Deformation Monitoring of the Flinders Street Station Administration Building

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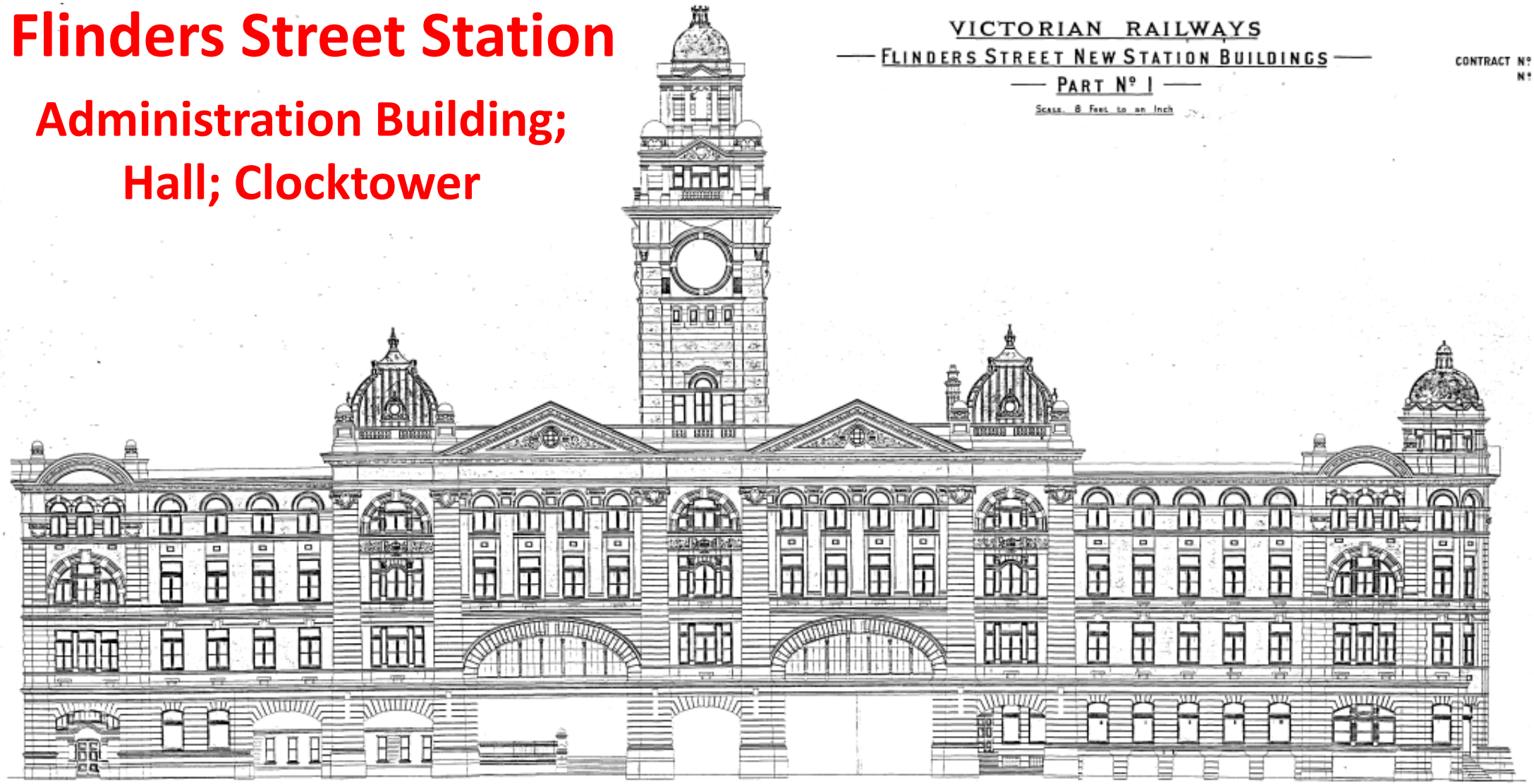
- **Background**
- Overview Tilt-sensor Measurements
- Analysis Methodology/Results
- Overview Photogrammetry Measurements
- Analysis Methodology/Results
- Concluding Remarks
- Questions

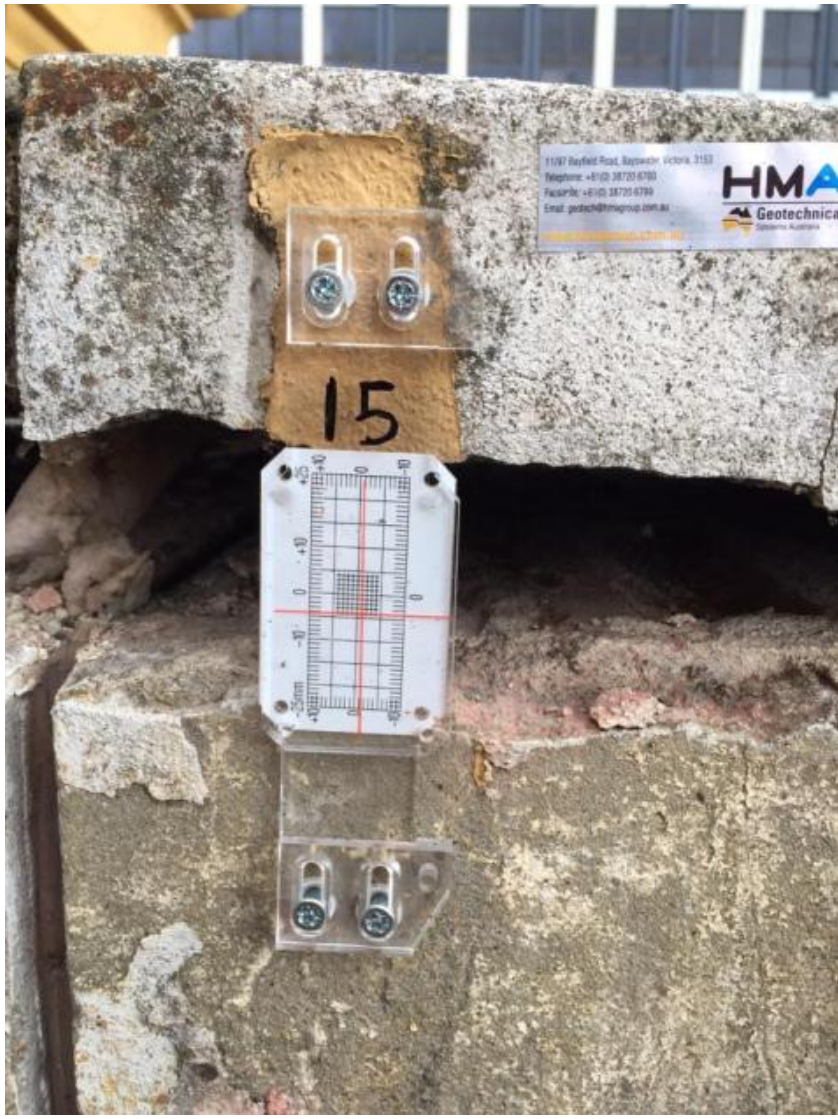
Flinders Street Station

Administration Building; Hall; Clocktower



Anecdotal “evidence” that building Façade has been moving Northwards i.e. towards Swanson Street.

