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An overview of aircraft vibration environment prediction using machine learning

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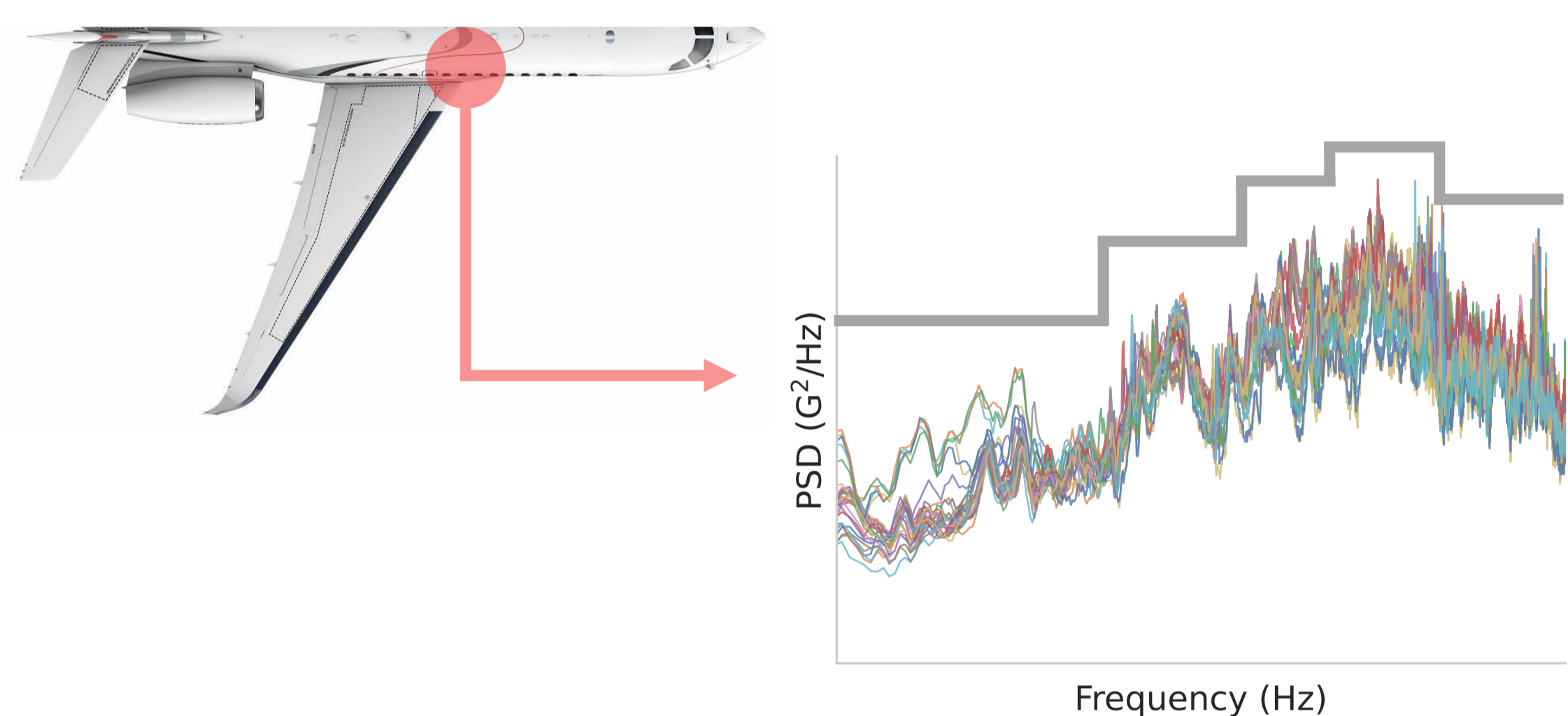
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Prediction of aircraft vibration environment using machine learning

Context

- Studying the **vibration environment** of an aircraft is fundamental to ensure the on-board equipment robustness with respect to vibrations **up to 2000 Hz**
- Challenge:** being predictive with the currently available models is a difficult task in the frequency band of interest
- Proposed approach:** to develop data-driven predictive models, based on flight test data and enhanced by physical models



