SPACEDUCKS IV 2024 REPORT

OWL

CLUSTERDUCK PROTOCOL™

SPACEDUCKS IV

SpaceDucks IV 2024 pushes the limits of the ClusterDuck Protocol to enable remote communication networks.

5
DAYS

6
LAUNCHES

7991
DATA PACKETS

INTRODUCTION

SpaceDucks is a collaboration between OWL Integrations, the ClusterDuck Protocol (CDP) Open-Source community, and the brilliant minds of California Polytechnic University. 2024 is the fourth year of this collaboration and the launch site is once again the Central Valley of California, a location that has proven ideal for high-altitude weather balloon launches. The launches at SpaceDucks IV test significant advancements of the firmware, SpaceDuck enclosure bodies, and analytics software. With every byte of data transmitted (and every quack received) this uniquely flexible Internet-of-Things hardware, firmware, and software solution continues to evolve for a wide variety of use cases from disaster resilience networks to carbon emissions monitoring in the United States and around the world.

MISSION

OWL's mission is to improve global resilience through connectivity. At last year's SpaceDucks 3 test launches, the OWL, CDP, and Cal Poly team demonstrated foundational SpaceDucks connectivity by closing data links at 90,000 feet (SpaceDucks III Report). The SpaceDucks 4 testing this year focused on building upon the high-altitude connectivity to develop a SpaceDuck that is significantly more integrated as a networking solution for austere environments.

WHY BALLOONS?

Back in 2019 OWL had made 6 trips to Puerto Rico, setting up solar-powered DuckLink networks across the island in San Juan, Humacao, and Mayaguez (Puerto Rico Report 1, Report 2, and Report 3). Throughout those deployments it became clear that while this low-cost, open-source technology could make a noteworthy impact in disaster response, there was still a problem: DuckLinks are just as susceptible to dangerous hurricanes as is the rest of the infrastructure on the island. This left OWL with an idea. There exists a location where DuckLinks could survive through a catastrophic natural disaster and continue operating when they were most in need. That location is space.

Getting to space, however, is very expensive [Cubesat Launch Cost]. As an early-stage startup, OWL must be capital efficient, and launching unproven cubesats to space is not. There is a solution to this that compromises "near space" with much greater capital efficiency - balloons. High altitude atmospheric balloon launches continue to be a useful tool for testing these specialized DuckLinks, putting them in an environment very close to space without needing a rocket to get there.

Weather balloons are not a finish line, but a stepping stone to solve problems and prove the technology in the most capital-efficient way possible.

FOCUS AREAS
A common topic of discussion with OWL's customers and the CDP community consistently led to three areas of focus: radio flexibility, integrating with other platforms, and more robust DuckLink hardware.

RADIO FLEXIBILITY AND SOFTWARE-DEFINED RADIOS
LoRa is a radio technology that operates on unlicensed ISM bands (915mhz in the US) and is rapidly growing in both the hacker and industrial world. Popular radio bands (UHF/VHF, 2.4ghz) can become susceptible to congestion and interference in areas of conflict or high traffic, and thus critical messages will not get through. Two approaches are taken, one is to leverage open ISM bands which are currently less targeted for jamming and interference. The second is to leverage more flexible technologies such as open-source powered Software Defined Radios (SDR) to connect into the SpaceDuck and DuckLink network.

INTEGRATION
In a world with an ever-growing selection of technologies, softwares, radios, and protocols, the solutions that do not quickly and effectively integrate with other tools impede deployment. OWL proved the integration capabilities of CDP by developing a plugin for Team Awareness Kit (TAK), a smartphone situational awareness app used to share critical information on a given network.

COMMANDS
At the moment, the CDP receives data from a Duck and sends it to the cloud hosted network. This is one-way communication (the data is flowing only one direction toward the cloud). However, what if we can send messages from the cloud to the network, enabling data to be sent both ways? The team was interested in deploying two-way communications because we can send commands from the cloud to the network through LoRa. An example where this capability could be useful is if a Duck is malfunctioning and requires a reboot, a command can be sent from the OWL DMS (Data Management System) telling the Duck to restart, as opposed to going out into the field for manual restart. In collaboration with Cal Poly, the students have laid the foundation for two-way communication in their QUAC'M payload.

