

Vibration-based fault detection of accelerometers in helicopters

LAGIS

Fault Tolerant Systems team

Polytech-Lille, University Lille 1

jean-philippe.cassar midzodzi.pekpe@univ-lille1.fr

victor.girondin@etudiant.univ-lille1.fr

EADS, Eurocopter

Research and Development Department

herve.morel@eurocopter.com

Vibration-based helicopter monitoring

Helicopter mechanical transmission system

Main objectives

- To improve helicopter's availability and safety while reducing operational costs through automated algorithms able to detect and diagnose degradations within a condition-based and data managing framework
- The scope is restricted to vibration-based analysis of the mechanical transmission: shafts, bearings, meshings, couplings and rotors

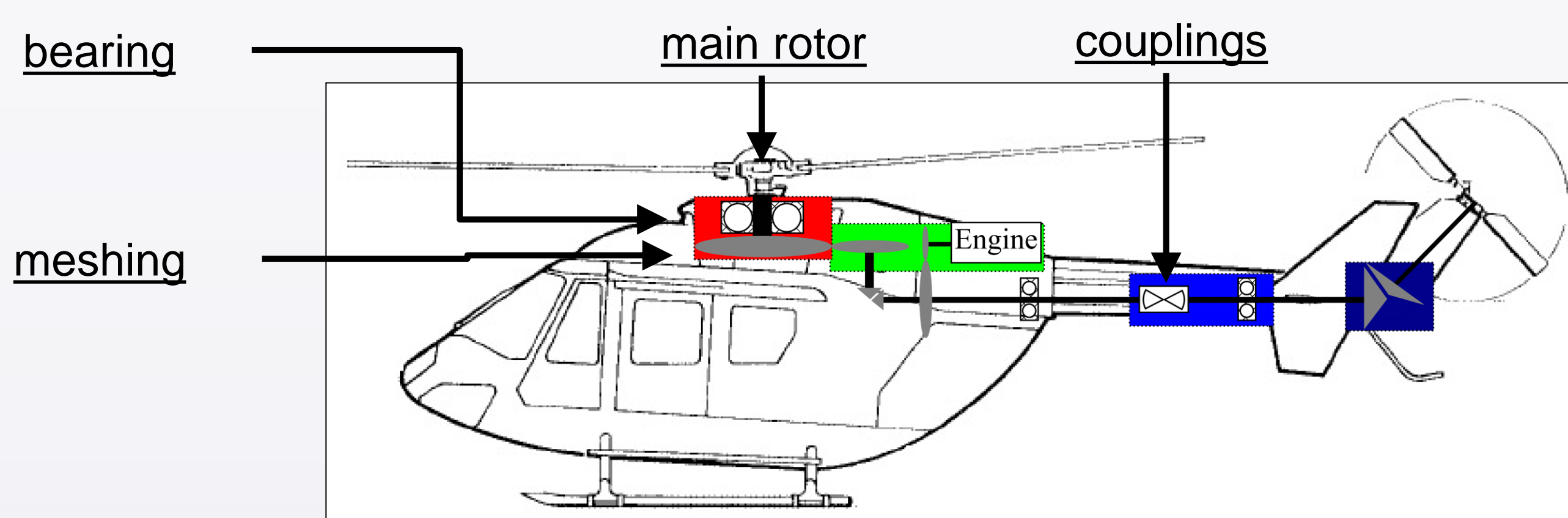
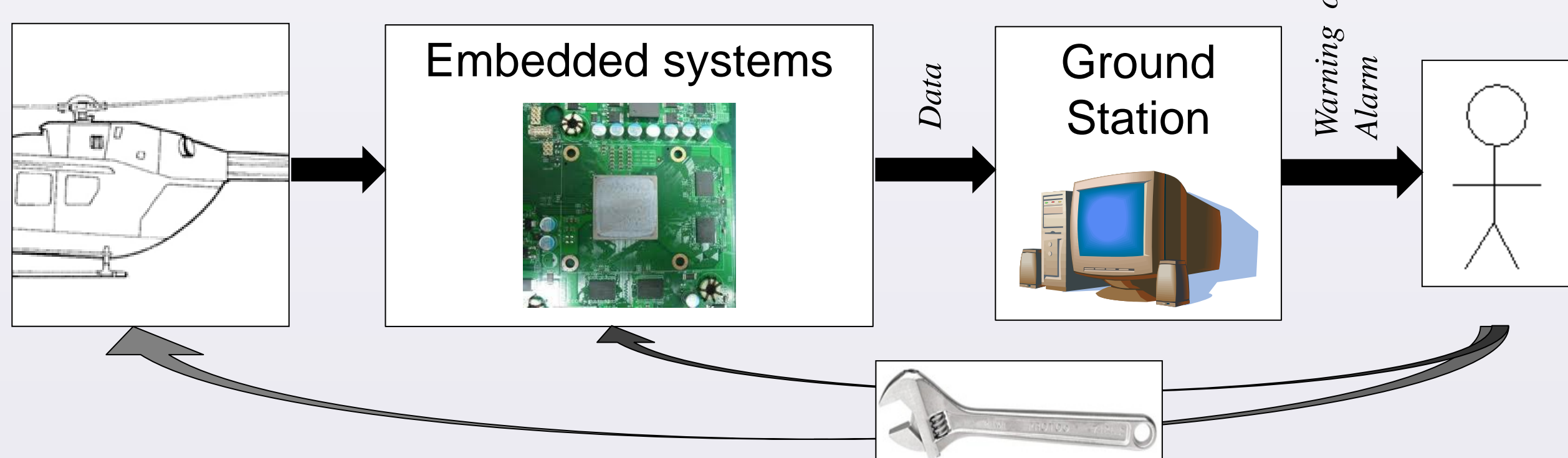
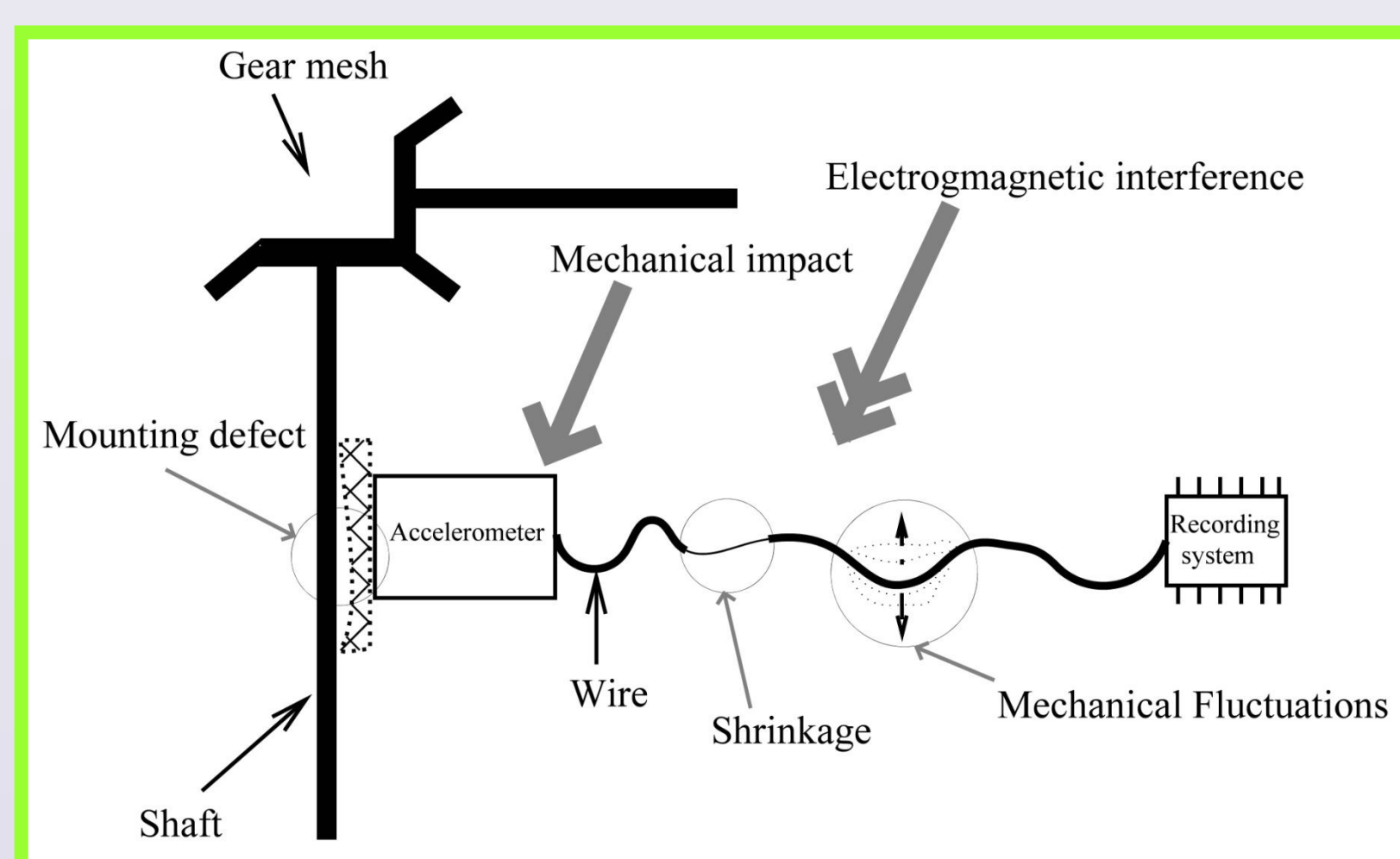