Major Projects Victoria (MPV) engaged several consultants to investigate movement in features of the building: cracks, a Corbel, the façade

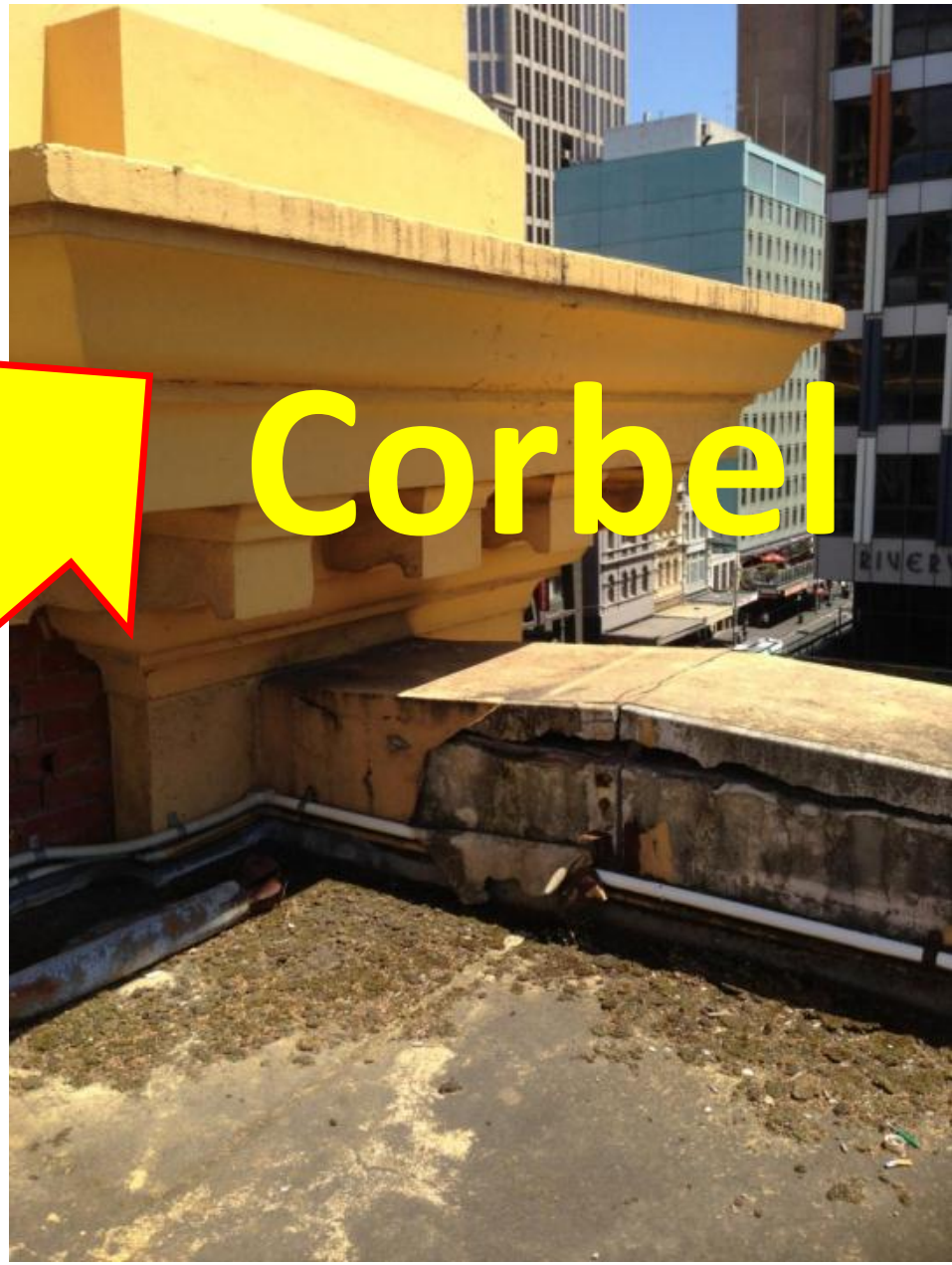


Crack opening/closing using electronic Demec gauges (on-the-spot readings) performed by others.

Cracking in Gymnasium on top of Admin. Building suggesting possible net outwards movement
Corbel on outside wall

Corbel on outside wall

Windows of
Gymnasium
on top of
Admin.
Building


Corbel

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GCDC X2-1 accelerometer in Water-Resistant enclosure bolted onto a plate adhered to Corbel.

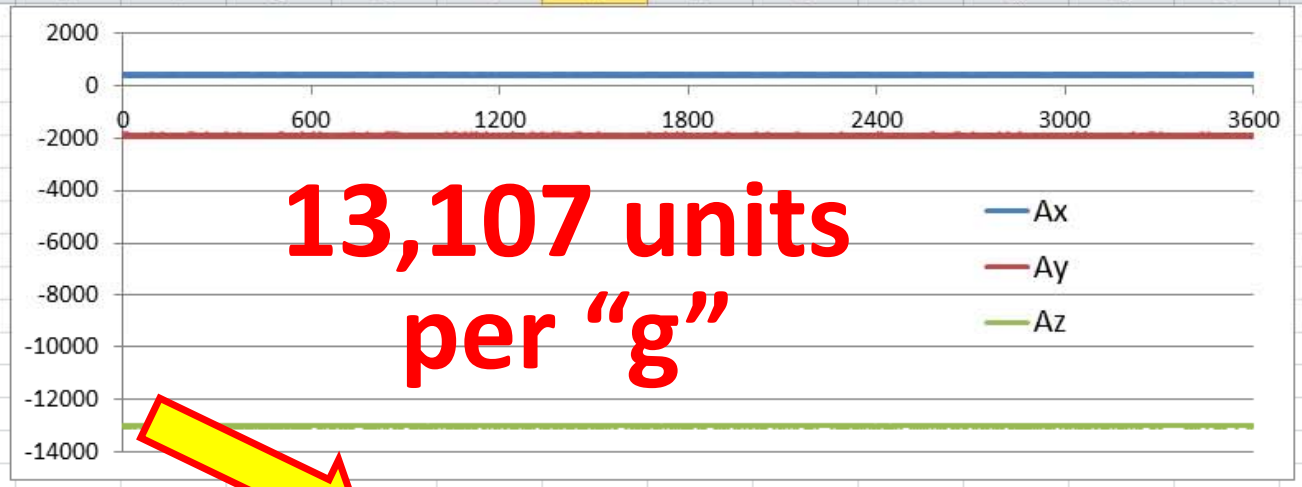
GCDC X2-1 accelerometer in Water-Resistant Enclosure can log data continuously for over one month (over 30 days). Precaution: enclose in zip-bag and bolt onto a plate adhered to Corbel.

Pair of GCDC X2-1 accelero-meters ~1/2 way up clock-tower inundated, destroyed by rain