KEY RESULTS

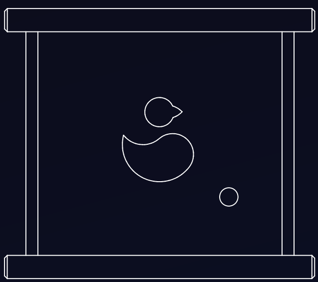
- Successful radio link closed using TAK to communicate between different ground stations using the SpaceDucks as a central link.
- Implemented commands to control the camera over LoRa.
- Integrated The Quacker Board custom hardware from OWL.
- 4 Payloads recovered, 2 Payloads lost.
  - Day 1: all recovered
  - Day 2 : recovered 1, lost 2

KEY METRICS

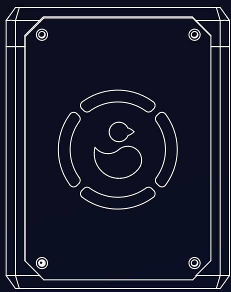
- 7,991 data points collected during the event
- Ending Battery Level: 3.84 V
- Total battery capacity consumed: 0.785 A
- Average time of flight: 3h 8min 35sec -> 188.5 min
- Lowest Temperature: -27.25 C
- Highest Altitude: 69,095 Feet

FIRMWARE PREPARATION

In March 2024, we released CDP version 4 with the help of the CDP community. This new version is packed with new features and improvements for resilient communication such as new LoRa chip support and PlatformIO support. We integrated sensors to collect temperature, pressure, altitude, latitude, longitude, battery voltage, and board temperature. Learn more about the ClusterDuck Protocol and latest releases here: https://clusterduckprotocol.org/