Figure 1 : Scheme of a EC145 with a simplified mechanical transmission

Context of maintenance



Accelerometers monitoring



The accelerometer is subject to several heterogeneous phenomena and to the complex dynamic response of the aircraft

Figure 2 : An accelerometer mounted on the casing of a shaft and several phenomena that can affect its functioning

Passive monitoring of accelerometers

Problem To design a passive method detecting loosening and fallings of the accelerometer that does not require trend analysis

Solution

- Operational feedbacks on **loosening** (low tightening torque) and **fallings** (mechanical shocks on the accelerometer).
- Extensive analysis of vibrations from lab experiments and flights** ⇒ strong asymmetry for degraded accelerometers.

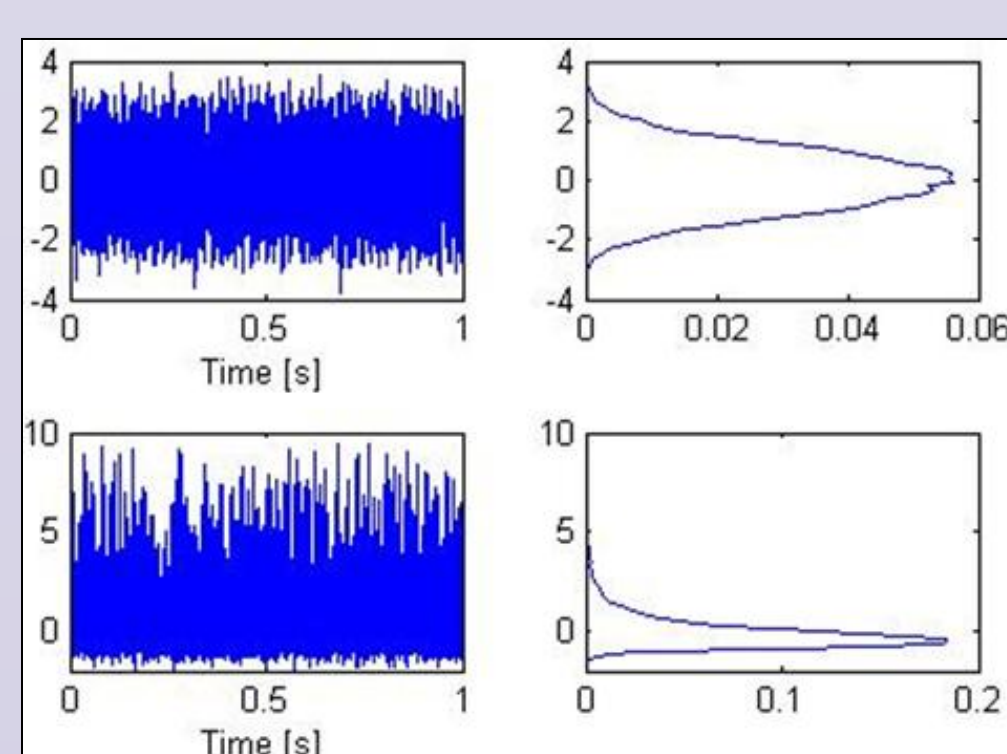


Figure 3 : Two reduced flight recordings before and after loosening. Because of this degradation, the skewness increases from 0.03 to 3.

- The third centered and reduced cumulant, called skewness, is able to measure the identified pattern.
- A linear filter optimizing the skewness is applied.
- Since this indicator is normalized, it does not make trend analysis necessary.

Acknowledgements: The authors would like to thanks J.F. Brunel and the mechanical engineering staff of Polytech'Lille for their help and support.

Resu Its for non-optimized and optimized skewness

Lab experiments : accelerometer with loosening

- Flight data that had been recorded on the **epicyclic stage** (EPI), the **main gearbox** (MGB) and the **tail drive shaft** (TDS) have been replicated with a shaker for increasing loosening.

