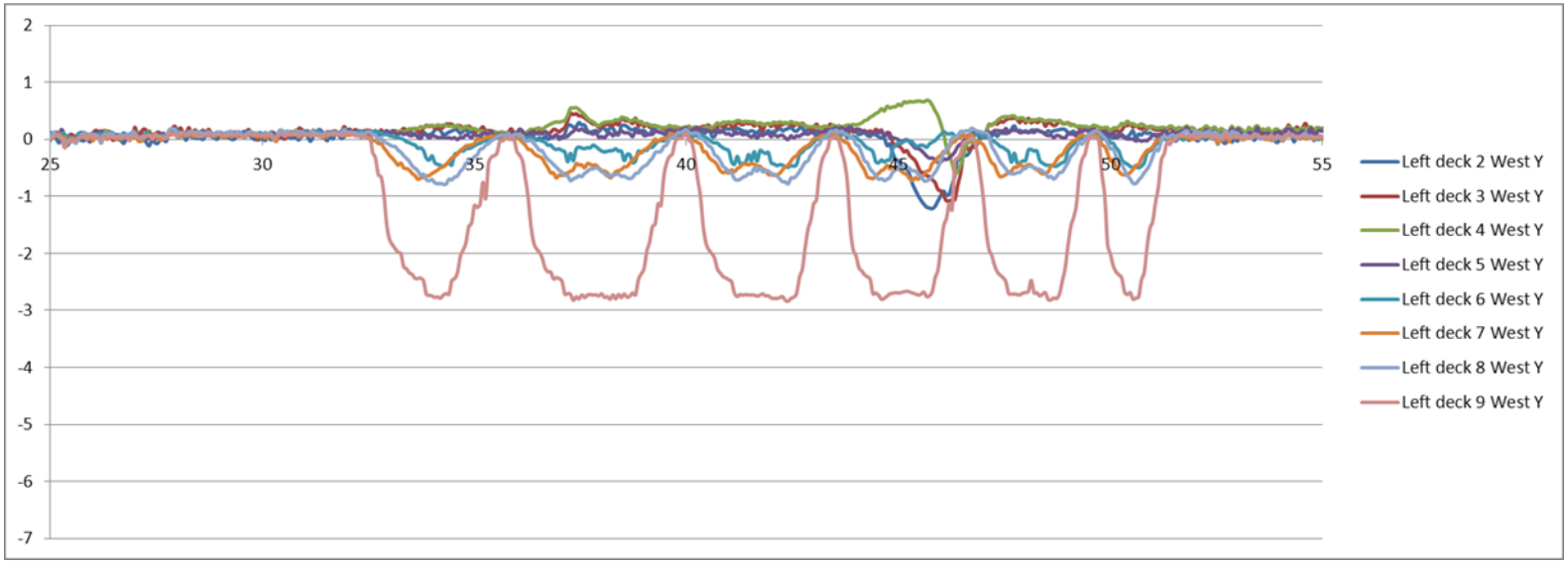
Vertical Displacement - Before





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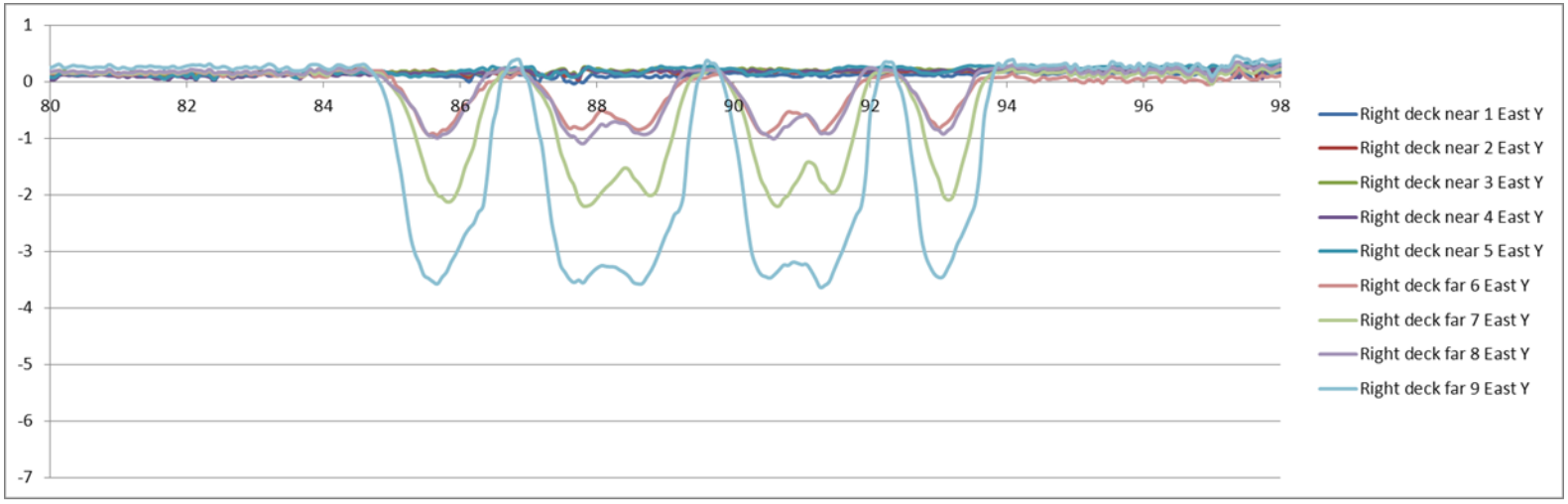
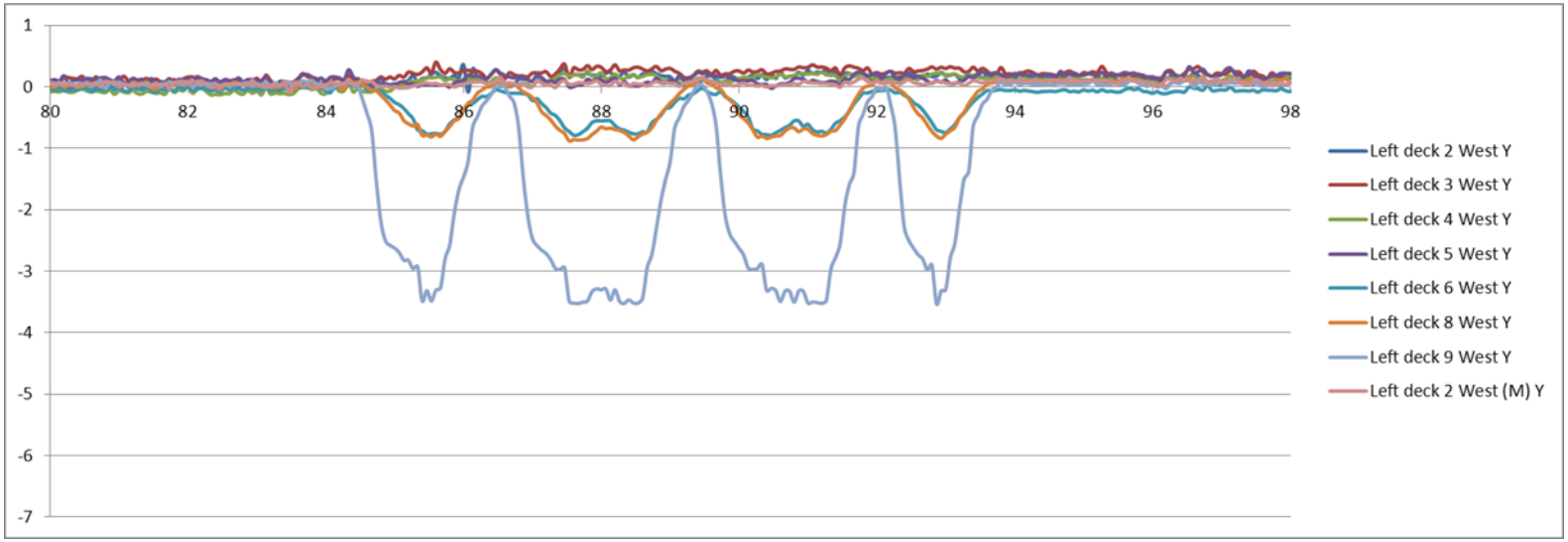
Vertical Displacement - After





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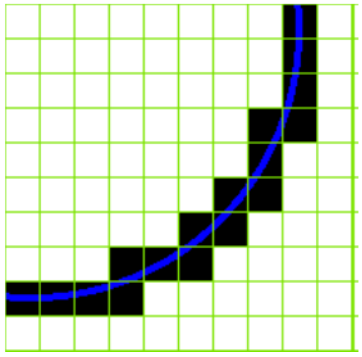
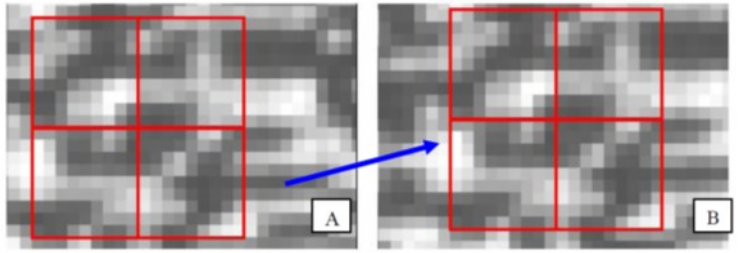
How Digital Image Correlation works

1. Set up a camera. Make sure it is stable. And will remain stable.
2. Identify a pattern in an image.
3. Accurately model exactly where that pattern is (it's an analogue world). This is the key to making it useful.
4. Find the same pattern in the next frame.
5. Record the difference between this location and the starting location.
6. Continue until the end of the test.
7. Interpret and analyse the data to determine appropriate repair / maintenance / monitoring strategies.





