7 CONCLUSIONS

During the course of this research, the merits of vibration monitoring for tamper detection were investigated. Firstly, vibration measurement processes, ways of implementing piezoelectric and MEMS accelerometers and data analysis methods were investigated. Secondly, A prototype device and tampering experiments for data collections were prepared. Finally, the data was analyzed and conclusions made relating to the research objectives. The aim of this research was to explore and examine the merits of vibration monitoring for developing an automatic tamper detection system. In order to achieve this the following research questions were posed:

1. What is the clarity of measured signals produced by tampering activities using MEMS and piezoelectric accelerometers and how are they affected by background vibrations?
2. How do the signal clarity of MEMS and piezoelectric accelerometers compare?
3. In what extent does spectral analysis allow to identify tamper activities and what are the limitations?

Vibration monitoring has potential to meet the technological and business requirements for a Starship Technologies Pod tamper detection. The signal clarity for both MEMS and piezoelectric accelerometers was found to be satisfactory and unaffected by background vibrations, although more environments need to be tested in the future. The piezoelectric accelerometer produces a larger signal-to-noise ratio compared to the MEMS but is more susceptible to the utility frequency. More sophisticated shielding and filtering solutions could be implemented in the future to mitigate this factor.

Using spectral analysis it is possible to identify specific tampering events such as hammering and prying and their location on the Pod. It is reasonable to assume that the system is scalable to a wide range of tools and events such as tampering with cordless powered tools such as drills, circular saws etc.; prying with screwdriver, hammer or crowbar; striking with hammer, feet or hand; lifting or tilting. However more data in a wider range of applications need to be tested in future research to give a better understanding of the repeatability of the results, in turn decreasing the potential false positives.

Merits of other sensing technologies need to be explored in future work. Combining vibration monitoring with sound monitoring, capacitive sensors and/or proximity sensors could improve the performance of the tampering detection system significantly. In particular with the detection of activities that produce weak vibrations, such as prying. The results of the investigation of accelerometer performance and spectral analysis are presented such that they can be used to aid in the design of an automatic taper detection system. Future work will be needed to investigate and implement the appropriate algorithms with spectral analysis to use for tamper detection and minimize false positives. Furthermore, distribution data of signals can be used as a measure of vibration power thresholds.

The cost of the vibration measurement prototype device was 902.06 euros including R&D (62.06 euros for parts and assembly). In series production, the device costs will be significantly lower with a final cost of 3.62 euros for parts and assembly. However, more resources will be needed to develop an automatic tamper detection. It is difficult to estimate the final cost before future work looking into other sensing technologies and utilizing machine learning with spectral analysis is conducted.