SPACEDUCKS II

REPORT MAY 2021

CLUSTERDUCK PROTOCOL™ PROJECT OWL QuackHeads

SPACEDUCKS II

SAN LUIS OBISPO, CALIFORNIA - MAY 2021

The payload crew were conducting last minute tests to ensure quality data was being transmitted. At the same time, the launch crew was filling up the balloon to the correct size. Too little helium, it won't reach the desired altitude, too much helium and it will not follow the predetermined path. It was already past 4 pm PST and the payload still had not launched yet. The wind is picking up as time is ticking.

After last minute tweaks, the payload is attached to the balloon. Assembly complete. Inch by inch the string that connects balloon and payload - just like a kite - is let out allowing the balloon to ascend the first few feet in altitude. But gusts of wind continued to batter the launch site. The balloon was bobbing left and right, meandering around a barbed wire fence. The payload must release with a gust that would avoid barbed wire and nearby trees, otherwise the most expensive balloon most will ever touch goes "POP!" Some were screaming, "Let go!" Others cautioning "Hold it!" Evan, in control of the payload let go at just the right moment and with that, SpaceDucks II is officially LAUNCHED!

Clockwise from top left: 1) Custom Project OWL electronics, the "Le Fourier" space helmet, 2) Assembly of AQUILA-1 on launch site, 3) Moment of launch for AQUILA-1, 4) Team operating ground station to communicate with AQUILA-1.

PHOENIX-1 at 85,000 feet above California.

BACKGROUND

Project OWL's mission is to connect the people, places, and things you care about the most. We deploy IoT devices called DuckLinks or "Ducks" that people or things can connect to and communicate with. Understanding the different environments that information can travel through is crucial to engineer a system where data consistently travels from sender to receiver. One of the toughest environments to address is space. If we can understand how to effectively propagate information through space, then we can harness this knowledge to enable more robust and resilient global connectivity.

Project OWL and students from California Polytechnic State University came together in San Luis Obispo on the week of May 10, 2021 to launch SpaceDucks II using weather balloons. A SpaceDuck is Project OWL's unique design of a CubeSat. The payload consists of customized electronics, firmware and enclosure and three different antennas. The SpaceDucks II event featured launches on three different days from three different launching sites in California: two locations in Parkfield and one in Creston.

MISSION

The mission for SpaceDucks is 1) Prove that DuckLinks can operate effectively in an extreme environment and 2) Test viability of sensors, communications, and physical design. On the ground station a Yagi antenna was listening carefully for data packets that were transmitting through LoRa from the Duck hardware. In space, Iridium satellites were listening for data packets coming from the flight electronics inside the payload.

The ground station crew waiting on the landing site with the Yagi antenna.

Google Earth was used to identify the best locations to launch the balloon, a predicted travel path, and develop an estimate where the payload will land. These predictions took into consideration weather conditions such as wind speed and direction.

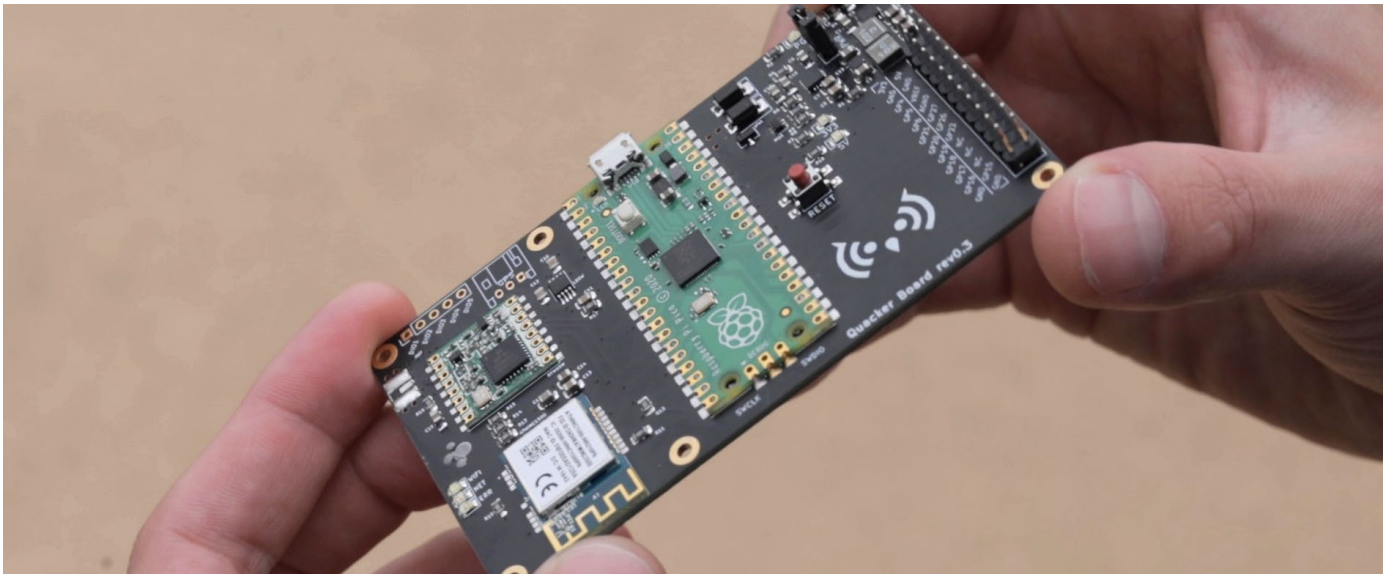
Predictions of the balloon's flight path for AQUILA-1