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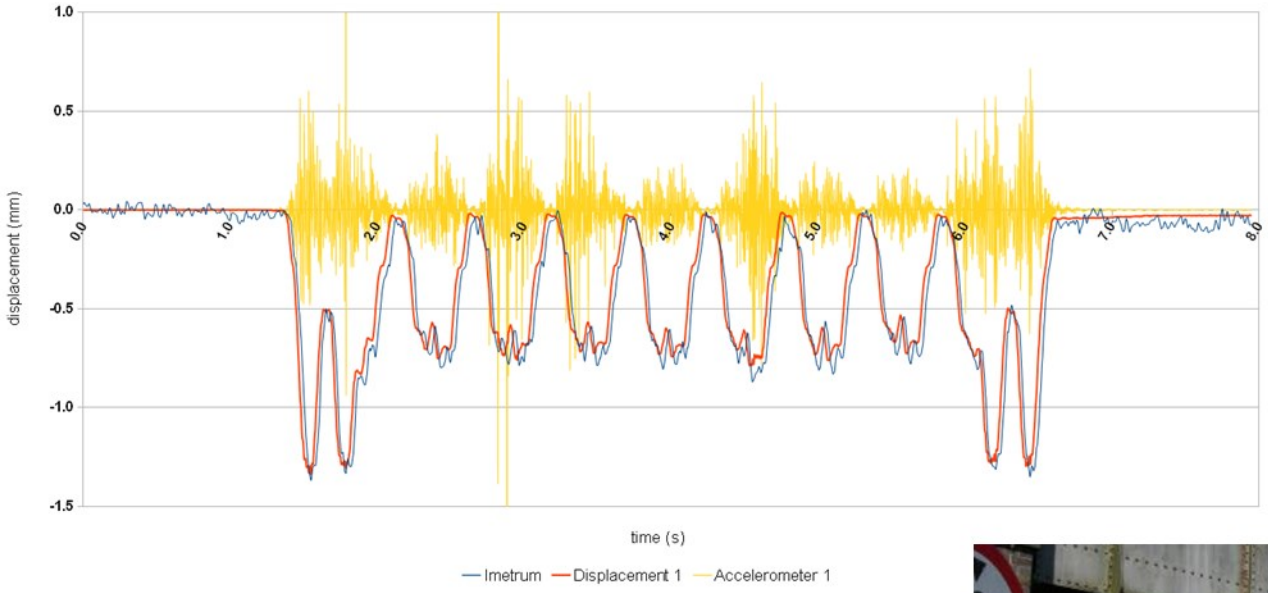
Benchmarking – HST on Rail Bridge



- Really? Can we trust this?
- People's lives depend on us after all.

- Year long project lead by UK National Measurement Office (NPL).
- Comparisons with conventional and new methods.
- Use in various weathers.

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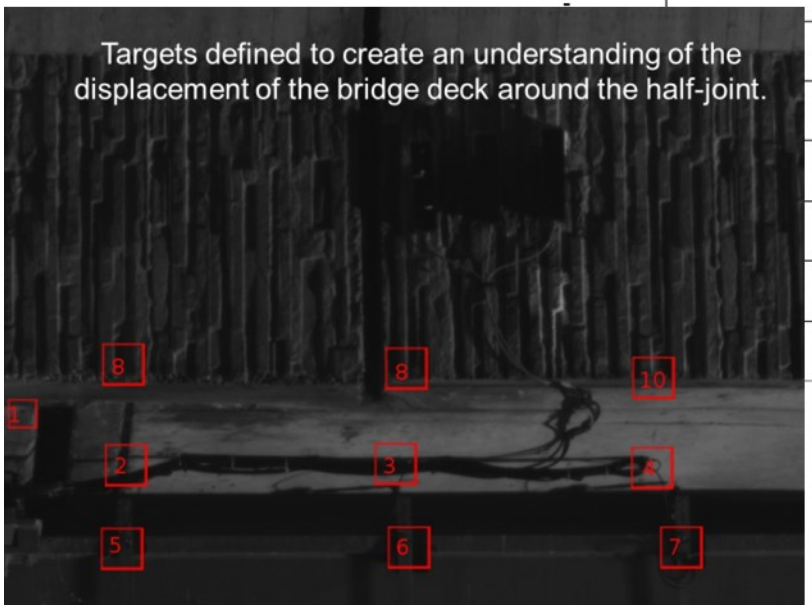
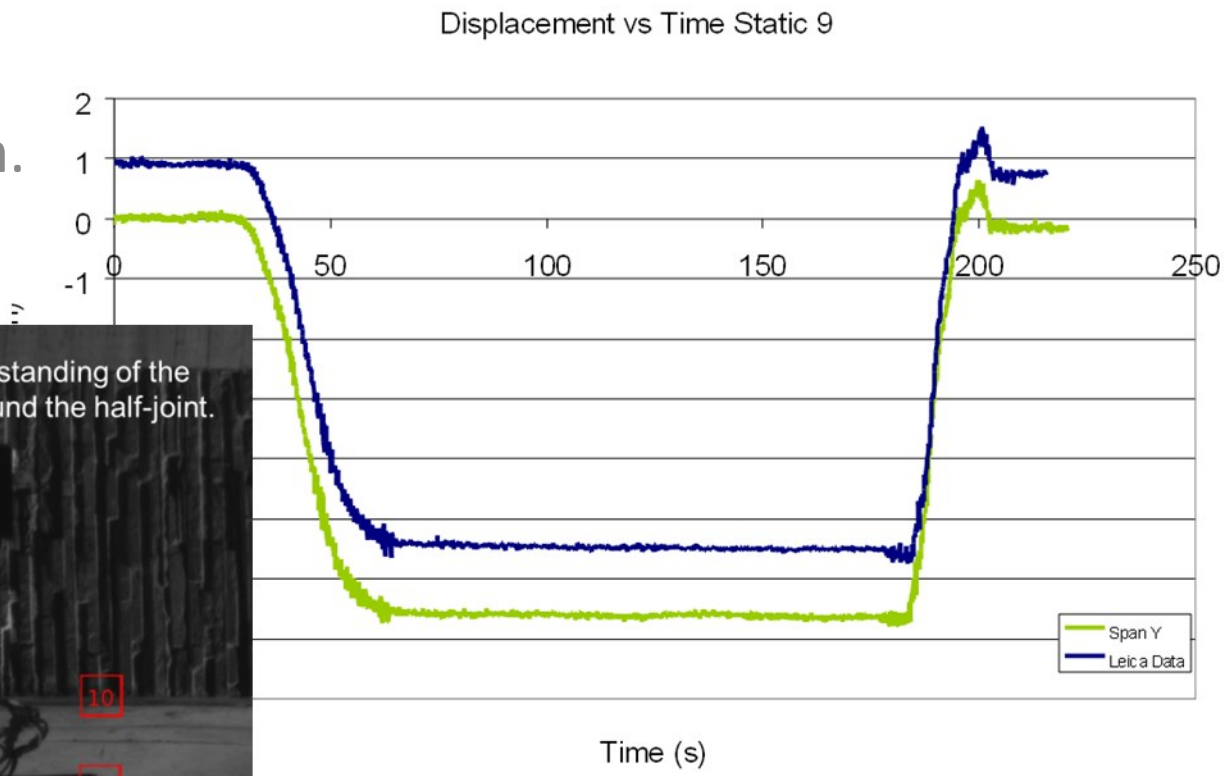
Benchmarking - Road Bridges

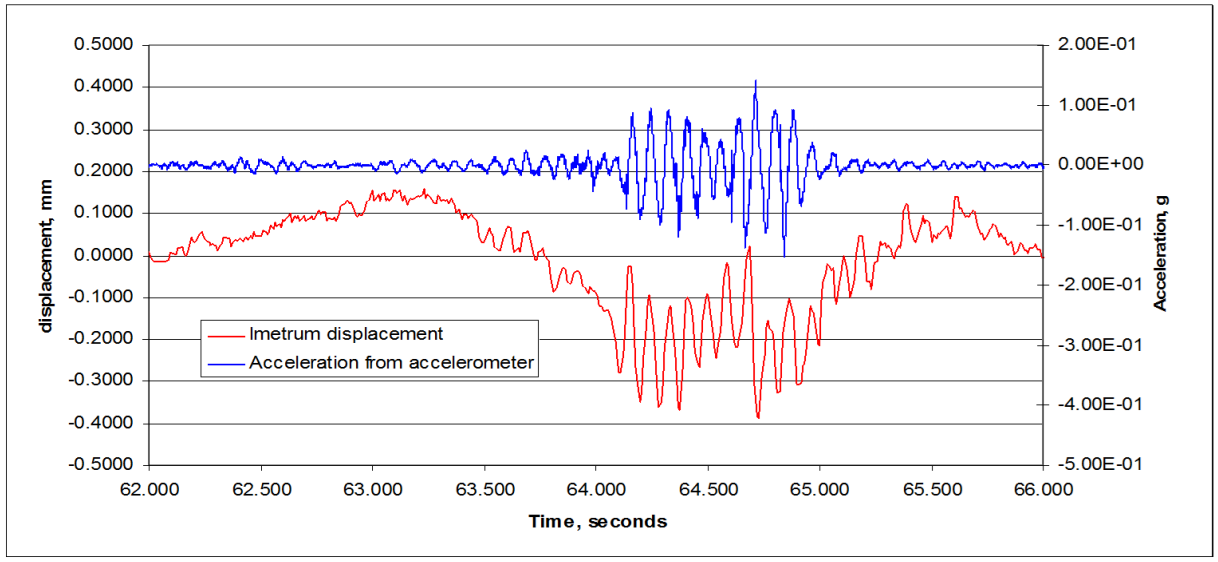
- Setup 45m away in car park
- Resolution of 0.02 mm.
- Testing at night.