SPACEDUCK III



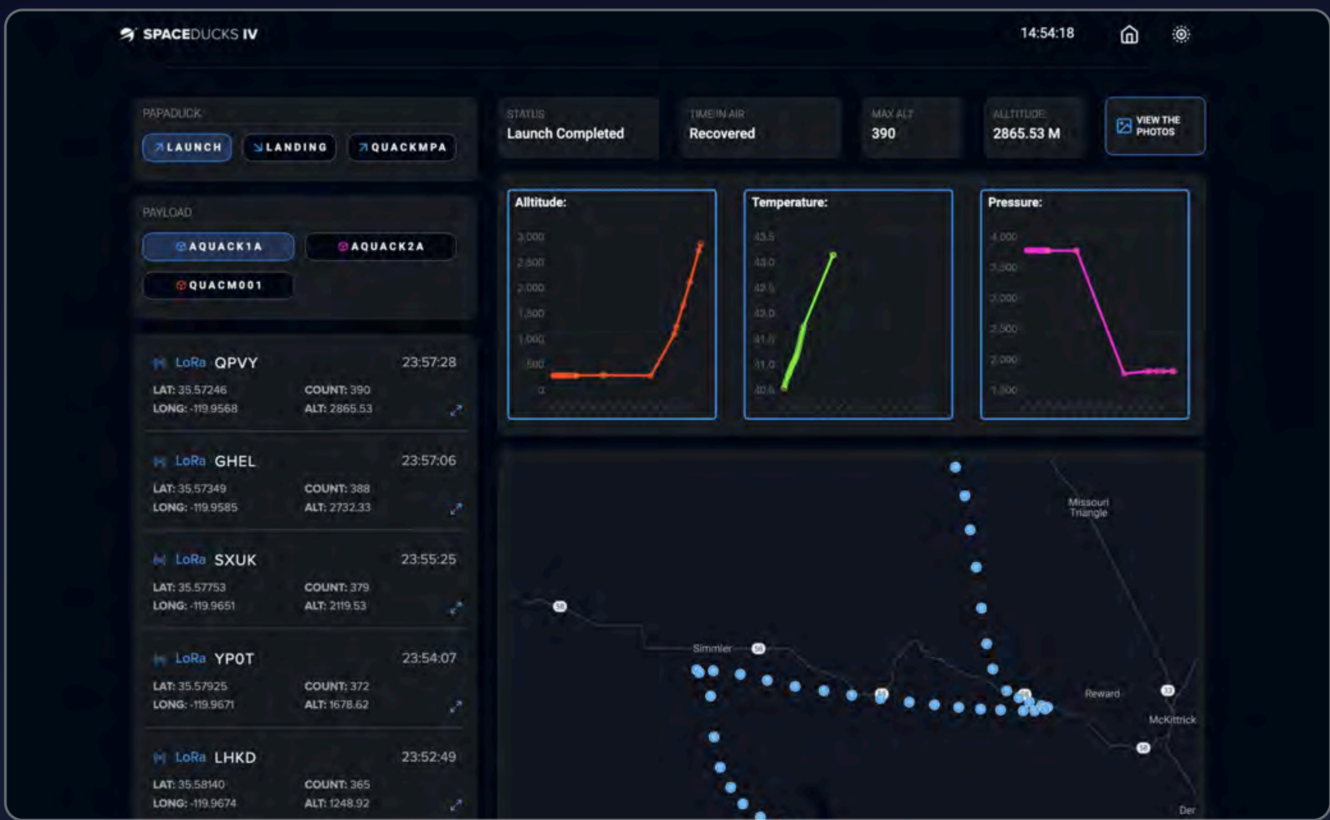
SPACEDUCK IV

ENCLOSURES

OWL invested a significant amount of time to improve the form factor of the enclosures for SpaceDucks IV. The resulting design closely mirrors the format of a 1U CubeSat, marking a significant advancement in our enclosure development process. This new design reduced the size by 30% from previous versions and it enabled the integration of more advanced technology into this smaller form factor. This was possible by using the walls of the SpaceDuck as the attachment structures for internal components and optimized internal organization such that every spaceduck leveraged the same outer shell.

SPACEDUCKS ANALYTICS TOOL

This year, OWL and participation from students in a Computer Science Capstone project at Arizona State University redesigned the SpaceDucks analytics tool. This tool provided a visualization of live data feed from the balloon, allowing teams on the ground to track its location and telemetry during the flight. With the incoming data, the ground team is able to determine if the balloon remained on its predicted flight path and access information about its temperature and battery levels. In case of a loss of connection over LoRa, analysts could quickly use the latest data to run an updated prediction and estimate a payload's landing location. Fortunately, we maintained a constant connection, and all our data was live-streamed to the analytics tool.



TESTING

The team at Cal Poly built a UAS fixed-wing drone that was efficiently utilized during this SpaceDucks. This aircraft was used to launch DuckLink hardware into the air to perform a set of test procedures evaluating connectivity from the sky. These UAS tests allowed the launch teams to simulate the conditions of the actual flight, identifying and resolving any potential issues beforehand. Through this testing experience, both OWL and the Cal Poly teams considered that moving forward, switching out weather balloons for UAS/Drones in following deployments might be a faster, cheaper alternative to acquire similar datasets. In the long run, UAS systems are cost-effective and require less resources from a logistics and operations standpoint. This idea will be explored in the coming months.

BALLOON PREPARATION

Preparation involved a full day at HQ, where the team meticulously assembled the payloads and conducted thorough testing. The SpaceDucks are given lift from atmospheric weather balloons filled with Helium (He). These balloons are capable of carrying the payloads to high altitudes sometimes in excess of 100,000 feet. This effort enables a unique vantage point for the experiments and testing from a very austere location. One critical aspect of the SpaceDuck launches is predicting the flight trajectory. The team developed sophisticated models to simulate the entire flight path from launch to landing. This involves analyzing weather patterns, wind speeds, and other atmospheric conditions that could affect the flight. Inputting these variables into the prediction models, the team was able to forecast the balloon's behavior and make adjustments as needed. This level of precision is crucial for mission success, as it helps plan recovery operations and ensures the integrity of the data collected.

Based on the amount of helium in the balloon, the size and design of the parachute, the team was able to predict the ascent and descent rate with a high degree of accuracy. These calculations are essential to ensuring that the SpaceDucks land safely and that the team can retrieve the payloads.

The combination of advanced engineering, thorough testing, and precise planning exemplifies the dedication to pushing the boundaries of what's possible with SpaceDucks IV.

LAUNCH 1

On the first launch day, we left HQ early to move to our predicted launch location in the Central Valley of California. Our plan was to launch three balloons to build a mesh network in the sky. The first launch involved AQUACK1, AQUACK2, and LIMESDR1. These three payloads communicated with each other in the air, creating an interconnected network. Additionally, they were able to connect with any Duck deployed around the Central Valley, demonstrating the effectiveness of our mesh networking technology in real-time.

