



SPACEDUCKS III

2023 REPORT

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ABSTRACT

“Height is Might!” is a phrase that our radio mentors incessantly repeated when OWL first hatched in 2018. What did that mean? Well, it means that the higher the elevation of the signal transmission, the higher the likelihood of receiving it due to the potential existence of a direct line-of-sight. This was an invaluable radio lesson we learned and experienced especially since we engage with LoRa technology.

While LoRa boasts impressive coverage capabilities (with a record of over 800 km), its range gradually diminishes when faced with various obstacles such as buildings, mountains, trees, and even air itself. If “height is might”, then what is the highest point we can deploy a Duck to mitigate this issue – space! Imagine a Duck as a satellite, poised high above the Earth's surface. The Duck in space or “SpaceDuck” becomes a critical relay point for messages to traverse unfriendly terrain. This report details the progress in the third installment of our journey building SpaceDucks and our unwavering effort to make the world more resilient through connectivity.



The SpaceDucks crew preparing for the deployment week that lies ahead.

INTRODUCTION

Since the beginning of SpaceDucks development, we have embarked on two remarkable SpaceDucks launches in San Luis Obispo, collaborating closely with the talented students and esteemed faculty of California Polytechnic University (BIO Section). These previous missions have paved the way for an eagerly anticipated third iteration, which promises to push the boundaries of this technology even further.

The initial launches in 2019 - SpaceDucks 1 - served as a foundational proof of concept by launching a payload with the objective of demonstrating its feasibility. Although lacking heavy scientific instruments, this maiden voyage gathered basic temperature and pressure readings, affirming the potential of our concept.



Our first iteration of SpaceDucks I. The goal was to transmit data using LoRa.

Building upon the success of that first deployment, the second endeavor in 2021 (SpaceDucks II) was marked by a significant milestone – the closure of a link using the ClusterDuck Protocol (CDP). Connectivity links were successfully established between payload and ground station utilizing the ClusterDuck Protocol (CDP). These flights also tested the first prototype of a new electronics device, the QuackerBoard. This milestone enabled the team to collect a wealth of sensor data, providing a deeper understanding of the capabilities and performance of the SpaceDucks (Read about it here <https://bit.ly/3NPFbDW>).



Our second iteration of SpaceDucks. In SpaceDucks II, we launched more balloons (left), 3D printed a CubeSat and attached sensors to it (center) and collaborated with additional partners (right).

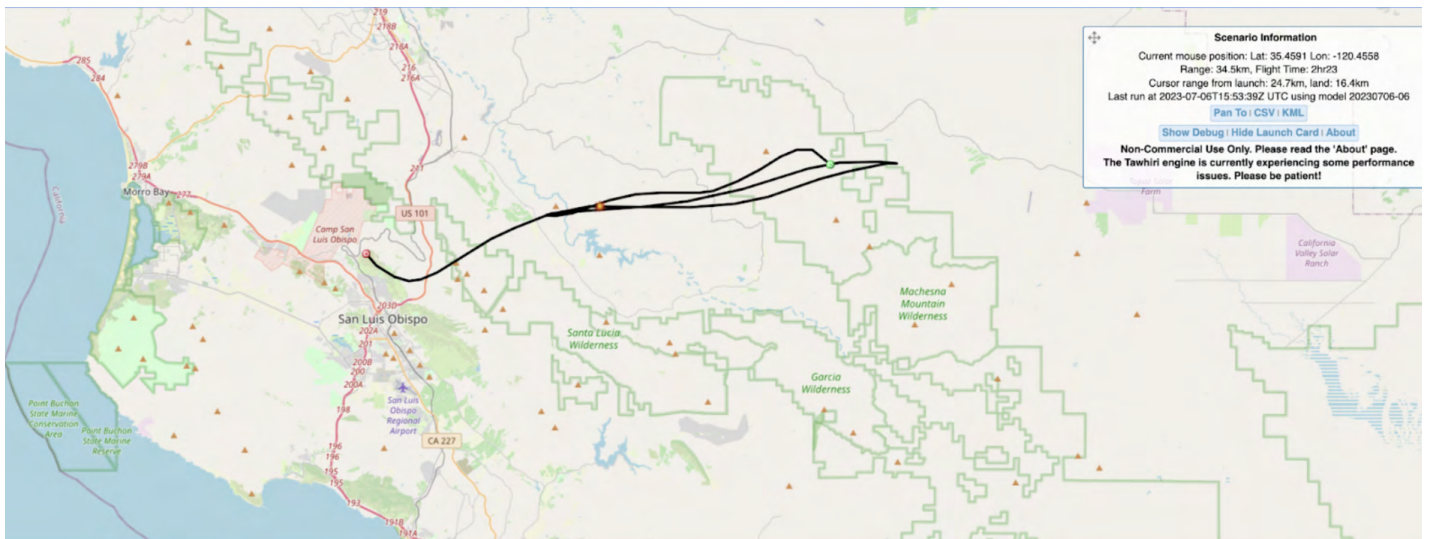
MISSION

We aim to create a new era of cost-effective, resilient, and reliable sensor communication by leveraging a SpaceDuck to establish a ground-space-ground network, seamless mesh network in the sky, and enhance the range of our network.