Laser Tracker offset by 1mm to make comparison clearer



Benchmarking - Vibration Analysis



- Traces from an accelerometer and the Imetrum system show how the Camera system is able to respond to and record vibration events. This particular trace is caused by a bus hitting a sunken manhole on Tuckton Bridge, Dorset.

- The deflection trace indicates the overall load being applied to the span in question, plus the impact event of each axle.

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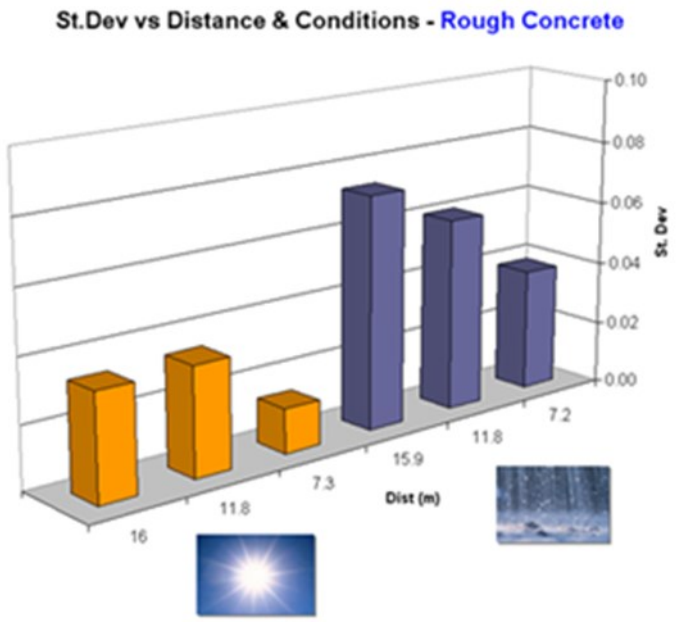
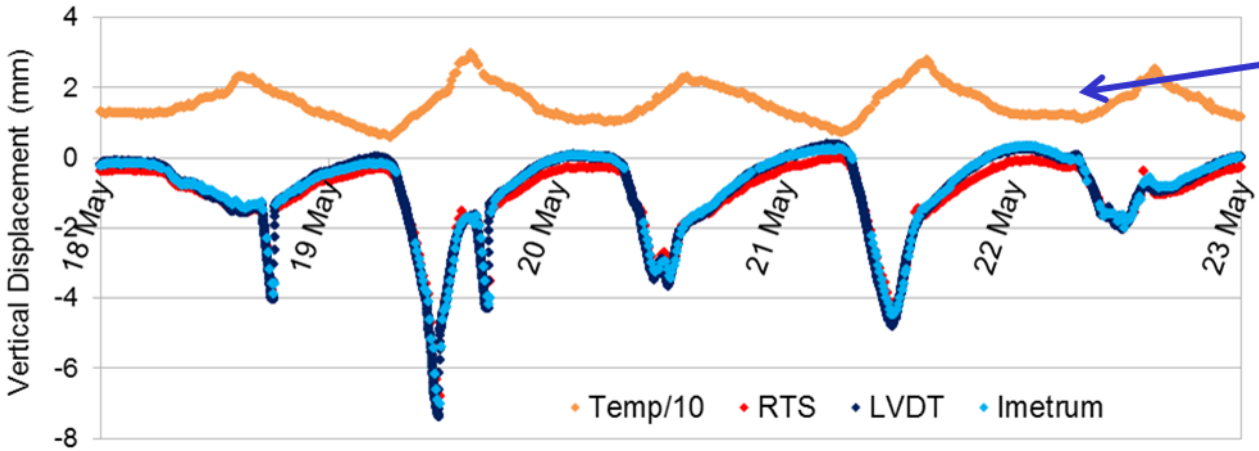
Benchmarking – Rain & Sun



- Part of NPL benchmarking process – as a rule of thumb, rain doubles the noise of the measurements.
- Consider changes in lighting carefully – Day/Night can work when done well.
- Consider solar gain carefully for long term.



A week at the NPL footbridge, measuring every 15 minutes day/night, including 3 load tests. IR lighting.

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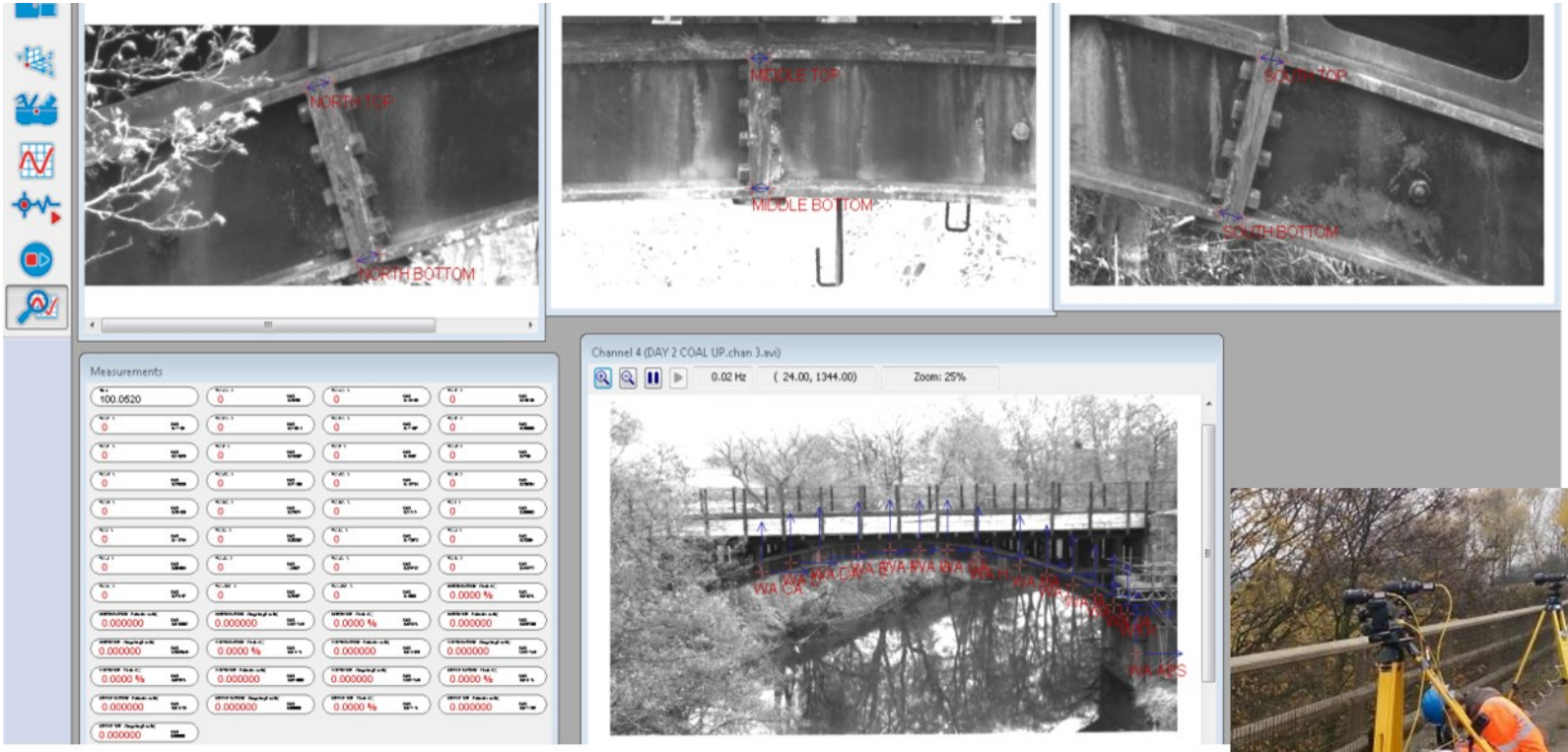
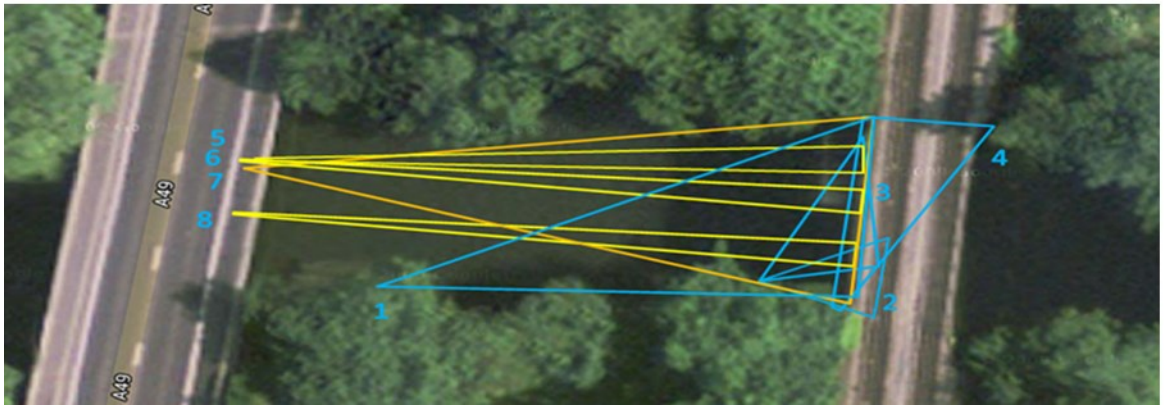
Case Study – Detail Investigation