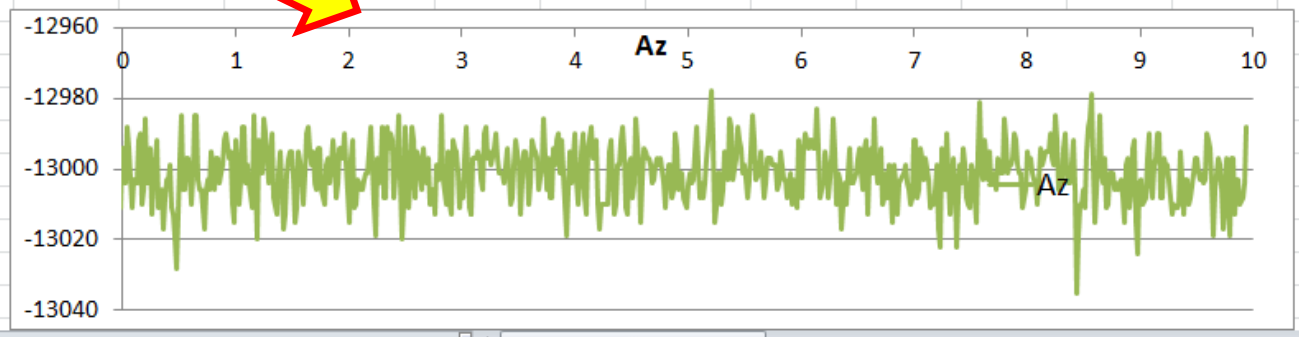
DATA-PLT-070.xlsx - Microsoft Excel

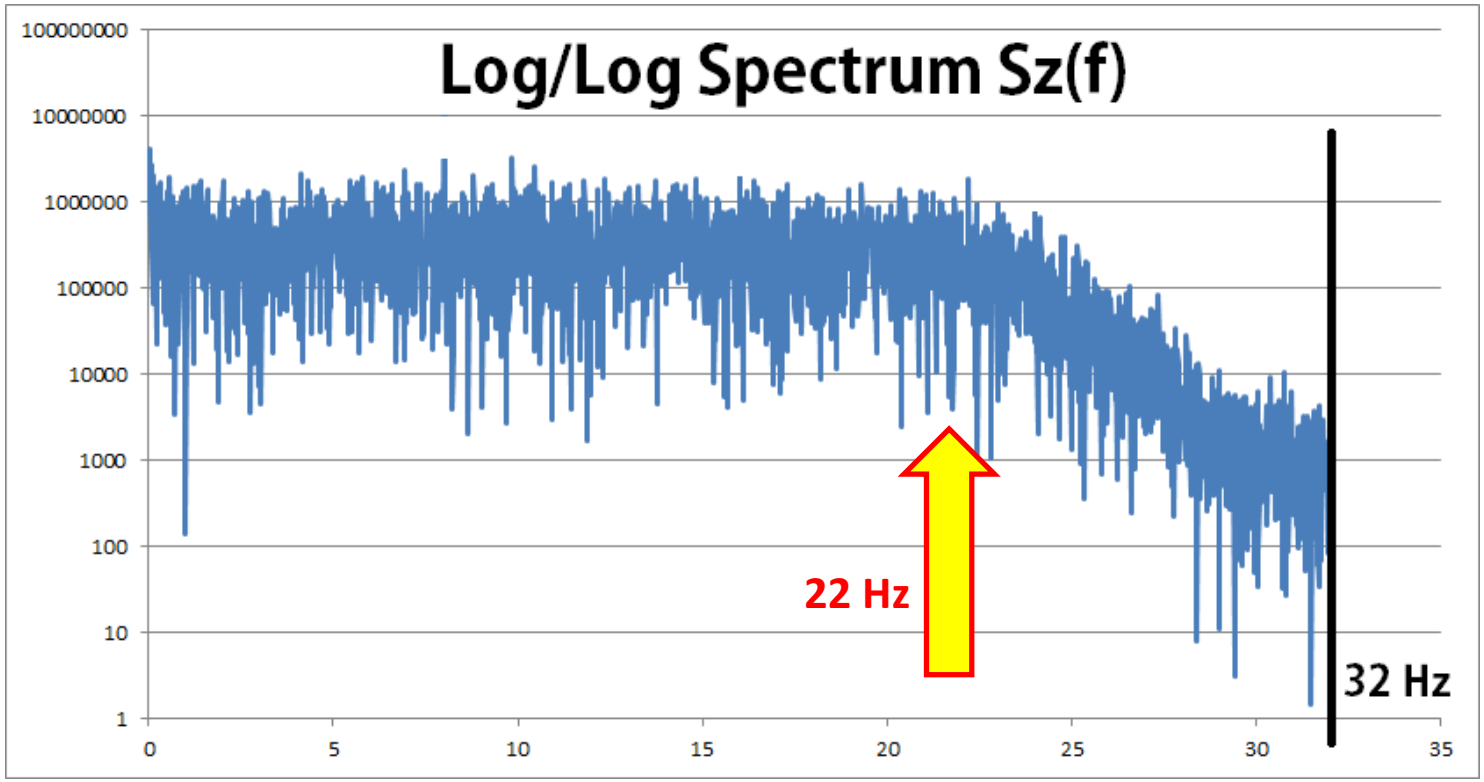
;Title	http://wv	x2-1	Kionix KXRB5-2050	
;Version	917	Build date	Oct 17 20:	SN:CCDC100213175C9
;Start_time	2015-02-1	05:08:20.000		
Temperature	14	deg C	Vbat	2534 mv
;Gain	high			
;SampleRate	64	Hz		
;Deadband	0	counts		
;DeadbandTimeout	0	sec		
time	Ax	Ay	Az	
-0.050995	408	-1922	-12994	
-0.03537	401	-1898	-13003	
-0.019745	401	-1882	-13011	
-0.00412	412	-1904	-12994	
0.011505	421	-1911	-12994	
0.02713	419	-1913	-13004	
0.042755	408	-1922	-12988	
0.05838	399	-1915	-12994	
0.074005	403	-1898	-13011	
0.08963	399	-1895	-13003	
0.105255	398	-1891	-13003	
0.12088	416	-1866	-13004	
0.136505	412	-1857	-12992	
0.15213	396	-1891	-12990	
0.167755	405	-1900	-13010	
0.18338	414	-1902	-13006	

64 Hz sampling rate
3600 s long files
(1 hr files)
24 files /day
Up to 40 days continuous sampling



13,107 units per "g"





Spectrum of acceleration measurements from background excitation "noisy" to ~22Hz with no significant resonances

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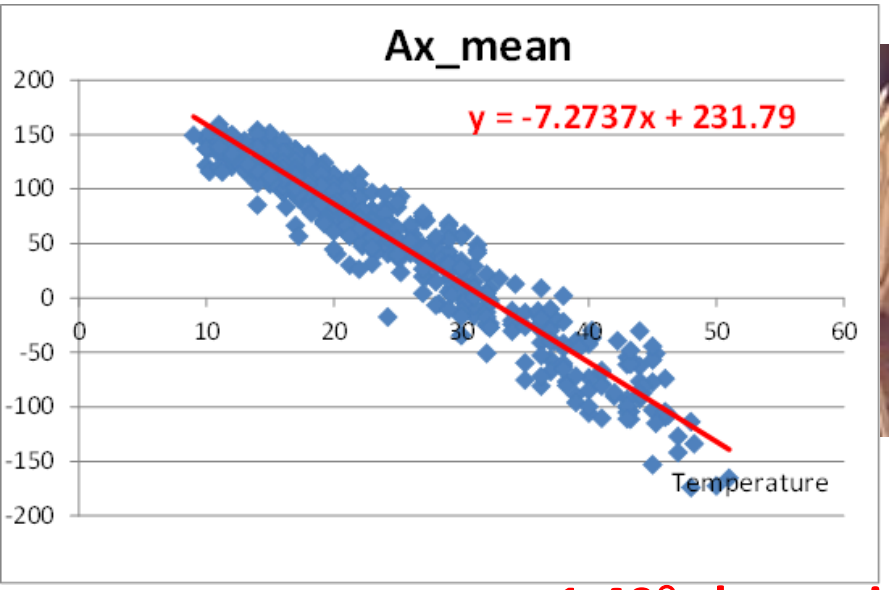
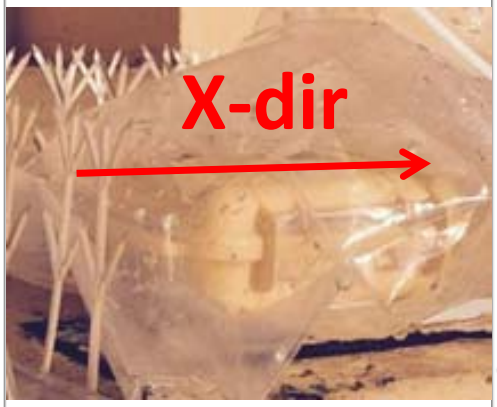
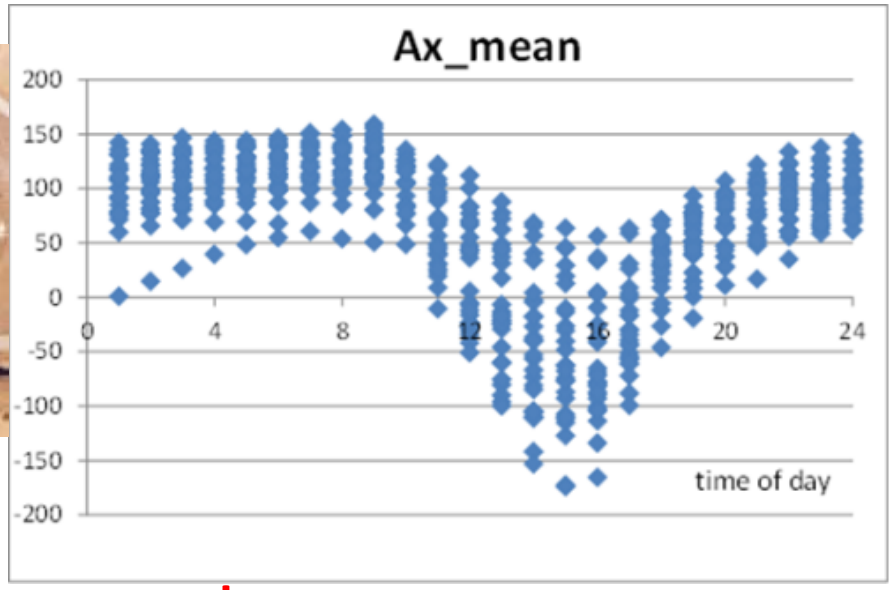
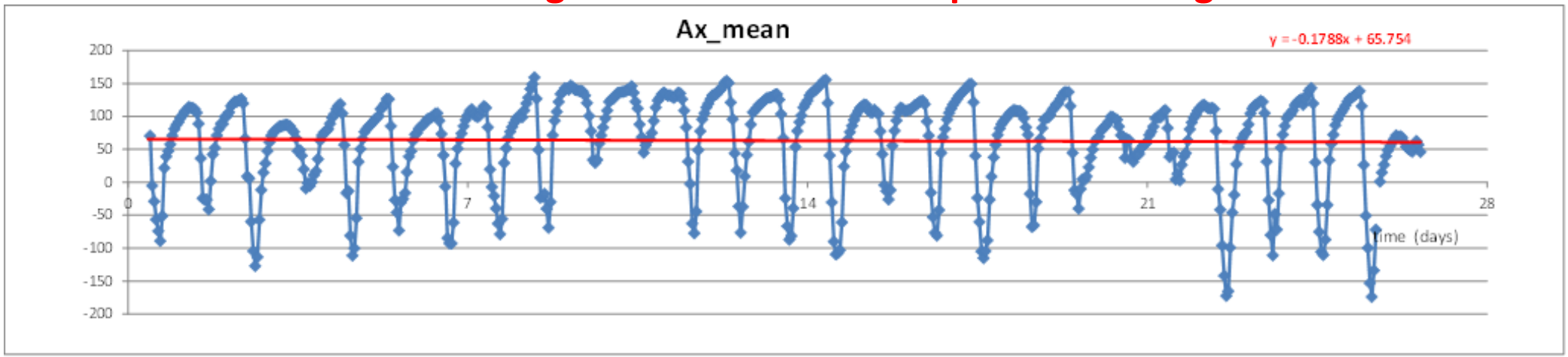