In the upcoming third deployment in June 2023, our team's focus expands beyond individual Ducks to explore innovative approaches for uninterrupted connectivity. We aim to create a new era of cost-effective, resilient, and reliable sensor communication through the use of SpaceDucks, establishing ground-space-ground (LAUNCH#1) and seamless mesh networks in the sky (LAUNCH#2), as well as enhancing our network's range (LAUNCH#3). This mission will involve various payloads, showcasing groundbreaking DuckLink and SpaceDuck networking technologies that drive innovation and enable transformative communication capabilities.

PREPARATION

In preparation for each SpaceDucks launch, meticulous steps were taken to ensure a smooth and successful mission. One of the key aspects of our preparation involved generating flight path predictions using KML (Keyhole Markup Language) files. These files are the result of weather pattern simulations anticipating the trajectory of SpaceDuck payloads, aiding in the strategic planning of the mission and retrieval.

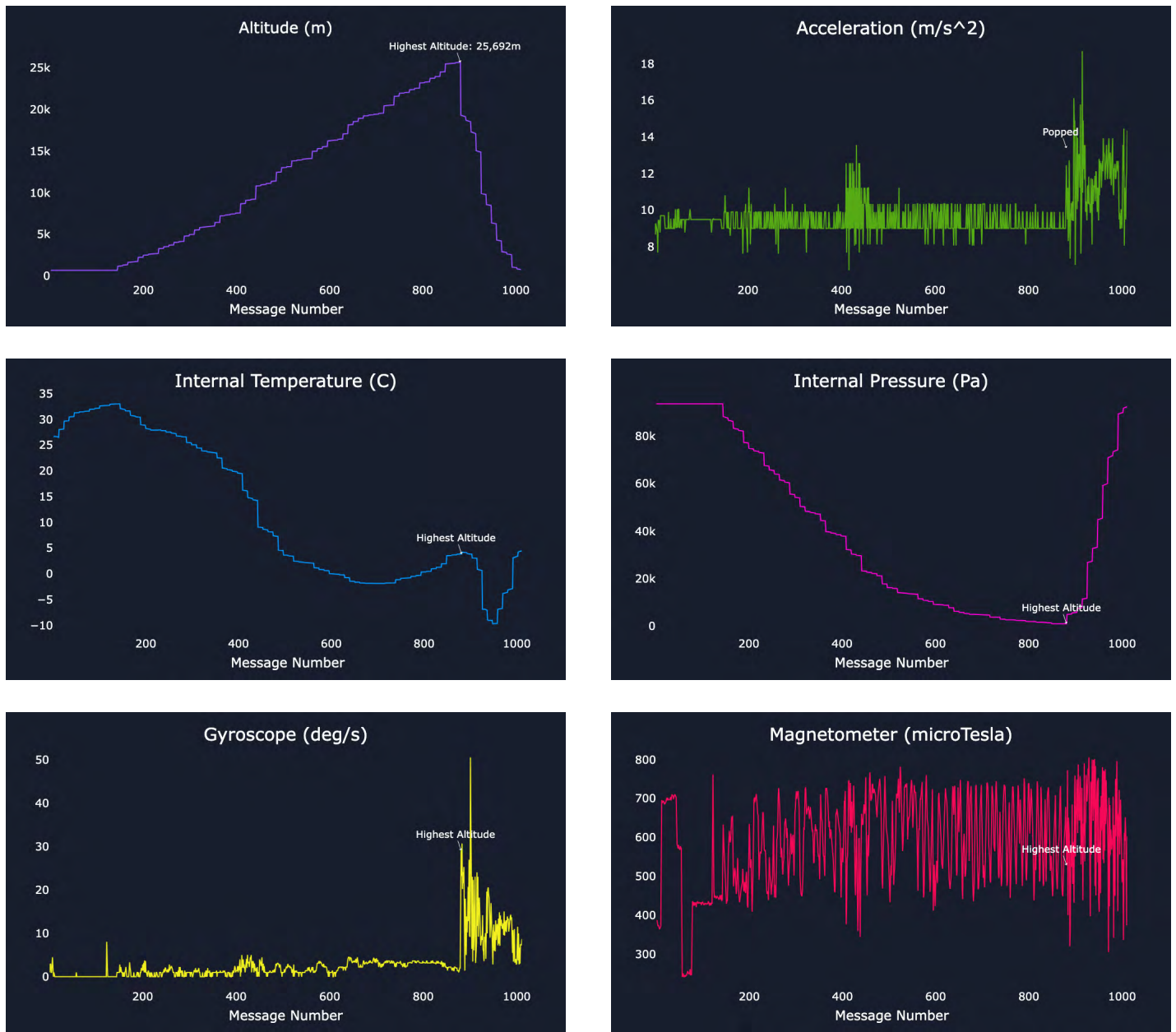


An example of a KML file we used to help us make predictions of the flight path of the SpaceDuck.

The payload configuration for each launch was carefully considered and tailored to meet the specific objectives of the mission. A payload typically comprised TTGO 915mhz T-Beams, QuackerBoards (OWL custom radio boards), Le Fourier Space Helmets (OWL custom integrator boards) and an array of sensors. These components were essential for data collection, communication, and monitoring purposes throughout the entire flight.

To optimize the communication between the launch and landing sites, Yagi antennas were used at the ground stations. These directional antennas ensured strong signal reception and transmission, facilitating efficient and reliable communication between ground stations and the SpaceDucks throughout their journey.

Live data monitoring plays a critical role in launch preparations. With advanced telemetry systems in place, ground station teams are able to receive and visualize real-time data from the SpaceDucks during their flight (<https://spaceducks.owlintegrations.com/launch-1>). This allowed the team to closely monitor various parameters, assess the health and performance of the payload, and make any necessary adjustments or interventions as required (see figure below).

