Field-Testing the First Cargo Drone Deliveries in the Amazon Rainforest



Dr. Patrick Meier and Mr. Juan Bergelund



February 2017



Field-Testing Cargo Drone Deliveries in the Amazon Rainforest

Executive Summary

The mission of WeRobotics is to scale the positive impact of social good projects through the use of appropriate robotics solutions. We do this by creating innovation labs (called Flying Labs) in Asia, Africa and Latin America. These local labs accelerate the transfer of professional skills and robotics technology necessary to scale the impact of local projects. Each of our Flying Labs are run by Local Coordinators who take the lead in identifying and managing priority projects across multiple sectors including humanitarian aid, development and nature conservation. The labs and their activities in Peru, Tanzania and Nepal are made possible thanks to funding from the Rockefeller Foundation.

In Peru, our Flying Labs team is focusing on the use of aerial robotics (drones) for the delivery of essential medicines in the Amazon Rainforest. To this end, a fact-finding mission was carried out December 12-21, 2016 to investigate use-case, challenges and opportunities. The mission included the field-testing of drone technology in the Contamana region of the Amazon. The plan for the field test was to deliver anti-venom and blood samples weighing up to 1 kilogram inside a refrigerated cold pack. The drone would fly between the town of Contamana and the remote village of Pampa Hermosa about 40 kilometers away. Regular riverboats (canoes) can take up to 6 hours to reach their destination. Three days had been dedicated for the cargo flights. During this time, as many deliveries as possible would be carried out. Juan Bergelund, the WeRobotics Coordinator for Peru Flying Labs, secured official, written permissions for the flight tests from both the Peruvian Civil Aviation Authority and the Peruvian Ministry of Health. The latter publicly described our proposed cargo drone efforts as being of "national interest" to the country of Peru.

Unfortunately, the relatively expensive cargo drone ("Drone A") that had been shipped from North America to carry out the field tests in Peru failed to work. The company that manufactures the drone was unable to fix technical issues after 3 days of testing and troubleshooting onsite. The platform could not fly for more than 30 seconds without becoming unstable. So our Peru Flying Labs team decided to improvise. They repurposed their E384 fixed-wing mapping drone (manufactured by Event 38) to successfully deliver anti-venom and blood samples between Contamana and Pampa Hermosa. The E384 is 90% cheaper than Drone A. It only weighs 2 kilograms and is hand launched. It is also cheaply and easily repairable onsite unlike Drone A. See Table 1 for a summary.

Two flights were carried out with the E384. The first delivered anti-venom in a cold pack (approximately 0.5 kilograms in total) from Contamana to Pampa Hermosa during the day. The second carried blood sample in a cold pack (approximately 0.5 kilograms) from Pampa Hermosa late at night. The successful field-tests were performed in collaboration with the



Ministry of Health, regional health centers and local doctors. Note that only two flights were possible with the affordable drone because all the time had been used up testing Drone A. The E384 flights were improvised at the last minute and we could not extend our time in the Amazon Rainforest further because of an important meeting scheduled with the Ministry of Health in Lima on December 21st.

Drone	Cost	Range	Weight	Max Cargo	Prep Time	Deliveries
Drone A	\$40,000*	60km	8kg	2kg	3 days	0
Event 384	\$2,799	60km**	2kg	0.5kg	6 hours	2

Table 1: Comparing the the 2 drones field-tested in the Amazon Rainforest. (*) The cost is reportedly \$30,000 for the drone and\$10,000 for the ground station and batteries. Note that the 60km range and 2kg payload has *not* been independently verified byWeRobotics. (**) This estimate is based on the fact that the E384 only used 60% of the battery to fly about 40km.

This explains why Peru Flying Labs is returning to the Contamana in February 2017 to carry out additional flights between Contamana and Pampa Hermosa with E384's. In May 2017, we plan to carry out additional cargo deliveries with a modified version of the E384 between Contamana and the city of Pucallpa, approximately 105 kilometers away. Both of these field-tests have been requested by the Peruvian Ministry of Health and local doctors.

Why the Amazon?