All data from the SpaceDucks, whether transmitted over Iridium satellite or LoRa radio, flows through the network into the OWL Data Management System. Using the data, such as GPS, acceleration, and altitude, an estimate location of the landing site is updated in real time. The final launch predictions were so accurate that the PHOENIX-1 SpaceDuck on launch day 3 was nearly caught by hand when it landed.

"Vanalytics" team tracking the baloon using live data.

Kevin Dixon watching live data over LoRa.

What made this deployment more special than any other preceding it is the implementation of the QuackerBoard for the first time. This board was the brains of the SpaceDuck and was responsible for collecting all the data from the attached sensors and sending that data over satellite and LoRa, while also storing it on an integrated SD card. The QuackerBoard is a circuit board made by the Cal Poly students featuring a Raspberry RP2040 chip, a LoRa Module, and a WiFi module. It performed exceptionally well, beating all expectations. The results of SpaceDucks II will inform the next round of revisions for this development board that will run the ClusterDuck Protocol.



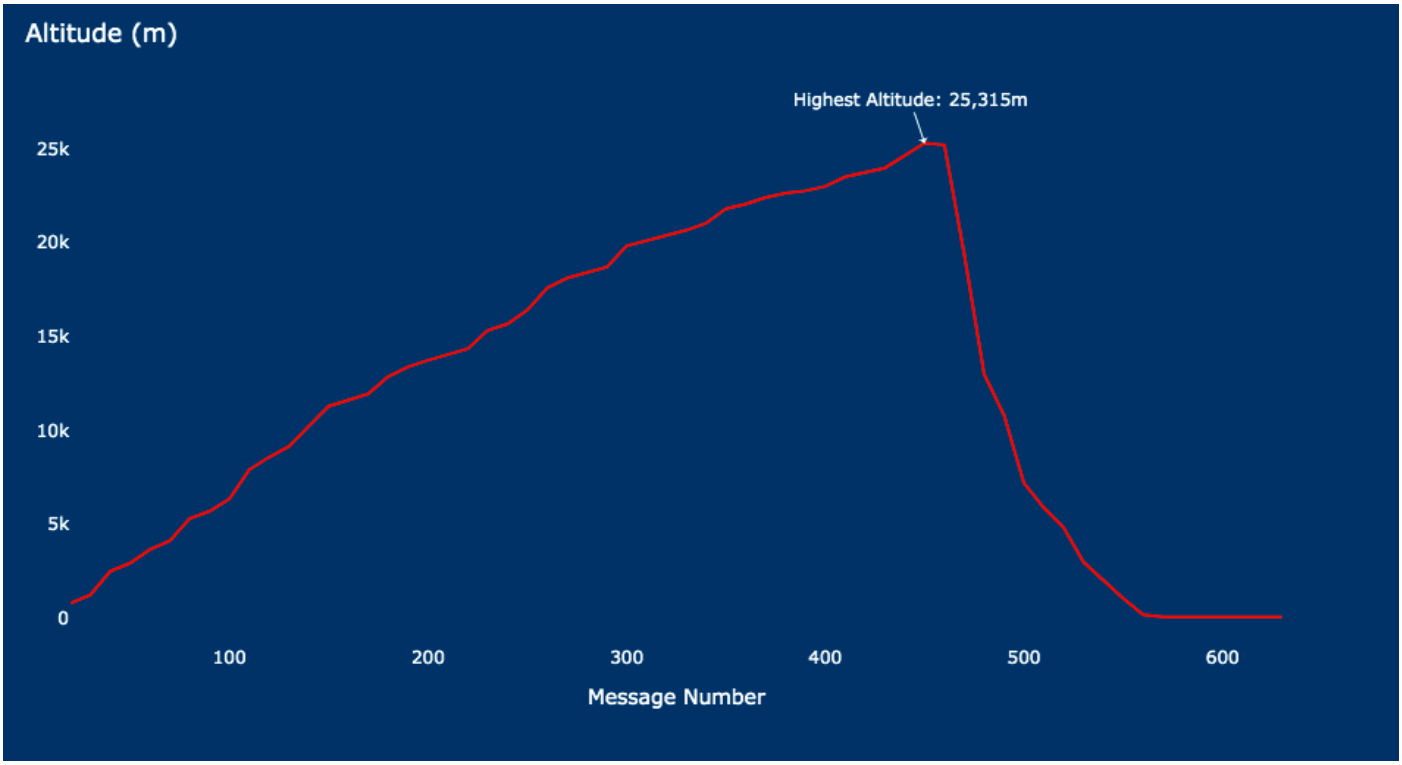
Custom OWL electronics developed by Cal Poly students known as the "QuackerBoard", used as the core flight computer.