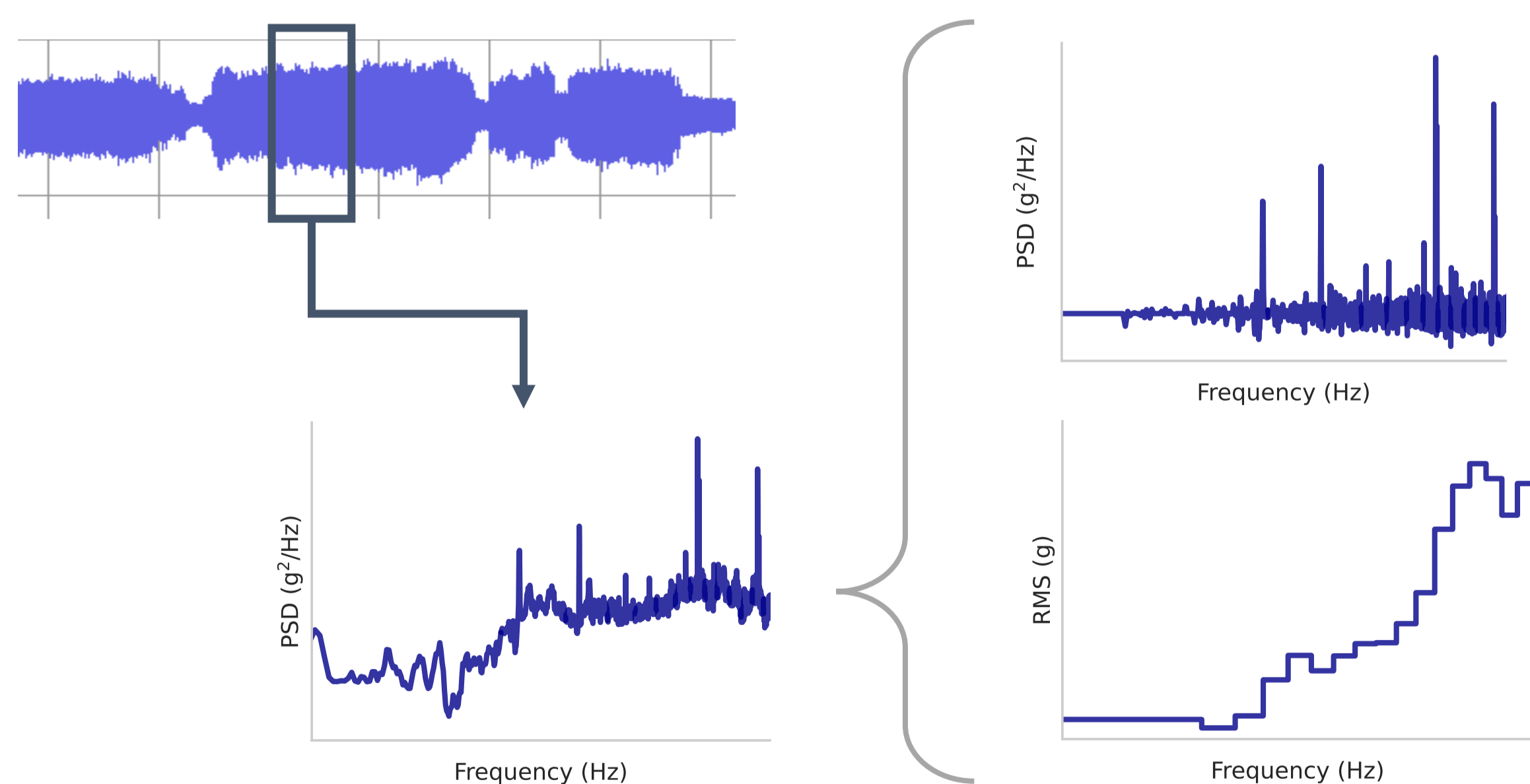
Measurements from an accelerometer close to an equipment are used to characterize the maximum vibrational levels it needs to withstand.

Thesis Objectives

- Develop new **insights** of the data: better understand the vibration environment to improve specifications
- Local model:** predict the vibration environment at one point of the aircraft depending on the flight parameters
- Global model:** predict the vibration environment at any point of the aircraft (equipment & structure)

