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Personal progress

In the past two weeks, I have continued to make progress on the final system hardware and flight testing. I helped with a number of major milestones recently: We flew with weights to test dynamics, testing the communications system and got the full hardware working and flying for the first time.

One of the big pieces of work during this project sprint was getting all the system hardware completed and on the quadcopter so that we could run our full software stack and begin to introduce new features and improve on the old ones. As I've mentioned before in previous IRLs, one of the big concerns that we had on the hardware side was the overall weight of the quad. In order to solve this, I had to go through the careful process of removing the Velodyne electrical box from the VLP-16 unit and shortening the data and power cable attached to the Velodyne, so we could save about 300 grams.

Table 1: Cable assignment for the Velodyne VLP-16 I used for reference for matching up the correct data lines.

Wire	Signal	Input/Output	Specifications
Black	Ground	Input	System Ground
Red	Power	Input	9-18 V_{DC} / 12 W
Yellow	GPS Sync Pulse	Input	0 to 15 V
White	GPS Serial Receive	Input	0 to 15 V
Light Orange	Ethernet TX+	Output	Differential
Orange	Ethernet TX-	Output	Differential
Light Blue	Ethernet RX+	Input	Differential
Blue	Ethernet RX-	Input	Differential

Table 1 shows the wires coming out of the Velodyne. For our application, we are only concerned about the power and the Ethernet lines (we aren't using the GPS lines on the LIDAR). I then compared that table to the wiring diagram that is supplied for the Velodyne Interface box to figure out which cables map to which pins on an Ethernet cable, shown in Figure 1.

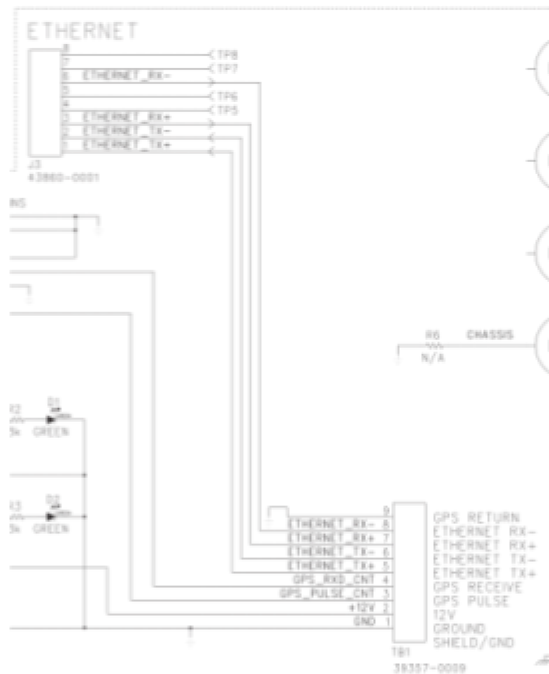

Figure 1: Interface box mapping to ethernet pins

The final assembled result is shown in Figure 2. I put fuses on the output lines to protect both the Orbitty/Jetson and the LIDAR. The connection box that I removed had some circuit protection, including a 3A fuse, so in order to have and equivalent level of current protection while still keeping the weight down, I added a fuse holder and fuse in line with the output from the power module. I added another 3A fuse on the power supply to the Jetson/Orbitty carrier since that is normally unprotected (the power module we are using does not have fused outputs, a sacrifice we are making because of weight.