The firmware that collected and transmitted all data is a modified version of the Open Source ClusterDuck Protocol. The ClusterDuck Protocol was originally built to run on ESP32 development boards but it had to be rewritten to support a new microcontroller called the RP2040. The engineering effort took a committed team of students to get the ClusterDuck Protocol running on the new RP2040 chip that was integrated into the custom electronics showcased in this report.

THE DATA

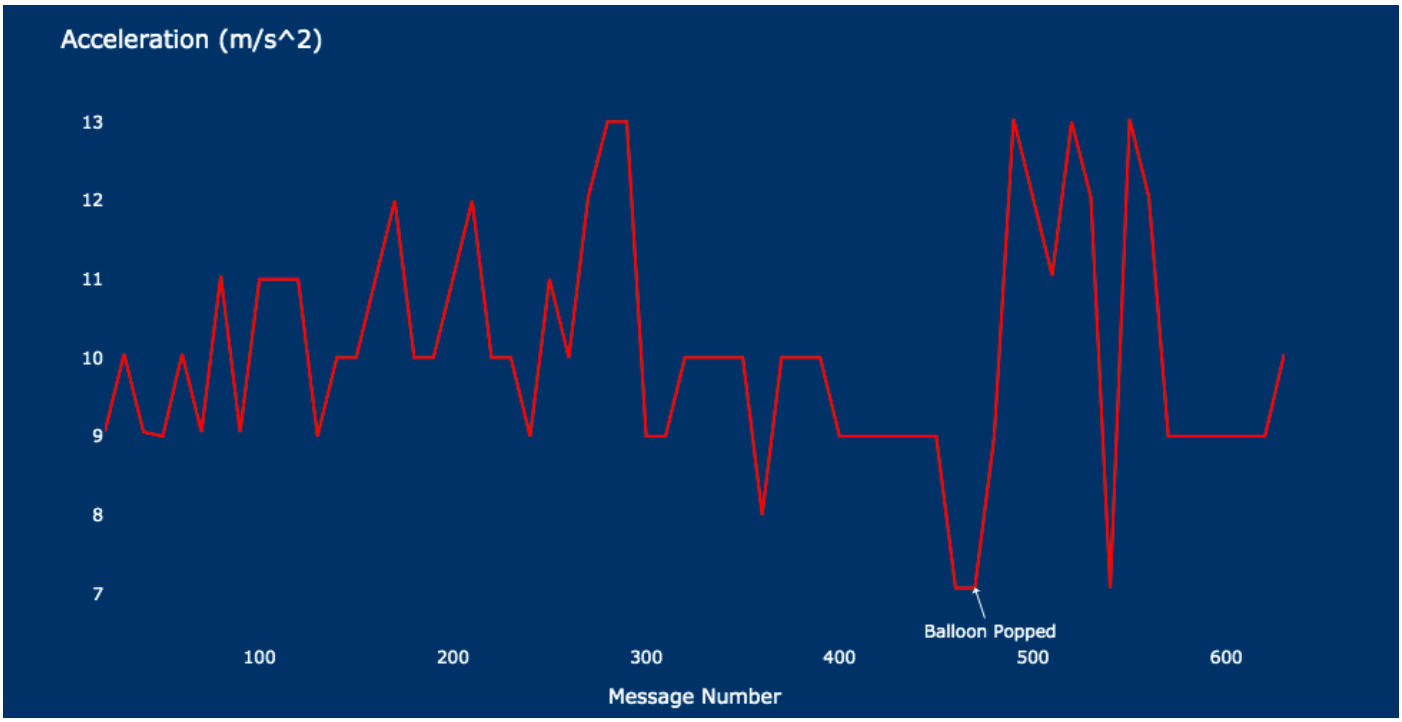
After four arduous days of preparations the first SpaceDuck, AQUILA-1, was prepared. From launch and throughout flight, telemetry received from the SpaceDuck is monitored in real time. The duck will send information about temperature, pressure, altitude, acceleration, gyroscopic readings, geomagnetism, GPS, and signal strength of the LoRa transmissions. After each launch, the data would be reviewed and the team went back to the drawing board making tweaks to improve the next day's launch.

