Exploratory Concepts 3.2

Our group explored several different creative directions to design a system that can measure fatigue on trailer coupling components and specifically the kingpin. Each of the 3 design concepts considered sensing capabilities (temperature, humidity, strain, and rotation) and reliable power management systems in a challenging environment of outside on a road. Each concept is broken into 3 different controllers with 3 different power systems. These are not hard attached to one another and can be mixed and matched to provide a more robust system.

The first concept uses the Heltec WiFi LoRa V3 microcontroller. This was chosen for its integrated LoRa wireless capabilities and straightforward implementation off the shelf. Paired with our sensors, this design would be powered by a large rechargeable battery capable of lasting several months without the need for a recharge. This setup allows for rapid prototyping with minimal custom engineering for a PCB. However, this system's reliance solely on battery power introduces concerns about the long-term reliability. Batteries over time are subject to degradation especially in harsh environments with rapid hot to cold temperature conditions and would create maintenance.

The second concept builds upon the same sensing framework but shifts to a completely self-powered model. This system shifts to a less power-hungry microcontroller, the ESP32-C3 which offers similar features to the Heltec controller with Bluetooth capabilities, wide operating temperature ranges, and I2C sensor compatibility. Instead of depending on a battery, this system would use an array of linear inductors to harvest energy from trailer vibrations as it travels on the road. This would reduce maintenance by removing the need for battery replacement. At the same time, the ESP32 microcontroller brings a slightly larger operating temperature range compared to the Heltec board and consumes slightly less power. The downside lies in the complexity of designing a reliable vibration harvesting power system and the potential inconsistency of energy on smoother roadways.

The final concept attempts to balance the power system drawbacks while providing another potential microcontroller that could be used to operate this embedded system. This system uses the nRF52840 microcontroller which has a significantly more powerful processor (ARM Cortex M4 compared to ESP32) while still maintaining Bluetooth, WiFi, I2C, and Zigbee protocol capabilities. It does operate a higher average power than the two other microcontrollers however. For power, this system would combine the linear inductor vibration power farm and a rechargeable battery. Energy harvested from bumps in the road would in theory, slightly recharge (or trickle charge) the battery which would in turn increase the battery life while still providing a constant power output to the microcontroller and its peripherals. The biggest drawback is that this power system adds significant

complexity, since now a custom power distribution PCB will be required to allow for the charge and discharge of the battery.

When viewed together, these concepts (or a mix of concepts) create a wide range of possibilities to solve our problem statement. Each design has its own distinct strengths and weaknesses and further exploration into these potential solutions will be required before making our final decision.