Cheaper
Better
Faster

BLUMESH SOLUTIONS

UNIVERSITY OF CAMBRIDGE

How using modern electronics and open source libraries in python;

- ➔ **advanced data collection and analysis systems;**
- ➔ **can be made at very economic costs.**

Cheaper - using low cost electronics + Pi + Open Source Python Libraries

Better - better for fast design, + retrofit, + sensor choice & range, + AI Libraries.

Faster - faster to deploy + over the air data transfer in 4G, 5G, WiFi and Bluetooth.

High Level Design …

Data Creation

Physical data is captured by sensors - and digitised.

0010001011100101010010101011010101010101010101 … etc

Data Removal

The data is removed and transmitted by WiFi / 4G / 5G / BLE Mesh, Open RAN / WiFi Networks etc …

Data Processing

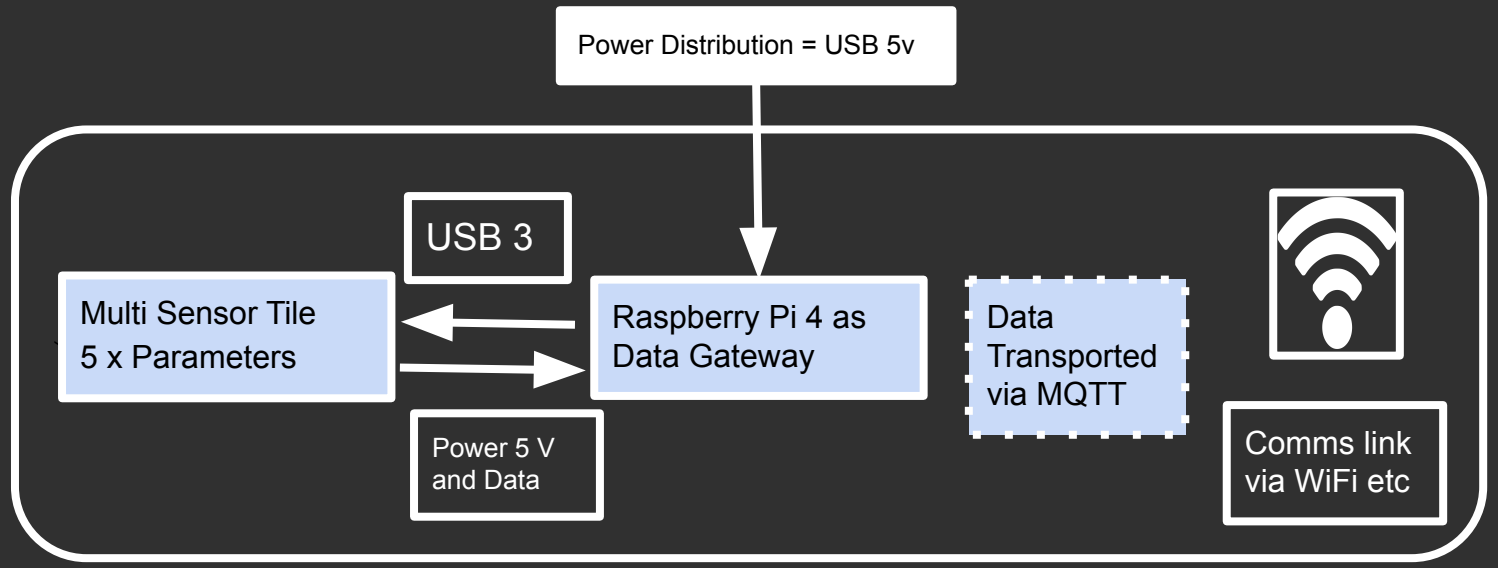
Sensor Data is then delivered to the Data Processing service cleaned, filtered and the presented for analytic analysis.

Add in PLC Data and combine for X,Y effects.

Data Reporting

Once analytic analysis is complete the data is then stored and presented via a REACT Reporting Tools.

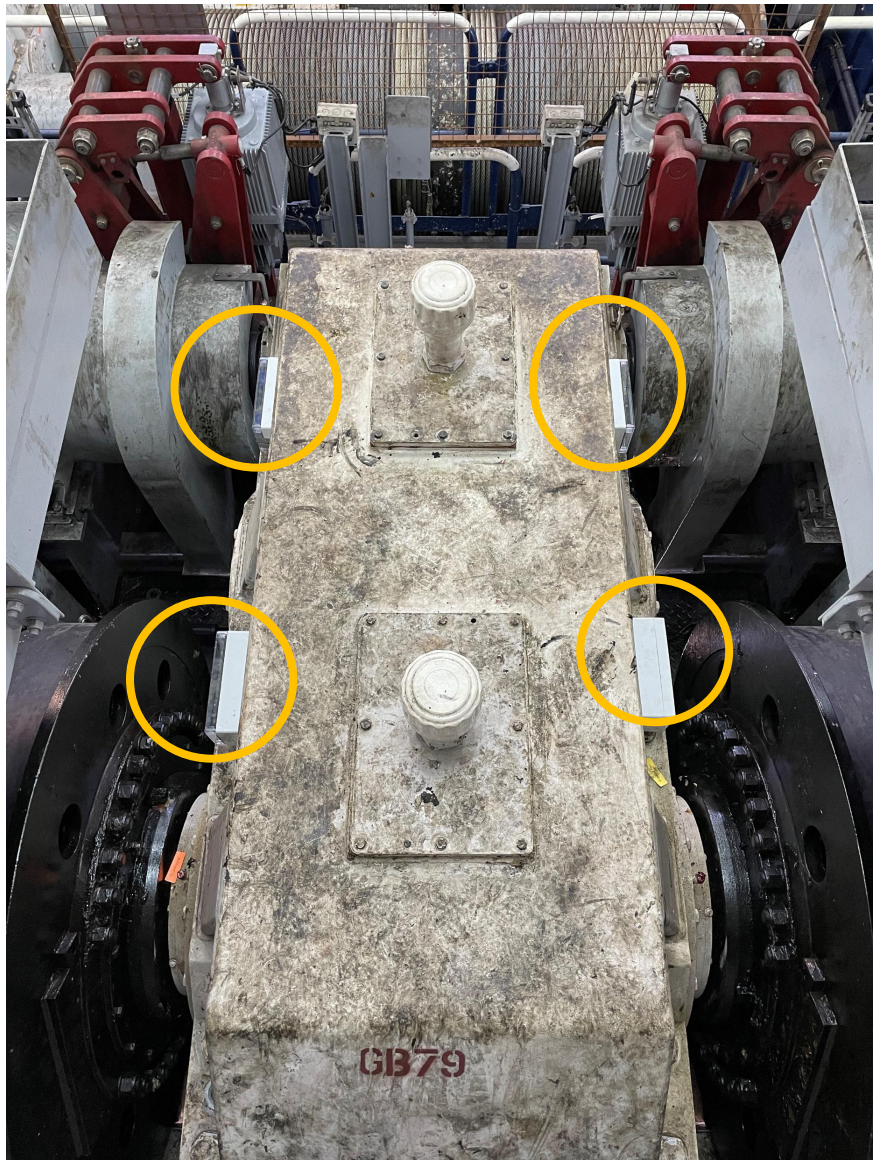
Low Cost - High Value Data



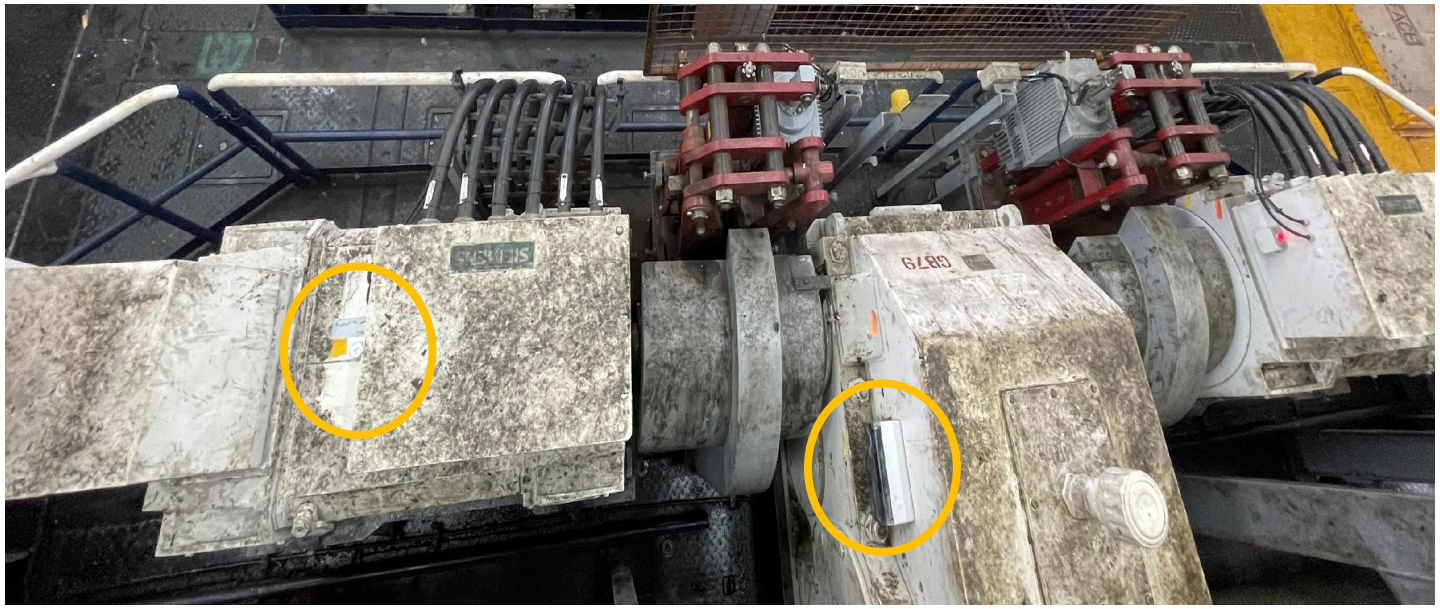
£95.00 + £10.00 + £30.00 + Open Source = Not Too Much