Key data points from the SpaceDucks II launches.

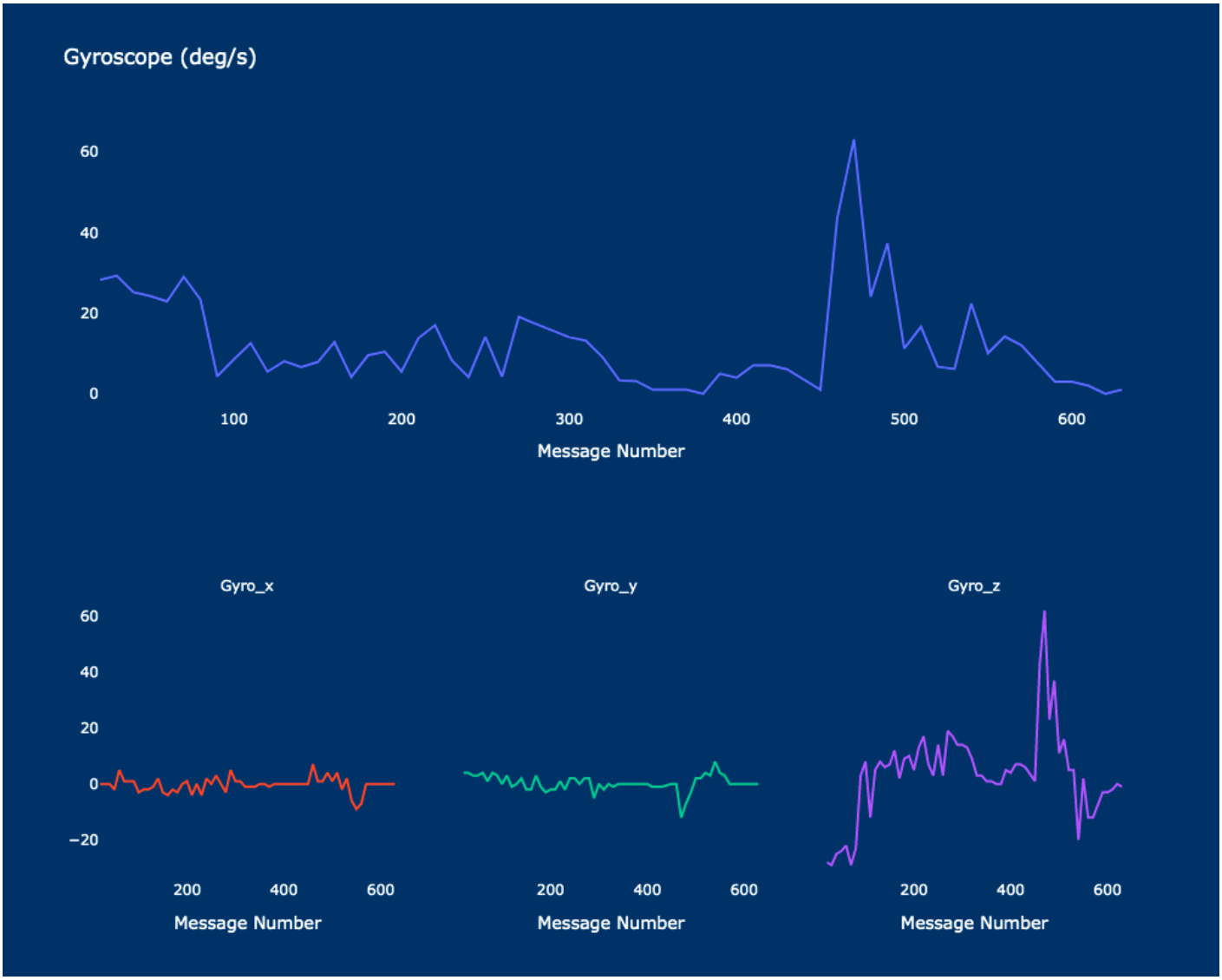


In this launch we reached the highest altitude 25,315 m (~83,054 ft).

The popping of the balloon can be determined by looking at the acceleration graph from the accelerometer sensor. Before the balloon popped, there was a steady acceleration (accounting for acceleration due to wind). As the payload ascended higher and higher, there was less atmosphere, and thus less wind to affect the acceleration and as a result overall acceleration decreased. Suddenly acceleration skyrocketed because the balloon popped and it was free falling back onto Earth.



Accelerometer data from PHOENIX-1.



Gyroscope data from PHOENIX-1.

Observing the z-axis data from the gyroscope, there is a spike around Message Number 450. This gyroscopic anomaly serves as a secondary identification of when the balloon popped and the payload began to freefall. At this time, the payload started aggressively rotating due unbalanced weight and lack of aerodynamics.

THE CAL POLY TEAM

EVAN AGARWAL

I'm a fourth year aerospace engineering student at Cal Poly, graduating in June 2021. My focus was on all things related to launch and flight planning, logistics, and operations. This involved generating numerous flight predictions with updated weather models in the days and hours before launching, choosing launch and landing times and locations based on these flight path predictions, filing necessary flight documents with the FAA (NOTAMs), and monitoring live telemetry and tracking data while the system was in flight. Additionally, I assisted in payload assembly and integration.

KEVIN DIXON

My name is Kevin Dixson and I'm a graduating fourth year computer engineer at Cal Poly SLO. For the spaceducks crew, I lead the software development on the main flight computer. I wrote the code that controlled our radios, sensors, and general program flow. Given the importance of this code, it was an exciting yet stressful journey. Watching the program execute flawlessly and send live data to our ground station was the most rewarding experience of my college career.