AQUACK SPACEDUCK

TAK is a smartphone situational awareness app used to share critical information on a given network. At the moment, it is lacking a local offline solution to help navigate the unknown. For this payload, we partnered with Raytheon to tackle this problem. The Raytheon and OWL collaboration developed a plugin for TAK called the AQUACK. This plugin bridges TAK and the ClusterDuck Network. The data flowing through this network will be exported to TAK. This payload was a test to see how well the current version of AQUACK operates by using the messaging system of the ClusterDuck Protocol. OWL had a launch station and a landing station with TAK-enabled Android devices. While the SpaceDucks were afloat, the launch team sent messages in TAK that were relayed through the ClusterDuck Network via the AQUACK plugin. The ground teams were able to send and receive messages from both the landing and launch site therefore succesfully creating an off-grid chat network.

SDR ENABLED SPACEDUCK

SDR, or software-defined radio, is a radio that can be manipulated through software. This allows us to choose what radio frequency we want to transmit or receive data. Traditional radios are locked into a certain frequency range due to the hardware chips installed. OWL's LoRa-based DuckLinks operate at the 915 Mhz frequency. To change to a different frequency range, completely new hardware would be required. With an SDR, we can alter the radio settings to communicate with other frequencies. This flexibility provides resiliency in communication networks such as monitoring systems or disaster relief. If a certain frequency is crowded, through an SDR, we can change the frequency to a less populated one to communicate data.

During this flight, we created an SDR Ducklink using a Raspberry Pi, gr-lora_sdr, and Dragon OS software. We launched the balloon and using the SDR on the ground, we altered the SDR to operate over 915 Mhz frequency to communicate with the SpaceDucks.

LAUNCH 1 RESULTS

Launch day 1 was a success. OWL attempted to test the AQUACK plugin for TAK using the SpaceDucks as a relay. There was a firmware issue in these payloads that prevented successful demonstration of this capability. Regardless, all payloads consistently transmitted their telemetry and were recovered later in the day. Photo/video media was successfully acquired from the payloads after landing.

Launch 1 data available here

PACKETS SENT	2900
LOWEST TEMPERATURE	-3 Celsius
MAX ALLTITUDE	84,000 Feet
TIME IN AIR	204 Minutes
DISTANCE TRAVELED	35.8 Miles

LAUNCH 2

Launch day 2 included a special research payload designed by the team at Cal Poly. The physical layout looks like a normal SpaceDuck with an additional mechanism to control a camera mounted on the SpaceDuck. What makes it special is that it was the first time we were able to control parts of the payload from the ground over LoRa. We accomplished this by sending specific data packets to the payload and have the camera move to a certain orientation based on our input.

This is a huge step in bringing resilience to communication networks. In a scenario such as the oil and gas industry, if a Duck detects fugitive methane leaks, it can send a command to a satellite to monitor a specific location to detect methane. This can be cost-effective, save time and save resources.

LAUNCH 2 RESULTS

Launch Day 2 was more challenging. Three payloads were launched, and only one was recovered. Running SpaceDucks is a complex operation involving technology, logistics, and organization to execute a launch successfully. Sometimes, even performing all steps correctly can still result in failure. On this particular launch day, one payload was lost as it had landed in a private reservation that was closed off to public access. Unfortunately, had the predictions proved more accurate the launch teams would have adjusted the launch location. The second payload was lost as a result of team error. Filling the balloons is a carefully calibrated exercise accounting for a variety of factors including size, weight, and weather conditions. QUAC'Ms balloon was slightly underfilled (by a couple cubic feet of Helium), and as a result the payload strayed far off its intended path. Far beyond the reach of our recovery teams. We confirm that QUAC'M later landed that day...about 40 miles into the pacific ocean.

Launch 2 data available here

PACKETS SENT	3400
LOWEST TEMPERATURE	-3 Celsius
MAX ALLTITUDE	76,000 Feet
TIME IN AIR	196 Minutes
DISTANCE TRAVELED	38.6 Miles

IMPROVEMENTS

One thing to improve for the future is the ballon filling procedure. The QUAC'M payload was a little heavier than other payloads and needed more helium. Unfortunately, it was not considered a significant change and so we filled the balloons the same amount of helium as the others. This was a mistake. The second we deployed the balloon, it drifted on a different trajectory and unfortunately, we could not retrieve it. Later on we found out from a GPS sensor attached to the SpaceDuck that it was in the Pacific Ocean!