Machinery House
(housing the motors, PLC, trolley drives etc.)
Drivers Cabin
Spreader
Gantry
Port of Felixstowe
PORT OF FELIXSTOWE
THE PORT OF BRITAIN

Hoist Area - High Energy - High Maintenance Area



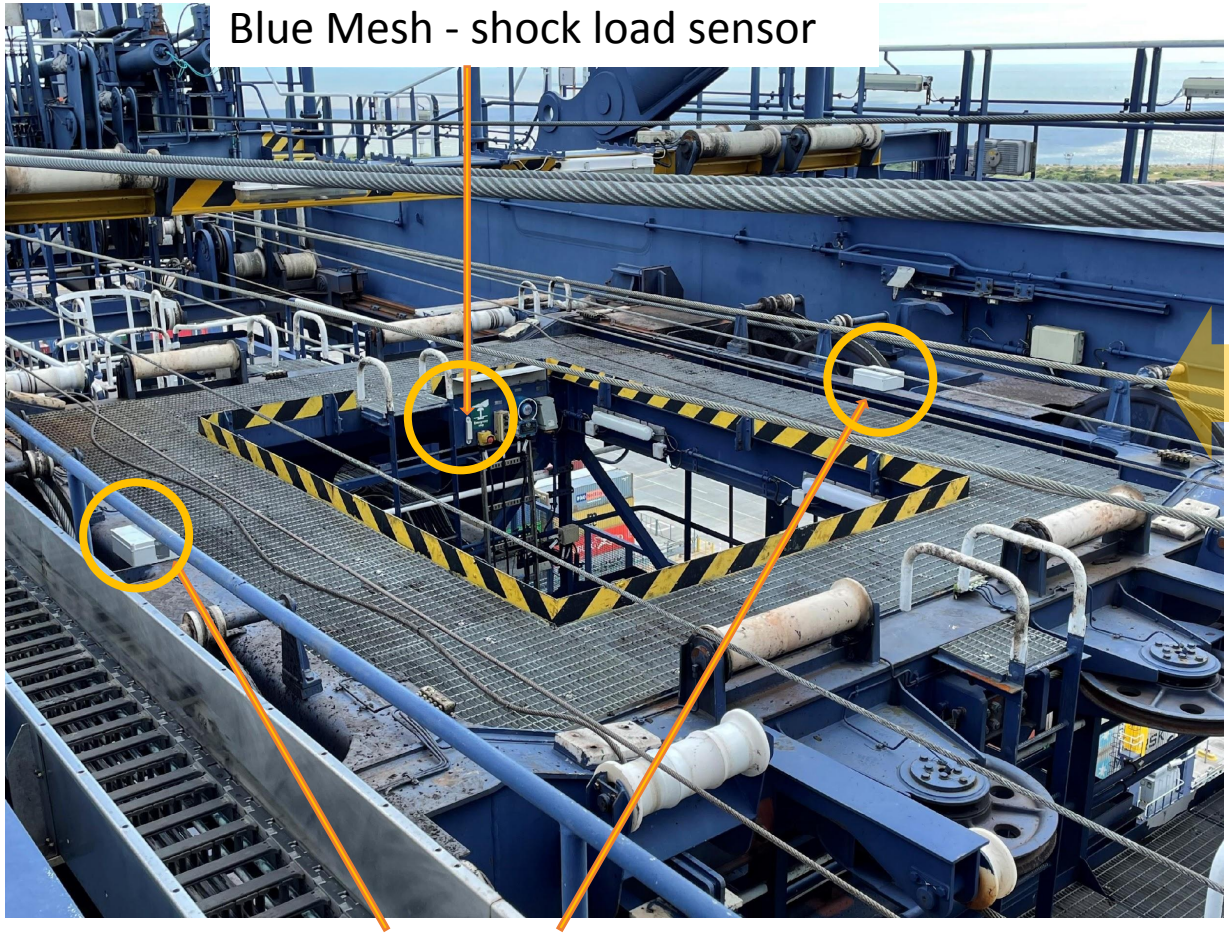
BMS Multi-sensors fitting in weather protective boxes.



Gantry

Strain gauge

Driver Cabin and Rail



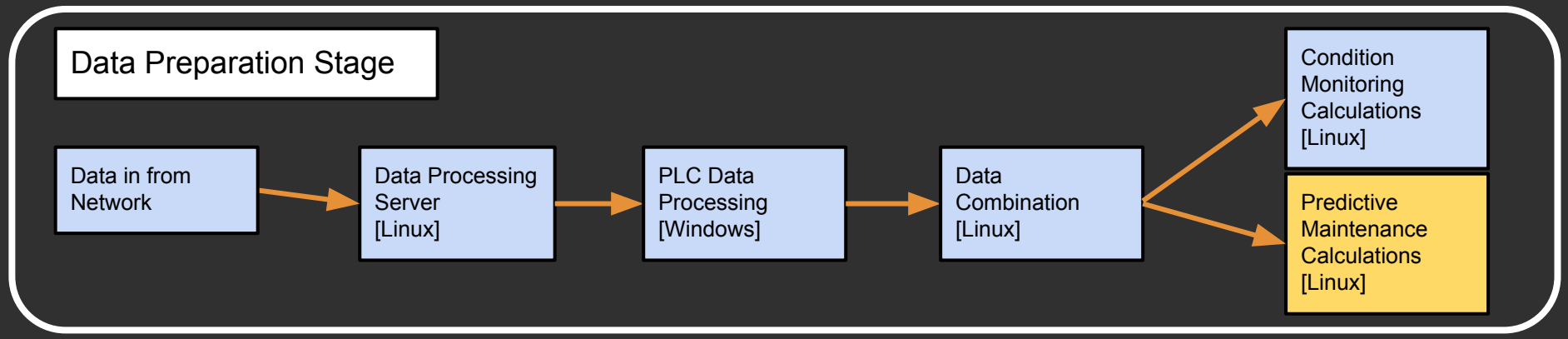
Could I have the Bill Please ?

One Crane

7 multi-sensors - vibration temperature humidity acceleration acoustics
7 Pi Gateways
2 reasonable spec WiFi Devices in MESH config.
Some cables and bits for mounting
4 Bluetooth MESH devices for Strain Gauges
1 4G / 5G Access Point

Around £2,500.00 of hardware per crane.

What else is needed ? Data Processing using Open Source



to Data Reporting >>>

Open Source = Linux + Python + Numpy + SciPy + Matplot + GP Plot .

We paid for OPC data tool on Windows - sorry!

So what do I get ?

Condition Monitoring Tools

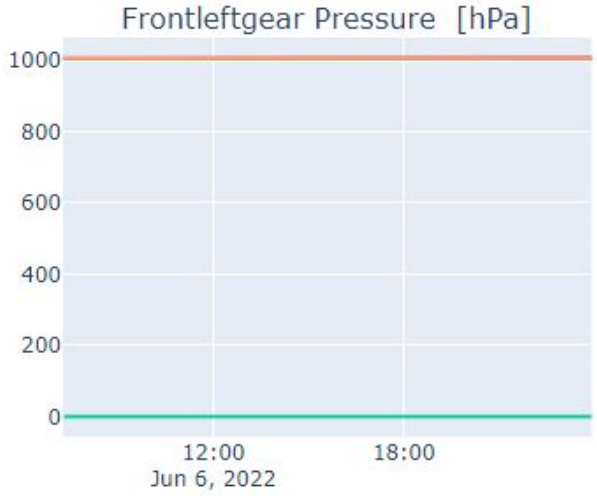
Vibration Analysis/Dynamic Monitoring

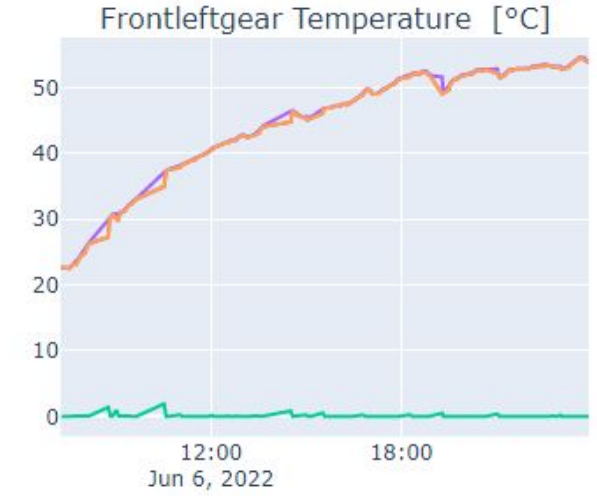
Wear on machine parts, bearings, rotors or shafts can cause them to vibrate in unusual patterns that can be monitored, recorded and analysed. These vibration patterns can be used to identify defects and potential failures, including those due to misalignments, imbalances or even design flaws.