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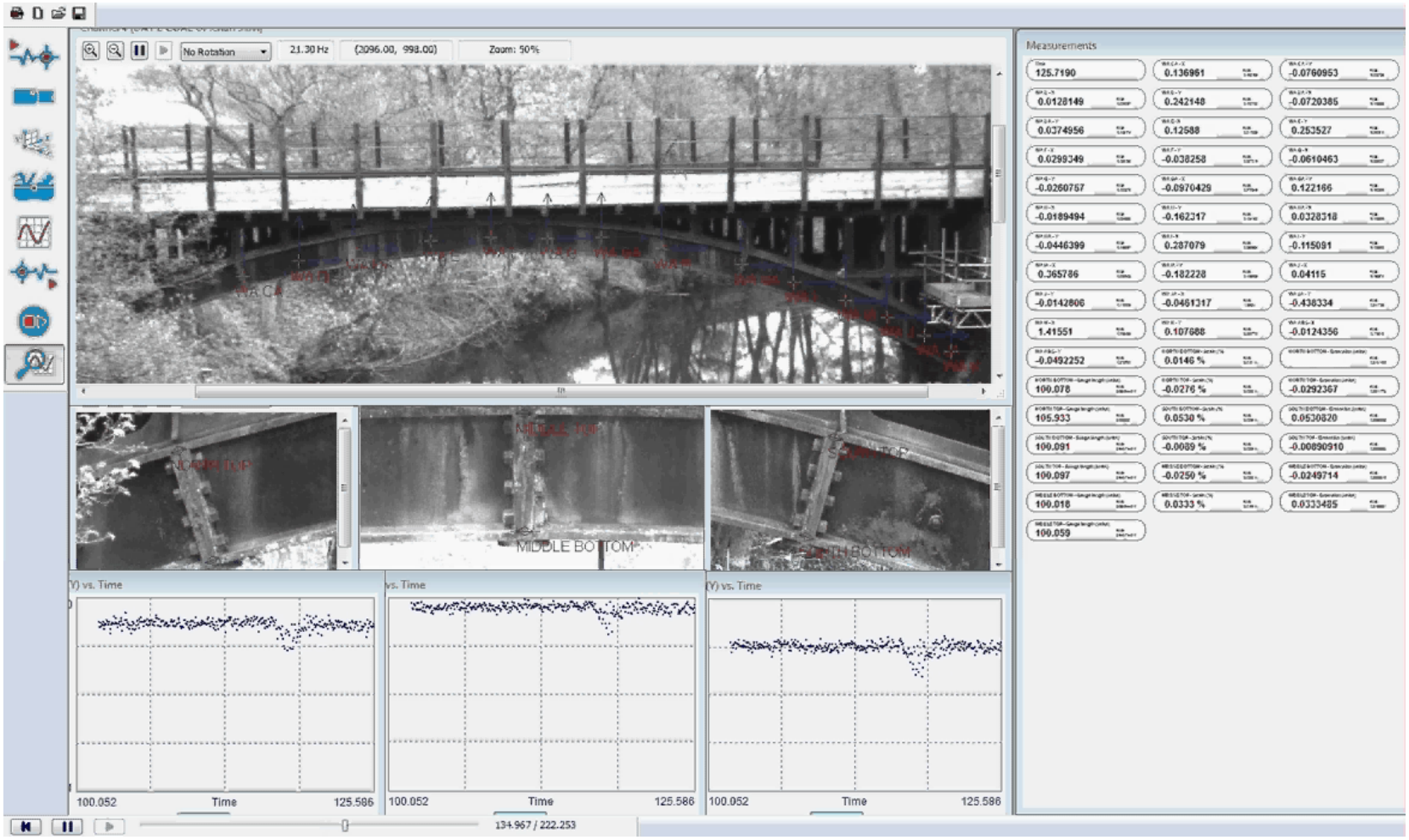

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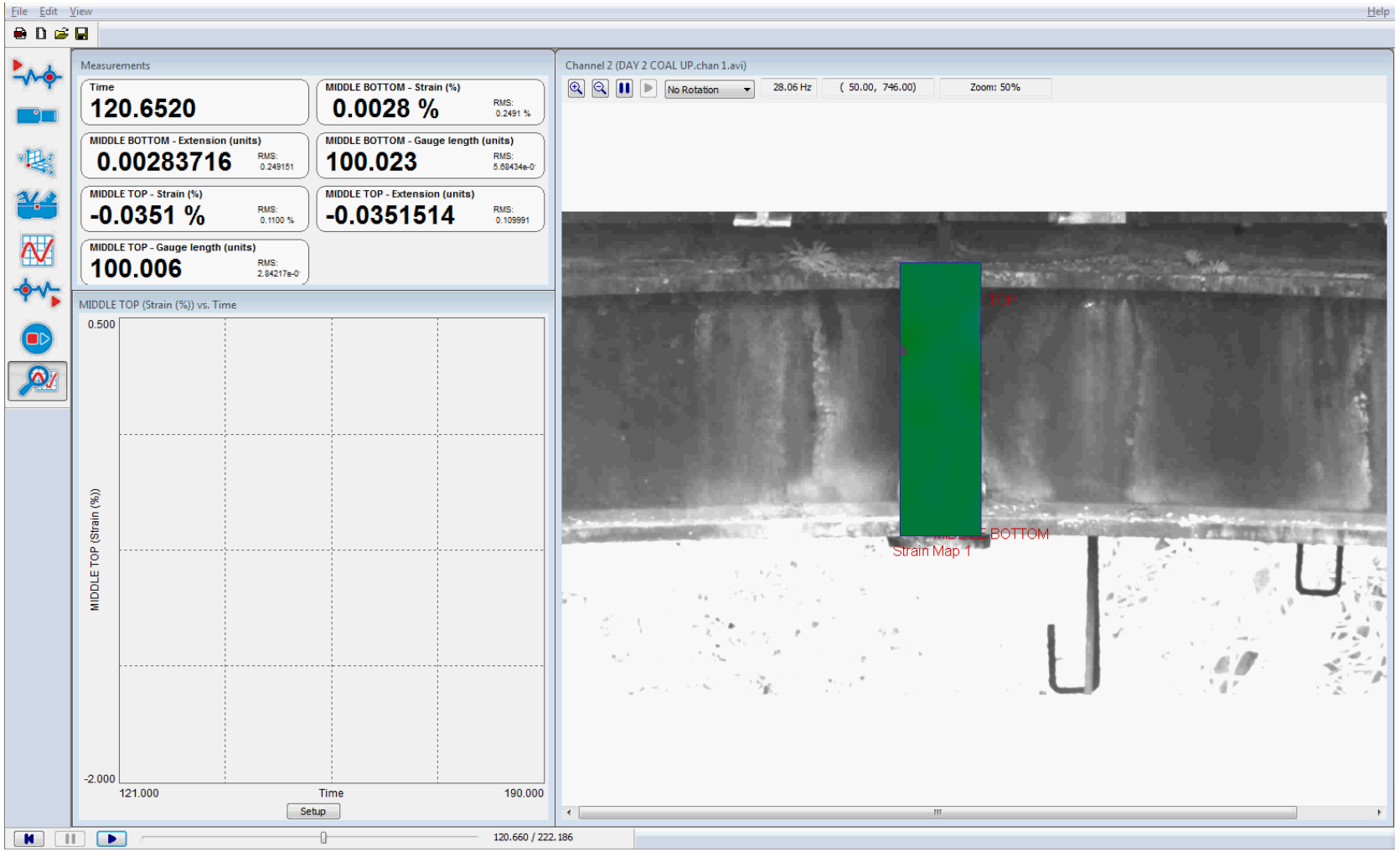

