The Effect of Vehicle Design on Noise and Vibration

A case study from Sydney, Australia

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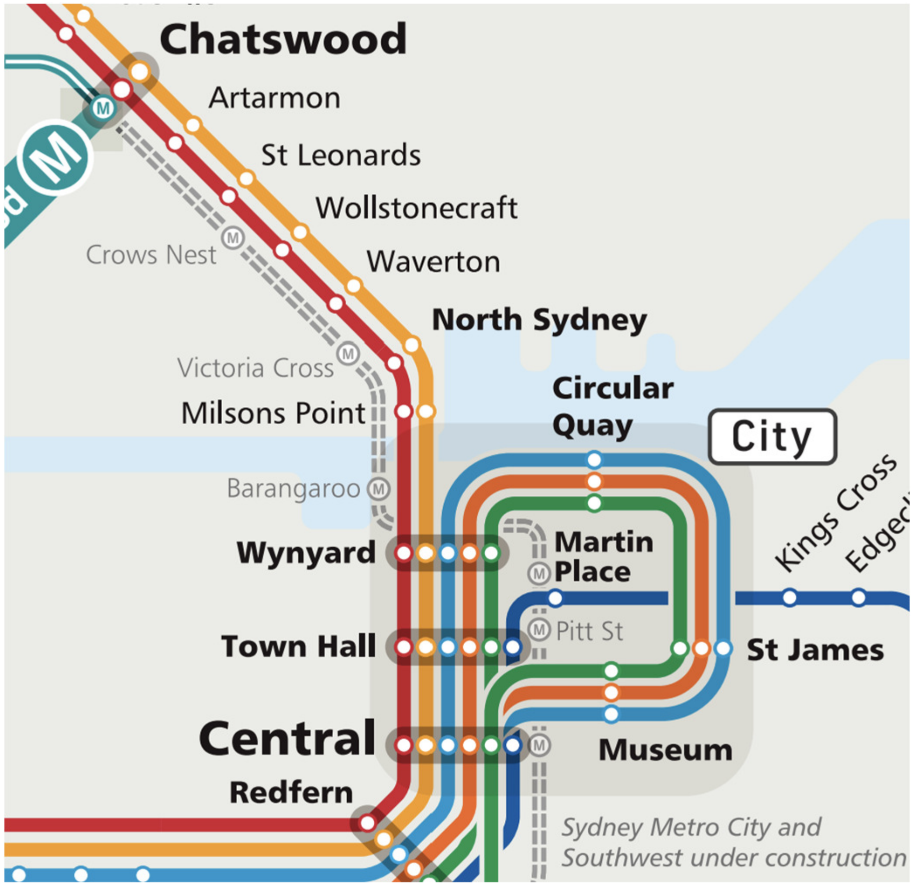
Context

New metro line under construction

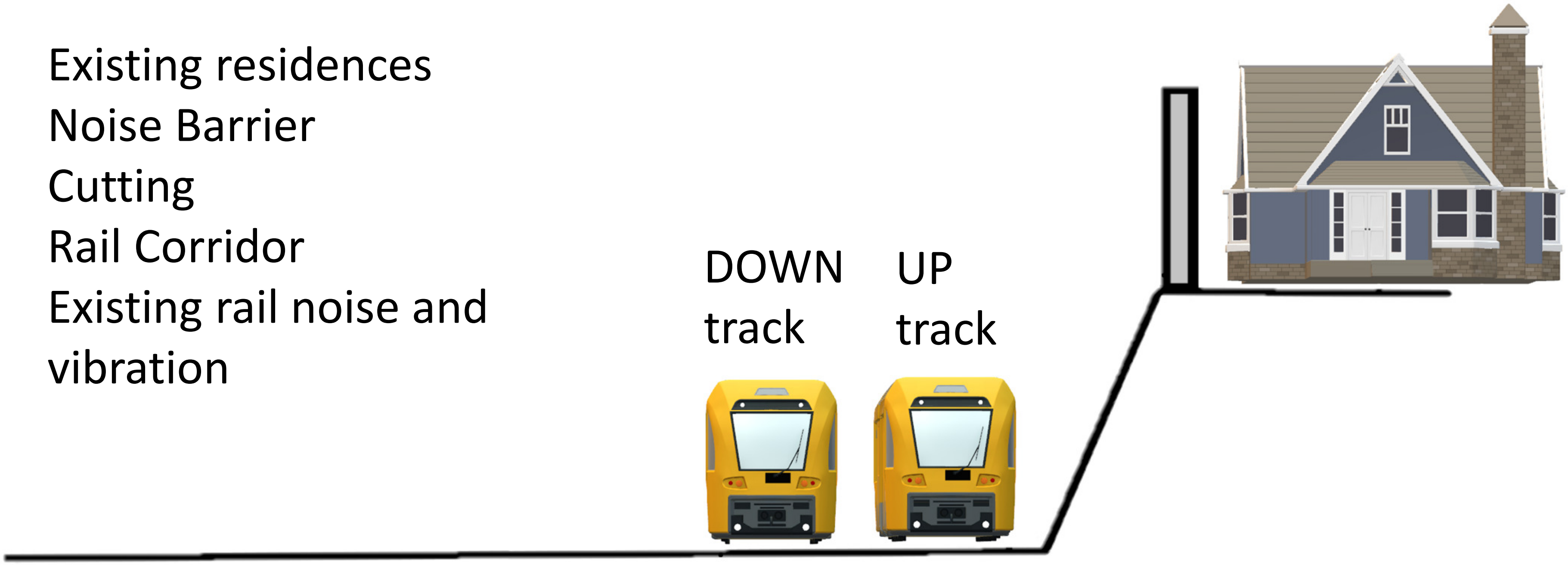
Existing heavy passenger rail corridor through suburban area in North Sydney