JOSH FRANKLIN

I am a fourth year aerospace engineering student at Cal Poly. For Project OWL, I served as the ATLO team lead. Throughout the project, I was in charge of designing the ground station that would meet the requirements of our high altitude link. I led the the design and implementation of various hardware tests to ensure payload functionality. Additionally, I was the leader in the physical assembly of the payload. Throughout the flights, I was tasked with finding the relative location of the balloon and to use that information to point our ground station at the payload.

WALDEN HILLEGASS

I'm a second year Software Engineering student. My main focus for this project was developing the antenna pointing device which told the ground station operator where to point the directional yagi antenna. Additionally, I helped with balloon launch preparations and searching for the missing balloon.

INAKI MADRIGAL

I'm a fourth year, graduating computer engineering student at Cal Poly. My focus was on the integration of the Rockblock satellite communications module into the custom QuackerBoard. This involved ensuring the wiring setup and the signal interfacing with the custom quackerboard was correct. I helped port a software library to control the satellite communications module, which enabled multiple data links during the flight. Not only do my talents lie in the terminal, but also on the grill. I thoroughly enjoyed my experience with Project Owl!

JACK McGUINNES

I just completed my undergraduate degree in Industrial Engineering at Cal Poly and will be transitioning into the Engineering Management graduate program at Poly as well. I have been involved in weather ballooning for the last few years and have discovered it is a great low-cost, high-value tool for experimentation and media. In the Space Ducks project my role was running ballooning operations and safety. This means I was involved in proper transportation of helium, balloon filling, launch location and landing, live balloon tracking, running flight path predictions, payload attachment, and overall logistics and safety.