The Amazon Rainforest is home to thousands of local indigenous communities spread across very remote areas. There are few roads in the Amazon. Riverboats on slow winding rivers offer the only means transportation for many isolated communities. As a result, these sparsely populated communities rarely have reliable access to essential medicines or public health services. Local doctors report an average of 45 snakebites per month in the Contamana regional alone . These bites are often life-threatening and it can take hours to have anti-venom medicines delivered by boat. So we traveled to the Contamana Region of the Amazon Rainforest to learn more about these challenges and to explore whether cargo drones could realistically be used to overcome some of these challenges in a sustainable manner.

When we reached the remote village of Pampa Hermosa by riverboat from Contamana, we learned from the local doctor that he had treated a villager for snakebite just the week before. As a result, he only had one anti-venom vial left. So if two other villagers were to be bitten by snakes in coming days, he would either have to send the second villager to Contamana by boat or have more anti-venom delivered to Pampa Hermosa. According to the local doctor and others in Pampa Hermosa, it can take a regular boat (canoe) up to 6 hours to travel to Contamana.





Picture 1: Satellite image showing the locations of Pampa Hermosa (top left) and Contamana (bottom right)

There are faster, publicly available boat options which typically take 3 to 4 hours. But these boats don't leave every hour. There are typically just 1 or 2 of such boats scheduled every day. And even then, the boat owners typically wait until the boat fills up before departing. It can take hours before a boat is filled up and ready to leave. And then another 3-4 hours to reach the destination. The only alternative is are the canoes which can take up to 6 hours to complete the journey assuming the boat leaves right away. These slower boats are also limited in how often they service Contamana and Pampa Hermosa. But these boats serve as the primary means of transportation because they are far more affordable for villagers.

In our case, we were lucky to have the invaluable support of the Peruvian Navy, which meant we were able to use very fast boats to Pampa Hermosa, reducing the travel time to an impressive 2 hours. We were also able to leave within an hour's notice. Note that the Navy boat cost \$140 per return trip in fuel alone and that this boat is otherwise strictly not available for public use, not to mention prohibitively expensive in any case for villagers. The slow boat (that takes up to 6 hours), costs about \$4 return while the faster boat that takes 3-4 hours costs about \$10 return. It is important to understand that all of these travel times (including the Navy boat) are also in part dependent on the Ucayali River itself. Amazon rivers are often full of heavy tree trunks and large branches floating with the current. River plants also wind around boat propellers, which forces the boat to slow down considerably and often stopping entirely. A lot of zigzagging is also necessary to dodge the debris which further adds to the trip time. This makes traveling the river at night particularly risky and ill-advised.





Picture 2: The only means of local transportation in the Amazon Rainforest is the riverboat

Note that the village of Pampa Hermosa is not directly on the Ucayali River itself but rather an hour-long walk inland through a narrow dirt-path in the rainforest. When it doesn't rain, there are motor taxis available to take boat passengers to the village. The drive takes around 20 minutes. When it does rain, those narrow paths quickly become muddy and unusable by motorbikes. Local doctors have also noted that traveling to remote villages like Pampa Hermosa is not without danger. There have been cases of snakebites occurring while on riverboats when they pass too close to overhanging trees on the riverbank as these will occasionally have snakes on them. More risky in terms of snakebites are the narrow foot trails that lead from the river to remote villages inland. There is also the issue of the intense heat and humidity in the Amazon.

The local doctor in Pampa Hermosa noted that transporting a patient suffering from a snakebite to Contamana was hardly desirable. The intense heat and long 6-hour trek could worsen the patient's condition. The better option was to phone Contamana and a resupply of anti-venom medicines put on the next public boat to Pampa Hermosa. This too is not an ideal solution, and not only because of the long time it would take to finally get the medicines to the remote village. Transporting essential medicines via public means of transportation is not ideal. The doctor also noted that he doesn't have the equipment necessary to test blood samples in Pampa Hermosa. This means that when he is unable to diagnose a problem, he has to send the patient to Contamana where they can get their blood drawn and tested. Cargo drones could thus play an important role in the transportation of both anti-venom and blood samples, as well as other medicines. We also spoke at length with local partners and stakeholders in both Contamana and Pampa Hermosa about their other transportation needs beyond medicines and samples.