Vibration monitoring to establish baseline and impacts of rail changes

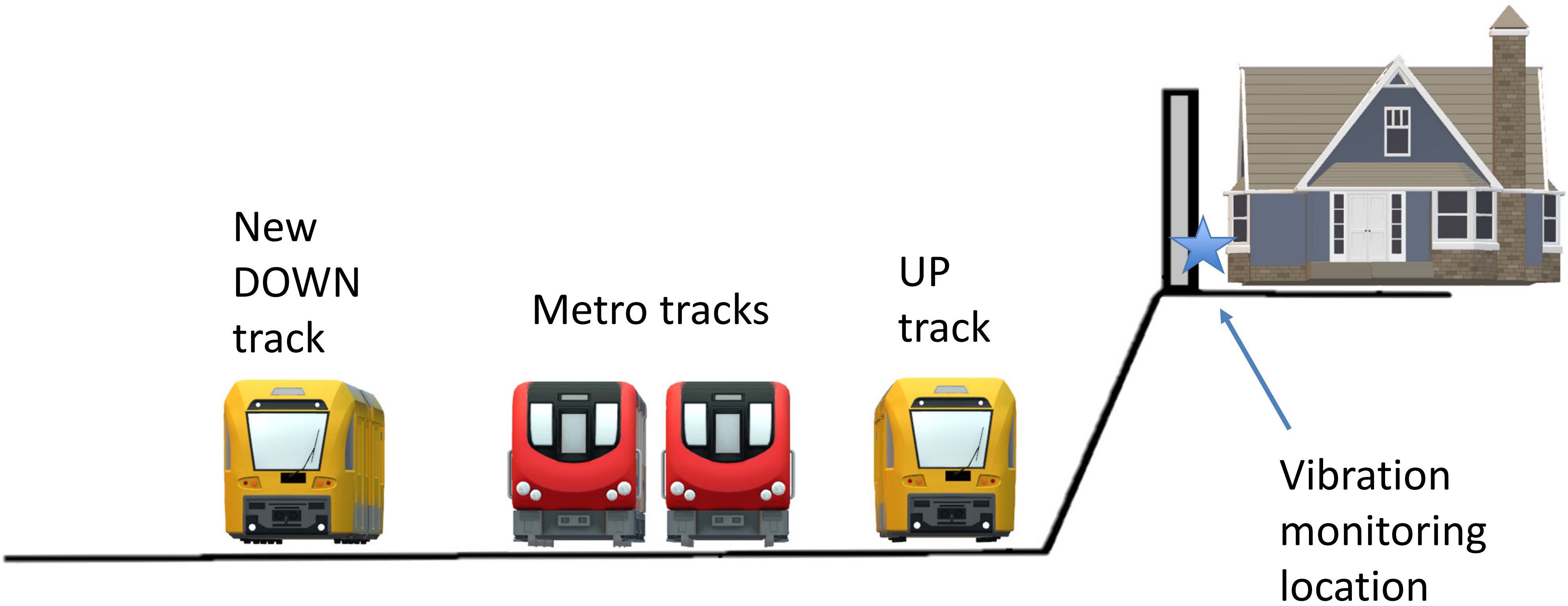


Initial Situation

- Existing residences
- Noise Barrier
- Cutting
- Rail Corridor
- Existing rail noise and vibration