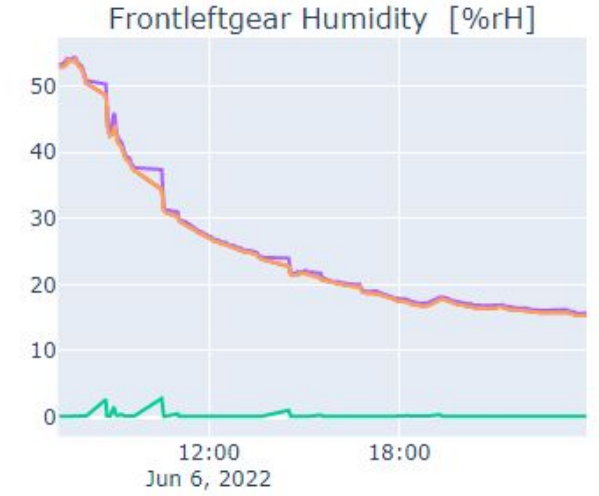
Techniques include:

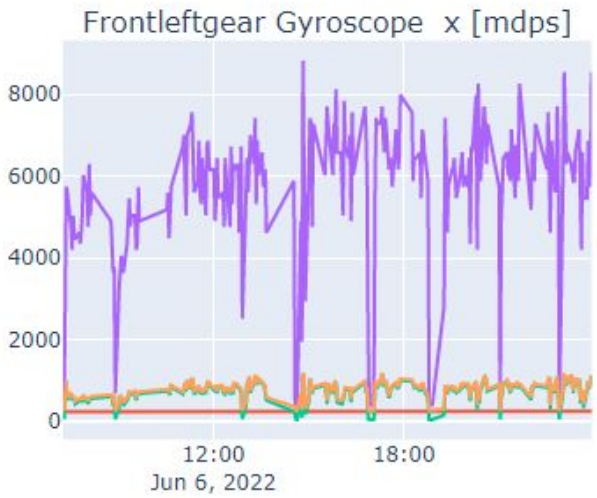
- Shock (velocity) pulse analysis
- Broadband vibration analysis
- Fast fourier transforms
- Power spectral density (PSD)
- Spectrogram/spectrum analysis
- Time waveform analysis

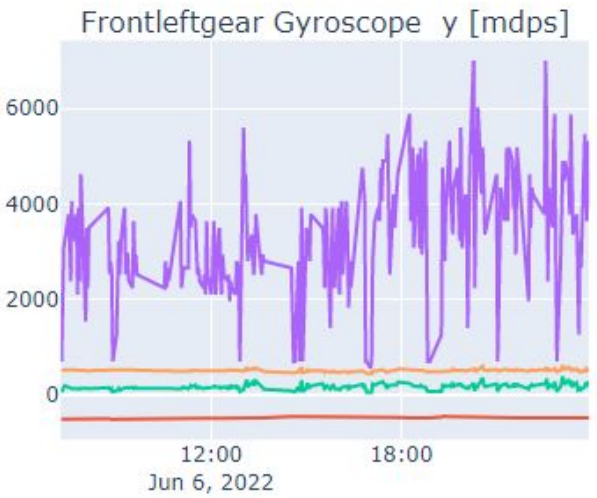
All sensors: Mean, Standard deviation, Absolute Max and RMS