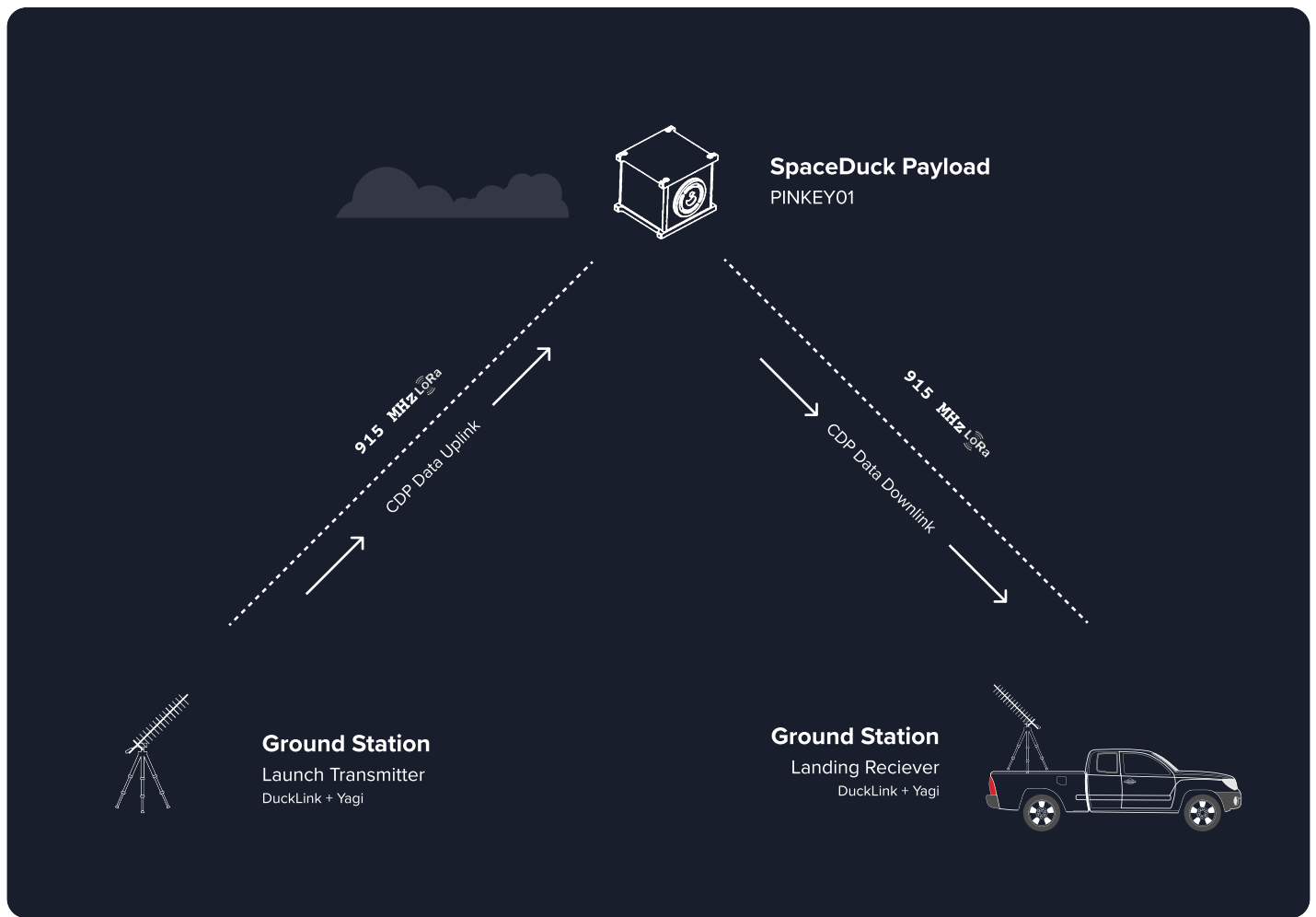


The live sensor data we were monitoring from the SpaceDuck in the second launch. We can infer from the data (except for magnetometer) when the balloon started its descent. Each sensor reached a maximum or minimum before it changed directions, signaling that it started its descent.

With meticulous attention to flight path predictions, payload configurations, antenna optimization, and live data monitoring, the SpaceDucks team ensured that each launch was poised for success. These preparatory measures exemplify the commitment to precision, innovation, and continuous improvement in the pursuit of advancing the frontiers of connectivity through the remarkable SpaceDucks project.

LAUNCH 1: Ground-to-Ground Network

In the year 2021, the research team achieved a momentous milestone by establishing a connection at an altitude soaring approximately 85,000 feet using the ClusterDuck Protocol. Inspired by this triumph, the team was interested in pushing the boundaries of CDP capabilities even further in the next launches. PAYLOAD #1 (named PINKEY01) transmitted messages from a terrestrial ground station to a weather balloon, and subsequently retrieved and relayed data from the balloon to a ground station situated at an entirely distinct location.



This is the ground-to-ground network we established. The launch site will send data, it will hop off the balloon and land at the landing site.