Future Situation



Overview

Vibration monitoring on rail corridor boundary

More than a year of vibration data

~250 trains per day

Vertical and lateral vibration

Motivation

Original objective in collecting data was to understand difference in vibration due to track configuration changes to construct Metro

Opportunity to review data to examine:

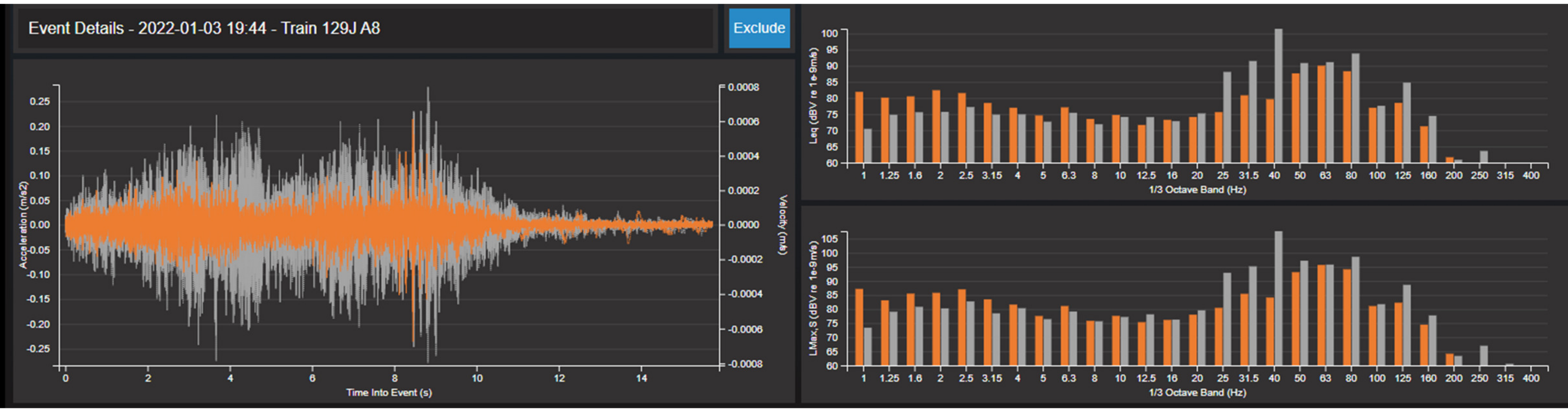
- Long term trends in vibration level over time
- Differences between tracks
- Relative vertical and lateral vibration levels
- Repeatability of short-term vibration monitoring
- **Effect of train type**

Monitoring Details

- 8m horizontally from nearest (UP) track centreline
- Cut / retaining wall / noise barrier
- Convergence Instruments VSEW mk2 vibration logger
- 1000 Hz sample rate
- Cloud data processing
- Train identification via NSW Government live data feed
- Remotely accessible data portal