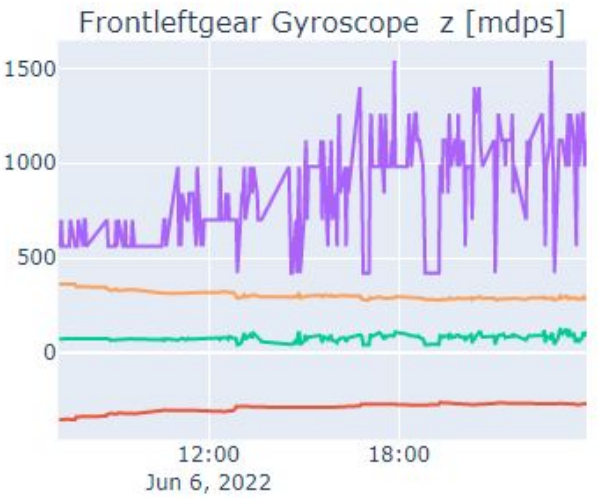








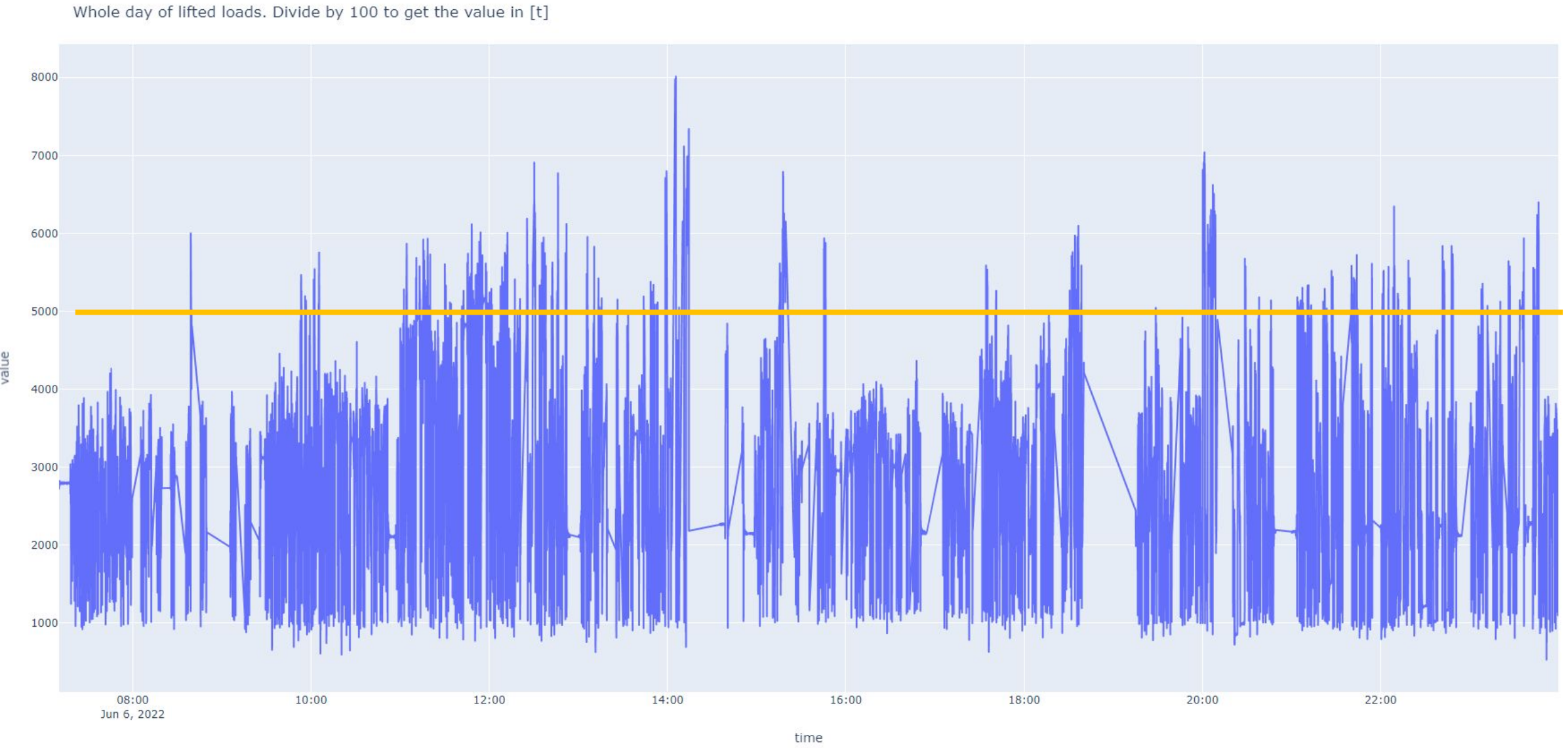




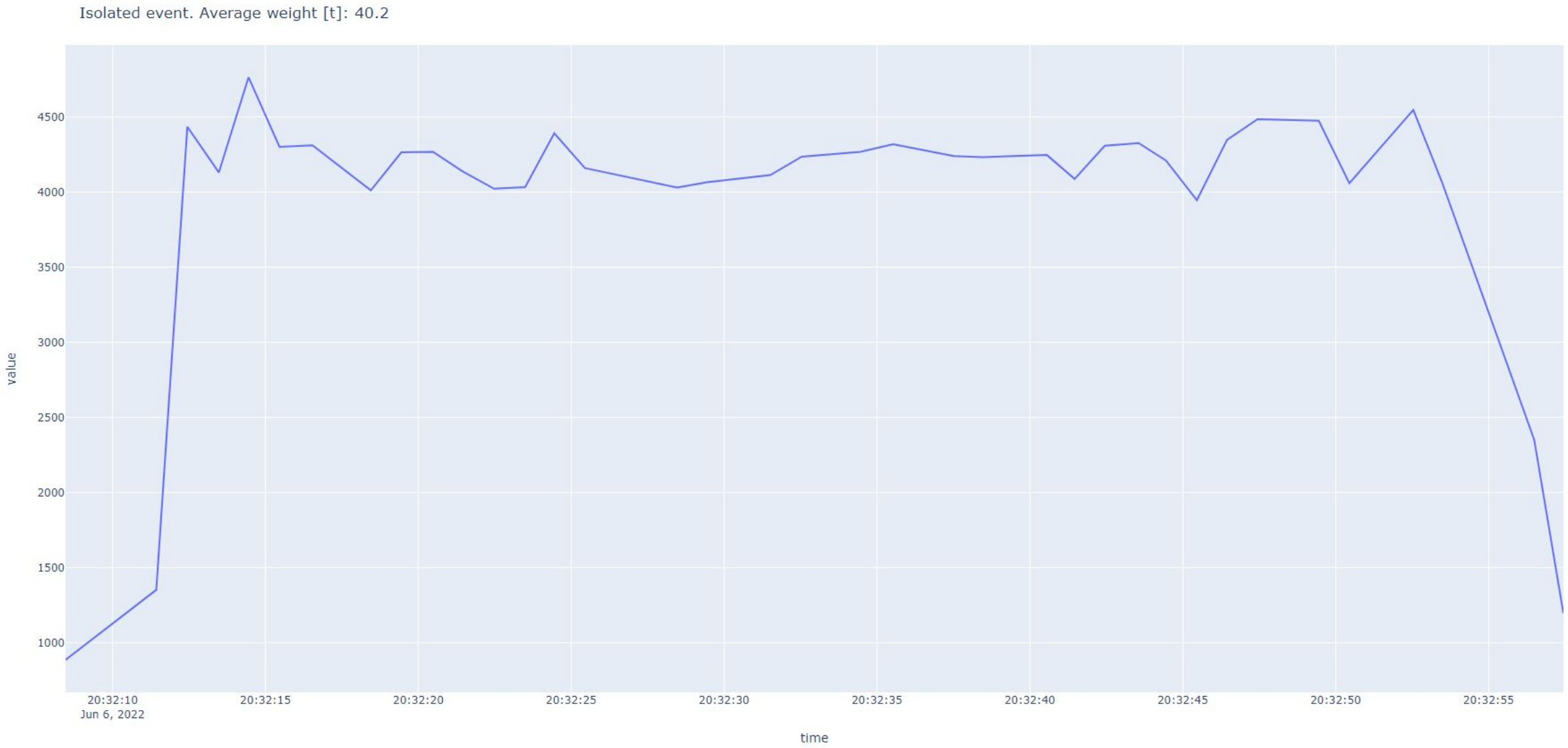
Vibration and acceleration in x y z = 3 axis.

Mean SD RMS

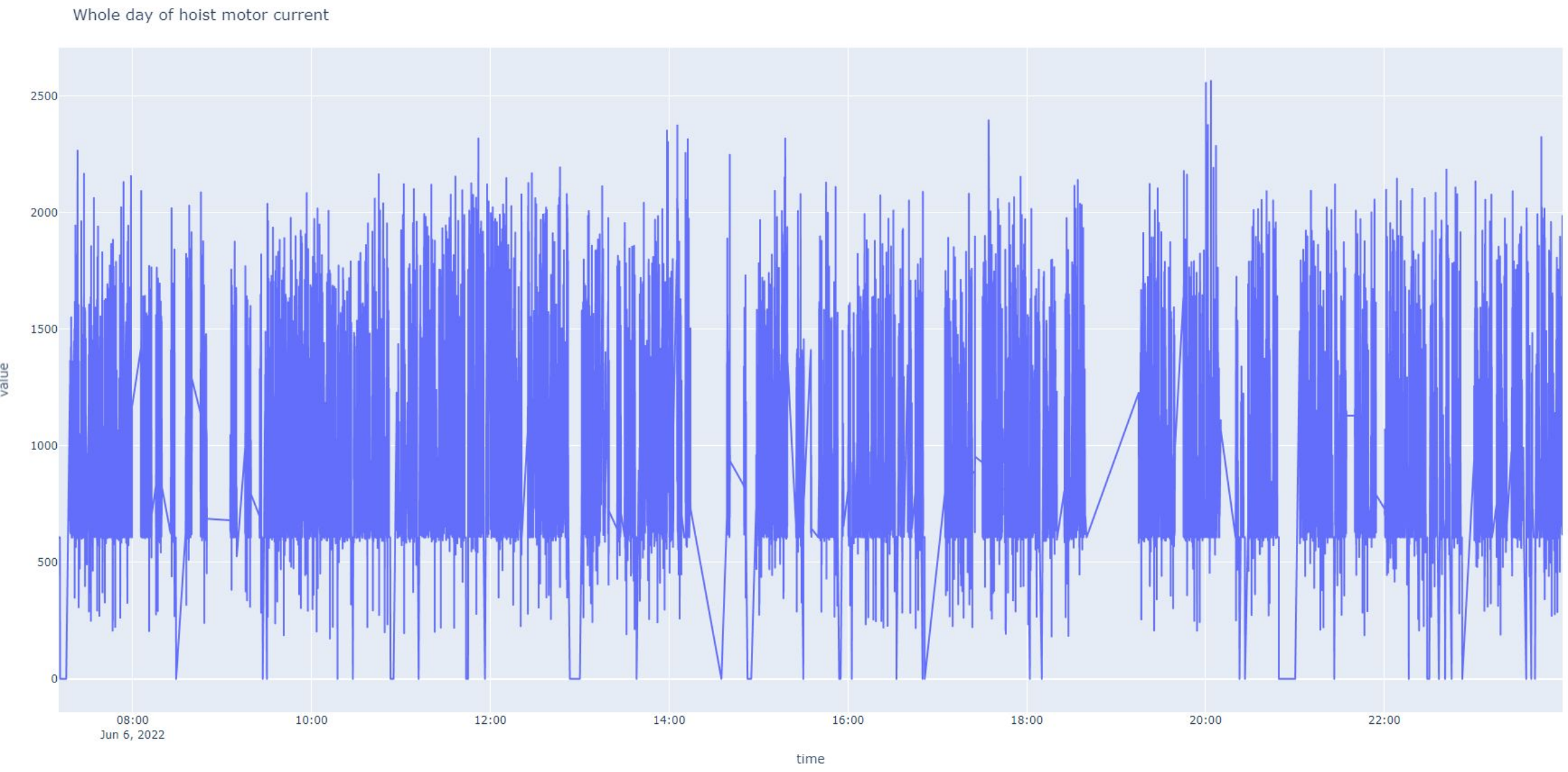
PLC Data - Load lifted
5000 = 50 Tonnes.