Data transformation

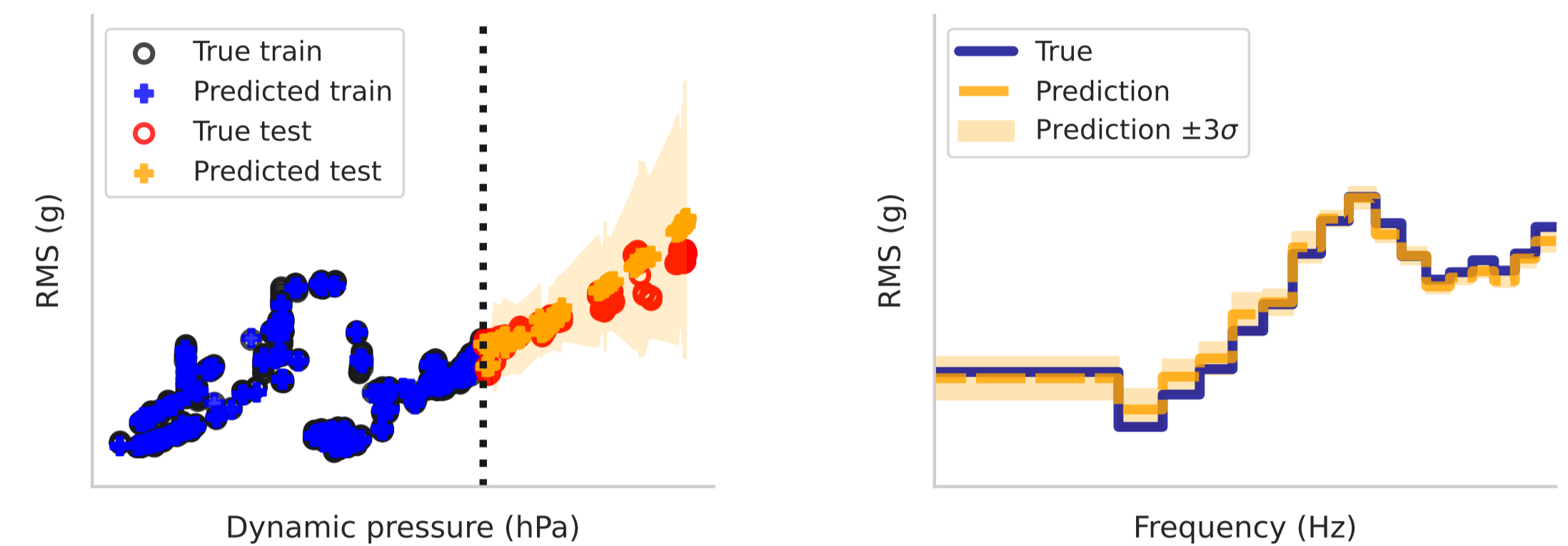
- Objective: handle the **high sample rate temporal data**
- Methods: Flight phases identification, Power Spectral Density (PSD), Root Mean Square (RMS) frequency bands compression, order analysis
- Results: data takes up **0,01% of its original size**



Data transformations from the temporal domain.

Broadband prediction

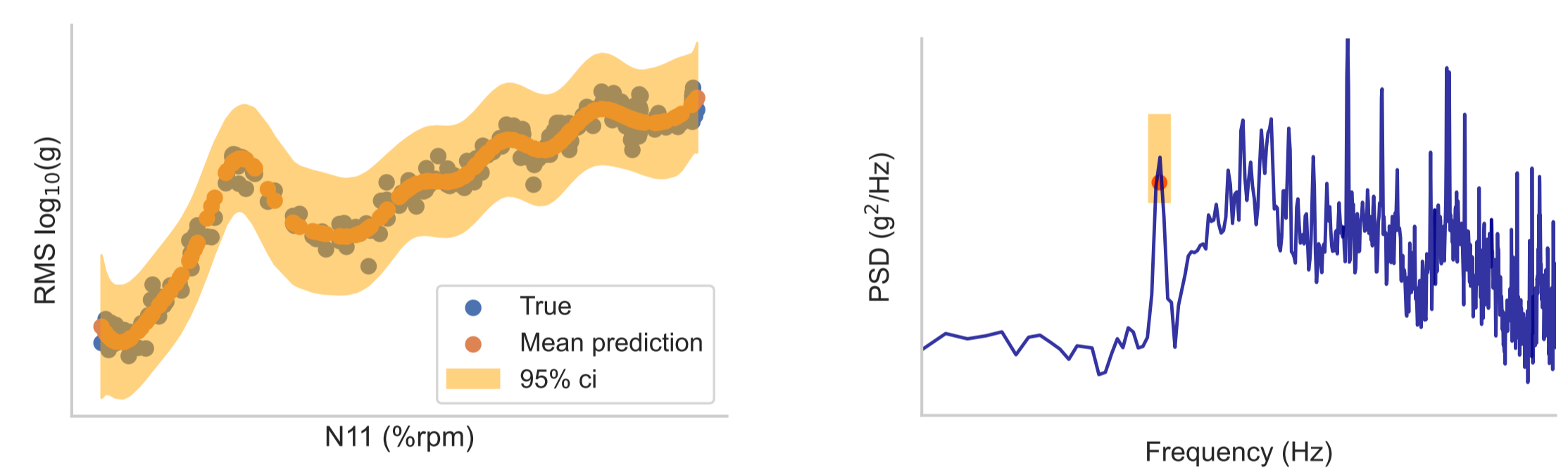
- Objective: predict broadband response generated from a **high variety of sources**, without separating them
- Methods: multivariate multi-output **ensemble model**
- Results: **1%** (random split) / **10%** (extrapolation split) **error**
- Applications: anomaly detection, flight envelope extension