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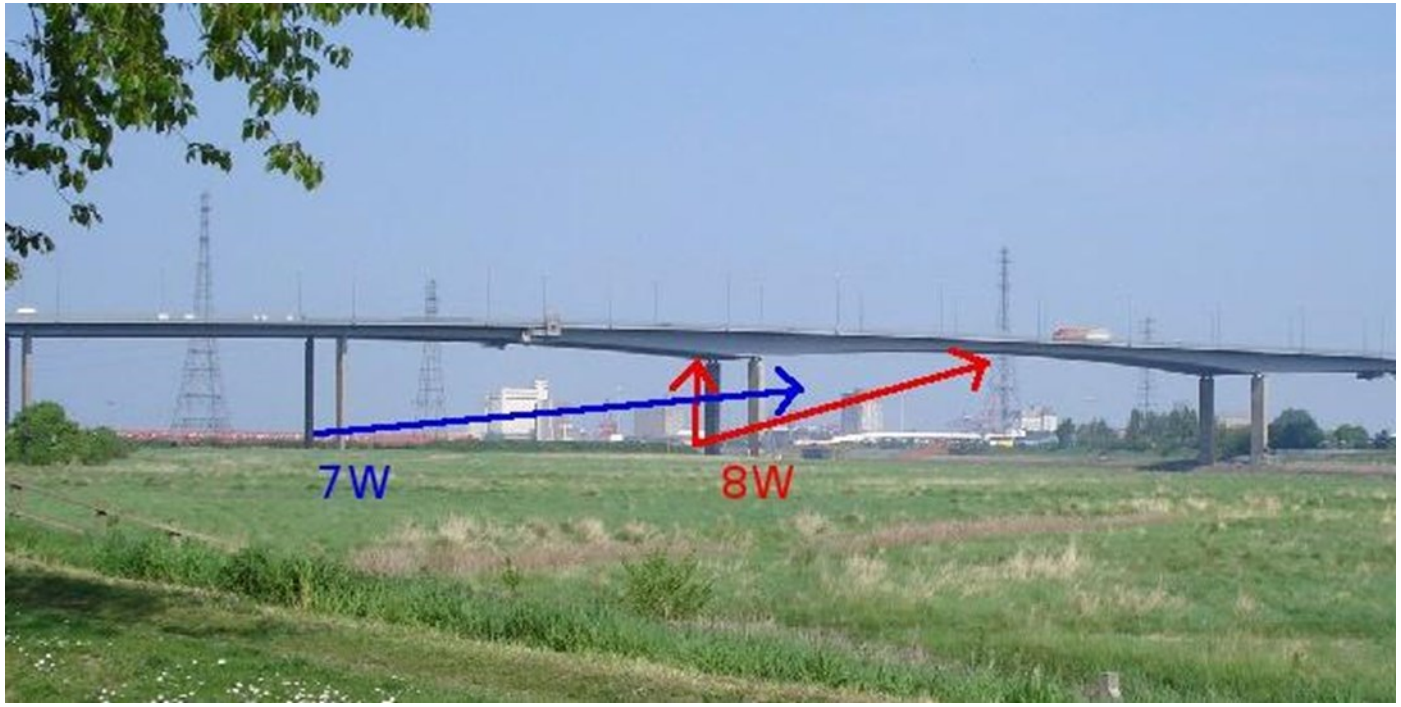
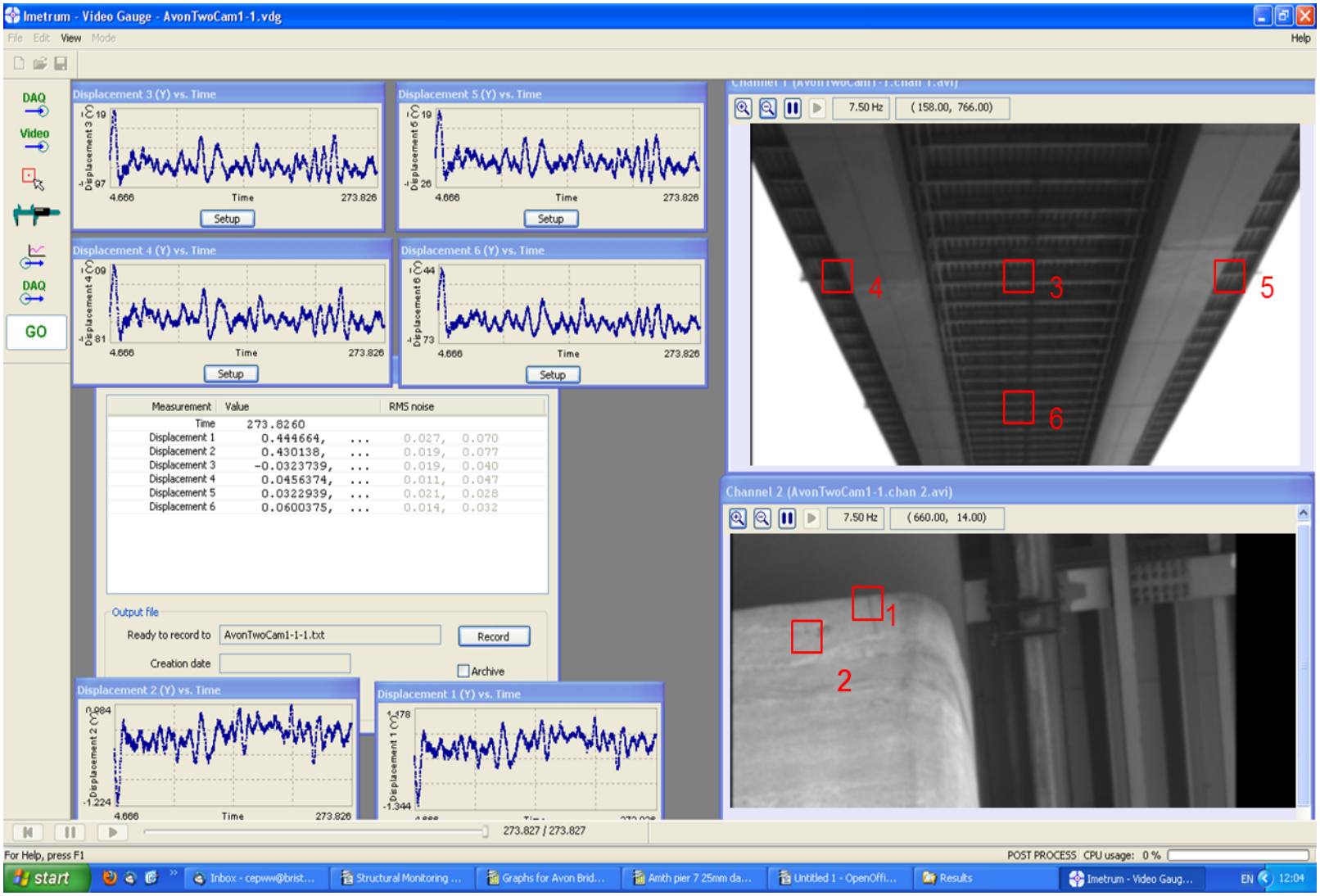
Road Bridges

- Used for Dynamic Testing under normal traffic conditions, and also specific Load Testing.
- Access costs minimised, and resolution increased over other non-contact techniques.