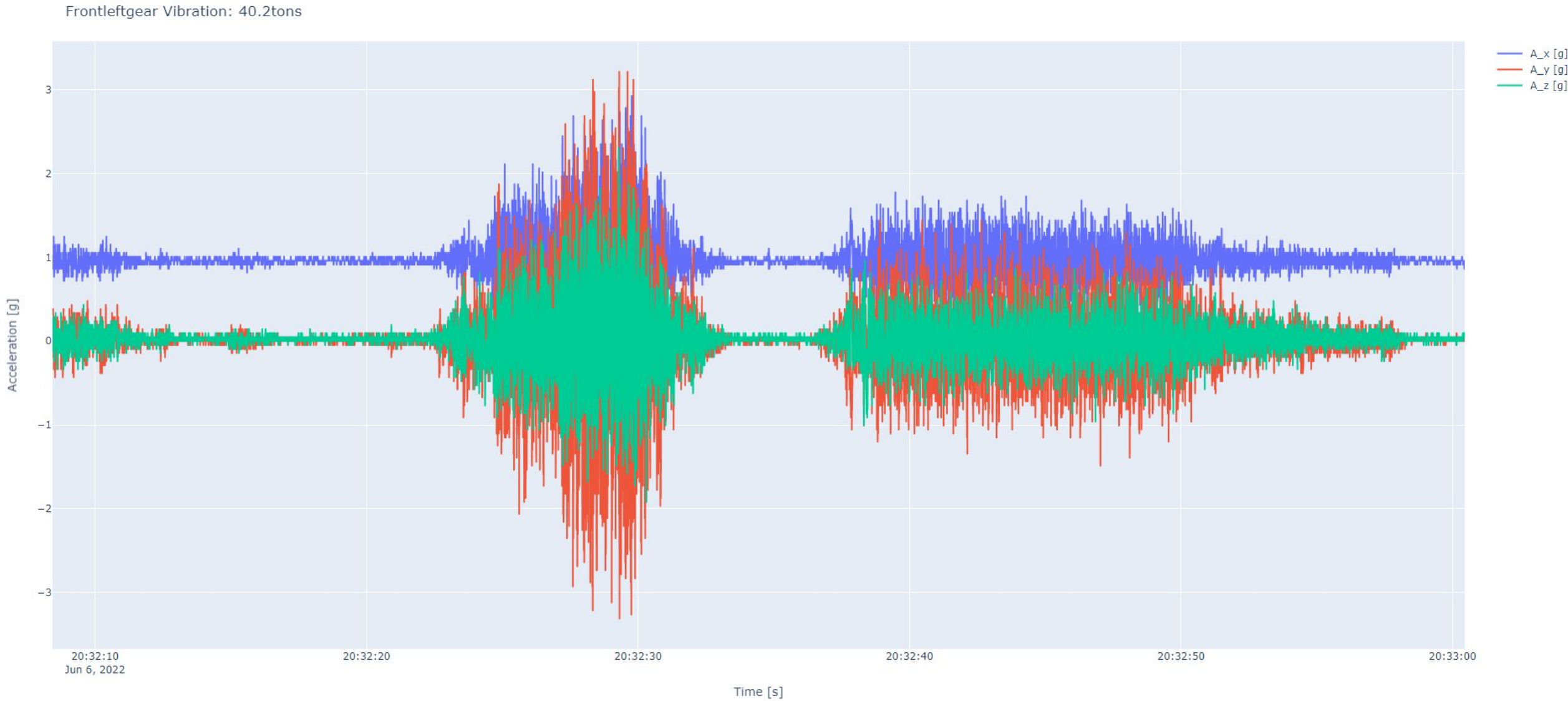
PLC = 40.2 Tonne lift across 45 seconds



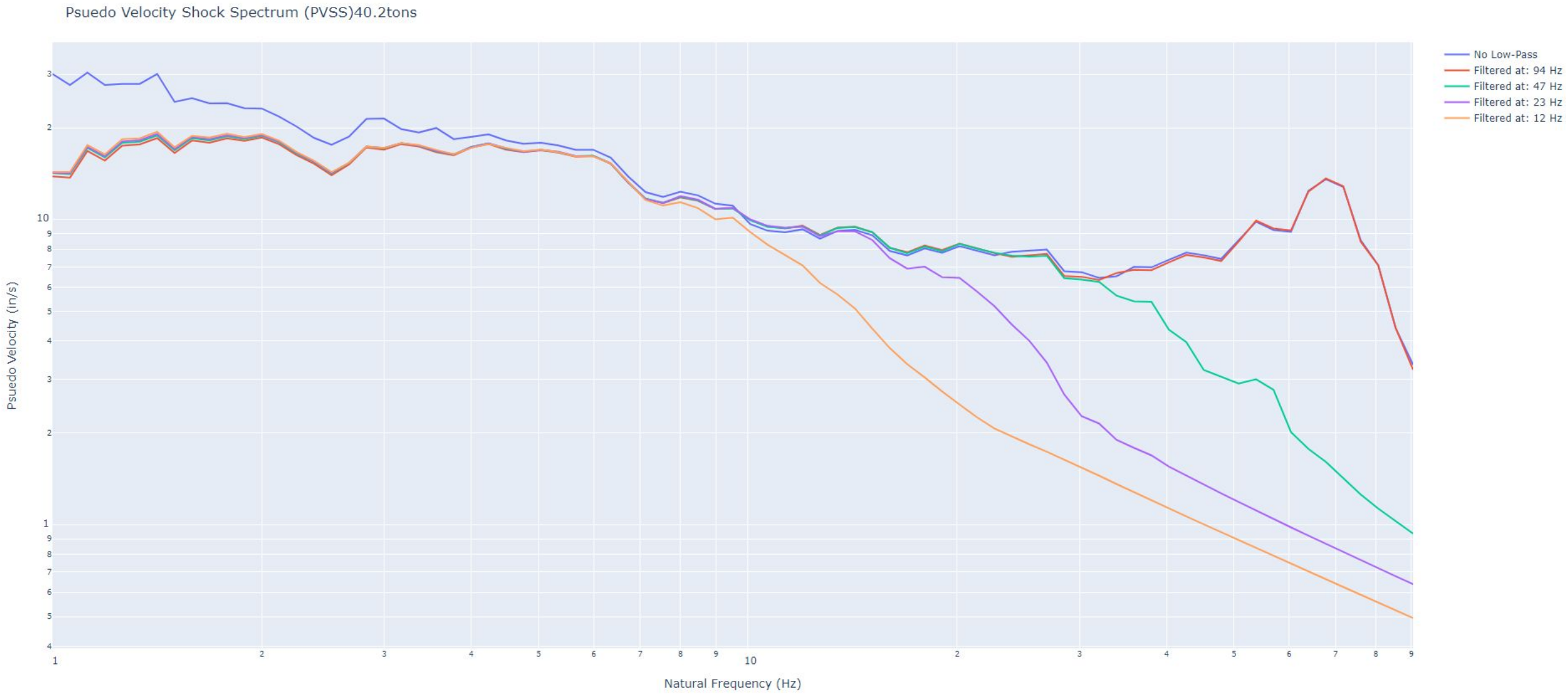
PLC = current for 1 day
Yes that's really 2000 Amps!



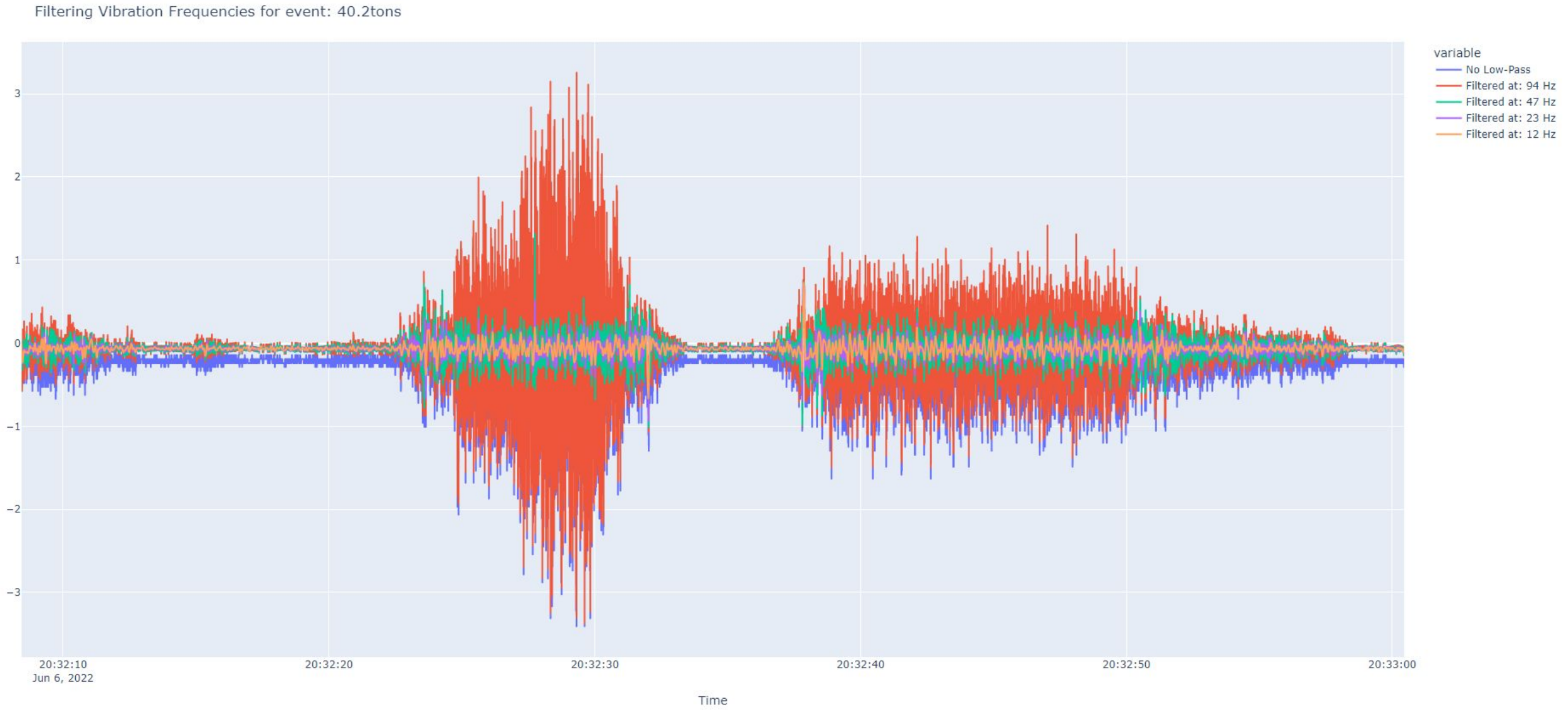
Vibration by direction
z = green = includes gravity damper