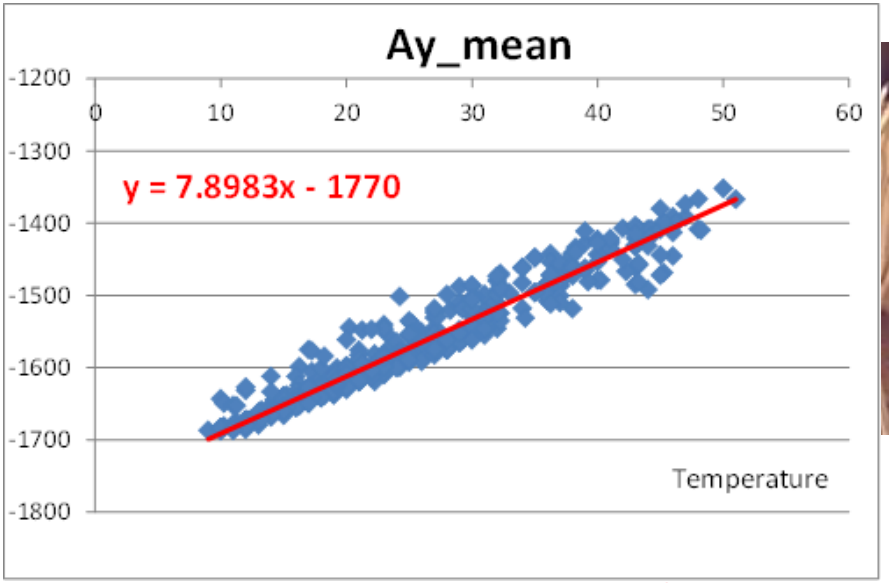


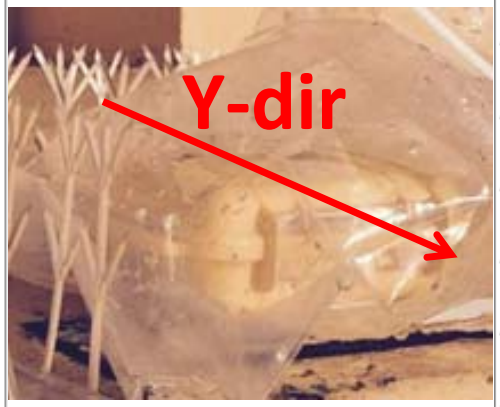


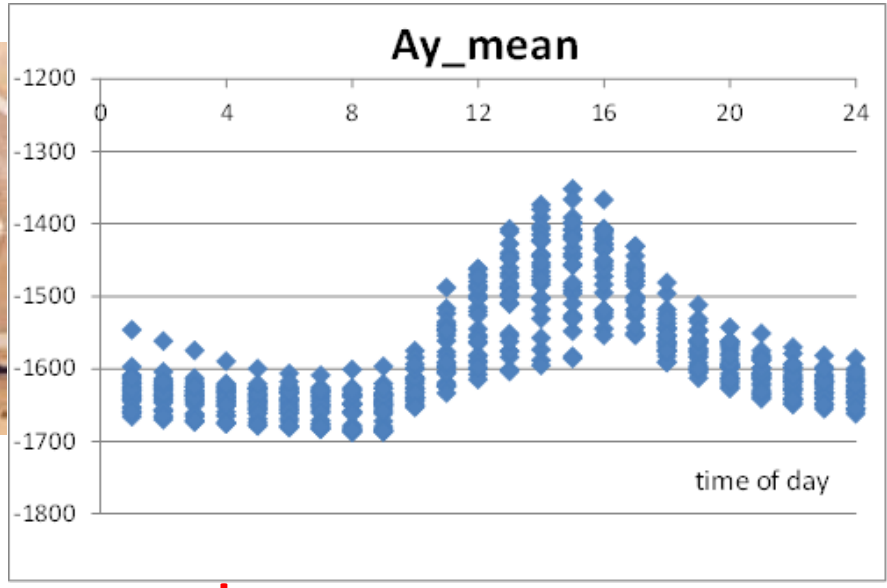
1.40° change in tilt for a 40°C temperature change



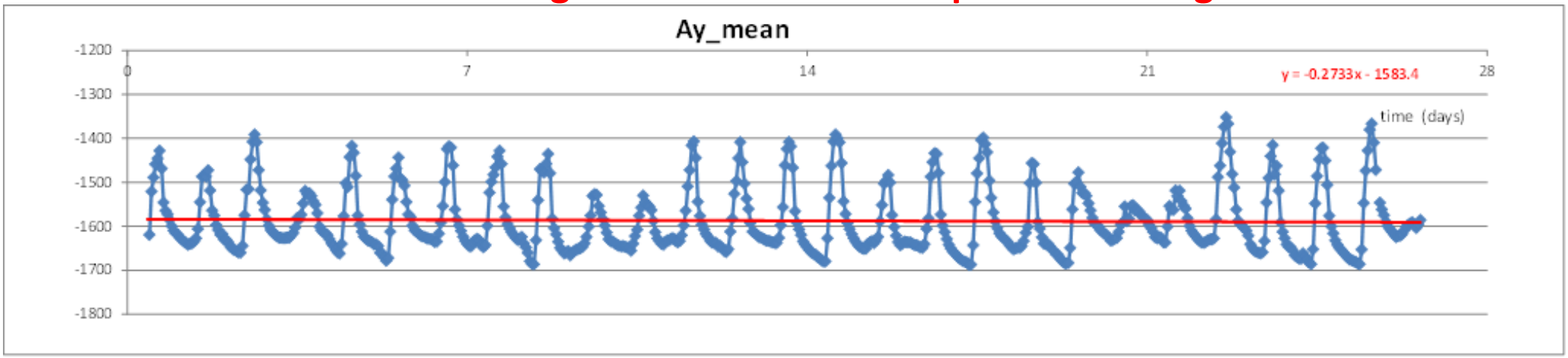
Mean hourly "X-acceleration" vs Temperature is highly correlated and varies with time of day more or less with Temperature for that time. Over ~1 month no net change in $Tilt_x$