CONNOR McKEE

I'm a fourth year computer engineering student at Cal Poly, graduating in June 2021. I focused primarily on the integration of the BMP388 sensor with the QuackerBoard. This sensor allowed for the tracking and logging of important flight data such as temperature, pressure, and altitude while the payload was in flight. I adapted API libraries that currently exist to support the QuackerBoard firmware API. This data was crucial in the tracking of the payload and final data analysis of the flight path. Additionally, I aided the team on launch day with the dispatch, operations, and tracking of the payload up until it fell into our arms!

KEVIN NOTTBERG

I am a fourth year student at Cal Poly San Luis Obispo studying computer engineering. I was part of a group called the QuackHeads who's focus was on all things related to the flight electronics. The flight computer was a from the ground up custom design for Project Owl. A lot of what I focused on for the months and weeks leading up to launch was hardware design, component sourcing and final assembly of the electronics. I also worked on software and sensor integration as well. Then during flight week, I assisted in final assembly and testing/ debugging of the flight software to make sure we had successful flights.

THE OWL TEAM

NICK FEUER

I worked on the flight firmware used in the payload. It's not often in software development that you can have such a tangible experience as SpaceDucks. It's impossible to describe the highs we felt at the end of each successful launch and recovery. Each time we push the ClusterDuck Protocol (CDP) boundaries, we are always amazed at how far we can go and have come. It's been over 2 years since I've been working on the CDP and it still brings new opportunities to do amazing things with amazing people.

BRYAN KNOUSE

In 2019 I met Evan Agarwal at Scout Coffee in San Luis Obispo on a whim to talk about a project he had done for school. Later that year, together, we duct-taped a "Duck" together in a cardboard box and launched it to 100,000 feet. To our sincere surprise, it worked. Since that moment two years ago, we have been coordinating a return to the skies in California. I focused on overall systems design and operation for this event, working closely with product development and design teams to ensure the payloads would launch, fly, and recover successfully.

TARAQUR RAHMAN

During the SpaceDucks mission, we were collecting data points from a few different sources as it was climbing higher and higher into space. My main focus was on that data: understanding what data is being collected, how to process the data, how to visualize it, and what improvements we can make for future missions. Seeing the data flow through the network into Project OWL's DMS was confirmation that all the hard work made by the SpaceDucks crew finally paid off.

ZACH NEUHAUS

I am a recent resilient technologies and disaster management graduate from the University of Maryland Baltimore County (UMBC). My task prepping for the launches was to make sure the RockBlock Sattelite modem worked and we were getting consistent data transmission. Then during the actual launches, I was remote support and watching the data come into OWL DMS and space ducks dashboard. It was an amazing experience working with OWL and the amazing CalPoly students I can't wait to see what the future launches and prototypes hold.

TIMO WIELINK

SpaceDucks was an amazing experience. After working on this project for over a year, I can't describe how great it was to be together in the same room with the whole team and work on this together. My role at Project OWL is to oversee the product development for all the things we built, my role for the spaceducks was very similar. I designed the payloads that we launched and made sure all our systems were working together. And if I wasn't building payloads late at night I was capturing video and photos for reports like these.

THE FUTURE

SpaceDucks would not have happened without the collaboration from an exceptional group of hardworking CalPoly students. Throughout the week, the team worked late nights to assemble the payload, triple check the firmware, and continuously observe signal and system quality. This recipe led to successful launches. The goal of the launch was to be able to communicate over LoRa and have a backup using satellite communications. We successfully closed LoRa links using the Yagi antenna covering a max distance of 50km. New engineering techniques and processes were learned from these launches: what worked and what didn't work from a technological standpoint as well as deployment efficiency. The team is actively developing new methods to solve these technological issues and improving operations for future SpaceDuck missions. This is just the beginning for SpaceDucks.

The full SpaceDucks team after retrieving PHOENIX-1.