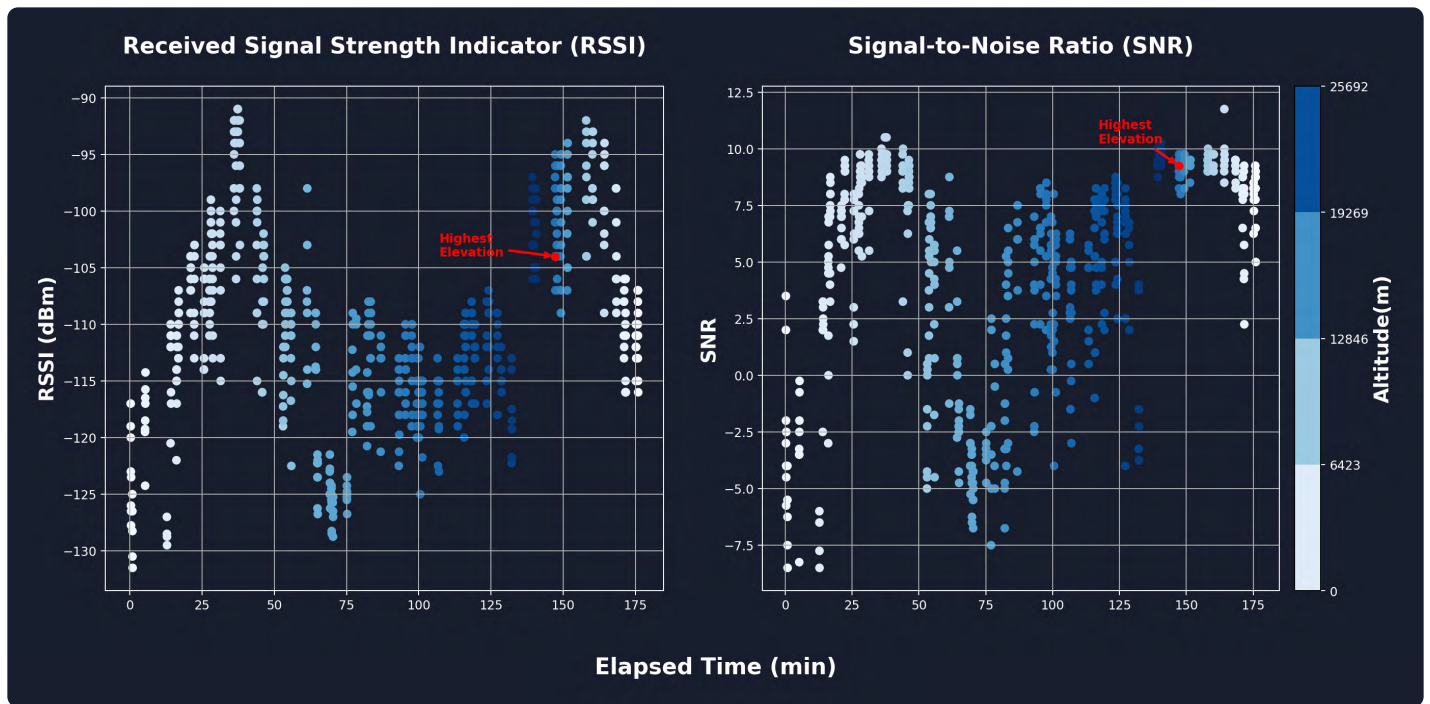
PINKEY01 exceeded the previous record altitude of 85,000 ft by reaching 91,000 ft. Not only was altitude exceptional, but a connection of exceptional signal strength at this height was observed throughout the flight. To achieve this, the ground stations were equipped with Yagi antennas and carefully aligned with the flight path of the balloon payload. Regular updates, based on pre-calculated coordinates, were manually implemented every minute to ensure precise alignment with the balloon's trajectory. In a remarkable feat of communication, we achieved successful message reception at the landing site, located approximately 20.6 miles away from the launch site! The geographical separation between these two sites was compounded by the presence of challenging mountainous regions and dense forestation. Under normal circumstances, establishing a direct link using other cost-effective radio technology would be a challenging task. However, leveraging the capabilities of the DuckLink radios enabled messages from the launch site to space and subsequently back down to the ground to complete.

While acknowledging the inherent margin of error associated with manual adjustments, the team successfully received the majority of the packets with outstanding signal strength and an impressive signal-to-noise ratio.

Launch Site 1

35°11'52.4"N 119°58'08.0"W
5 Miles west of Soda Lake, CA

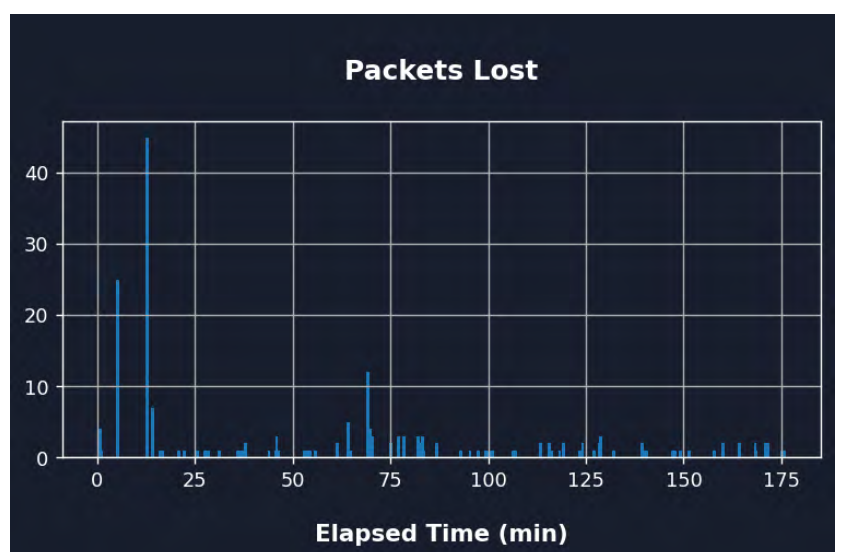




These figures show how strong the signal was during the SpaceDuck flight. For RSSI, a great signal ranges from -20 to -110. A bad signal would be less than -120. For SNR, the larger the ratio, the better.