CONCLUSION

The SpaceDucks initiative has undergone a remarkable evolution, transitioning from a humble microcontroller attached to a styrofoam box in 2019 to the sophisticated achievement that is SpaceDucks IV today. Guided by a commitment to innovation and collaboration, the team at OWL, alongside Cal Poly students and faculty, and the CDP community, has achieved significant milestones in the testing and evaluation of resilient communication networks. This includes addressing radio congestion with software-defined radios (SDR), seamlessly integrating the CDP with platforms like TAK, and developing two-way communications through the QUAC'M payload.

Despite challenges such as incorrect altitude sensing and unexpected balloon drifts, each setback has strengthened our resolve to innovate and refine our approach for future missions. Our dedication to resilience and precision in global communication remains unwavering.

As we look ahead, we are excited to continue evolving the DuckLinks and all of their adjacent species, expanding OWL's network capabilities, and making significant contributions to the field of radio communications networks. Together with our partners and supporters, we are focused on deploying innovative connectivity on a global scale. Stay tuned as SpaceDucks and OWL continue to make waves and quacks in the skies above. The future of communication is becoming more resilient than ever.


GMC

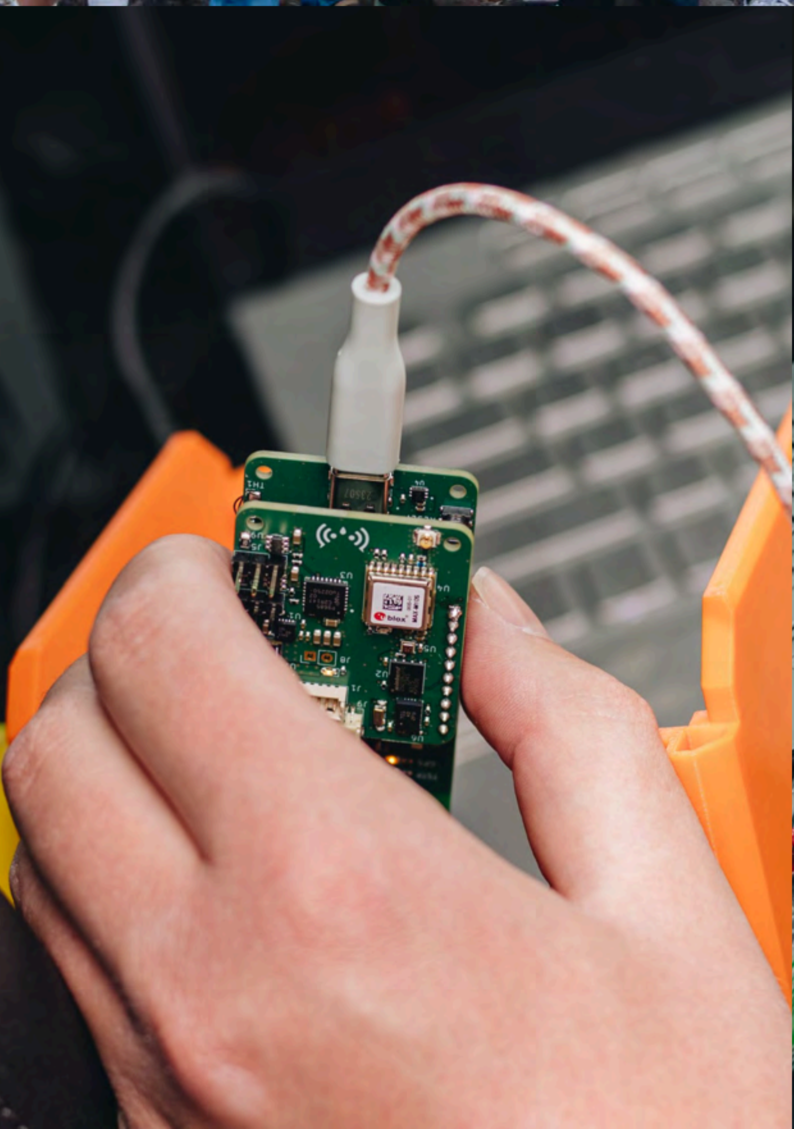

LAUNCH CREW


LAUNCH CREW

GALLERY


SPACEDUCKS IV

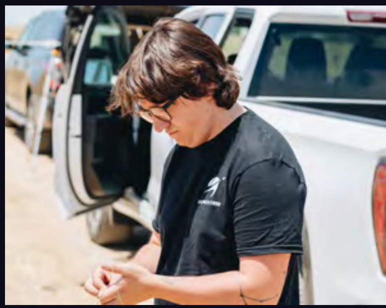

ACEDUCKS I
UIS OBISPO , CA | JUNE 2024
CLUSTERDUCK PROTOCOL TM
OWL
BY TRAINED PROFESSIONALS. PLEASE DO NOT TRY THIS AT HOME.




M3 x 14mm

LUCAS LUCIA

A returning member of the Launch Crew, now a grad student in electrical engineering. Working on sending Ducks underwater as well as into the air. Landing team vanalytics driver and grillmaster (along with s/o!) for SpaceDucks IV



NOOCH

4th year Electrical engineering student, worked won automated test code for squad board TVac testing. Did secondary Lora connection testing for short range drone tests. Winner of plastic duck throwing competition at landing zone

DANIEL GHARIB

Senior Electrical Engineering major focusing in RF/Comms. Helped out with landing activities and recovering payloads during Spaceducks 4.

DOUGLAS LIU