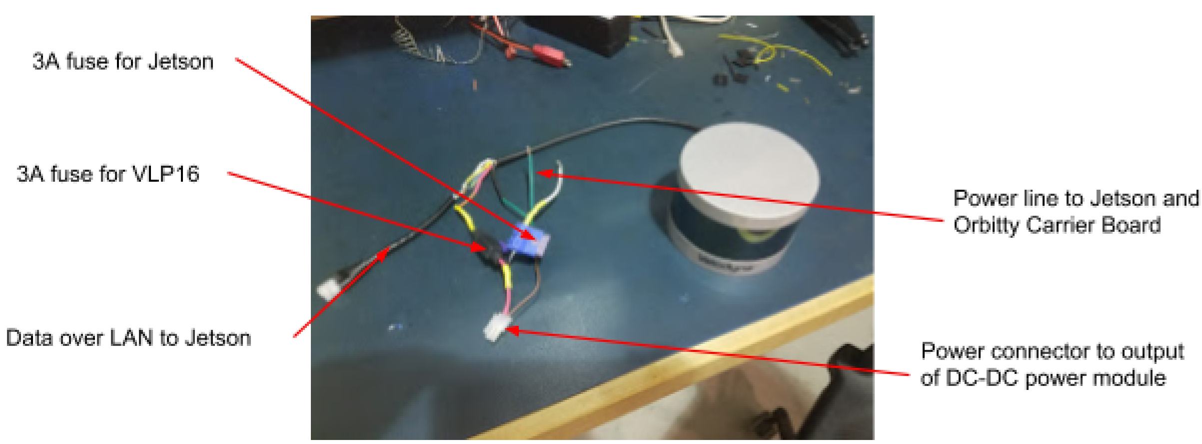

Figure 2: Shortened Velodyne cable with box removed

Speaking of the power module, I finally got the power module in after a few delays in the shipping process. At least for this phase of the project, we chose to use a COTS part with as low a weight and as high a reliability as possible. After some research done at the beginning of the semester, we chose the Castle Creations BEC 2.0 Voltage Converter, a programmable DC-DC converter taking in 25 volts. When I first got it, the default output setting was only set to 5V, so I had to connect the DC-DC converter to a programming board and hook it up over US to my computer, from which I was able to change the output to 12 volts (the recommended voltages for both the Velodyne and the Jetson). Once that was done, I tested the output to verify that it was stable and could drive a load, and then put it on the quad to power up our 2 main electrical system components.

Additionally, I made some small changes to how we mount the LIDAR. In the past, I used a 3D printed block attached to the top of the quadcopter. I was a little worried about initially starting the Velodyne out too high and throwing off the vertical center of mass, which could result in instability when translating in the air with such a heavy component so high up. I decided to at least start with the Velodyne lower down, removing an extra stack to the mounting frame and removing the 3D printed attachment plate. In order to actually attach the Velodyne in its place, I drilled straight into the mounting frame, put a ¼-20 bolt straight up into the threaded hole just like before, but this time I added a jam nut on the bolt. This allow me to position the Velodyne much more precisely than before (no jam nut), and much more secure than it was before (previously the Velodyne was slightly loose since there was no locking on the bolt itself since the Velodyne has only a single blind hole for mounting. The overall system is shown in Figure 3.

Figure 3: Flight system with LIDAR and Jetson onboard ready to detect obstacles

I also worked with Shivang and a a rotating cast of team members to test the system in its various forms. The summary of the flight tests are shown in Tables 2, 3, and 4.

Table 2

Flight Number 1: Dynamics Test	
Takeoff Weight	3.65kg
Duration	~8 minutes
Tests Performed	• Fast Climb, Fast Descent • Yaw continuously • Forward and backwards (full speed)
Notes	• All dynamics and pilot input data recorded as bag file on Jetson

Table 3

Flight Number 2: Communication Test	
Takeoff Weight	3.65kg
Duration	~10 minutes
Tests Performed	• Jetson publishing Bird's eye view image (prerecorded via bag file)

	● Fly around various distances, altitudes and quad orientations ● Point directional antenna at the moving quad ● Check the latency on the base station computer screen
Notes	● No lag seen with image when flying at 10-15m in altitude and <= 40-50m from base station ● Some lag seen when flying at higher than 15m altitude

Table 4

Flight Number 3: FVE Test	
Takeoff Weight	3.65kg
Duration	~5 minutes
Tests Performed	● Takeoff, hover in open area ● Gradually approach trees, move away from trees ● Land
Notes	● DJI, Velodyne LIDAR data recorded in bag file ● Bird's eye view image came live and accurate ● Jostling of landing disengaged power connector to Jetson

Challenges

Getting the cable cutting right and completing the electrical assembly required a lot of delicate work and attention to detail to get right, so that was certainly a challenge. I plan on writing up a How-To on the course Wiki page for how I did it in case anyone needs to do that in the future. Having enough time and cooperative weather to test has always been and continues to be a significant challenge, though luckily the past couple of weeks had stretches of better weather, and we were able to get a lot of testing done.

Teamwork

Joao: Joao created a model for how the quadcopter behaves based on the pilot inputs, creating a simulation that closely matches the ground truth data of the actual quadcopter velocity. He also work on refining the user interface and the obstacle coloring, which has been developed offline, to be integrated soon.

Shivang: Shivang worked on leading the flight testing and worked on getting all the communications and data logging parts of the system set up to work smoothly. He also worked with Joao in defining the parameters for the dynamic model.

Hari: Hari assisted with the flight testing, recording data and experimental procedures. He also worked with Joao on the coloring and has been doing work on generalizing the sound warnings to 3 dimensions

Nihar: Nihar was been working on the user interface and the FPV camera, which is one of the next immediate steps for us to integrate onto the system.

Future Work

We essentially have the FVE system running in the air, so our main goals is to improve robustness of the existing system while gradually adding in more features while continuously testing in simulation and the real world. Specifically:

- Make hardware more robust
- Conduct more flight tests to improve obstacle warning algorithms
- Test pilot control override in simulation

For me personally, I will be working on the following to support these team goals:

- Hardware robustness
    - better securing of wires, better connections
    - Add FPV camera with dedicated 3D printed mount
- Flight testing
    - Continue operational support and data collection
    - Improve process for moving stuff
        - Get directional antenna mounted on the tripod
    - Software support
        - Help in the development of the obstacle algorithms where needed