The ability to establish ground-to-ground connections is a breakthrough for the ClusterDuck Protocol as it enables deployment in regions where direct line-of-sight communication is unattainable. Visualize a terrain abundant with rugged mountains or dense forests. The presence of such obstacles weakens LoRa connectivity as the signal must traverse numerous obstructions. In these situations, a SpaceDuck may gracefully hover above acting as a relay. A Duck stationed on the ground can cleverly circumvent obstructive barriers by leveraging the SpaceDuck to relay messages to the nearest neighboring Duck on the ground. This innovative approach enables seamless communication and bypasses the challenges posed by geographical impediments, propelling the potential of the ClusterDuck Protocol to new heights.

During ground deployments, DuckLink testing had less than 1% packet loss. However, during flight operations, packet loss increased to around 37% due to factors like obstructions blocking line-of-sight at lower altitudes and human error in manually pointing the Yagi antenna on a Tacoma truck. These factors caused increased packet loss during the flight.

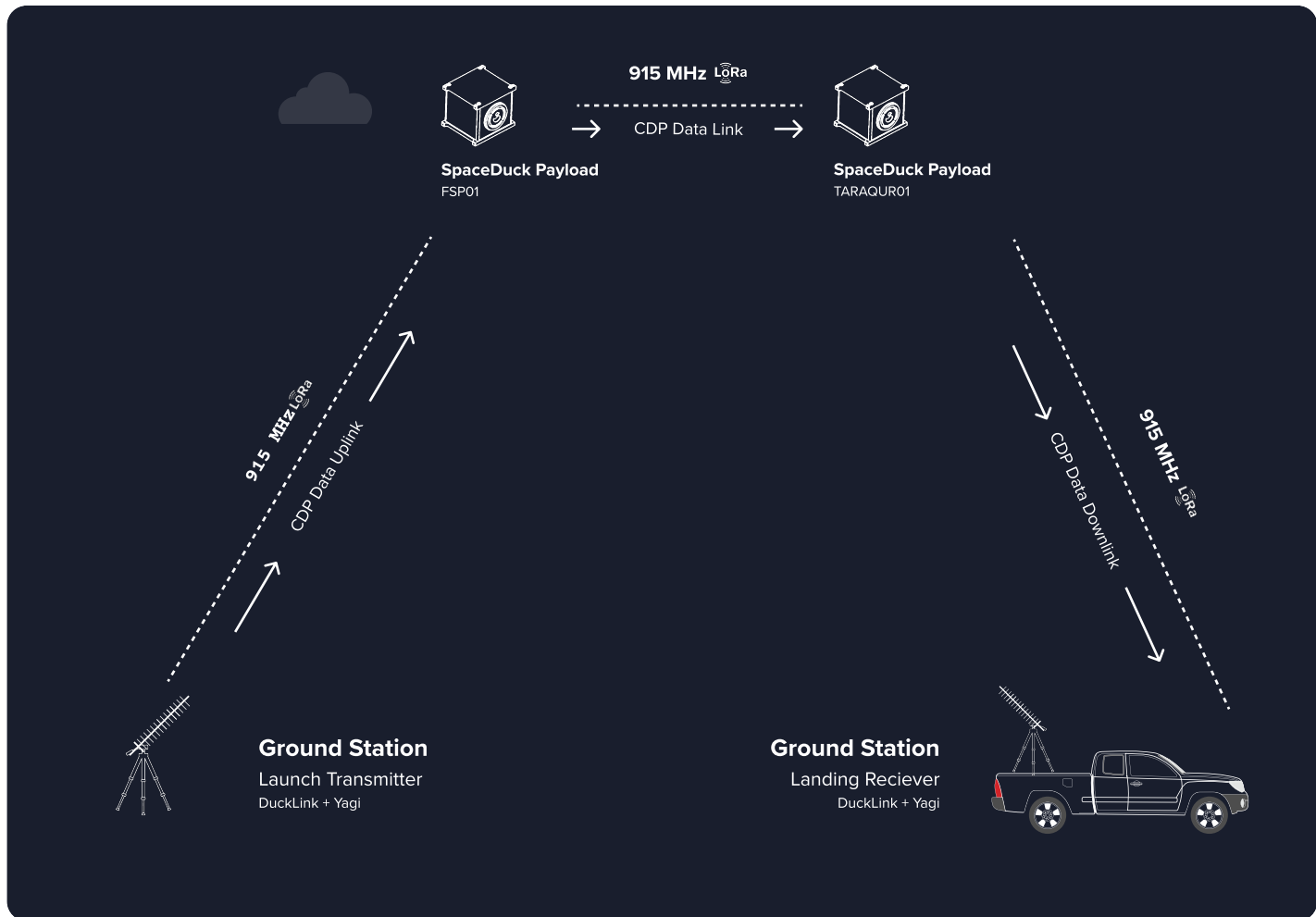


Packet loss over time. Majority of the packet loss occurred during the beginning when the SpaceDuck and the landing site did not have line-of-sight due to mountains and trees.