Road Bridge Screen Shot



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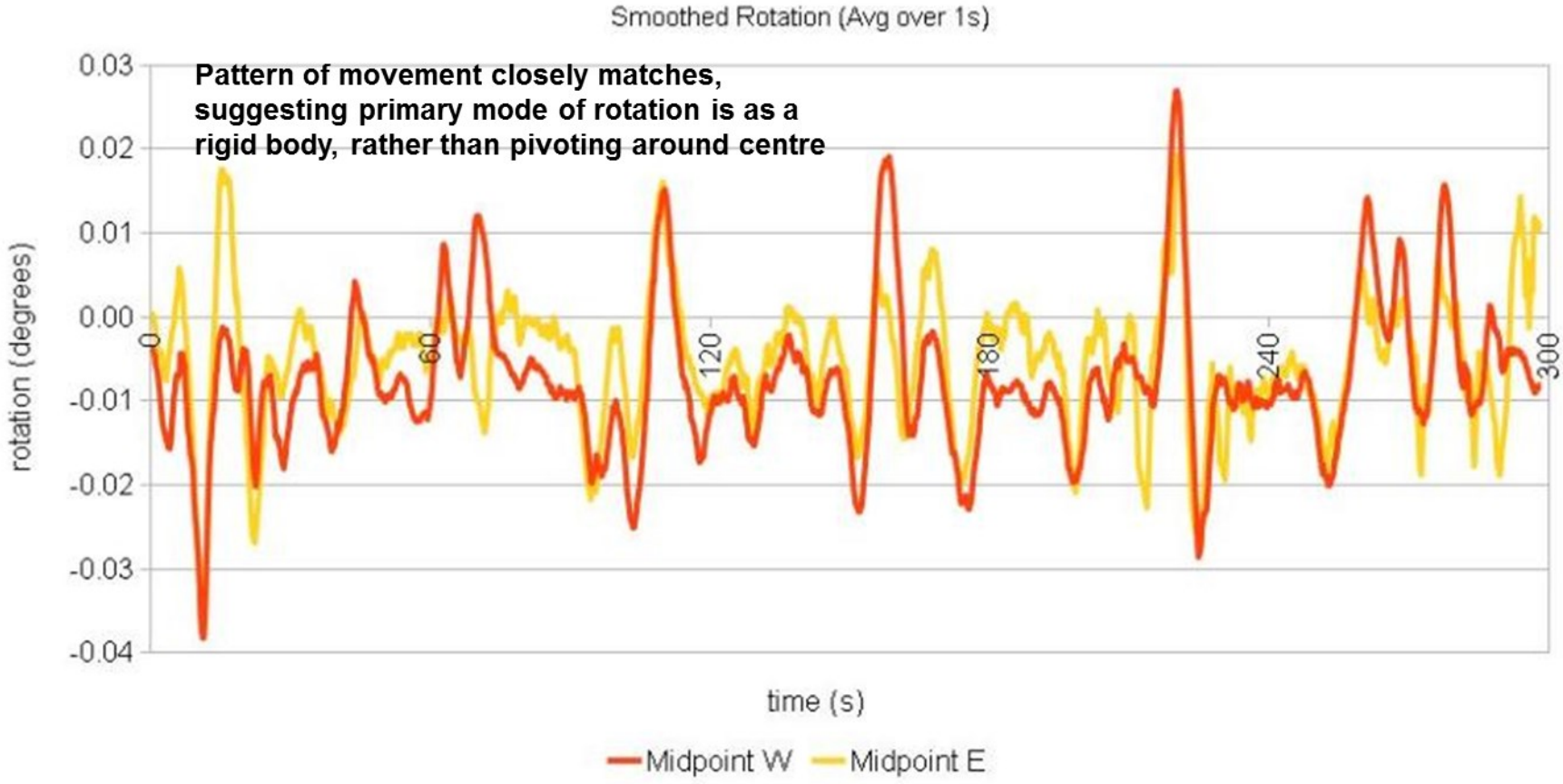
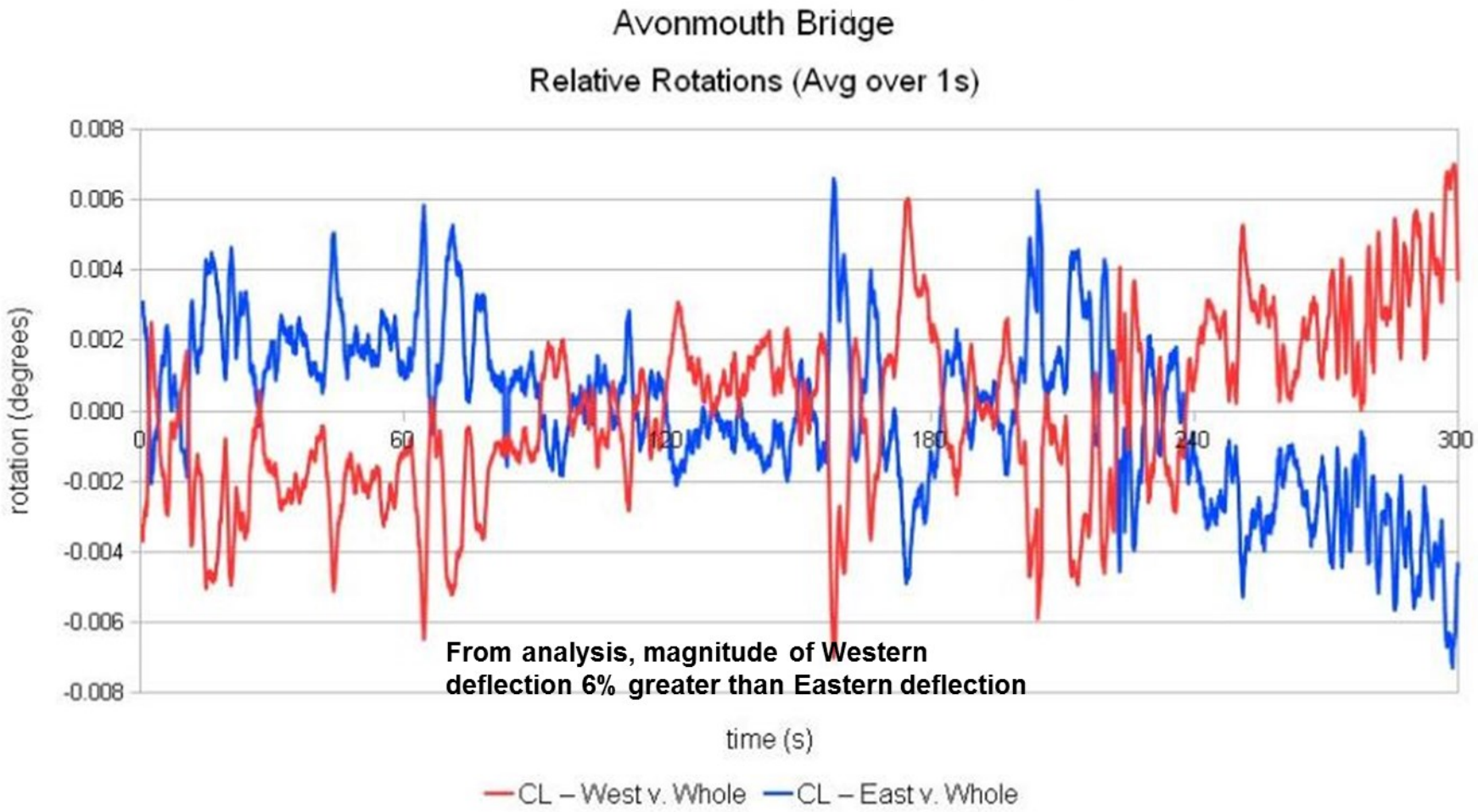
Rotation Data



Rotation Data



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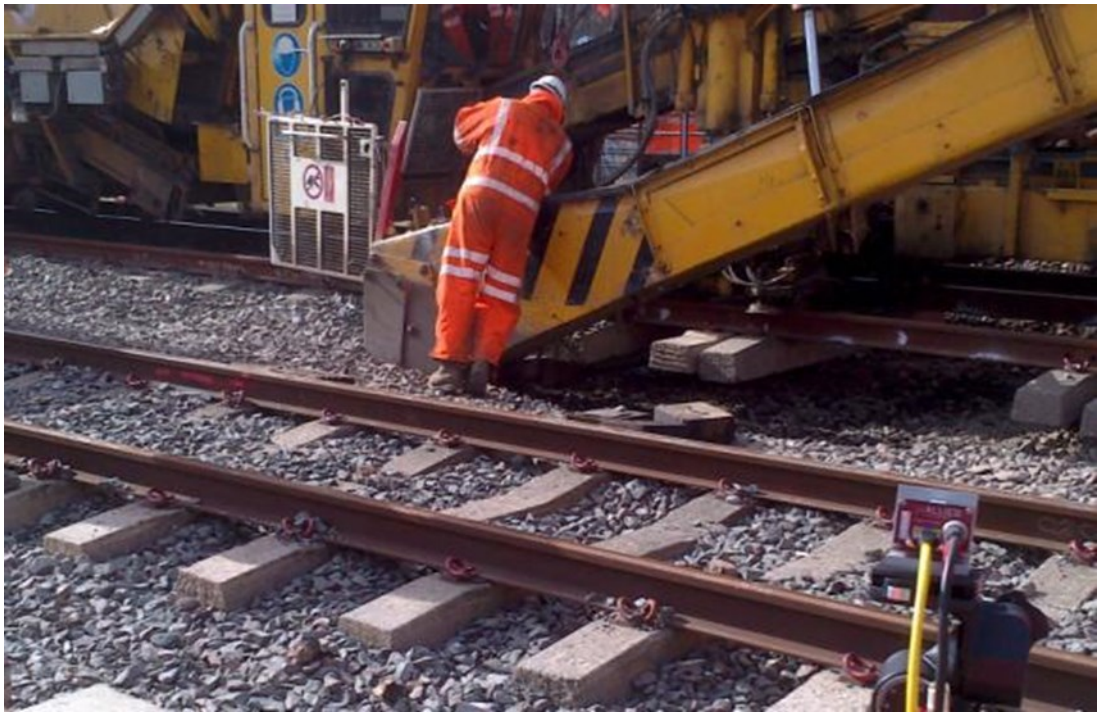
Technology Summary

- Imetrum have developed & patented specialist software that measures movement in structures highly accurately in real time.
- The system is a point to point and full-field optical measurement system - we use pattern recognition technology and sub pixel interpretation of video images – ie non-contact.
- Benchmarked by NPL (National Physical Laboratory), Strainstall & Airbus.
- UKAS Calibration to BS/EN/ISO 9513, class 0.5 and ASTM (E83) calibration to class B-2.
- Resolution and frame rate are camera and setup dependent. Reliably 0.1mm resolution for a 10m FoV.
- The main setup challenges: Camera movement, pattern quality, weather.
- Usually 10 – 100Hz, but up to 1kHz possible real time.
- Videos & data can be stored for analysis later, or processed in real time.
- Multi-camera systems enable detailed understanding of structural movement.

Conclusions

- A flexible system, offering potential for time & cost savings.
- Turn up and measure solution for a wide range of structures.
- Potential for extremely high resolution.
- What could you use it for?