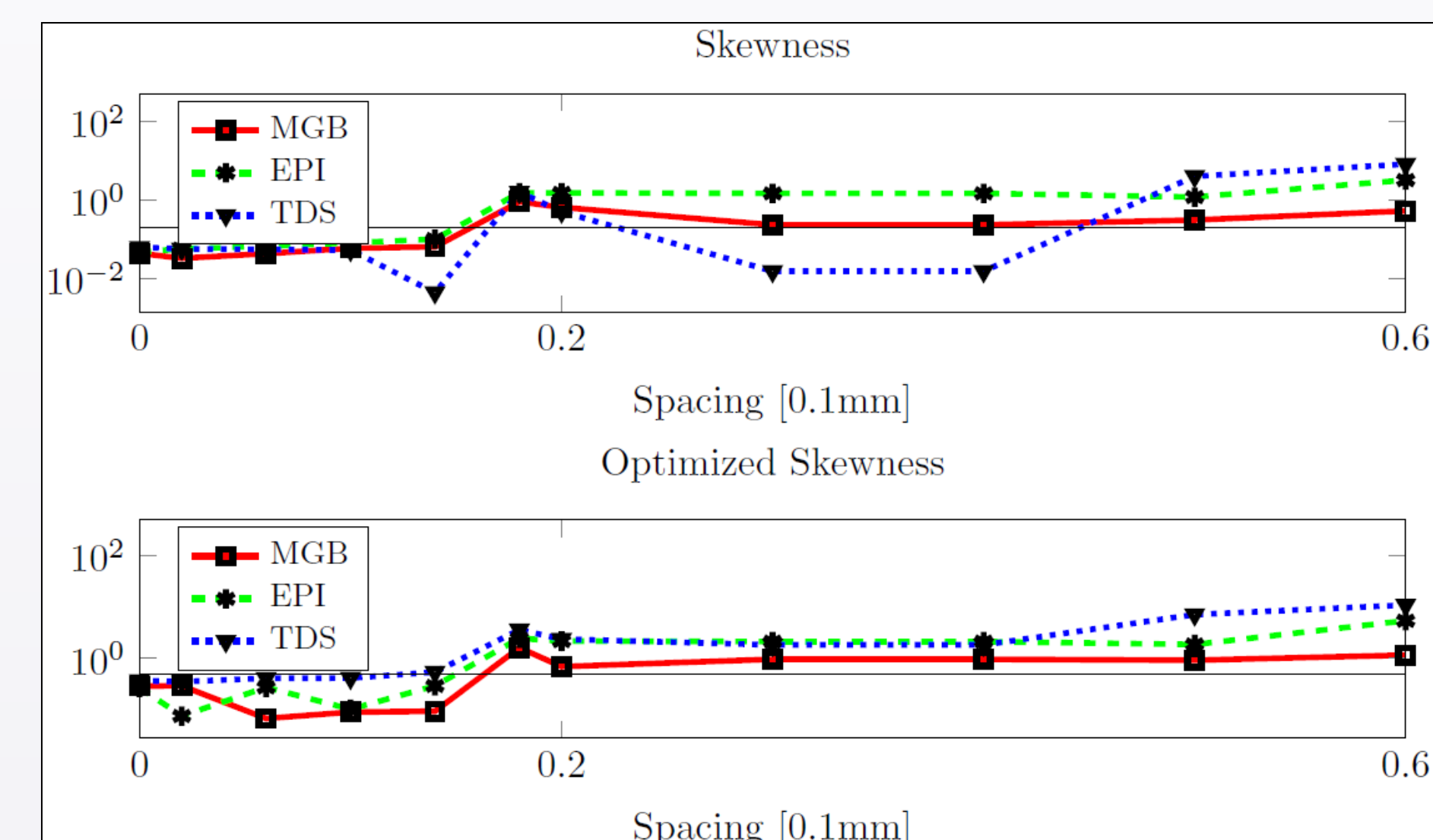


Figure 4 : Skewness and Optimized Skewness in log-scale for loosening experiment. The spacing is in 0,1 millimeters from the nominal position. Thresholds are plotted in solid line.

- **Asymmetry is visible in the global shape of the values and also through transients** ⇒ non-linear phenomena.
- Levels and patterns of asymmetry strongly depends on the locations of the accelerometers.

In-flight loosening

- 3 days of flight : 350 recordings during various flight stages (steady, hover, turn...).
- 2 accelerometers on MGB and 2 accelerometers on TDS : 50000 samples at 15kHz.
- 1 maintenance action has been applied after the 137th recording (vertical line).
- After verifications, it appeared that these MGB2 and TDS2 sensors were under-screwed.