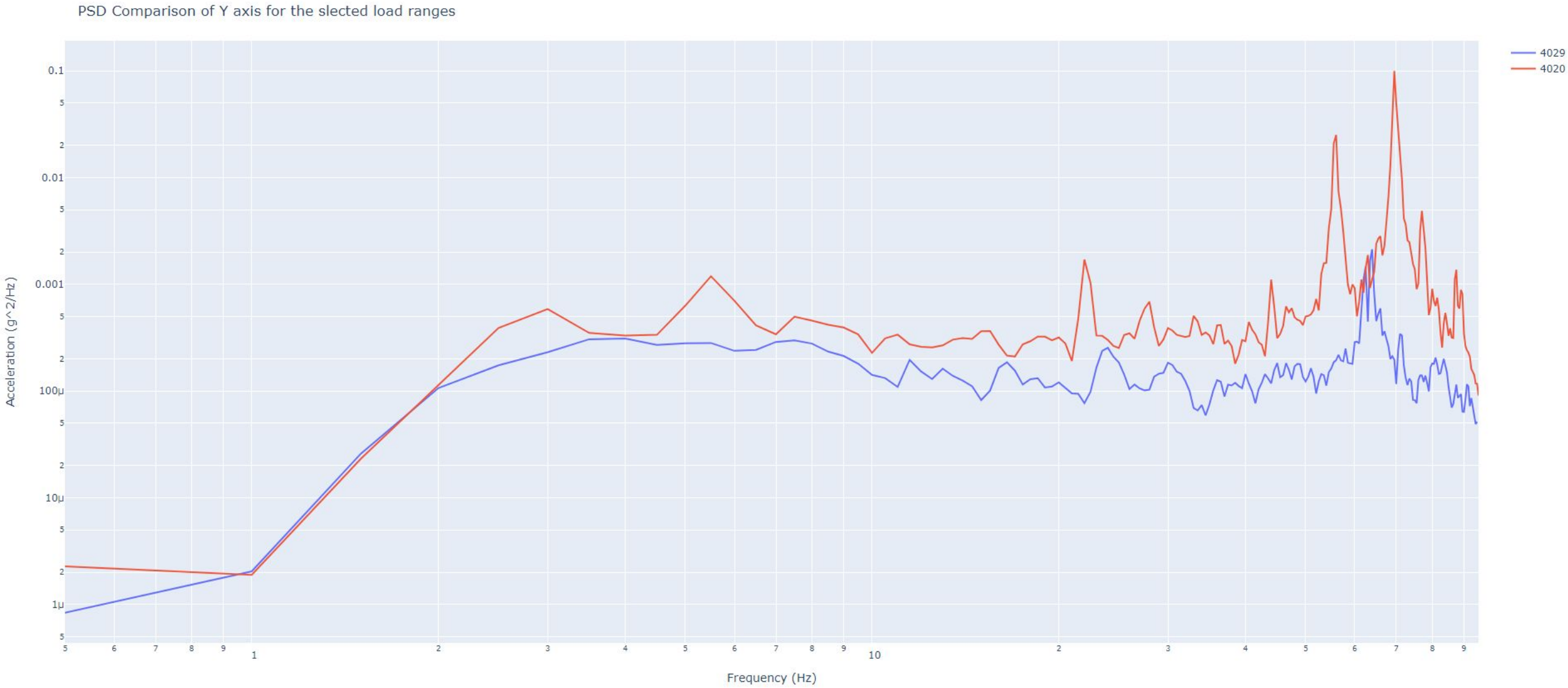
Velocity Shock in System



Frequency Filters



PSD comparing 2 lifts 40T and 40.3T

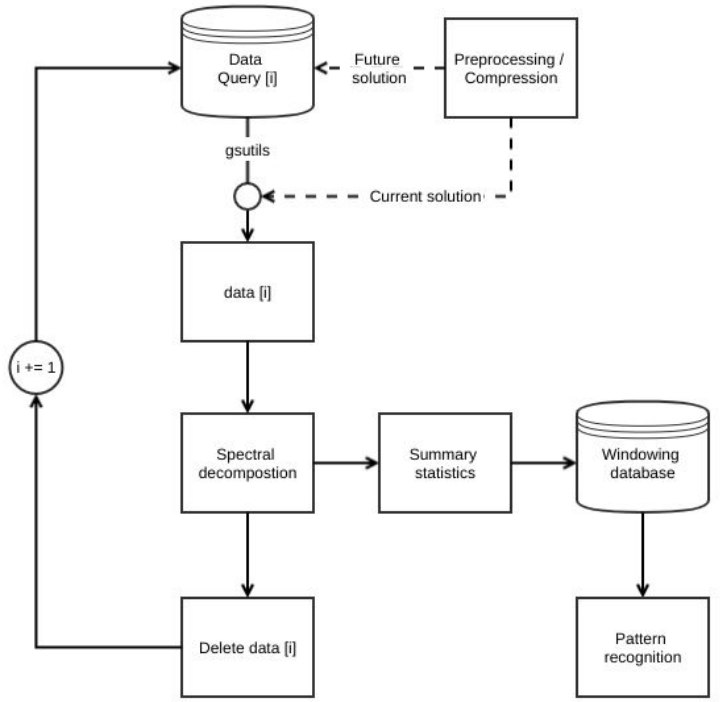


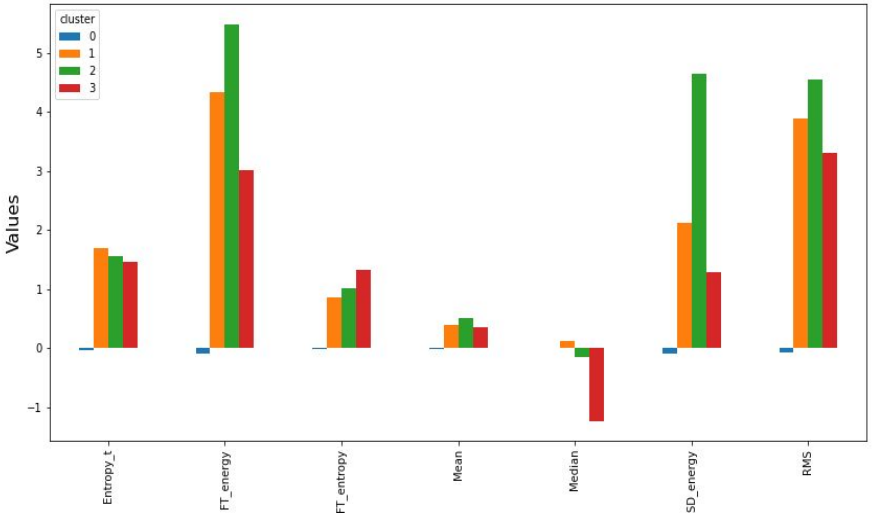
So what do I get ?

Predictive AI Tools

Discord Detection

1. **Feature extraction** from spectral decomposition (DFT/PSD or DWT/CWT)
   a. FT: Entropy, energy, cross-mean counter, main percentiles, mean, std, var, …
   b. WT: scalogram
2. **Feature selection** (max variability in the system)
   a. Peak analysis / Quantile analysis (to detect discordant data)
3. **Clustering** (k-means / PAM, others)
4. **Labelling** cluster configuration groups by PLC action
5. **Out-of-sample** classification
   a. Distance to clustering groups (to detect discordant data)
6. **Update clustering** after a number of new data. **Go to 3**.