Data Portal

Statistics, individual events and spectra



Lateral – grey

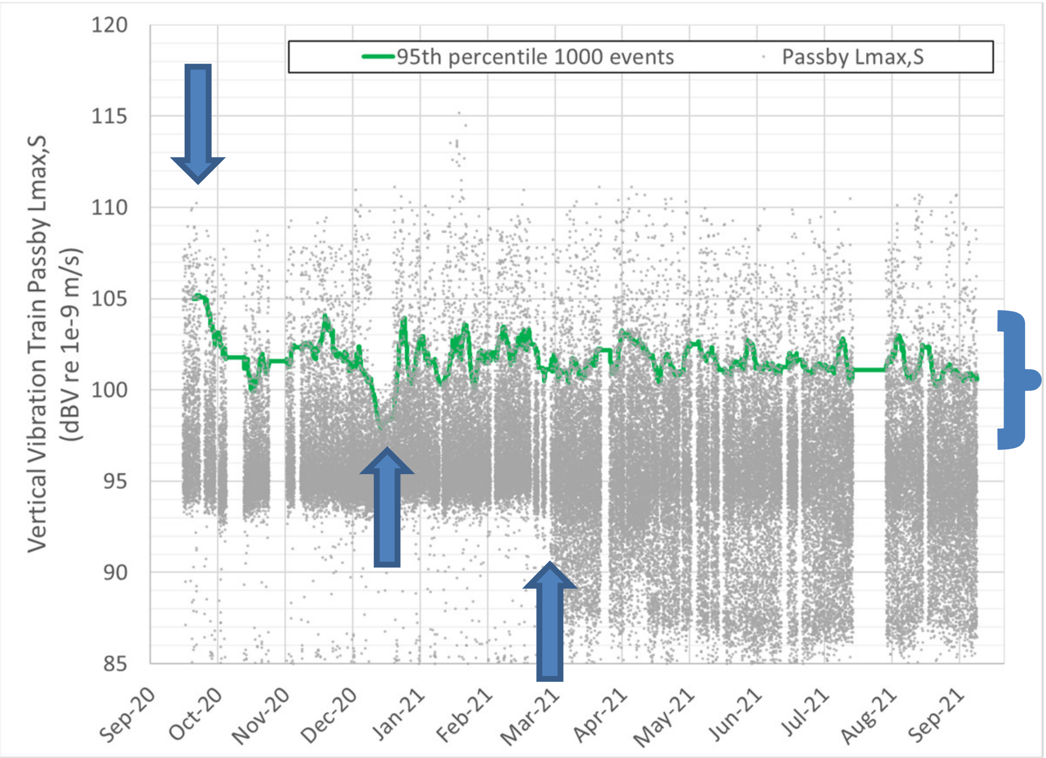
Vertical – orange

Note: Lateral vibration levels consistently higher at this location

Results – and questions!

Vertical vibration, all events, and 95th percentile from rolling 1000 events (~5 days)

- What happened March 2021?
- 95th percentile high in Oct 2020?
- 95th percentile low in Jan 2021?
- How does the number of trains measured affect the 95th percentile?



Some answers…

March 2021?

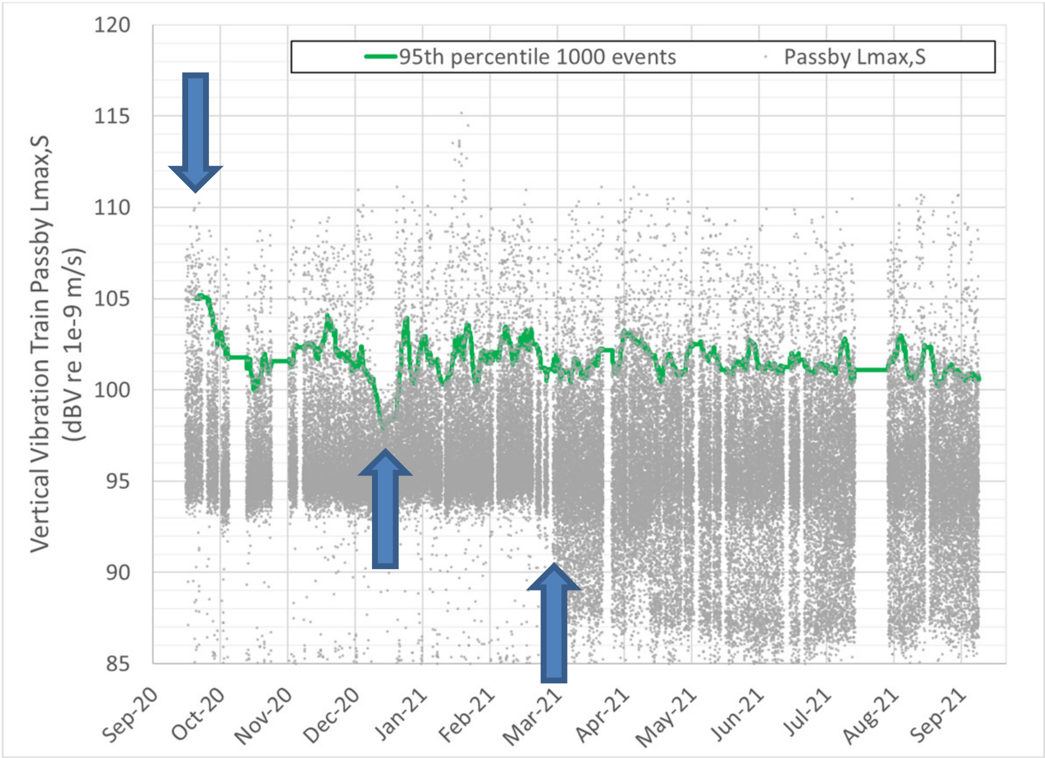
DOWN trains changed tracks onto NEW DOWN, further from sensor

September / October 2020?