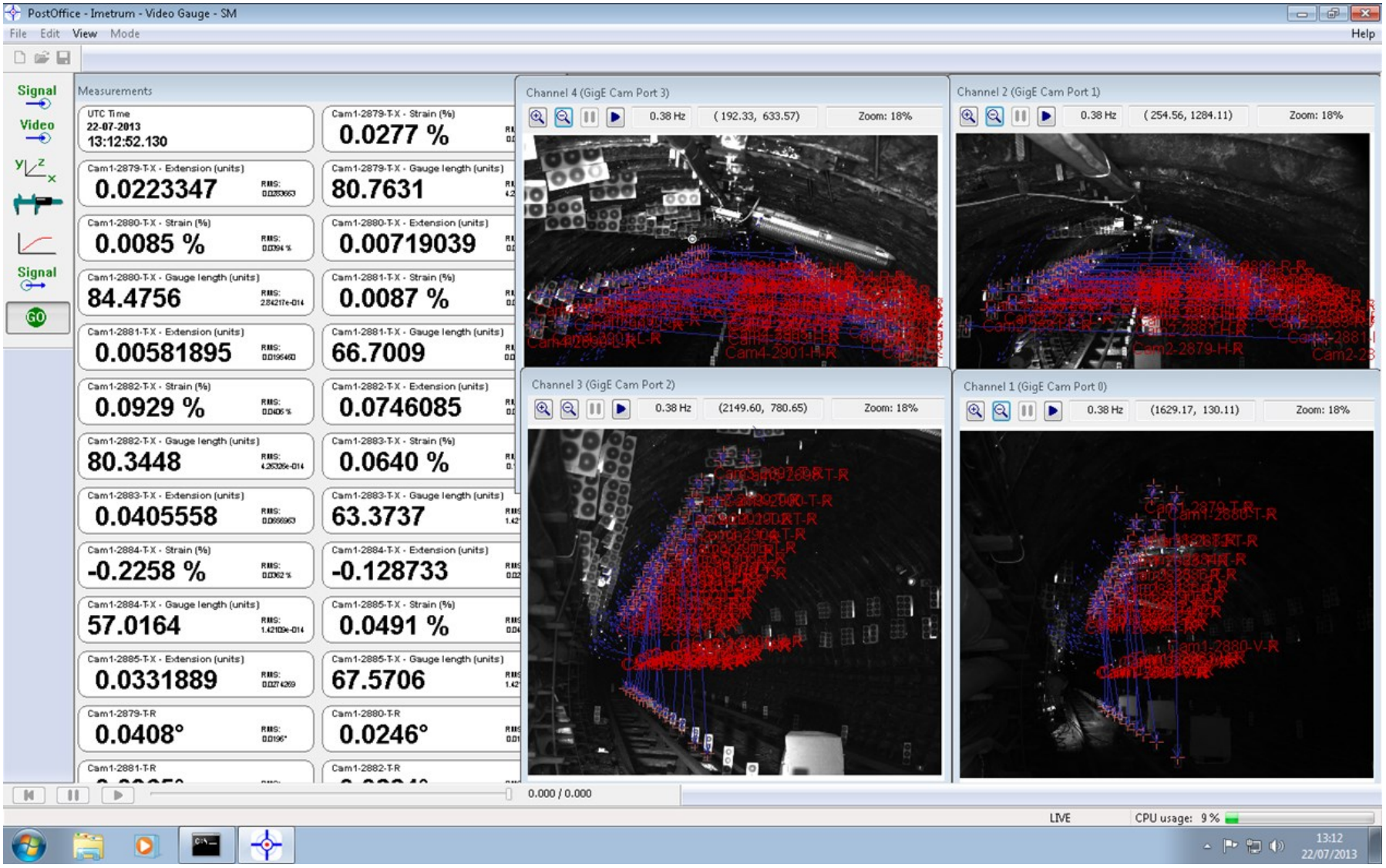


Tunnel Monitoring

- Convergence & Ring Separation.
- Track Monitoring within tunnels.
- Demonstration project with Crossrail / CSIC.
- 250 measurement points, with 4 cameras.

- Infra-Red lighting used, so no obvious visible clue of monitoring ongoing, and no negative impact of work lights.
- Measurement resolutions of 0.1mm or better (unfiltered).
- Remote access to equipment, and live reporting of results.

Tunnel Monitoring



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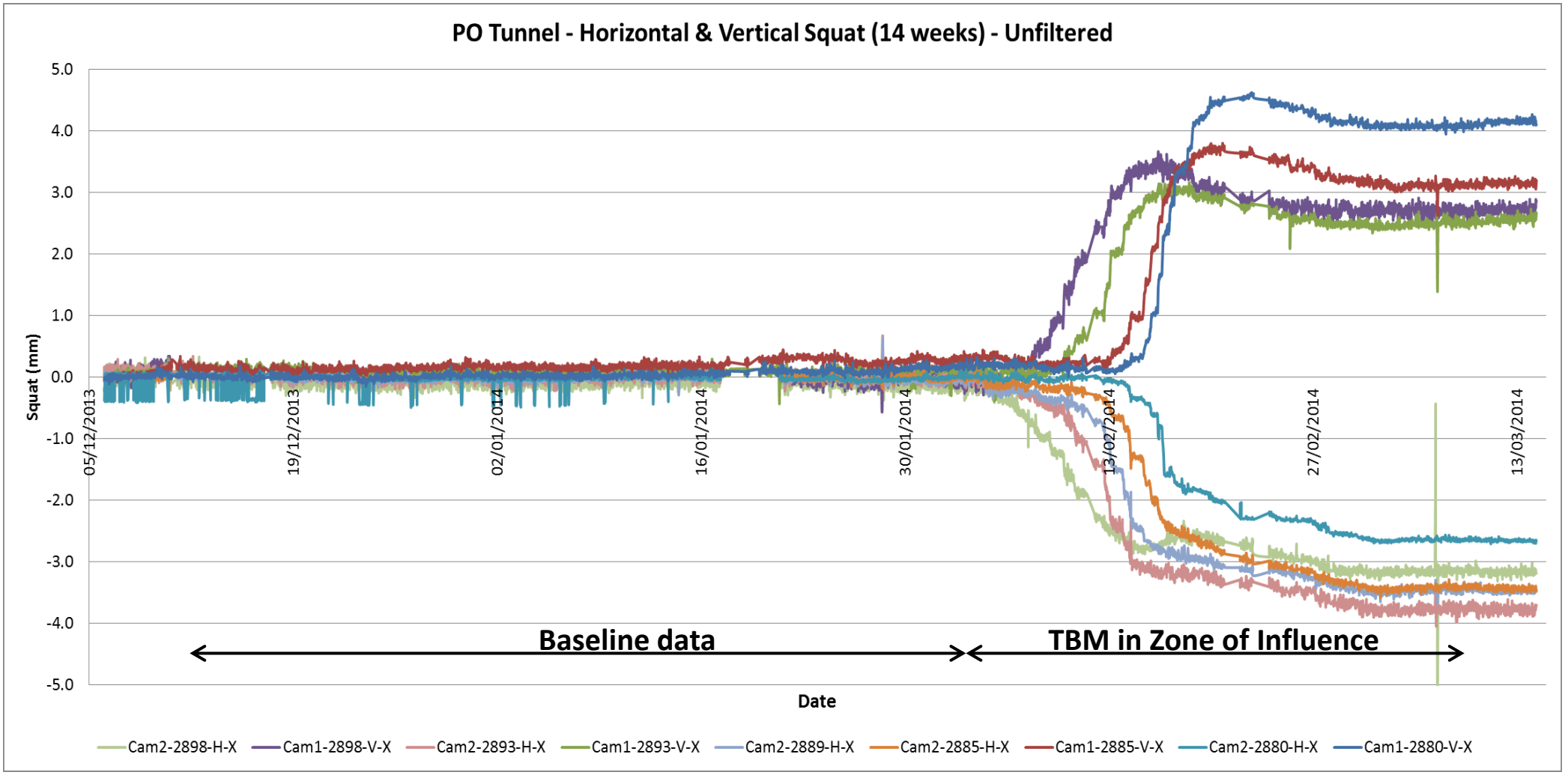
Extensions Over Three Months