Community Engagement and Flight Permissions

When we landed in Contamana, we were warmly welcomed by Doctor Giovanna and her team, local government officials and local students. Doctors and public health officials with the Peruvian Ministry of Health were also directly involved in the project, including Dr. Lucchetti and Dr. Rojas. We took the opportunity upon arriving to share our proposed cargo delivery flights and to answer questions. In order to raise community awareness in Contamana vis-a-vis our proposed cargo drone flights, we gave an interview to the town's very popular local radio station, Radio Feroz. The interview lasted 30 minutes and was conducted in Spanish. We explained the purposes of the flight tests, the positive impact that drone could have on public health in the region, and answered questions about how the technology works.



Picture 3: WeRobotics and team from Peru Flying Labs raising local awareness before the cargo flights in the Amazon

When we visited Pampa Hermosa during our first trip there, we were met by the Mayor who warmly welcomed us with other officials in the village. A public meeting was organized by the Mayor so that we could officially present our proposed cargo flights and ask permission from the community. Present at this public meeting were WeRobotics and Doctors Giovanna and



Lucchetti who each spoke at length about the importance of these efforts and what they entailed. The meeting was closed by Pampa Hermosa's Mayor who said: "We are honored that you have chosen us for this project and we are ready to help you in any way you need."

Before, during and after our flight tests, we were sure to always communicate with locals who were interested in learning more. We also gave an informal presentation to children in Contamana and Pampa Hermosa. The dates/times of the flight tests were shared with the public and the authorities in both locations. Our flight paths were also programmed to avoid flying over any populated areas. Just minutes after completing our flight tests, we convened a town hall meeting at the central square in Contamana to share the results of the test.

Juan Bergelund, the WeRobotics Coordinator for Peru Flying Labs, secured official, written permissions for the flight tests from both the Peruvian Civil Aviation Authority and the Peruvian Ministry of Health. The latter publicly described our proposed cargo drone efforts as being of "national interest" to the country of Peru. In sum, we closely followed the International UAV Code of Conduct which was developed by the Humanitarian UAV Network (UAViators) in partnership with leading international humanitarian and development organizations.

Field Tests - Plan A

We planned to carry out a dozen flights between Contamana and Pampa Hermosa, about 40 kilometers away. The drone was to carry anti-venom vials as well as blood samples, both during the day and at night. Alas, Plan A didn't work as expected.

Our cargo drone flight tests were originally supposed to be carried out in partnership with an American drone startup. The company had designed and manufactured a prototype drone based on a hybrid, Vertical Take-Off and Landing (VTOL) model; enabling the drone to takeoff and land vertically like a helicopter while flying horizontally like a plane. The drone costs \$30,000 plus \$10,000 for the ground station, batteries and spare parts. The company had previously reported successful flights elsewhere in the world. For our field tests in Peru, the company requested 1.5 days to set up, test and prepare for the cargo flights. The cargo drone is reportedly able to carry 2kg across a distance of 60km but the company requested that the Peru tests be kept to 1kg over 30km. They also requested complete privacy and carried out initial takeoff tests at a secret location, which was not disclosed to WeRobotics or our local partners. In addition, we were not allowed to approach the workspace that the company was using to assemble and test their drone. Nor were pictures or videos permitted.

In any event, due to technical difficulties that were not made clear to WeRobotics, the company ended up taking a full 3 days to get ready. Alas, when the final opportunity came on Sunday afternoon, December 18th to fly the cargo drone from Contamana to Pampa Hermosa, said drone barely flew for 30 seconds before it became unstable and had to be landed. The field-tests with the company were thus called off and the company left Peru on December 19th.



Field Tests - Plan B

Sensing that the Drone A tests might fail completely, the Coordinator of our Peru Flying Labs, Juan Bergelund, had already proposed a backup plan using a small fixed-wing mapping drone he had brought with him. Juan and team would simply remove the drone's camera and place the antivenom in its place. The drone in question was an E384 fixed-wing drone by the company Event 38 costing just under \$3,000. It is a small, simple and easy to use drone which can be repaired locally. The drone is hand-launched and programmed to fly autonomously. The model that Juan and team had with them had already been flown many, many times in 2016, which was evident from all the dents, scratches and duct tape holding the drone together. In fact, Juan's team had actually named their drone Franky after Frankenstein, due to the many repairs that the drone had gone through. There were no guarantees that this basic low-cost mapping drone repurposed for cargo delivery would be able to fly 40km north with a small medical payload instead of a camera.