Moving forward, it is evident that improvements are necessary to enhance the accuracy and effectiveness of the data reception process. To address the issue, acquiring better instruments capable of accurately calculating the angle and direction for pointing the Yagi antenna would be beneficial. By leveraging more advanced technologies and automated systems, such as autonomous pointing mechanisms, human error can be minimized thus improving the reception of data during future flights. These enhancements will significantly contribute to reducing packet loss and improving the overall reliability of the system.

LAUNCH 2: Mesh Network in Space

Coming off a great start to this year’s deployment, the second launch added significant complications. One SpaceDuck exhibited great connectivity, but can the team create a mesh network in the sky? This intriguing question motivated the second launch, where OWL and Cal Poly researchers sought to find the answer.



The mesh network architecture we are testing for in LAUNCH 2.

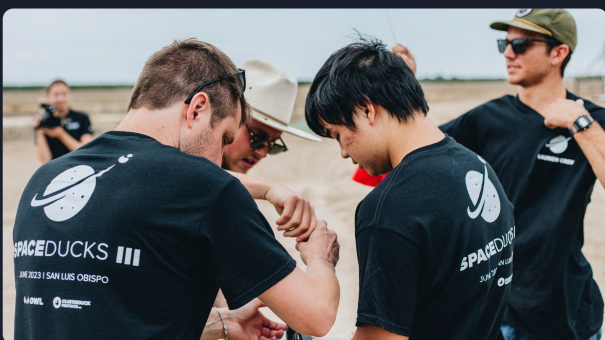
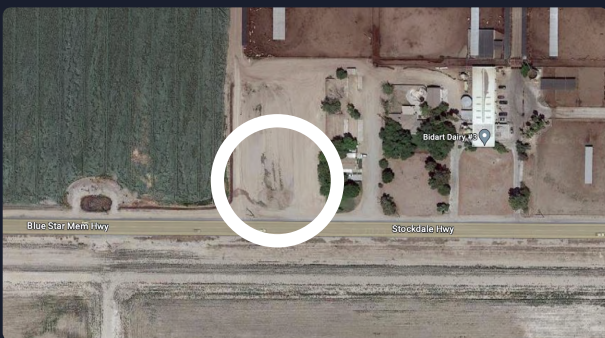
In this groundbreaking endeavor, OWL and Cal Poly released three meshing SpaceDucks. As these balloons gracefully floated above, message transmissions from the launch station were initialized. The objective was twofold: 1) relay messages to the designated landing site but also 2) achieve this by seamlessly hopping from one balloon to another before reaching the final ground station. The successful accomplishment of this task would demonstrate the efficacy of the ClusterDuck Protocol (CDP) in aerial and potentially space environments. We are excited to report that this mission was a success. We received a few packets that showed it hopped from a balloon to the other balloon and to the landing site.

The establishment of a mesh network in the sky substantiates two crucial aspects. First, it signifies a significant expansion in the coverage capabilities of the CDP when deployed on satellites. This breakthrough holds immense potential for implementing cost-effective monitoring systems on satellites, enabling simple yet highly efficient communication. Messages can effortlessly traverse from one satellite to another, facilitating seamless transmission until they ultimately reach the desired ground station.

This leap in the SpaceDucks deployment not only demonstrates the versatility of the network but also unveils an array of possibilities for enhanced communication in the sky and beyond. Furthermore, a remarkable achievement was made by one of the SpaceDucks, surpassing the previous altitude record and reaching an astonishing height of 28,062 meters (92,068 feet)!

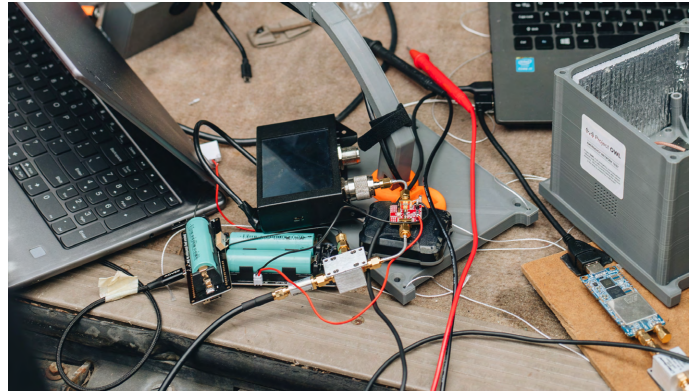
Launch Site 2

35°21'18.6"N 119°17'27.5"W



LAUNCH 3: Frequency Shifting (STUDENT PAYLOAD)

One way to make satellite-terrestrial (S-T) connection as reliable as possible is to increase transmission power. However, LoRa operates in the Industrial, Scientific, and Medical (ISM) band which has regulatory limits transmission power to 100 milliwatts. The research team at Cal Poly accepted the challenge and investigated non-ISM communication bands and their feasibility for satellite-terrestrial (S-T) communication links. By varying power and frequency, the research team seeks to demonstrate the feasibility of a low error-rate communications link using amateur bands with SpaceDucks.



The electronics going in the the frequency shifting payload. In the right image, the team is reassembling the payload after the two hour car ride.