Wheel maintenance issue – increased numbers of train wheels with surface defects

1-10th Jan 2021?

Harbour bridge trackwork – reduced timetable of shuttle services – Waratah trains only



Train types

Waratah (A-set) – introduced 2011-’18

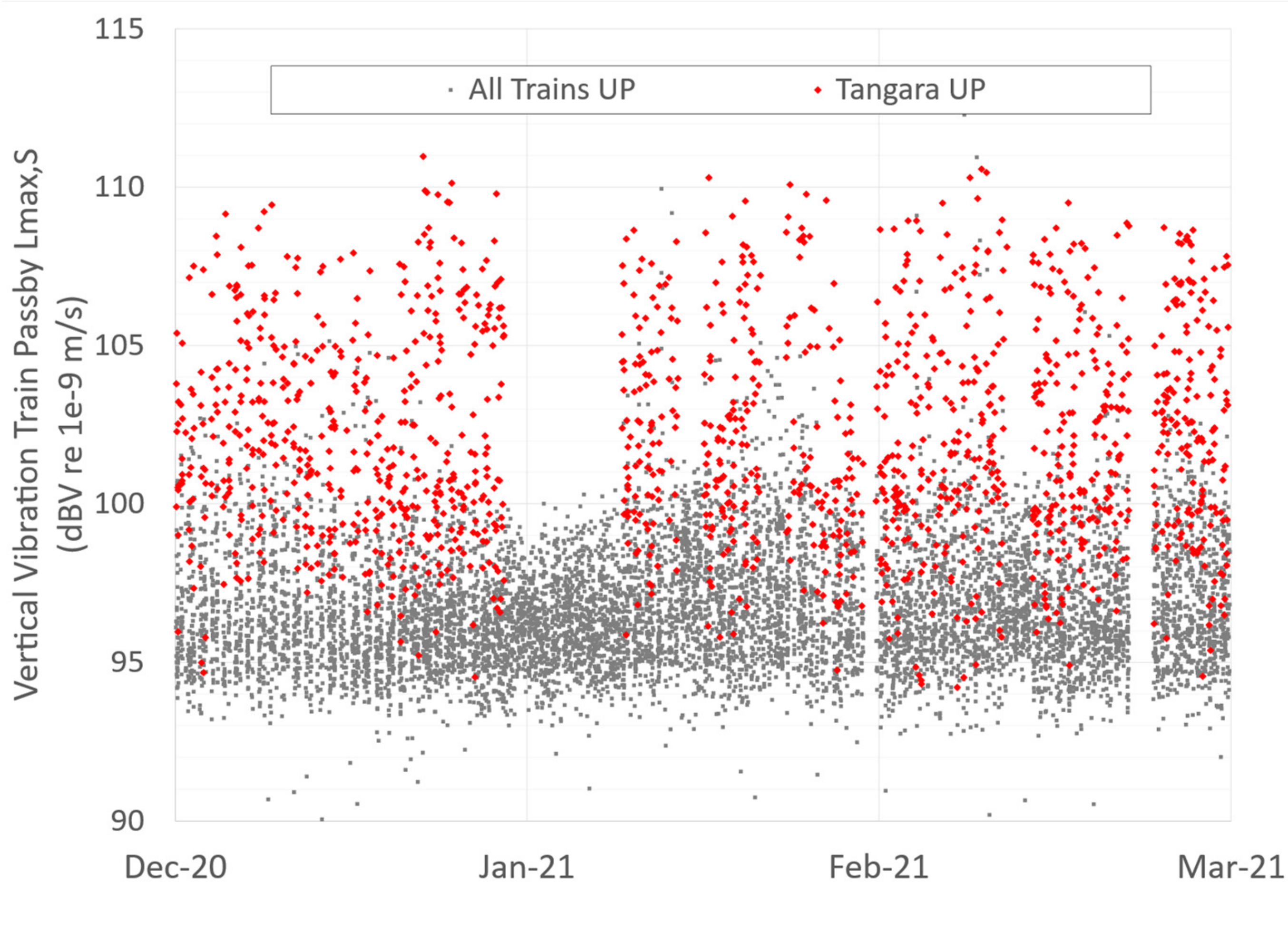
Tangara – introduced 1988-’95

81% Waratah Trains 16% Tangara Trains 3% other train types

Effect of train type

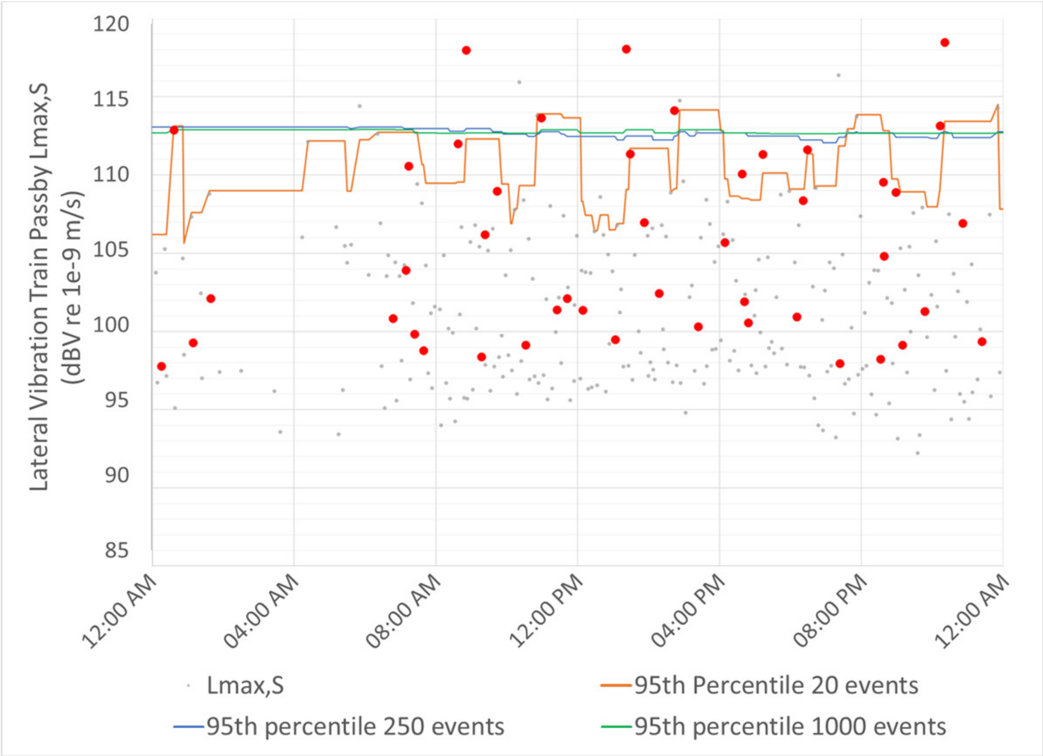
Tangara trains on UP track (in red) vs all other events

Note change from 1-10th January with A-Sets only



How many trains to measure?

- One day of data shown
- 20 events before vs after lunch in this example would give ~7 dB difference in 95th percentile level
- Visually, a full day of data gives similar results to 5 days
- Number of samples depends on acceptable error and required confidence



Vibration summary results

Train type	Number of events analysed in year	Vertical vibration	Lateral vibration
		Mean Lmax,S dBV re 1e-9 m/s	Mean Lmax,S dBV re 1e-9 m/s
Waratah – A Sets	26469	96.5	103.3
Tangara	5062	101.4	109.9

+ 5 dBV

+ 6 dBV

Contributors to vibration

EU project RIVAS investigated:

- Unsprung mass
- Suspension stiffness
- Axle spacing
- Wheel defects / out of round (OOR) wheels