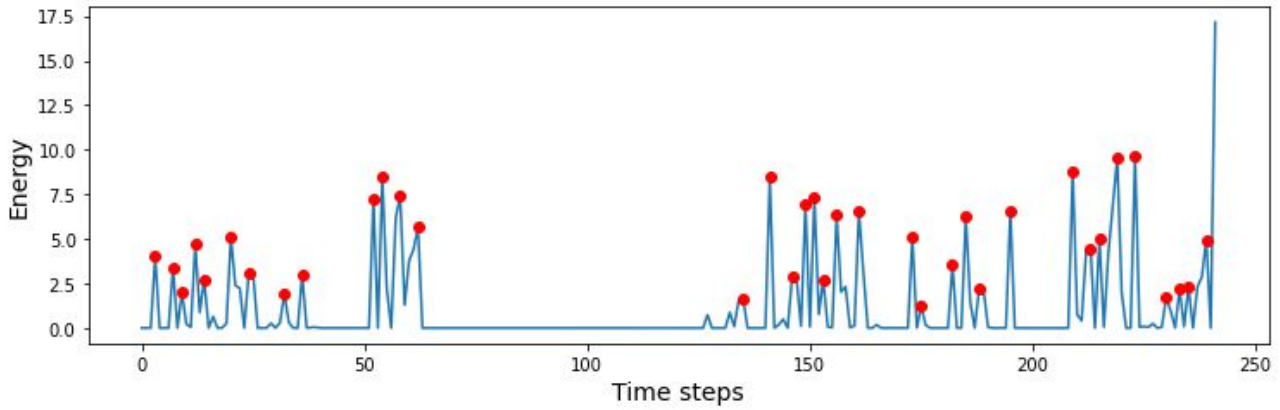


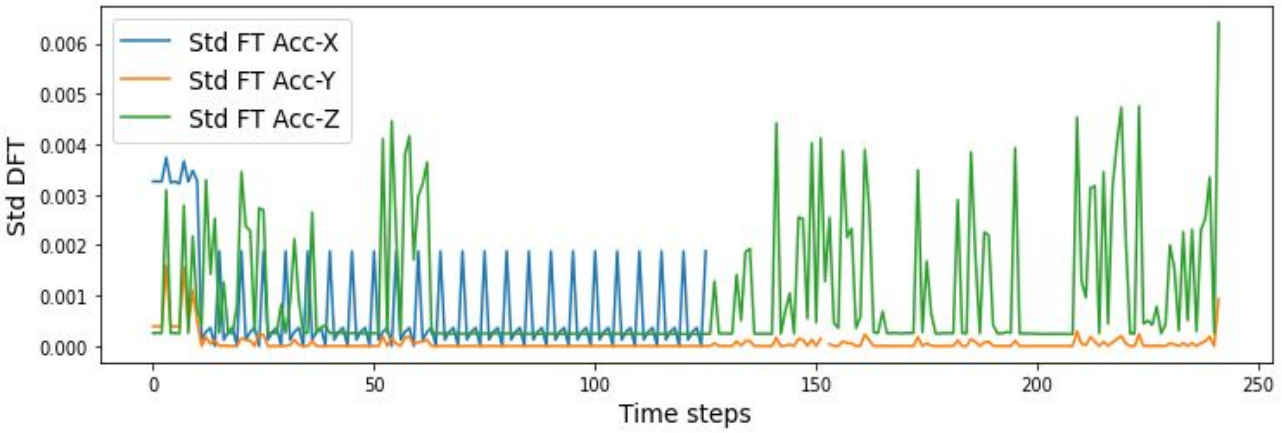
Discord Detection

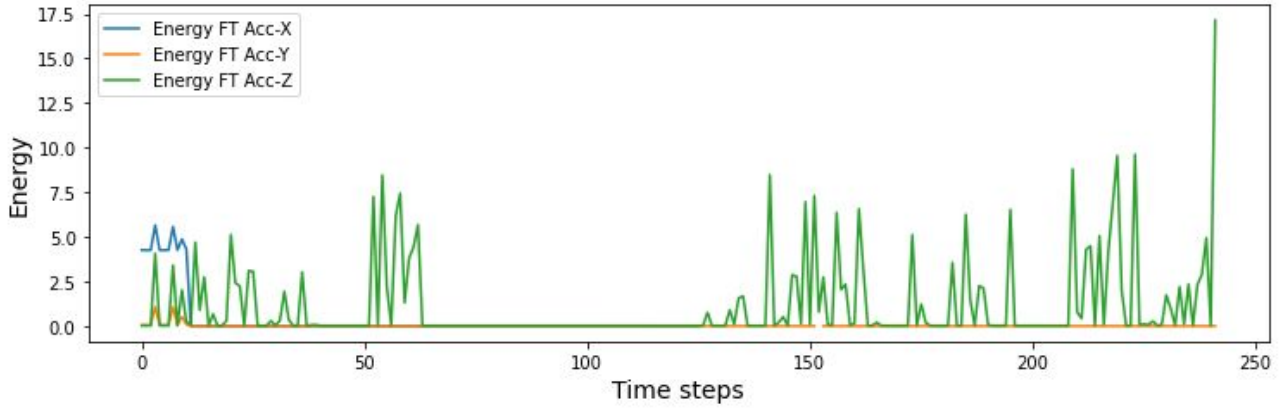
Features considered for DFT and PSD:

- Entropy,
- energy,
- cross-mean counter,
- main percentiles,
- mean, std, var, …

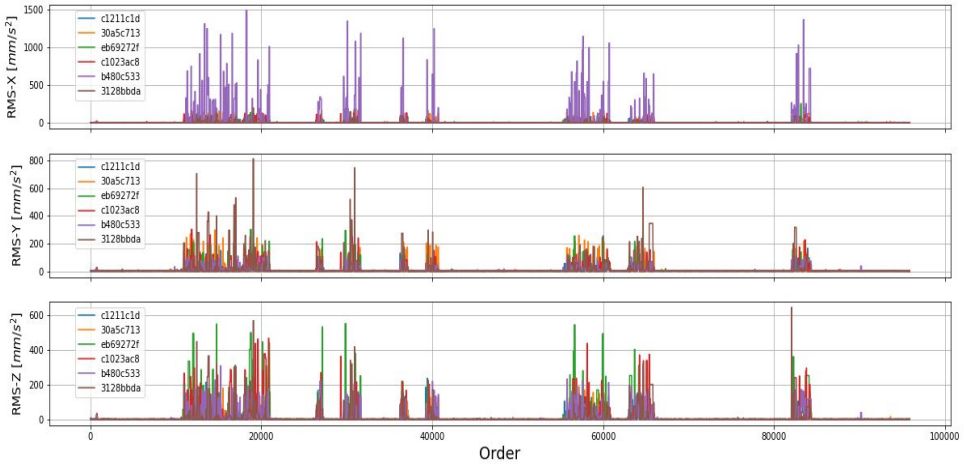
Note: Energy spectral density describes how the energy of a signal or a time series is distributed with frequency.



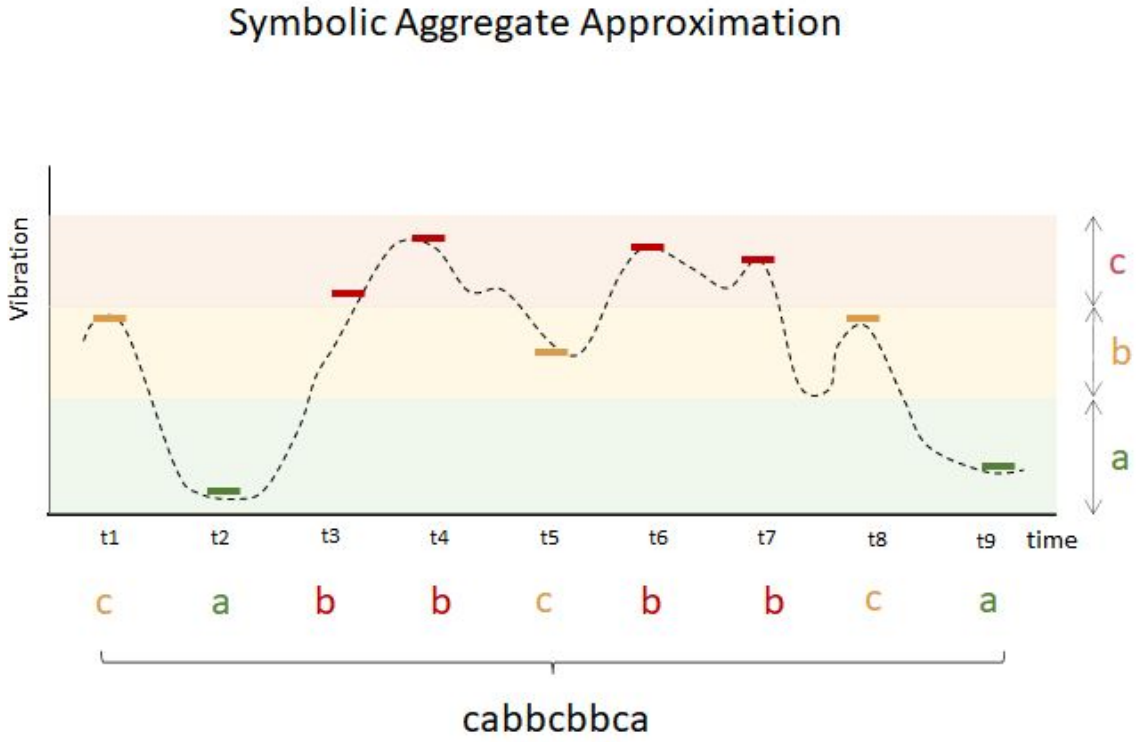




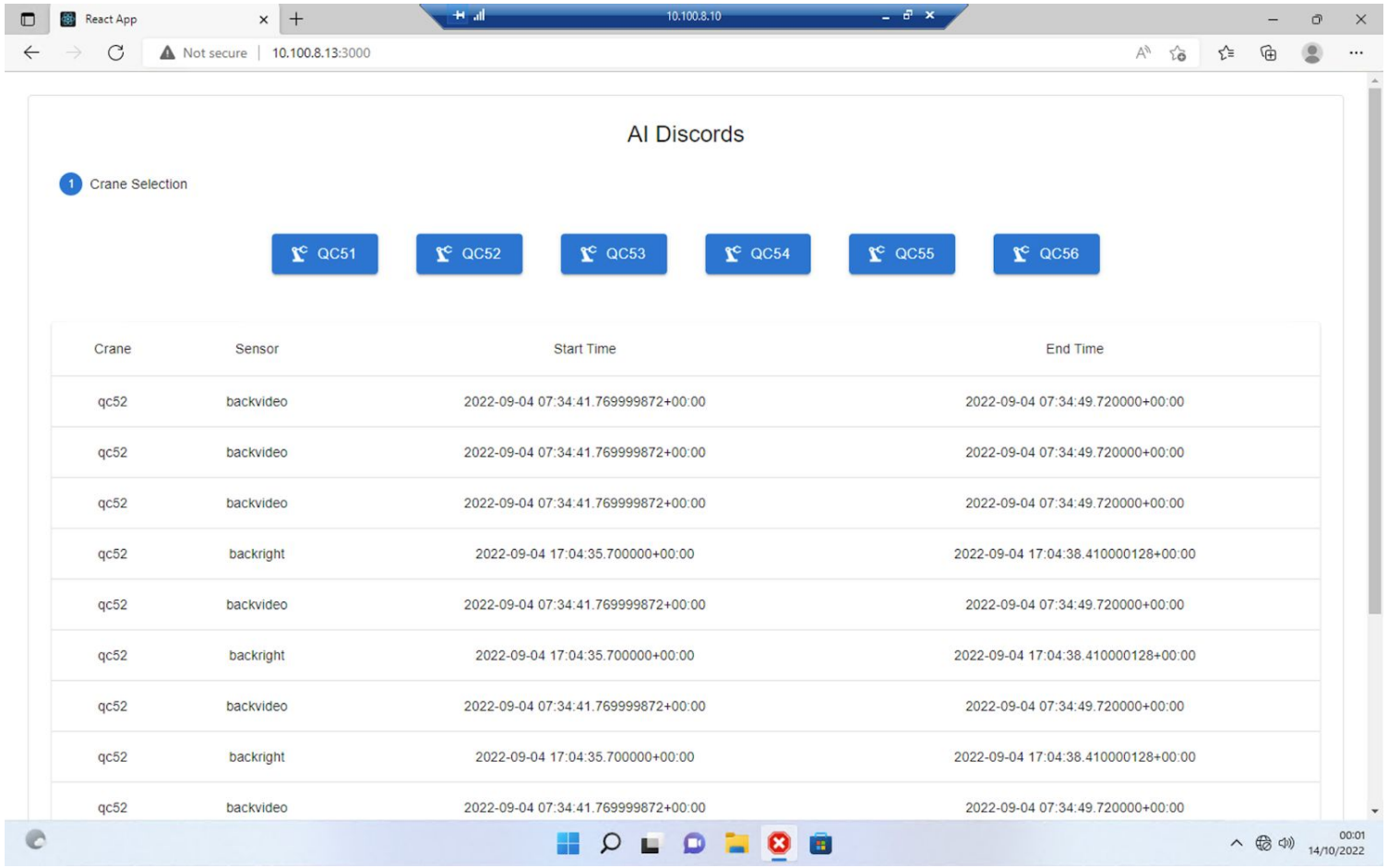
Discord Detection



Reducing dimensionality with SAX



Discord Detection ⇨ Decision Making



Engineers can investigate the crane's operational data for the Discord Timestamps and make an informed decision on reducing unplanned inspection

Web Platforms for enterprise wide / global access.