Regrettably, the setup did not withstand the rigorous two-hour car journey to the launch site, necessitating an on-site reconstruction of the payload. In the absence of appropriate instruments amidst the expanse of empty fields in the central valley, retesting the payload became unfeasible. Nonetheless, driven by our commitment to the mission, the launch proceeded albeit encountering a data outage from the reconstructed payload shortly after liftoff. This experience served as a valuable lesson, emphasizing the need for meticulous attention to the assembly process of future payloads, ensuring their resilience against external forces.

Moving forward payload design will focus on reinforced mechanical design to withstand potential external influences. This strategic approach will fortify the integrity of the payload, enhancing its resilience and reducing the likelihood of similar setbacks in the future. By incorporating these vital lessons there is high confidence in the reliability and success of our future launches.

CONCLUSION

Today the expectation of constant connectivity has become ingrained, often causing all of us to overlook its true fragility and importance. However, during natural disasters, individuals can find themselves isolated and unable to communicate their immediate needs such as access to essential resources like food and water. The extensive network of oil and gas pipelines spanning across nations can suffer from undetected methane leaks due to the lack of connectivity for monitoring. And similarly, governments and militaries need to deploy resilient networks of related design. These pressing issues are at the forefront of OWL's mission to develop simple and cost-effective communication technology. The SpaceDuck initiative represents an exceptional opportunity to amplify the impact of the ClusterDuck communication protocol, as Ducks floating above can establish connections and relay crucial information that ordinary terrestrial networks cannot. By embracing that mantra "Height is might," OWL and Cal Poly are working to create a more resilient world through connectivity.

SPACEDUCKS III CAL POLY TEAM



KEVIN NOTTBERG

B.S. in Electrical engineering and is completing a M.S. in Electrical Engineering at California Polytechnic University. Kevin led development of the Quacker 2, 3, and QuAD electronics for the SpaceDucks payloads from 2021 to present day.



LUCAS LUCIA

Senior Electrical Engineering major with a focus in RF/ Communications, heading into the graduate program. I worked on designing, assembling, and testing the LoRa channel modeling setup, including up convert & amplify, and the 13-cm band beacon payload. I also drove fast on dirt roads during launches and took on the important role of eating the leftover food.



DANIEL XU

Electrical Engineering B.S. at Cal Poly with a concentration in RF/ communications engineering. Focused on device characterization (comparing and verifying datasheet parameters), and verification of the overall system. During SpaceDucks, I learned many things, especially how good Steve Dunton is at making an awesome bbq!



DANIEL MONTGOMERY

I collaborated with the senior project team to design, assemble, and test the LoRa bench top channel modeling setup, including the up convert & amplify additions, and the 13-cm band balloon beacon payload and worked on the automation software. I was a Senior Electrical Engineering major with a focus in RF/ Communications.



ABIGAIL OUTCALT

B.S. in Aerospace Engineering at California Polytechnic University. Led overall aerospace conops for balloon-based payloads and assisted in launch operations during the SpaceDucks 3 event.



ARIEL FREIMAN

B.S. Electrical Engineering at California Polytechnic University and pursuing a masters in EE next year. Focused on research and development of doppler shift and mitigation tactics for SpaceDuck payloads.

SPACEDUCKS III TEAM



JOHN GHARIB

Senior Electrical Engineering student at California Polytechnic University, and pursuing a Master's degree in EE next year. Focused on research and development of doppler shift and mitigation tactics for SpaceDuck payloads.



ANTONI GONZALES

Senior Electrical Engineering major with a focus in RF/ Communications, heading into the graduate program. Lucas worked on designing, assembling, and testing the LoRa channel modeling setup, including upconvert & amplify, and the 13-cm band beacon payload. I also drove fast on dirt roads during launches and took on the important role of eating the leftover food.



MICHAEL LEE

Electrical Engineering B.S. at Cal Poly with a concentration in RF/ communications engineering. Focused on device characterization (comparing and verifying datasheet parameters), and verification of the overall system. During SpaceDucks, I learned many things, especially how good Steve Dunton is at making an awesome bbq!



DENNIS DERICKSON

Dennis Derickson received his BS, MS and Ph.D. in electrical engineering from South Dakota State University (1981), the University of Wisconsin- Madison (1982) and the University of California – Santa Barbara in 1992.

SPACEDUCKS III TEAM

COMMUNITY SUPPORT



EVAN AGARWAL

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, and filing necessary flight documents with the FAA (NOTAMs).



JACK MCGUINNES

For SpaceDucks, 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.



JOSH FRANKLIN

Throughout SpaceDucks, I was in charge of designing the ground station. I led the the design and implementation of various hardware tests to ensure payload functionality. Additionally, I was leading the physical assembly of the payload. Throughout the flights, I was tasked with finding the relative location of the balloon to point our ground station at the payload.



ISAAC WIGGINS

First-year data analysis student through Southern New Hampshire University. Enamored with their rapid development capabilities and open-source community. I supported the balloon experiment by performing active recovery of Space Ducks upon landfall, as well as assisting in operating the ground station responsible for tracking payloads in flight over 915 MHz.

SPACEDUCKS III OWL TEAM



TREVOR RICE

I discovered OWL during a senior design capstone program and was instantly drawn to their mission. After graduating in August 2022, I joined OWL's engineering division. I assisted with balloon operations and worked on improving communication between the payload and our Software Defined Radio (SDR) project.



BRYAN KNOUSE

Co-Founder of OWL and focused on SpaceDuck 3 launch operations. Focused on payload design, systems integration, and data handling.



