Executive Summary for the HALE Rocket Communications System

Description of the problem

The HALE Rocket Team intends to send a rocket up to the Karman Line 100 km above the Earth's surface. This is the boundary between space and the Earth's atmosphere. But before the HALE team can do that they aim to send a rocket 60,000 feet into the air as a test run. They have a number of sensors on board, such as an altimeter and an accelerometer, that they want to monitor for the duration of the flight. They also wanted to send commands to abort the flight, if needed. But since the rocket is high up in the air, no wire can send data back down to a computer. So instead, HALE wanted a wireless communication system that brought data back down to Earth and sent commands up to the avionics unit. They put us in charge of designing the system. The requirements they had were that it had an uplink and a downlink, that it transmitted some form of written data (not audio), that it transmitted reliably up to 60,000 ft and that the communication module for the rocket would fit inside the body.

How we approached the problem

At first, this project was daunting and it did not help that our original project partner did not respond to our email. Eventually, we got in contact with the HALE team leader, Connor, and he described to us the goals of the communication system. The biggest challenge we were facing was how we would design the electronic components of the system and get them to receive and transmit. No one had any experience with designing transceiver and receiver systems, so it seemed impossible to design one that was good enough to transmit and receive up to 60,000 feet. So instead we opted to buy the Hamshield module, which contained all the electronics for a transmitter/receiver. It was also really sensitive to faint transmissions (signals down to -124 dB in strength) and communicated through AFSK modulation. Plus, the Hamshield was designed to work with the Arduino, which is an inexpensive microcontroller that we all have experience with. So this was the best platform to use in our opinion.

What we designed were the antennas, enclosures, code and the power supplies. There were still plenty of design issues we had. For one, we were worried about the rocket body interfering with our signals. We opted to use four antennas, spaced 90 degrees apart and two for transmitting and two for receiving, and a switch, which is triggered by the Arduino, to control which antennas receive or transmit signals. Then we figured we'd have to design a protocol system, which would have been just as daunting as designing the transceiver electronics. We decided to try to tackle this later on in the project, but we ended up not having enough time to. The HALE Rocket team never requested a protocol for their system specifically, so this was not an issue.

Before fall term ended, we bought some materials for our project, including the Hamshields. It was good that we did that because the company that sold them went out of business by the time winter term started. If we had tried to purchase them later, we would have had to redesign our system from scratch. All of winter term, we did our own blocks, but we did meet together occasionally to update each other on the blocks. The enclosure was 3D printed with hard plastic. The construction was sturdy but holes needed to be drilled into the box to allow for connectors. The power supplies were constructed on breadboards and were verified that way. The code was adapted from some sample code on the Hamshield GitHub page and modified to fit the needs of our own system. Finally, the antennas were built based on the designs that were made in fall term.

Each block seemed to turn out well and by the end of winter term we were already assembling the final project. We were able to get close range one way communication working, which gave us a head start in spring term. (Once we had figured out how to get messages to send and print out on the serial monitors, we knew we were almost done.)

Once spring term arrived, we started distance testing our communication device to see if it would work at 60,000 feet. However, we soon realized that this was not an ideal way to test since it took a lot of time and planning just to do one test and inclement weather also stopped us. The more efficient way to test this requirement was doing measurements of the antenna gain and power transmission and use those to calculate the range of our system using an online RF calculator. Additional difficulties we faced were working with the unreliable and undocumented Hamshield codebase as well as the power supply overheating and shutting off. Eventually, we just bought a power supply and used it as one of our purchased blocks and got our code to work for two way communication.

Finally, system verification came and we were able to meet all of our requirements. We were able to create a successful product by meeting frequently and by planning ahead.

Lessons we learned

There were many lessons learned throughout this project and none of them were insignificant. Although, probably the greatest lesson learned was the importance of communication in a team. There were times throughout the terms where communication was poor about when meetings were, when components needed to be ordered, and when blocks or important items needed to be completed.

Another lesson we learned was how a well thought out approach in the early stages of the term will make life much easier come spring, there were blocks changed a few times due to poor planning, specifically the power supplies for both the ground station and rocket were changed three times for a multitude of reasons, being size, efficiency, and poor connections. In the designing phase we stayed too broad and general instead of diving into each and every last specification and connection which made the building and troubleshooting phase harder than it needed to be. It caused our team to spend extra time just trying to connect our system blocks and things we thought were a given turned into problems.

Perhaps a slightly less significant lesson we learned was the importance of engineering wording in documentation, wording used in engineering papers cannot use language that leaves interpretation up to the reader rather the wording must be concrete in what it means as well as concise.

Original Timeline