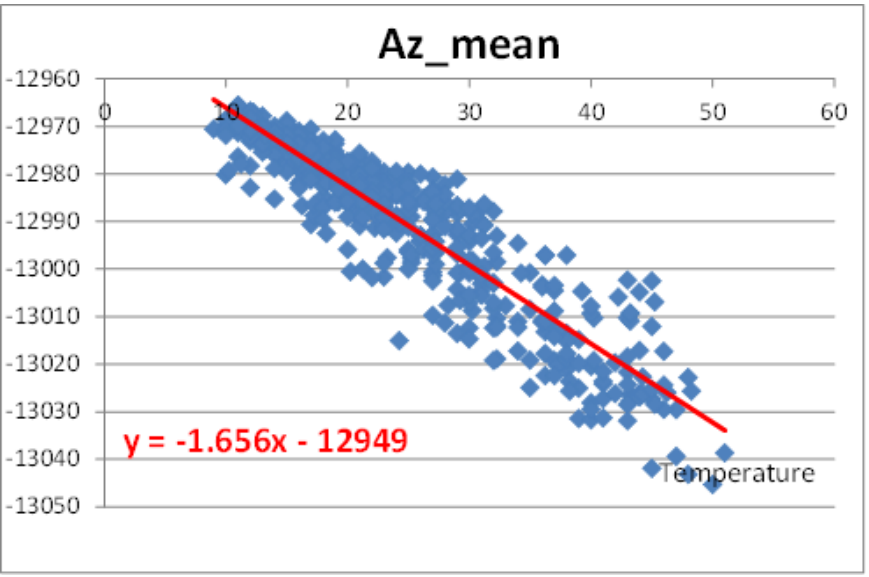


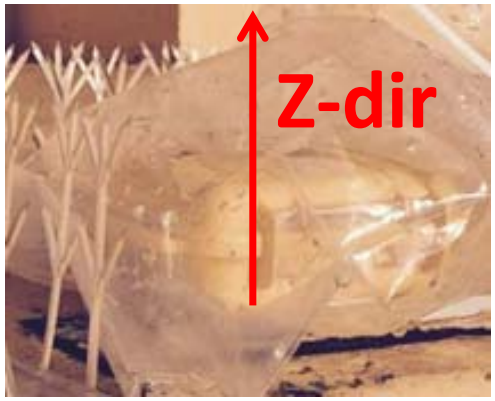


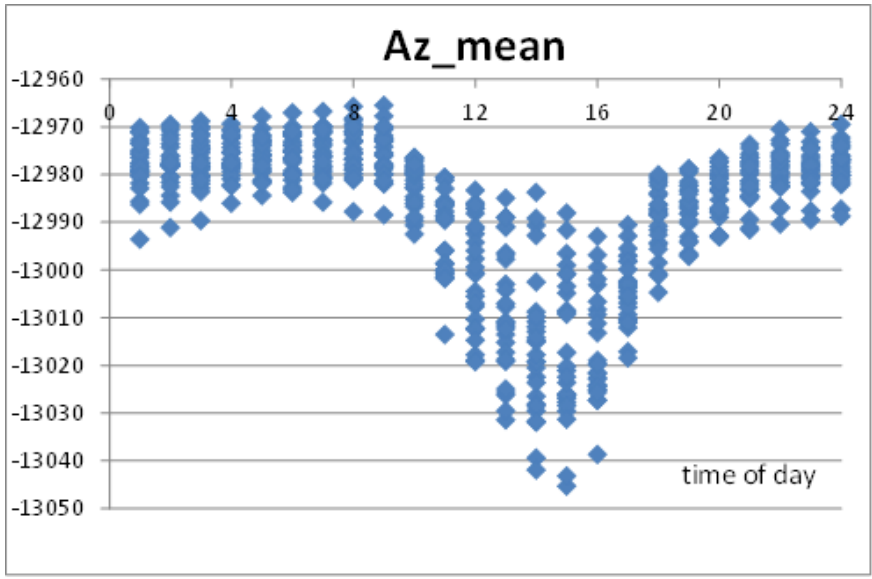
1.03° change in tilt for a 40°C temperature change



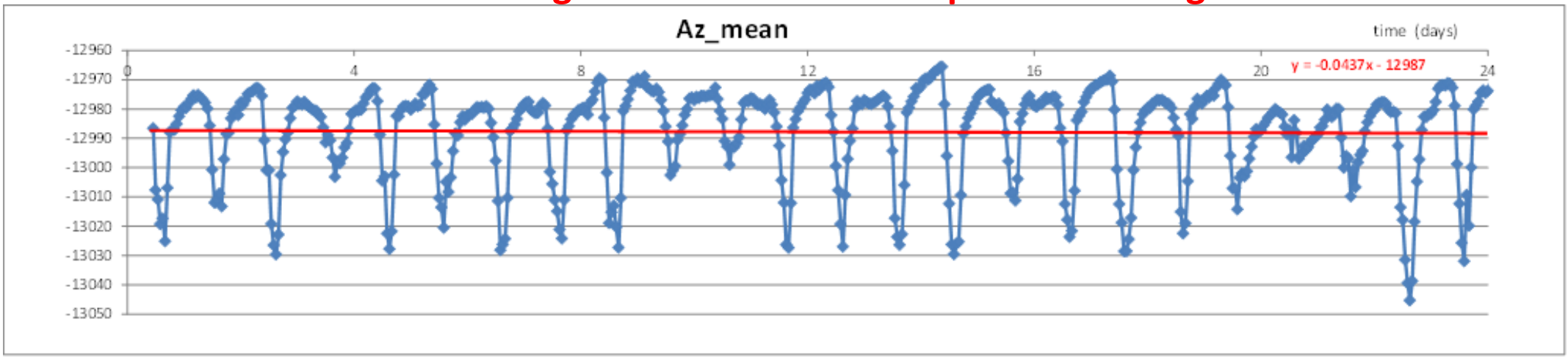
Mean hourly "Y-acceleration" vs Temperature is highly correlated and varies with time of day more or less with Temperature for that time. Over ~1 month no net change in $Tilt_y$