TARAQUR RAHMAN

Throughout the SpaceDucks launches, our team diligently gathered data from multiple sources. My role encompassed understanding the collection process, exploring methods to enhance data processing, and identifying opportunities for future mission improvements. Additionally, I played a crucial role at the landing site, ensuring seamless reception of messages transmitted by the SpaceDucks throughout its flight.



TIMO WIELINK

What a week, It was a lot of hard work and long nights. But I am super proud of our team and the students who supported during the event. I was not sure if we were able to launch 5 balloons at the same time, but we did it without any problems.



CHARLIE EVANS

Charlie is a co-founder of OWL and the Chief Architect for the OWL team. He received his Bachelor of Science in Computer Science from the University of Tulsa in 2009. For SpaceDucks III, he focused on building the web application used in the field by the collective team to monitor payload information in real-time.

GALLERIE



The Quacker (OWL's customized board) that is going to be used for SpaceDucks.



Collecting the completed 3-D printed SpaceDucks enclosures.



The launch team securing the SpaceDuck on the weather balloon.



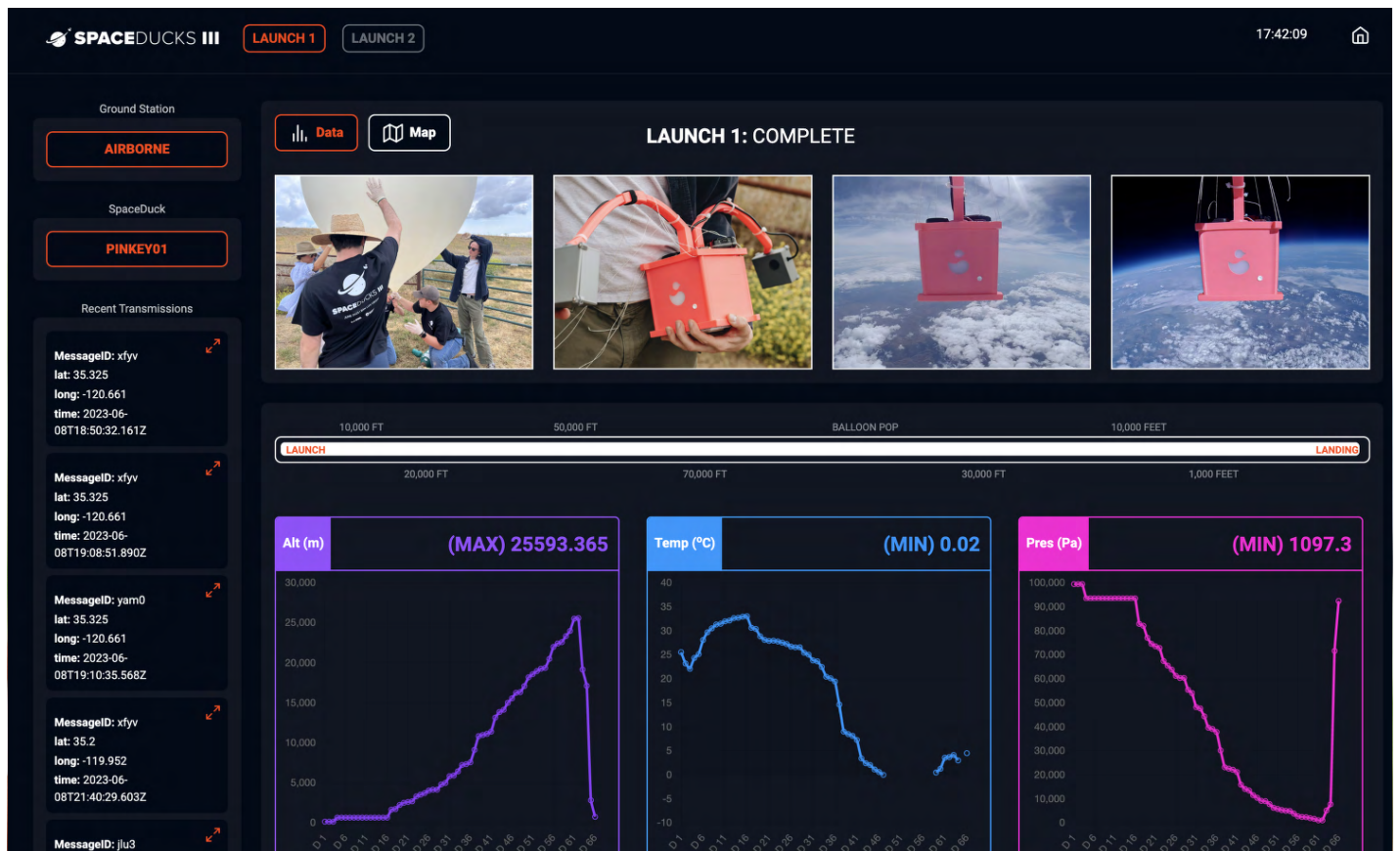
The landing team successfully collecting data using the Yagi antenna.



The landing team for LAUNCH#1 operating the Yagi antenna to follow the flight path of PINKEY01 in the back of a Tacoma.



The launch team making final flight path calculations just before launch.



OWL's Data Management System that was visualizing the data in real-time during the launches.



The SpaceDuck as it was descending into an almond farm.



PINKEY01 whimsically soaring through space transmitting data to the ground.



That is a wrap for SpaceDucks III. We could not have done it with our supportive partners.