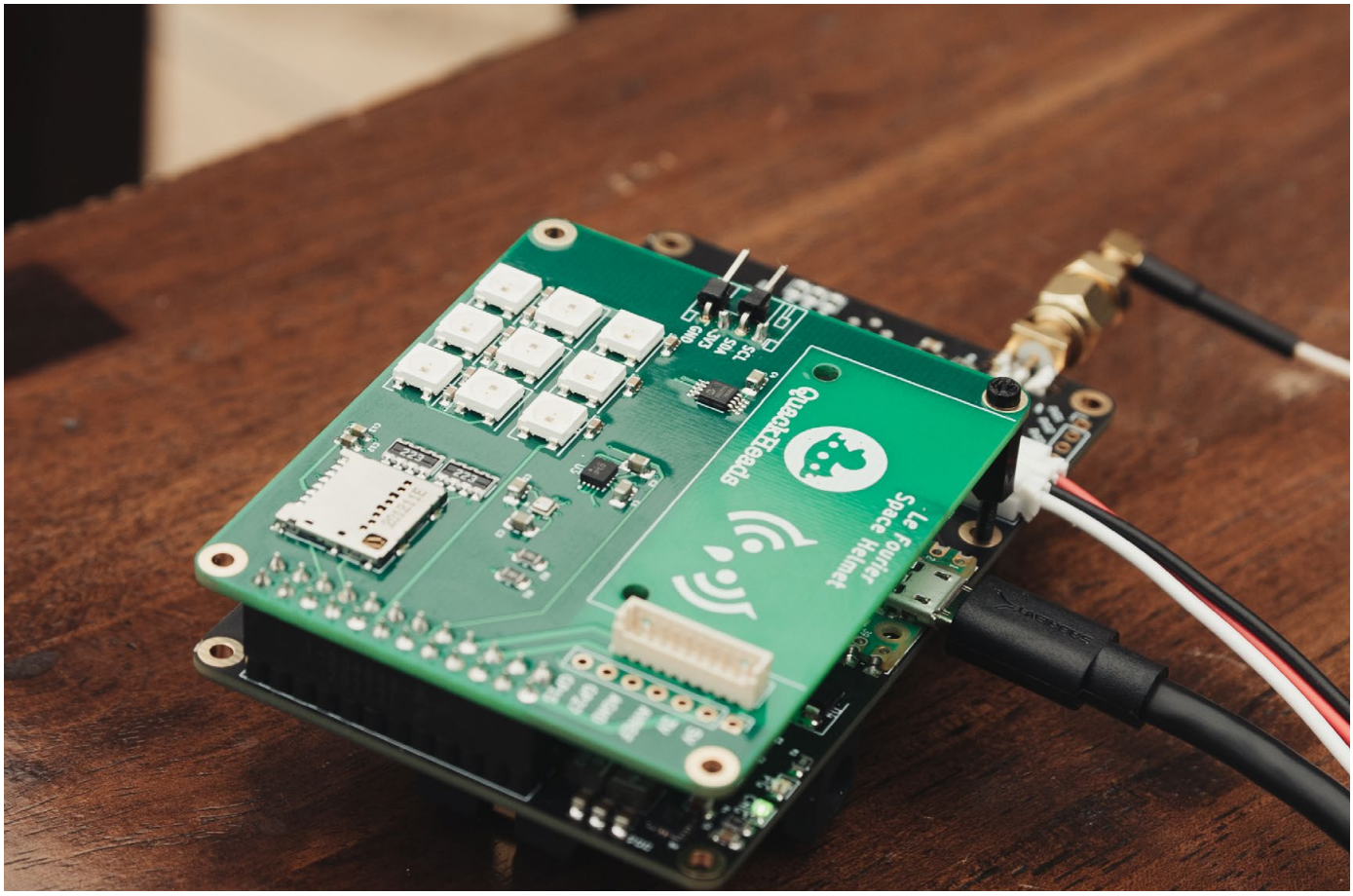
PHOENIX-1 at 85,000 feet above California.

Josh Franklin making the final preparations on PHOENIX-1 before launch.

Walden Hillegass modelling the SpaceDucks jersey.

SpaceDucks launch crew performing final balloon preparations before release of PHEONIX-1 and AQUILA-1.

Kevin Dixon pointing the Yagi antenna.



Custom OWL electronics developed by Cal Poly students, used as core flight computer.

PHOENIX-1 atmospheric balloon popping at 25,315 M (82.359 feet) altitude.

Launch crew team after retrieving PHOENIX-1 from its landing location.

Josh Franklin operating the “mobile ground station”.

Launch crew team reviewing procedures for the morning launch of AQUILA-1.

PHOENIX-1 and CYGNUS-1 during preparatory testing.

“Vanalytics“ mobile team heading to the PHOENIX-1 landing location.

LEARN MORE

This report, a short film, and all datasets from SpaceDucks II are publicly available at [www.project-owl.com/open-source.](www.project-owl.com/open-source)

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