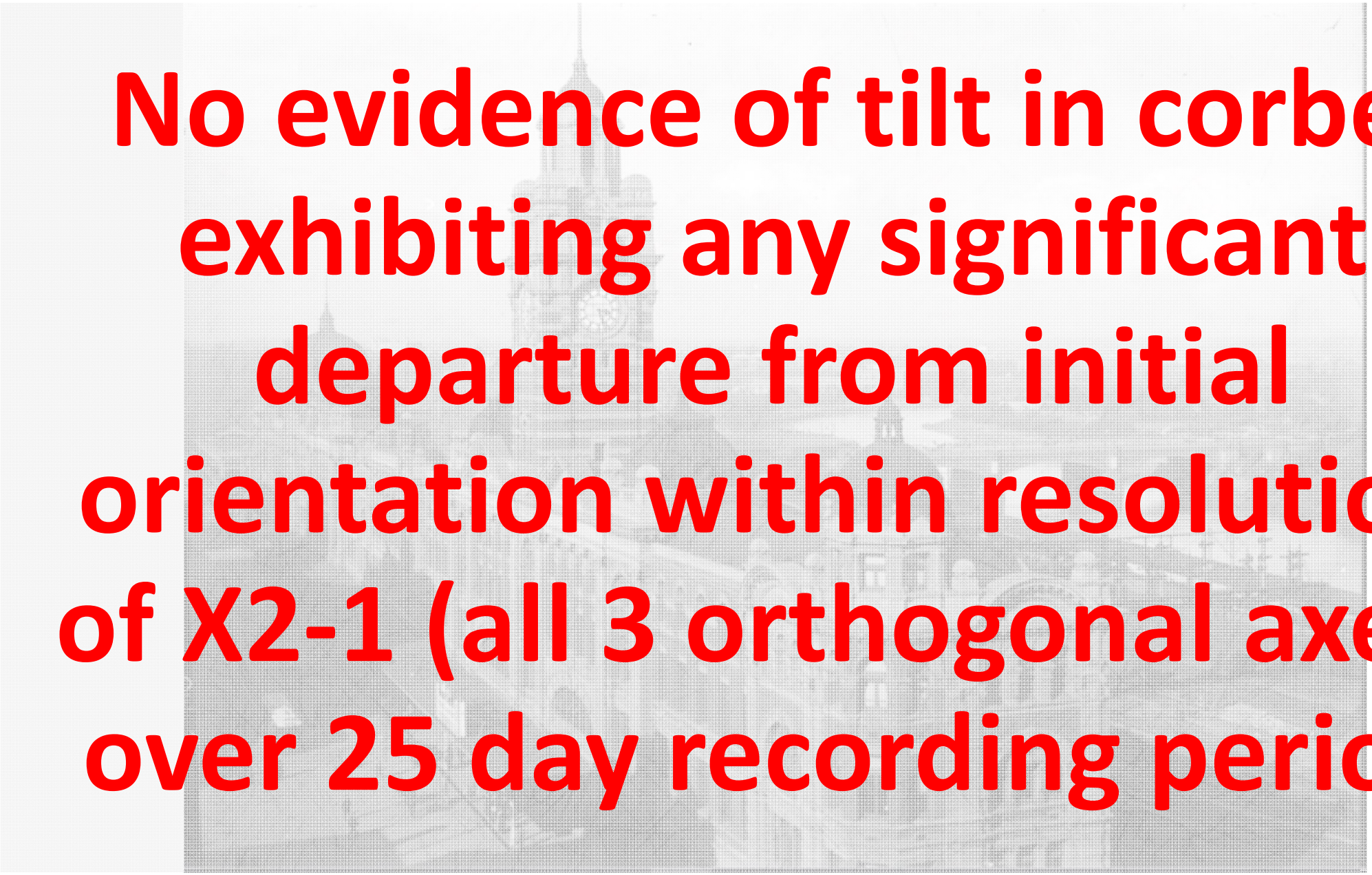




2.19° change in tilt for a 40°C temperature change



Mean hourly "Z-acceleration" vs Temperature is highly correlated and varies with time of day more or less with Temperature for that time. Over ~1 month no net change in $Tilt_z$



No evidence of tilt in corbel exhibiting any significant departure from initial orientation within resolution of X2-1 (all 3 orthogonal axes) over 25 day recording period

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- **Overview Photogrammetry Measurements → Danny Brizzi**
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Deformation Monitoring of the Flinders Street Station Administration Building

Danny Brizzi
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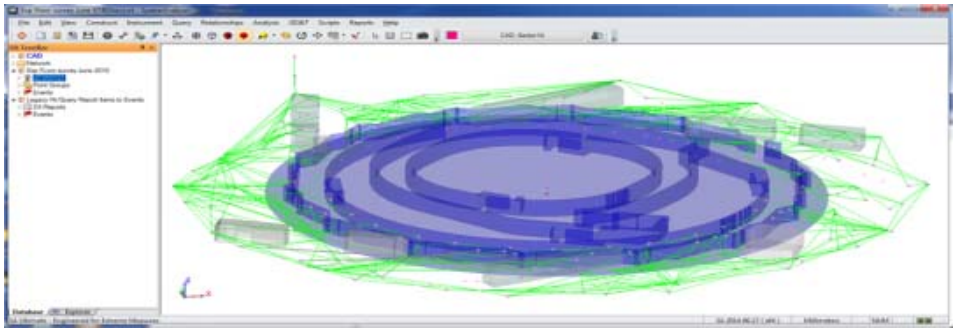
About the Dimensional Metrology Services

- 3D Metrology Services Company based in Melbourne
- Very Unique blend of measuring equipment including:
  - 3D Laser Trackers
  - Leica TS30 Total Station
  - V-STARS Photogrammetry System
  - Precision Optical Levelling
- All tied to together using SpatialAnalyzer Ultimate Software
- Capable of 3D Accuracy of 0.025mm over a 10m Volume.

About the Dimensional Metrology Services



Deformation Monitoring

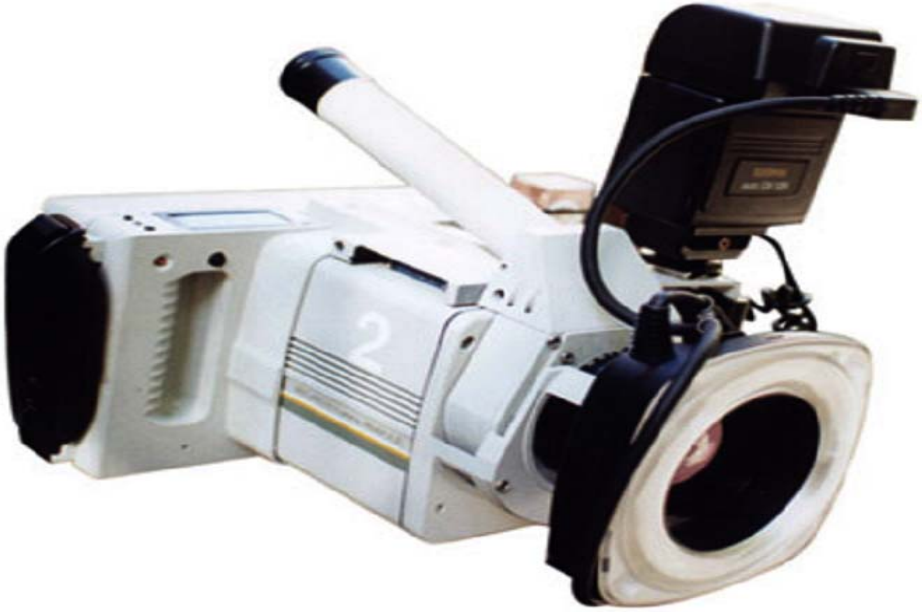
- Concern
  - Some cracking was occurring in the façade
  - Needed to determine if the cracks were localised or due to larger structural problems
  - A large section of the façade needed to be accurately monitored for deformation over a 1 year period.

Survey Parameters

- Accuracy Requirement – better than 0.5mm (3D magnitude) and 0.3mm in any one axis.
- 30+ points covering a 60mx35m area
- Dimensional Control Targets
  - Points independent from the façade
- Façade to be measure once every month
- Compare every survey to the first survey

Possible Survey Methods

- Photogrammetry – Photo Based 3D Measurement
  - Accuracy **YES** 0.1mm
  - Affordable Targeting **YES** $5.0 per target
  - Image Geometry **NO**
    - Need to take a set of photographs on a parallel plane relative to the façade.
    - Would require for each survey:
      - Large Cherry Picker
      - Block off Flinders Street



Possible Survey Methods

- 3D Laser Trackers
  - Accuracy **YES** 0.1mm
  - Geometry **YES**
    - Could measure entire façade in on setup
  - Affordable Targeting **NO**
    - SMR Targets are $1500 each
    - Need access to 240V power to run the Laser Tracker

SMR Laser Tracker Target

FARO 3D Laser Tracker

Possible Survey Methods

- **Traditional Survey** Using and a Industrial Total Station (0.5mm - 0.5 arc-second Instrument)
  - Accuracy **YES/NO** 0.5mm
  - Geometry **YES**
    - Could measure entire façade in one setup
  - Affordable Targeting **YES**/**NO** $180 per target
  - Need to DynaBolt Targets to Heritage Façade
    - **NOT A POSSIBILITY!**