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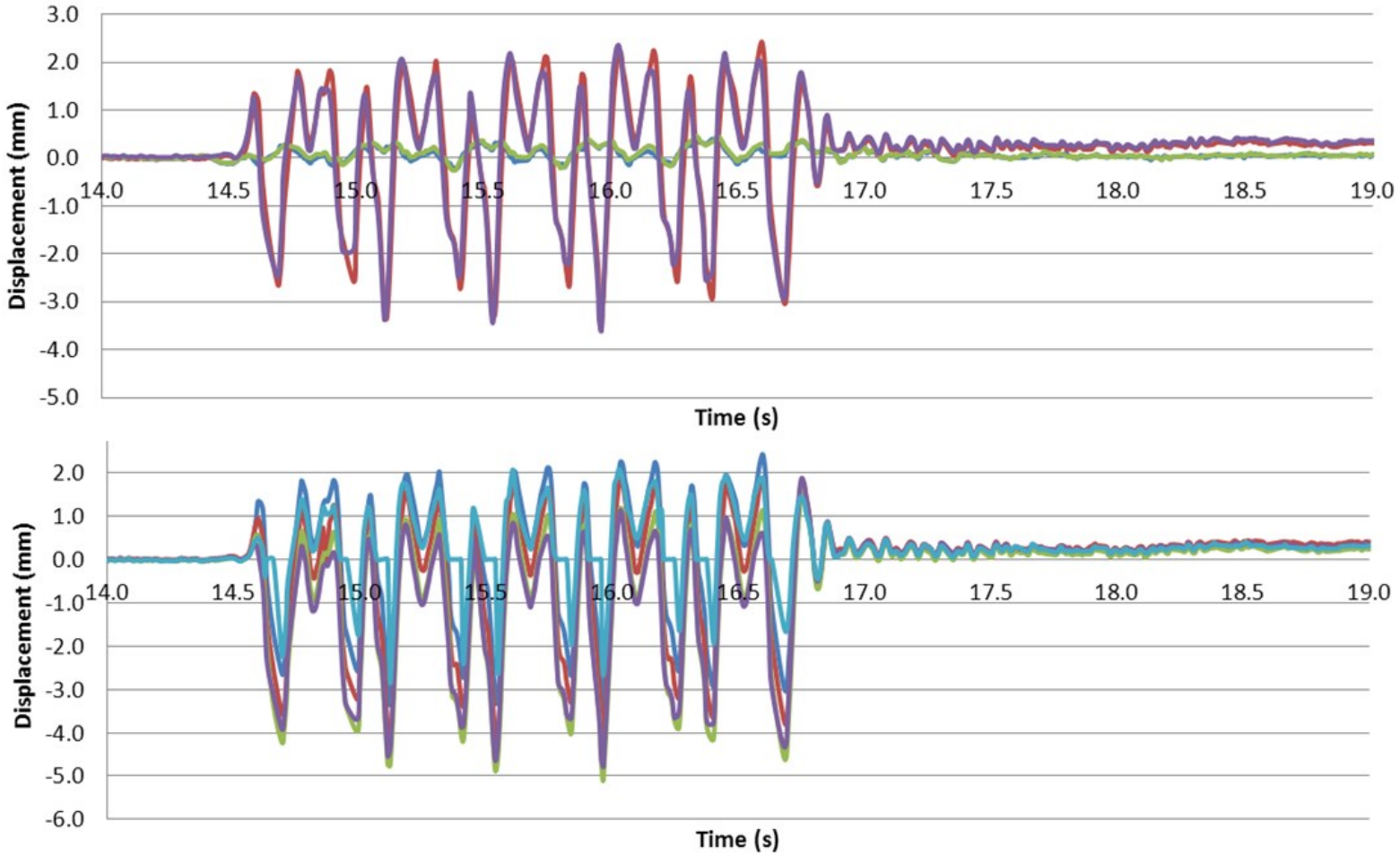
Case Study – Track Deflection

- Dynamic deflection monitoring of track, sleepers & ballast.
- Information on ground movement, track displacement / bending, gauge separation.
- Measurements taken at distance, under train loading.

- Set up between 3 – 60m from track. Camera measuring at up to 300Hz. Up to 30m track visible with 1 camera.
- Targets spray-painted to track where not enough natural pattern. Ballast & clips usually do not need paint.

Rail, Sleeper & Ballast Movement - WCML



- Dynamic response of various parts of the track bed identifiable.
- Vertical and Longitudinal displacement.
- Resolution much better than 0.1mm.

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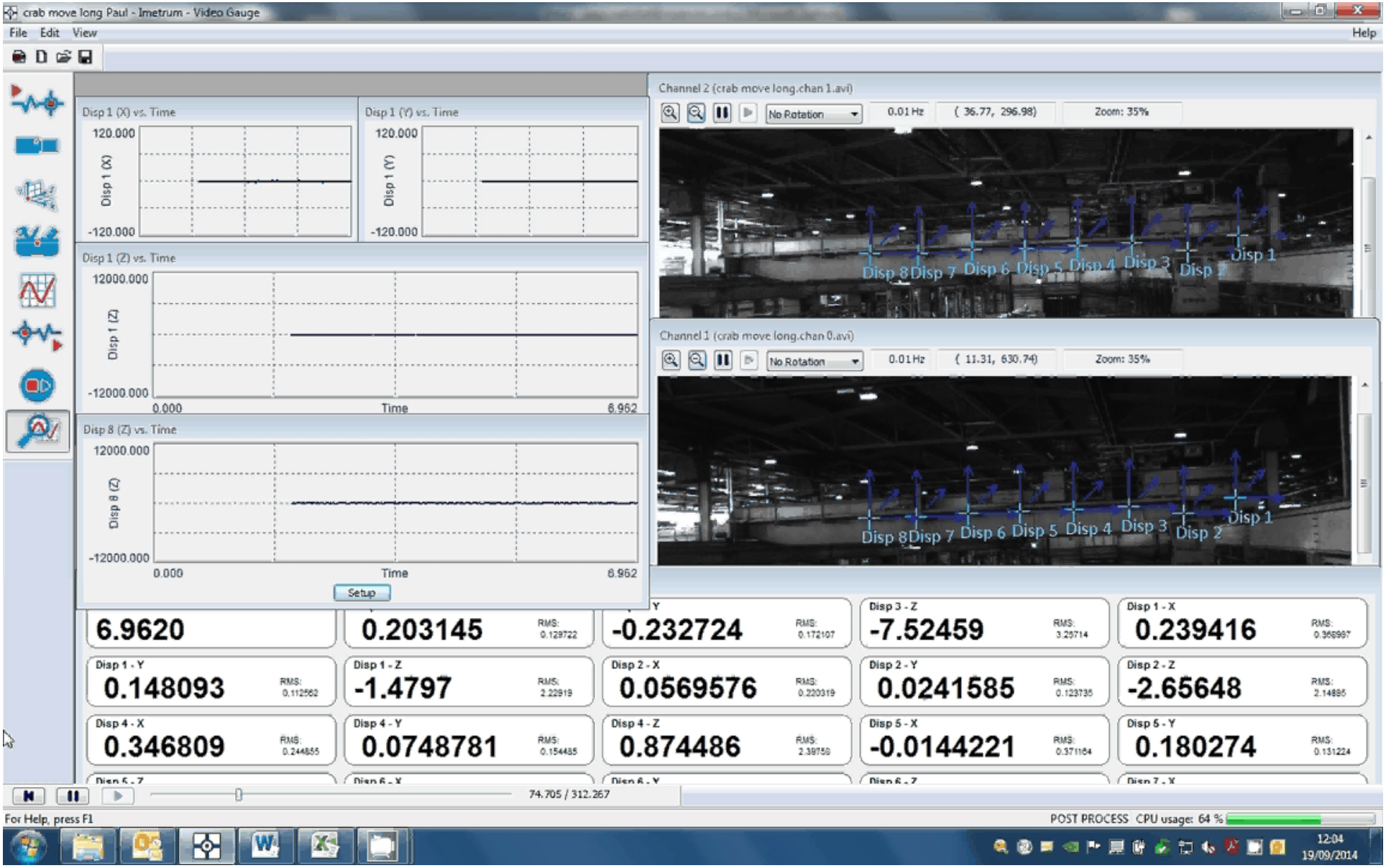
Case Study – Factory Crane 3D Deflection



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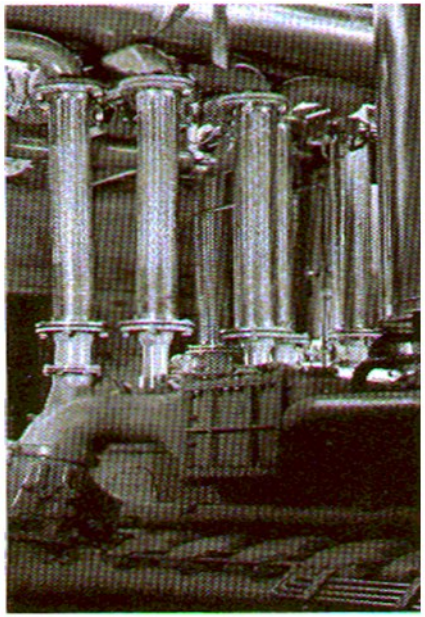
Vibration Analysis



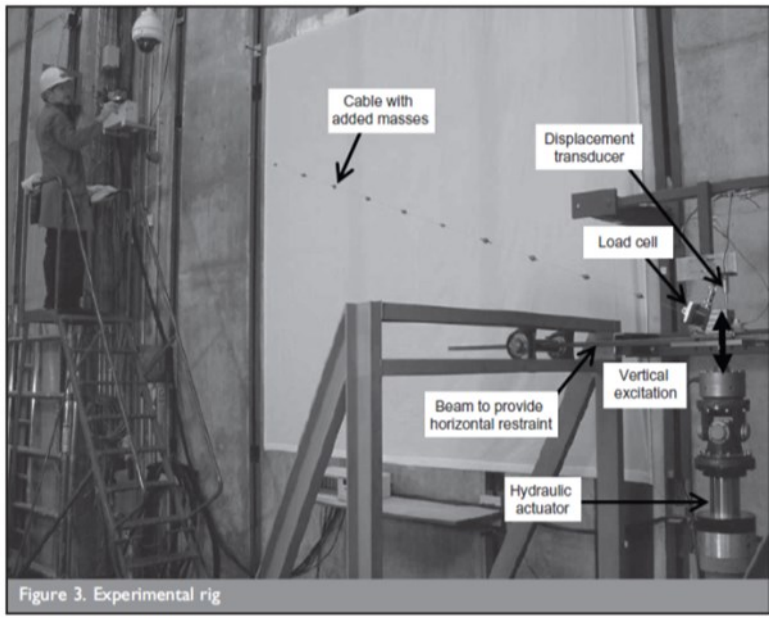


Figure 3. Experimental rig

- One of the most common research applications for Imetrum system within Civil Engineering.
- Suspension Cables and Conductors.
- Hard to access pipework.
- Vibrating machinery and components