Most important

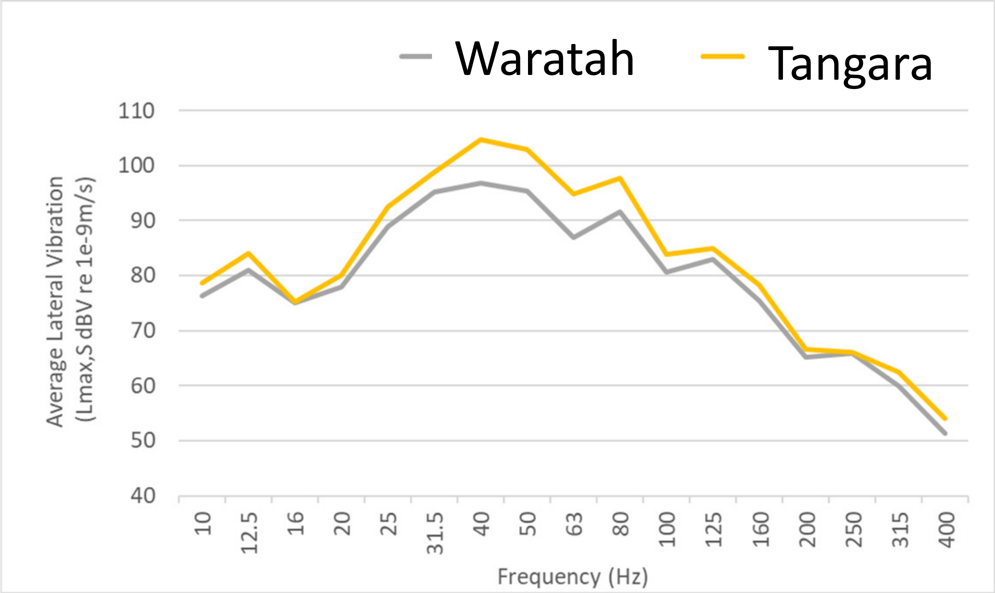
RIVAS findings:

- Suspension stiffness causes frequency shift
- 50% unsprung mass reduction – > 6 dB vibration reduction, broadband
- Wheel defects / out of round – > 5 dB effect on passenger trains

Suspension + axle effects

Spectral results do not show frequency shift, therefore unlikely difference is due to suspension stiffness

No difference in axle spacing between the two train types



Average lateral vibration level vs frequency – vertical is similar

Unsprung mass

- Waratah
  - 4216 kg (motor cars), 3100 kg (trailer cars)
- Tangara
  - additional 50 kg in wheels, 60 kg in motor axles and 90 kg in trailer axles
  - Approx 10 % heavier than Waratah

RIVAS indicates unsprung mass increase may add ~1dB to Tangara vibration

Wheel defects / OOR

Increased defect numbers and inherently higher vibration due to vehicle type could be due to:

- Wheel material / metallurgical properties
  - No differences identified
- Maintenance practices
  - each train type maintained in a different depot
  - Is there a difference in wheel condition related to maintenance practices?
- Other vehicle design differences
  - traction systems, braking, wheel slip protection

Wheel condition / impact data

Train type	Total Cars	New WILD Flags in year (% of cars)	Cleared WILD Flags in year	Average Days to Clear
Waratah	866	60 (7%)	56	91
Tangara	447	476 (106%)	504	44

WILD = Wheel Impact Load Detector

Indicative of number of wheel flats / wheel defects

Maintenance practices

- Tangaras generated 15 times more flags (wheel flats) than Waratahs
  - The defects were not more severe
- On average, Tangara defects were rectified twice as quickly as those on Waratahs
  - No evidence of a lack of maintenance attention

Other design differences

- Tangara traction control systems
  - DC systems
  - Dynamic braking only at higher speeds
  - Friction braking at lower speeds to stand still

- Waratahs – more modern AC traction system
  - Dynamic braking at all speeds to standstill

Summary

- No identified wheel metallurgical differences
- Same maintenance practice / standards
- Relatively small difference in unsprung mass
- Likely that fundamental design differences are key determinants of the number of wheel flats generated:
  - Newer trains have improved traction control, braking systems, wheel slip protection
  - Result is higher vibration levels generated by Tangara trains, relative to the newer generation Waratah trains.

More results

- Data presented from 2021
- Similar results observed in 2022: up to 6 dB higher vibration on average from Tangara trains
- 2nd site on same line shows 4 dB higher vibration on average in 2021, 2022
- Some variability across locations, but still a clear difference in vibration between train types

Implications

- In NSW Australia, vibration criteria are 95th percentile
- The worst performing train type determines compliance
- Events with high vibration levels may reduce in future as older Tangara trains phased out
- Caution needed in basing vibration predictions on measurements of nominally similar trains – are they truly similar?
- Any North American implications long term for reference levels in US FTA manual?

Questions / Discussion

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https://commons.wikimedia.org/wiki/File:2020-04-08_Tanraga_train_T45_at_Heathcote_railway_station,_Sydney.jpg