Picture 4: Preparing the repurposed drone for the first ever cargo delivery in the Amazon Rainforest



Unlike the company with the Drone A platform, Peru Flying Labs only had a matter of hours to prepare for the flight tests and and had not brought any spare parts or additional batteries. Nevertheless, within a few hours, the team had programmed the flights, tested the drone and was ready to fly to Pampa Hermosa. Doctor Giovanna supplied the team with a chilled anti-venom medicine bottle that was put into a cold pack and placed into the small E384 drone. The drone was then hand-launched from Contamana's football field. Approximately 35 minutes later, the drone appeared over the village of Pampa Hermosa and was manually landed by a member of Peru Flying Labs. The landing on the local football field was very smooth as the drone slid gently across the grass. Many villagers had come out to witness the first ever cargo delivery flight in the Amazon Rainforest. The drone's battery was at 40% when it landed in Pampa Hermosa, which suggests that we could have flown the drone across a distance of 50km-60km.

The team in Pampa Hermosa immediately removed the cold pack from the drone and handed it to the doctor. The doctor and his team of nurses in Pampa Hermosa simulated a snakebite response, with a young boy in the village acting like he had been bitten, limping forward with the help of a nurse. So the doctor and nurses got to work right away, helping him lay down on the grass and going through all the required medical steps to administer the life-saving medicine. This was done within 10 minutes of the drone landing on the football field. In other words, if a drone is on standby in Contamana, it can be used to fly anti-venom to Pampa Hermosa and the patient can be treated within approximately 45 minutes, compared to the 3-6 hours (best case scenario) that a riverboat would take.



Picture 6: Removing the cold pack and anti-venom from the drone right after it landed in Pampa Hermosa



After the boy was "saved" with the anti-venom, we got to work on programming the return flight for an 8pm (night time) departure that same day. This too would be the first time ever that a cargo drone would be operated at night in the Amazon. This time, the drone would be programmed to land automatically on the football field in Contamana rather than manually landed. The cargo would be a blood sample taken from WeRobotics. The simulation here would involve sending a blood sample (in a cold pack) to Doctor Giovanna in Contamana who would then be able to test the blood for diagnostic purposes and call the doctor in Pampa Hermosa with the results. These results would then enable the local doctor in Pampa Hermosa to make the right choice in terms of required intervention and medication. A bike light was taped to the nose of the drone.



Picture 7: Preparing the drone for the first ever night-time cargo delivery in the Amazon carrying a blood sample

The original 8pm departure time of the E384 was delayed due to some difficulties in having the drone switch to automatic flight upon takeoff. The flight was about to be canceled after several tests. But there was a small risk that the drone would be able to switch to automatic mode if it got to a high enough altitude where it could capture the data link from Contamana. However,



this would require launching the drone into the night and then manually flying it to a high altitude in complete pitch-black darkness, which could challenging. Still, Juan Bergelund took the calculated risk and gaven the go-ahead.

As it turns out, the drone was indeed able to switch to automatic mode at a higher altitude and promptly made its way back to Contamana. About 35 minutes later, the team in Contamana saw a clear bright light in the dark sky, which could only be the drone. The landing site was programmed to be the football field in Contamana, which had been lit up by the headlights of dozens of motorcycles that lined the field, mimicking two rows of lights like a real runway. Alas, the drone overflew the football field and landed in a nearby coconut tree instead because the GPS coordinates of the field were off. But the blood sample in the cold pack was completely intact, and the drone only required one servo replacement (which is very cheap and easy to do). Because the E384 only weighs 2 kilos and the propeller faces the back, there is virtually no risk that it could harm anyone. This is in contrast to the heavier and larger Drone A platform.

After retrieving the drone from the coconut tree, it was brought to the central town square where Dr. Giovanna explained the purpose of the flight and physically removed the cold pack from the drone in front a large crowd to demonstrate that the blood sample was completely intact.