Leica TS30 TotalStation

Leica Target

Possible Survey Methods

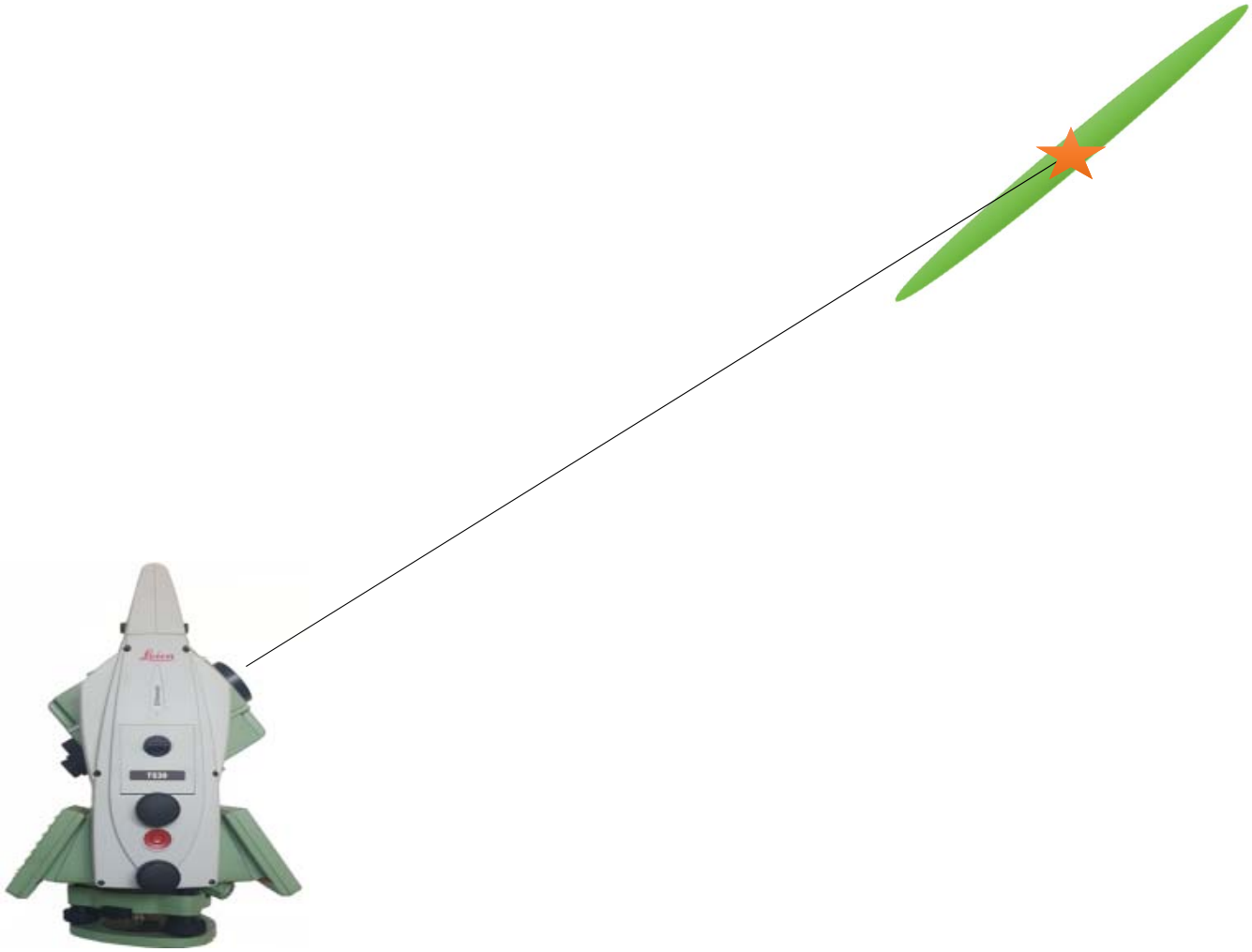
- **4 Station Network Adjustment** using Industrial Total Station (0.5mm - 0.5 arc-second instrument)
  - Specialist Software: SpatialAnalyzer (SA) a Unified Spatial Metrology Network (USMN)
  - Accuracy **YES** 0.25mm
  - Geometry **YES**
    - Could measure entire façade in 4-setups
  - Affordable Targeting **YES** $15 per target
  - Targets are stuck to façade using non-permanent adhesive
  - Targets will last 5 to 10 years for extended monitoring.

Leica TS30 TotalStation

Traditional Measurement using a Total Station

XYZ measurement of a single point

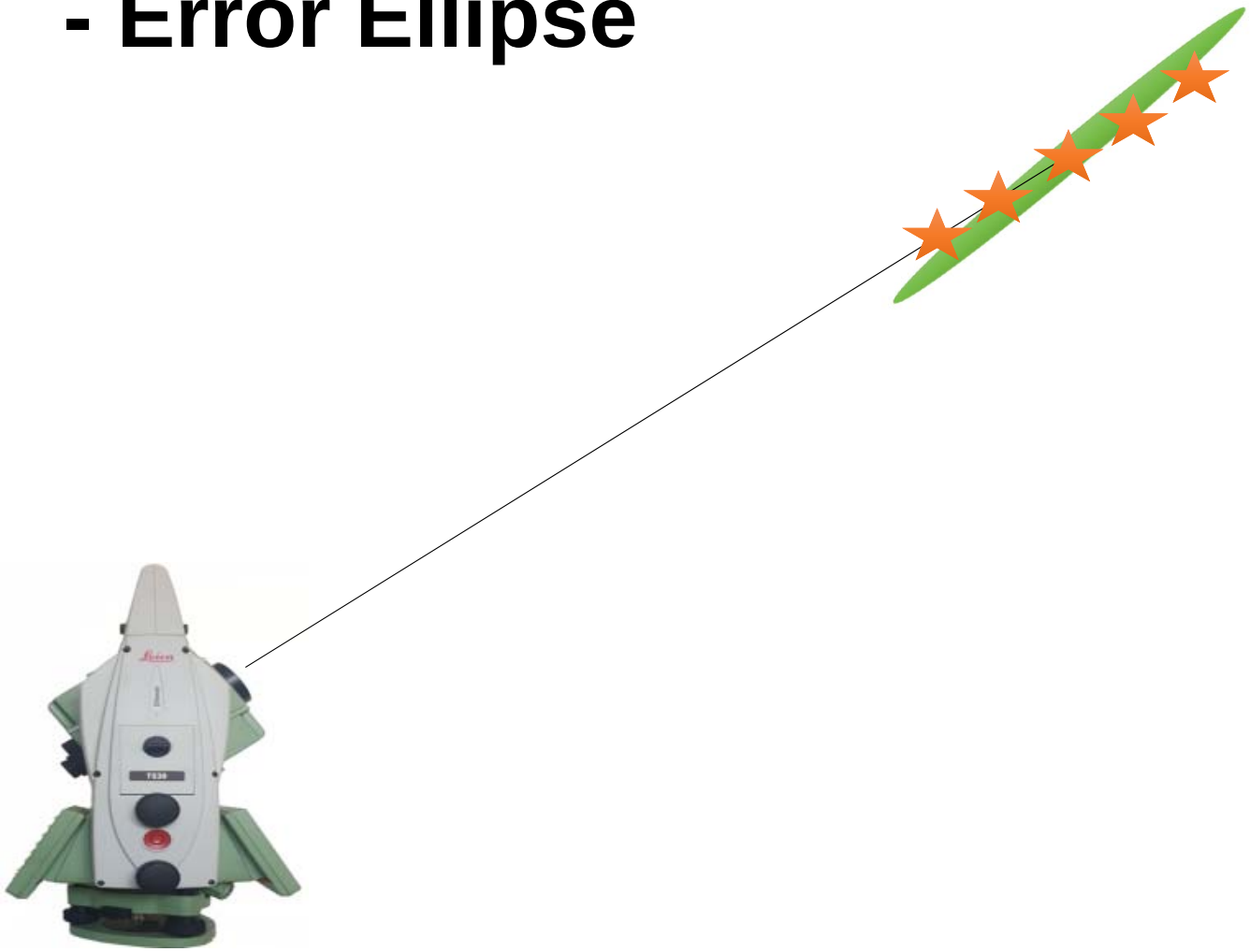
Traditional Measurement using a Total Station- Error Ellipse



XYZ measurement of a single point

- Over 50 meters the instrument has a larger length error (0.75mm) and small angular error (0.125mm)
- The orange ellipse represents the instrument error.
- At 50m the ellipse is 0.75mm long and 0.125mm wide.