Cumulocity IoT Platform - Software AG

CUMULOCITY IoT

COCKPIT

- Home
- Groups
- Alarms
- Data explorer
- Reports
- Configuration

powered by Cumulocity

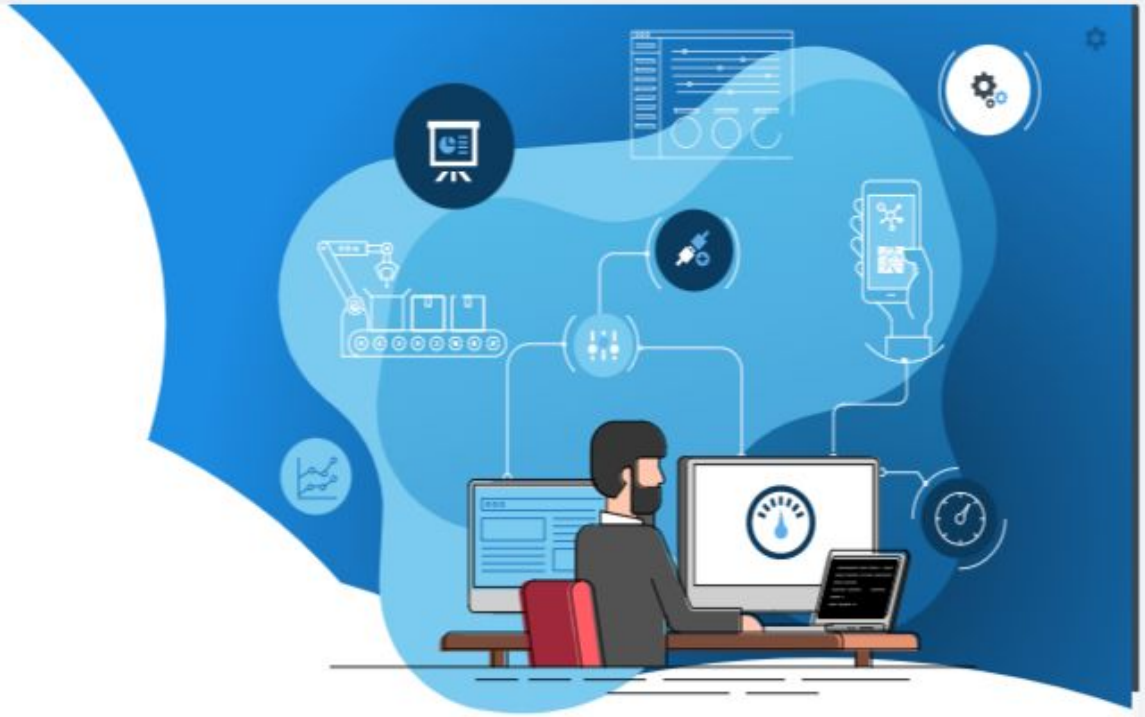
Home

admin

Add widget | Edit | Full screen | More...

Welcome to Cockpit

The Cockpit application provides you with options to manage and monitor Internet of Things assets and data from business perspective.



- Connect smartphone
- Register device
- Add group
- Reports
- Exports
- Smart rules

ACTIVE, CRITICAL ALARMS

No data received from device within required interval.
8 Mar 2022, 15:30:35 Objects

No data received from device within required interval.
7 Mar 2022, 10:02:24 Disconnected

No data received from device within required interval.

MAP

Home
Devices
Registration
All devices
Map
Simulators
Service monitoring
Overviews
Groups
Device types
Management

Info
Measurements
Alarms
Configuration
Control
Events
Location
Service monitori...
Tracking
Identity

No notes yet. Edit

DEVICE STATUS

Send connection: online
Push connection: inactive
Last communication
19 Oct 2021, 11:49:23

Required interval 5 minutes
Maintenance
Owner device_pho...

DEVICE AND COMMUNICATION

Select data points

DEVICE DATA

ID	18581175
Name	Device 001
Type	c8y_SensorPhone
Last updated	2021-10-19T09:44:24.063Z
Creation time	2021-10-12T07:56:55.220Z

ACTIVE ALARMS STATUS

ACTIVE, CRITICAL ALARMS

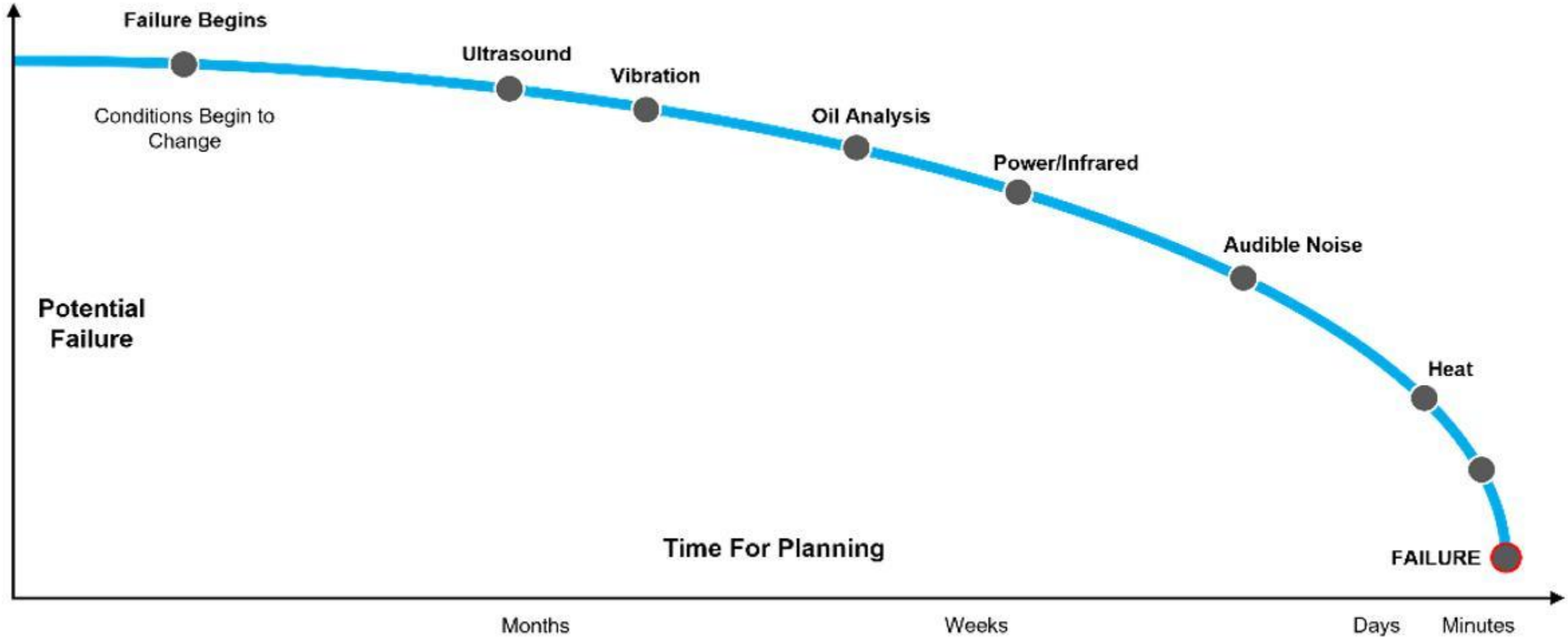
No alarms to display.

GROUP ASSIGNMENT

all devices
MySmartGroup
Smart Group
TestSmartGroup

Long Term Asset Health

Our sensors start at **Vibration,** and end at **Audible Noise** via an Acoustic Sensor and then Good / Bad analysis in the AI Discords.



Conclusions & Discussion

1. Modern sensors are cheap and wide variety
2. Deployment is fast using over the air data collection
3. Pis and Linux are easy to manipulate
4. Battery / solar can be used if power is hard to reach
5. Open Source Libraries are widely available
6. Data Analytics is an Open Source subject today
7. Combining PLC data and Sensor data allows much deeper analysis
8. Global Data Sharing platforms bring together distributed systems
9. AI and Predictive methods can significantly contribute to decision-making when augmented with expert-judgement
10. Short Term Condition Monitoring and AI Predictive
11. Long Term change of asset health for maintenance scheduling and prioritising investments
12. Low cost systems give high value data.

Thank you