Conclusion

Transporting Drone A from North America to the Peruvian Amazon was both challenging and expensive. The batteries had to be declared as dangerous goods and then shipped separately via cargo aircraft. After arriving in Peru, the drone itself had to be transported by road from Lima to Pucallpa, a 12-hour journey. Once in Pucallpa, the \$40,000 drone barely fit into the small 12-seater plane and seats had to be removed to accommodate the equipment. The drone in question was a hybrid VTOL drone which enables the platform to take-off and land vertically like a helicopter. This is particularly desirable when there is limited space, which is one reason it was selected for the field-tests. But this unnecessary in the Contamana region of the Amazon since both Contamana and Pampa Hermosa had large football fields where normal fixed-wing drones could be launched and landed. We originally planned to carry out a dozen flight tests with Drone A in the Amazon Rainforest. Once in Contamana, Drone A was alas unable to fly for more than 30 seconds due to technical problems that were not made clear to WeRobotics.

When it finally became clear that Drone A was not going to work, our Peru Flying Labs team improvised by repurposing an old, worn-out mapping drone into a cargo drone. The drone's camera was removed and replaced with anti-venom and blood samples. Despite the limited preparation time available, the \$3,000 E384 drone (officially priced at \$2,799) was successfully flown from Contamana to Pampa Hermosa about 40 kilometers away during day-time; delivering a cold pack with anti-venom. The return flight was carried out late at night and delivered blood samples back to Contamana. Alas, we did not have time to carry out additional flights with the E384 because all the time had been used to troubleshoot Drone A.





Picture 8: Team picture at the end of the field tests and fact finding mission

Based on these successful flights, however, the Ministry of Health and local doctors have invited Peru Flying Labs to return in February 2017 to carry out additional flights between Contamana and Pampa Hermosa. In addition, thanks to the success of our December flights, we have also been invited by public health authorities to carry out longer distance test flights (over 100km). We are thus working closely with them and our Flying Labs team in Lima to organize these follow up tests. Our local partners and stakeholders in both Contamana and Pampa Hermosa have also noted that their transportation needs go beyond medicines and blood samples. So we look forward to continuing those discussions as well. In the meantime, Peru Flying Labs is hard at work on another cargo delivery project focused on Zika reduction (funded by USAID). The field tests for this Zika reduction project are scheduled for late 2017. The Zika reduction project will draw directly on the lessons learned from all the field tests in the Contamana region.

In conclusion, the results of our initial field tests suggest that affordable drone models that have already been used extensively around the world (like the Skywalker frame used by the E384) are in some cases more preferable than the expensive, heavier prototype cargo drones. For the cost of just a single Drone A platform (\$40,000), WeRobotics could purchase *twelve* E384's



(including plenty of spare parts and dozens of batteries), making it possible to establish an actual cargo delivery *network*. In contrast, building such a network with the Drone A platform would cost \$440,000. For that amount of money, one could purchase over 150 (!) E384 drones, and thus establish individual drone delivery networks in *a dozen countries* with plenty of redundancy onsite should any of the drones need to be repaired or replaced. As such, even if the E384's are not as durable as more expensive prototype drones, their markup price-point of \$2,799/drone makes them more cost-effective than \$40,000/drone for certain use-cases.

This explains why making the business case for the use of very expensive drones can be quite difficult for several use-cases. Note that these more expensive drones also tend to have higher training, shipping, operational and maintenance costs. These factors coupled with the results of the field tests in the Amazon explains why WeRobotics is actively exploring the range of delivery uses-cases that can be effectively served by more affordable cargo drone solutions. Ultimately, however, this is not an either/or situation: there is a need for both affordable / disposable cargo drones as well as the more sophisticated drones to serve different use-cases. The aviation industry has many different kinds of aircrafts (ranging from Cessnas to 747's) serving different use-cases. The cargo drone ecosystem will evolve in a similar manner.

Contact

Dr. Patrick Meier, Executive Director of WeRobotics: patrick@werobotics.org Mr. Juan Bergelund, Peru Flying Labs Coordinator: juan@werobotics.org

Multimedia Assets

Short video documentaries on the Amazon project are available on the WeRobotics.org website along with hundreds of high-res pictures documenting the fact finding mission and field-tests.

Acknowledgements

WeRobotics Peru Flying Labs Juan Bergelund, Jose Manuel Alvarez, Elena Arguelles, Billy Rodrigue and, Orlando Cerro

Peruvian Partners Dr. Giovanny Flores, Dr. Aldo Lucchetti and Dr. Leonardo Rojas