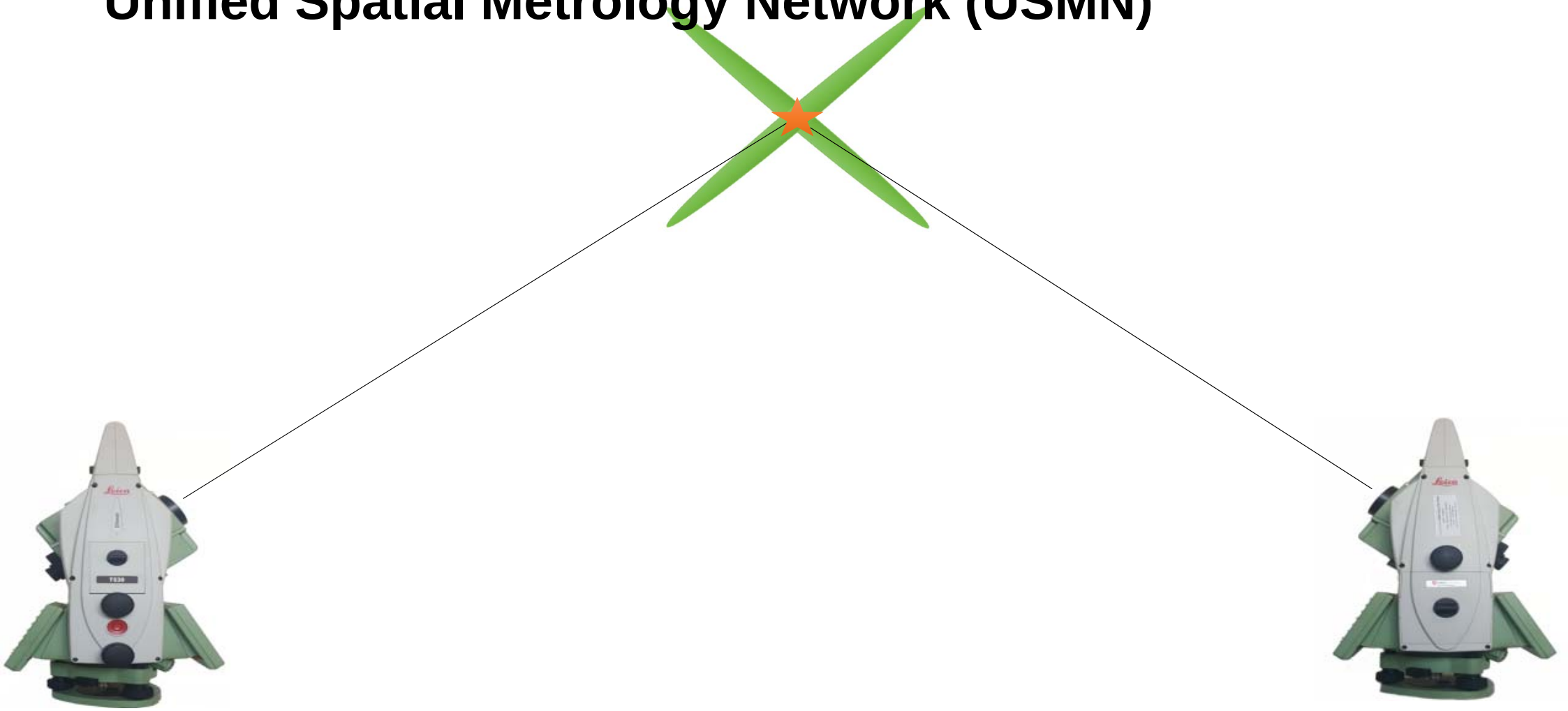
Traditional Measurement using a Total Station - Error Ellipse



XYZ measurement of a single point

- The actual measurement could fall anywhere in this ellipse.

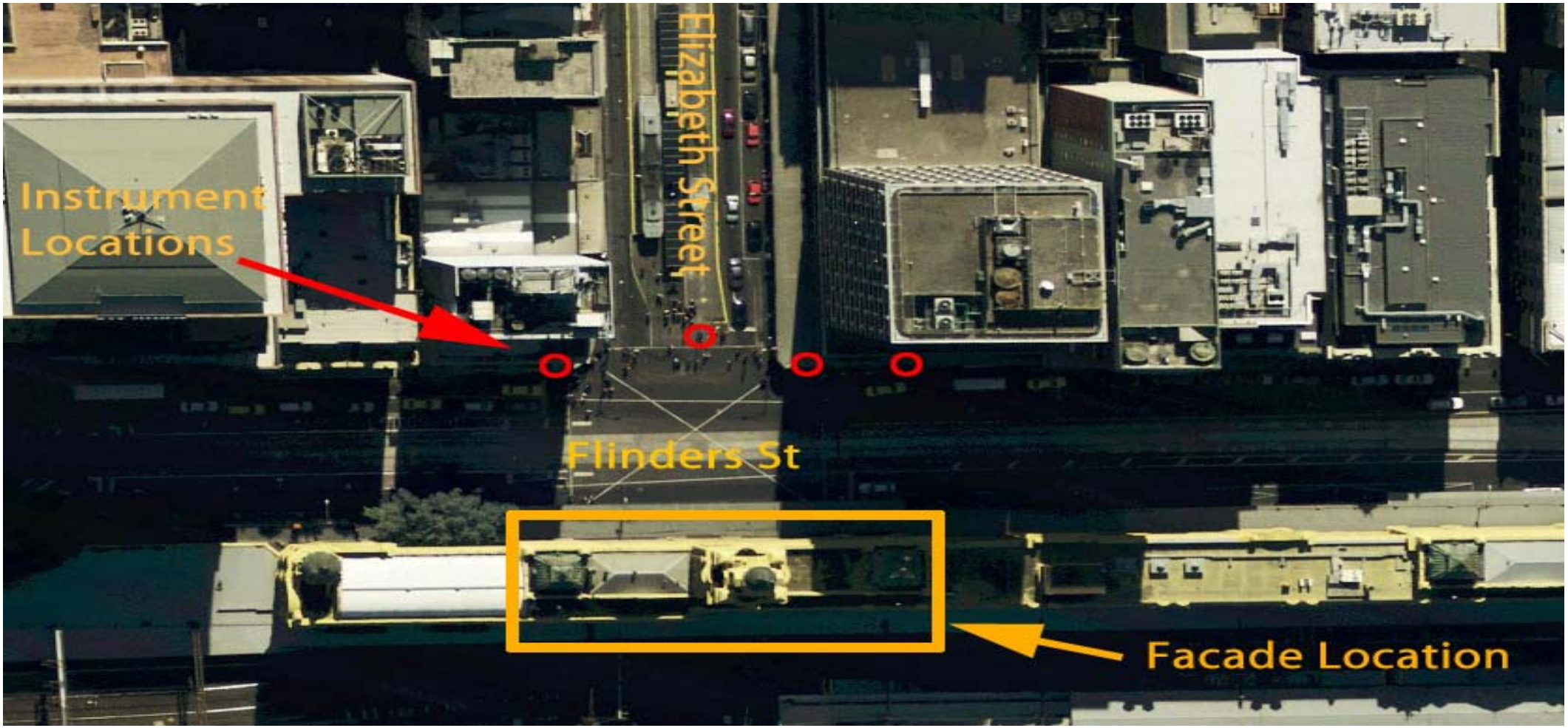
SpatialAnalyzer
Unified Spatial Metrology Network (USMN)



USMN - Simulation

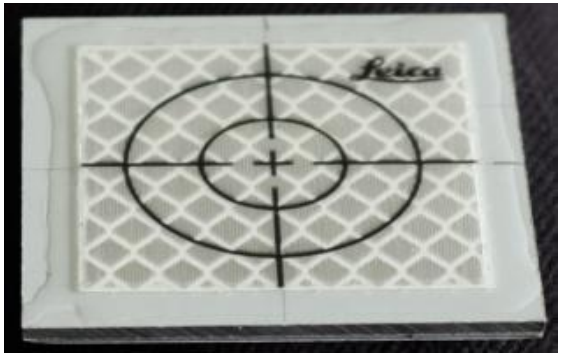
- SA USMN simulation was used to determine the number of measurement stations and their location.
- USMN determined that 4 stations located on the opposite side of the road would measure the façade with enough accuracy.

Instrument Locations



Custom Targeting Solution

- 3M non-permanent adhesive
- Composite aluminium backing
- Precision retro reflective surveying target
- Industrial weather sealing to stop the target delaminating from the backing



Target Layout

Hardware

- SpatialAnalyzer (SA) Ultimate Software & Laptop
- Leica TS30 Total Station
- Leica MT MeteoStation
  - providing real-time temperature, pressure and humidity compensations for every instrument shot
- Leica GST20-9 Tripod
- Leica GST4 Floortree (Tripod Star)

Survey Specifics

- Surveys conducted just after dawn as this is when the atmosphere is most stable.
  - 2.5 hours from arriving to competition
  - Record the start and end temp
  - Each measure was temperature compensated using the Leica MT MeteoStation

Transformation of Survey X onto First Survey

- Least Squares Transformation
- Lock points at the bottom of the façade and 6 control points
- For each point on the façade the dX, dY and dZ were determined and reported.

Result Summary

- Typical Accuracy for each survey:
  - Overall RMS better than 0.4mm
  - RMS in each axis ranged between 0.15 and 0.25mm
- Able to prove that the cracking was local and not the result of a larger structural deformation in the façade.

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Concluding Remarks

- Movement of façade features of Flinders St Admin. Building predominantly associated with temperature effects
- No evidence of net movement of façade features of Flinders St Admin. Building
- A much longer monitoring period is needed to be able to detect net movement of façade features of the Flinders St Admin. Building

Any Questions