RMS prediction for a specific accelerometer, projection along the dynamic pressure (left), reconstruction of a predicted spectrum (right).

Kinematic lines prediction

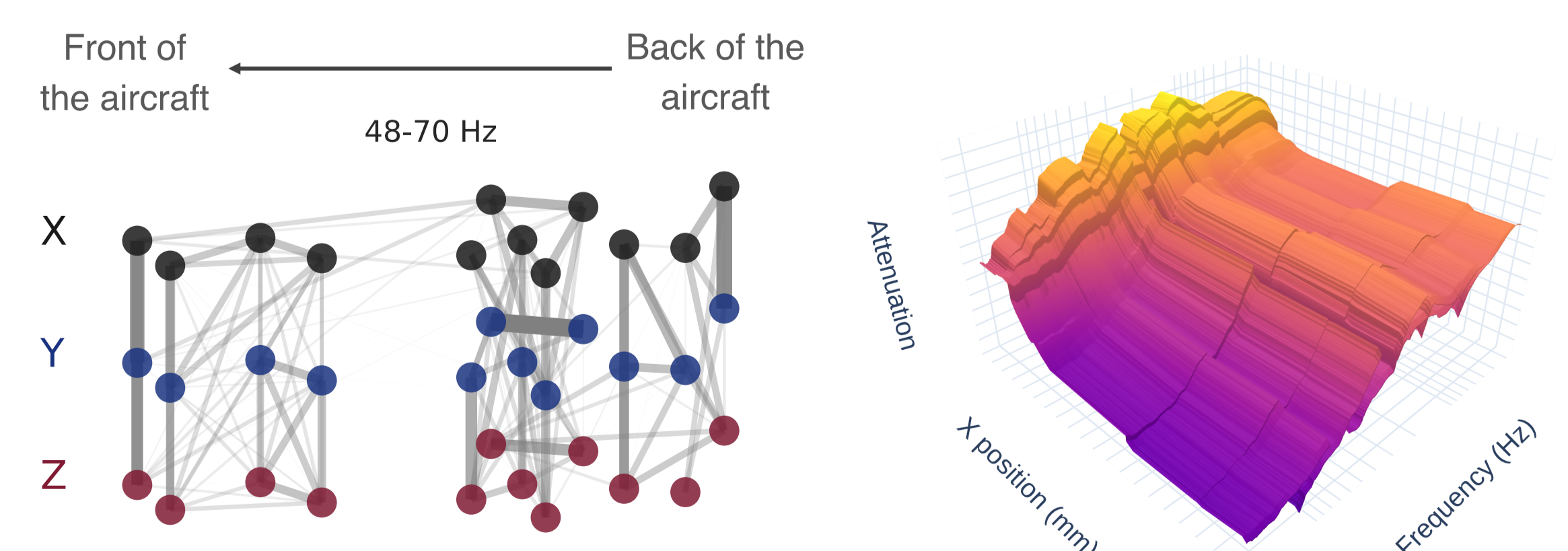
- Objective: predict engines kinematic lines, transpose ground test data to flight
- Methods: **gaussian process**, physical **transposition model**
- Results: **10% error with noise estimation**
- Applications: troubleshooting, unbalanced monitoring



RMS prediction for a specific accelerometer, along the engine %_{rpm} (left), reconstruction of a kinematic line amplitude (right).

Structural propagation

- Objective: predict vibrations environment at any point of the aircraft for a given source
- Idea: **propagation path identification**
- Methods: FE model + test data hybridization, graph signal processing techniques
- Preliminary results: **learned connections (graphs)**
- Future work: extension to new aircrafts (transfer learning)



Empirical graph learned from test data (left), kinematic lines attenuation through the structure (right).

Acknowledgments

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