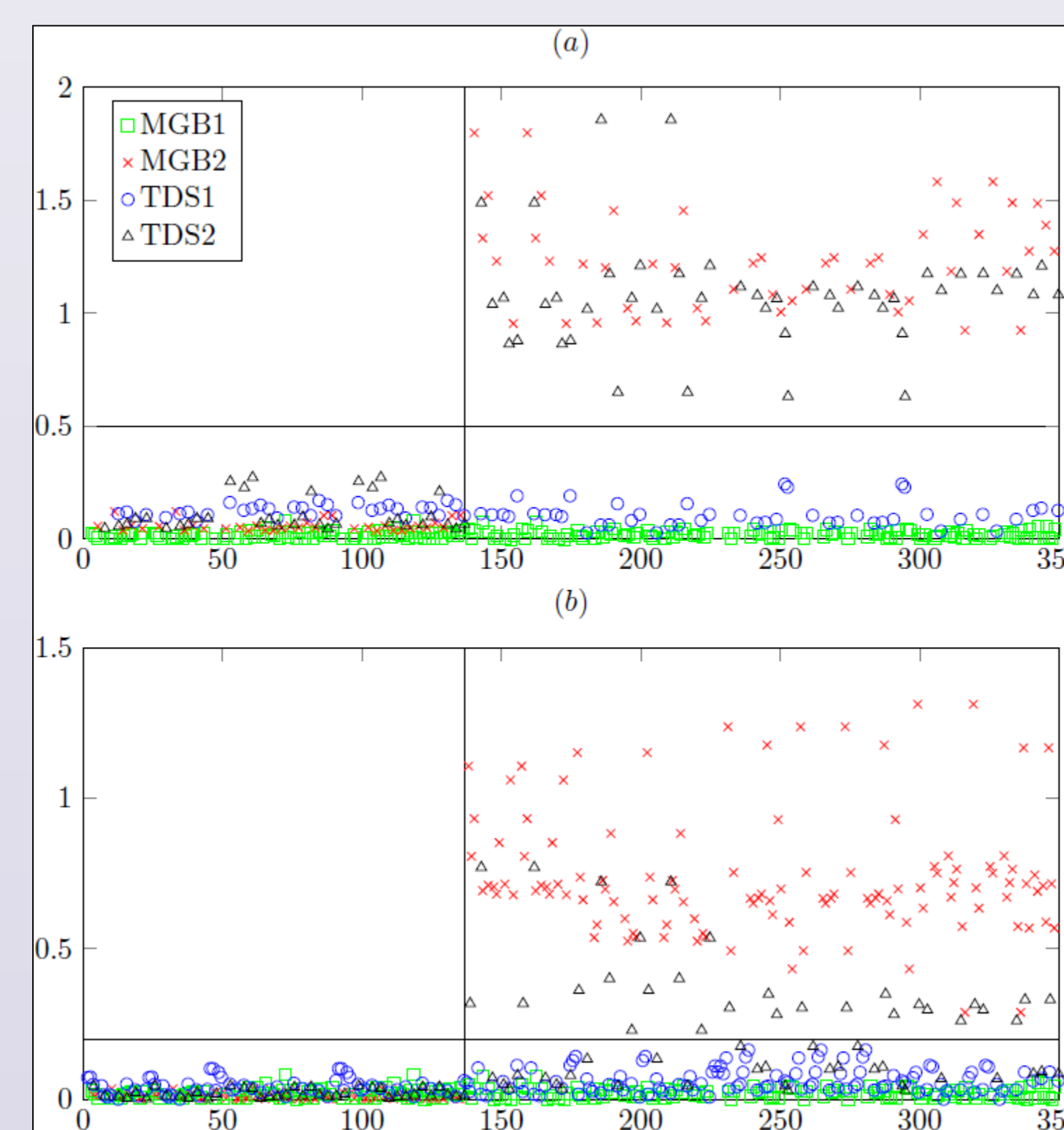


Figure 5 :

(a) Optimized skewness
(b) Standard skewness on MGB1, MGB2 (main gearbox) and TDS1, TDS2 (tail drive shaft) for 3 consecutive days. The thresholds used in figure 4 have been plotted with solid horizontal lines.

- The optimized skewness allows a better false-alarms/no-detections ratio.
- When the accelerometers are not well calibrated, they may saturate. This saturation lowers down the performances of the skewness.
- Vibrations need to « trigger » the fault.

Conclusion

- Monitoring the mechanical transmission of a helicopter ⇒ monitoring the monitoring system itself
- The two main cases of degradations have been studied and one statistical indicator has been designed : the optimized skewness
- According to lab experiments and flight tests ⇒ performance depends strongly on the frequential content of the recorded vibrations