4th year Electrical Engineering major at Cal Poly. I designed a two axis camera gimbal using servos for the QuACM payload. Competitive duck enjoyer. Professional servo tester. Dedicated 3D printer mule. Official co-owner of the skies.

ZACHARY NUMA

4th year Electrical Engineering major at Cal Poly. Worked on automated code development to test SQuAD boards in TVAC. Assignment for Spaceducks, was designated driver of Nick, Douglas, Eric and Nooch. As well as assisting in filling balloons and holder of Cheez-its ®.

LIAM McCARTHY

Liam McCarthy, 4th year Electrical Engineering major at Cal Poly going into the M.S. program next year. I worked on the SDR stuff and receiving LoRa/CDP packets on an SDR. I helped in Trevor's car as a navigator made sure the helium didn't blow up. On Saturday I helped to fill the balloons and recover a payload

ERIC HUANG

4th year Electrical Engineering major at Cal Poly. I wrote software to allow the GPS module to communicate with the MCU on the QuAD RC1 and RC2 boards, helped design the QuACM payload. Co-owner of the skies and two large blocks of cheese with Nick and Douglas.

KEVIN NOTTBERG

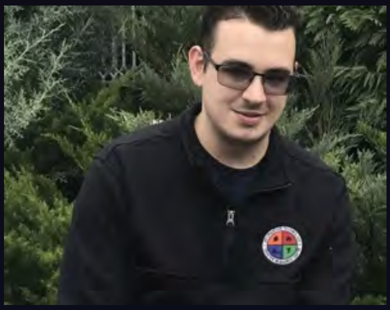
Kevin Nottberg is the mastermind behind the Quackerboard. He designed and developed the custom electronics that we deployed on the SpaceDucks IV payload.

RAVYN TRUSSELL

Embedded firmware engineer. Worked on protocol firmware for ATAK plugin helped with the SpaceDucks site, and tracked packet analytics in the field.

DEVON BOLT

I helped with setting up the UAV testing and monitoring making sure we were able to track all the data. And supported the launch crew with preparing and launching the Ducks.



ZACH NEUHAUS

Zach is an Open-Source contributor who helped us with the integration of the LimeSDR within the ClusterDuck Protocol and was on stand-by all week to fix any bugs we had. And there were many.

NICOLAS ALVAREZ

I helped and monitored all the launches of the SpaceDucks making sure we had all the correct measurement's for the balloons take off.

STEVE DUNTON

Steve joined Cal Poly's EE faculty in 2017 with over thirty years of engineering experience focused primarily on satellite payloads and electronics development.

DENNIS DERICKSON

Dennis Derickson received his BS, MS and Ph.D. in electrical engineering. And is on of the Cal Poly professors supporting the SpaceDucks program.

LEARN MORE

This report, a short film, and all datasets from SpaceDucks IV are publicly available at www.owlintegrations.com

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