Field-Testing Cargo Drones for Medicine Deliveries in Rural Environments of the Dominican Republic

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Table of Contents

1. Executive Summary

Local communities in the remote mountains of the Dominican Republic do not have regular access to healthcare services. This is not due to the lack of paved roads connecting their villages and local clinics to regional hospitals. Rather, it is the cost of local transportation that serves as the biggest impediment. This is particularly problematic when local clinics run out of medicines, or when they cannot test patient samples locally. When this happens, patients have to travel to the hospital in person. If the patient can afford the cost of local transportation, then getting to the hospital often requires a full day of travel due to the limited number of local transportation options. Taking a full day away from paid work and/or from supporting family is often not an option. What's more, some patients are too frail to travel on the back of motorbikes on bumpy and windy roads. Several have noted that the increasing number of motorbike accidents near their villages is another reason why they won't make the trip to the hospital. This explains why some nurses at remote clinics have had to make the journey to the local hospital themselves when patient samples needed to be dropped of and/or medicines picked up.

In November 2018, Pfizer partnered with WeRobotics and DR Flying Labs to carry out autonomous cargo drone deliveries over a 6-week period in 2019. DR Flying Labs is one of 25+ Flying Labs in Latin America, Africa, Asia and Oceania. Flying Labs are local knowledge hubs run entirely by local experts who are trained, equipped and supported by WeRobotics as needed. The purpose of the joint Pfizer-WeRobotics cargo drone project with DR Flying Labs was to test the following hypothesis: can affordable and locally-repairable cargo drones can be operated locally by health care professionals to reliably and autonomously deliver medicines on demand—much like any other medical instrument that is easy enough to use? As noted by the Ministry of Health Director for the El Valle Region, "This project is important in rural areas. With this project, people would have access to pharmaceuticals, lab tests and other data in an expedited way because of the drone. This is an opportunity to extend to our people a service at the right time at the right quality, warmth and quickly as well."

As such, an important objective of this joint project with Pfizer was to collect performance data on aerial deliveries and compare this with data on ground deliveries. This comparative analysis would provide a better understanding of the cost-benefit analysis of using drones for medical deliveries. WeRobotics therefore repurposed and customized the DJI M600 mapping drone into a fully autonomous cargo drone solution by developing dedicated Android software, onboard electronics, including embedded software, and a precision landing solution. The M600 industrial drone was selected because it is highly reliable, relatively affordable and locally-repairable. What's more, the M600 can continue to be used for mapping in-between cargo delivery projects.

DR Flying Labs drone pilots, who were all trained by WeRobotics, carried out 6 weeks of consecutive deliveries in the province of San Juan de la Maguana between June and July 2019. A total of 101 autonomous flights were carried out to two separate health facilities, traveling a total of 994 kilometers. Of the 51 outbound flights, 40 carried medicines totalling 21.25 kilos. To reach one of the two facilities, the drone had to gain an altitude of 784 meters above ground level. None of the risks identified at the outset of the project materialized thanks to a strong risk management and mitigation strategy developed by WeRobotics and DR Flying Labs. While there were a number of aborted deliveries due to weather, none of the 101 flights carried out over a 6-week period resulted in a crash or any material damage.

Left: M600 drone repurposed into an autonomous cargo drone with precision landing.
Right: DR Flying Labs drone pilot introducing cargo drone to local doctor at remote clinic.

A preliminary and independent cost benefit analysis carried out by VillageReach in September 2019 with respect to cargo drone deliveries in the Province of San Juan after the completion of this project suggests that the cost of delivery was approximately $0.40 per km for 5 flights per day with M600 drones, and $0.43 per km for land transport (a 7% cost savings per km). While this savings estimate seems relatively modest, one must consider that essential medicines are relatively easy to transport in San Juan Province given strong transportation infrastructure in the area. Further cost savings may be achieved if the number of flights per day increases from 5 to 8 ($0.33/km drone vs. $0.43/km land), resulting in 23% cost savings per km. With 26 flights per day, cost savings per km decreases to $0.25/km by M600 vs. $0.43/km by land, which represents a cost savings of 42%. That being said, there are only 69 health facilities in San Juan, so the frequency of 26 flights may not be feasible without diversifying the cargo being transported.

In any event, it is imperative that donors and other partners understand that these cost savings are *estimates* based on several general assumptions and proxy supply chain data. Furthermore, focusing the analysis on cost savings alone is a common mistake. Time and responsiveness are equally important measures. In San Juan Province, for example, the M600 drone deliveries saved 50+ hours of driving time and 1,000km of driving. The drone deliveries were also 42% to 70% faster than road deliveries, which is significant since San Juan Province already has relatively strong ground transportation infrastructure. Furthermore, knowledge transfer, drone technology transfer and opportunity transfer to local experts also generate direct benefits as demonstrated by the Flying Labs network.

Several lessons were learned during this 10-month project. On the organizational front, Flying Labs and similar local organizations are indispensable to ensuring the sustainable and ethical transfer of knowledge and emerging technologies for social good. Flying Labs strengthen local capacities, build local markets and incubate local businesses that support local drone projects, they coordinate efforts among key stakeholders, facilitate regulatory permissions and provide invaluable logistical support. They have local knowledge, partnerships and technologies already in place. They also enable long-term implementation beyond pilot projects. Flying Labs in the DR, Peru, Nepal and Fiji are each gaining the knowledge and the technology to carry out their own cargo drone projects independently of WeRobotics. Without local organizations like DR Flying Labs and the other 25+ Flying Labs in Latin America, Asia, Africa and Oceania, drone projects like this one with Pfizer would be unsustainable and would require considerably more time and significantly more resources to implement.

In terms of use-cases, the relatively limited range of the M600 cargo drone (15 km) was not an obstacle. There are several public health use-cases in the DR for which a 15 km delivery range is appropriate to provide value to the delivery of medicines. In fact, there are even use-cases where 1 km deliveries add value as demonstrated using the Dronistics drone. On the technical side, one important lesson was that field tests should take place both in Switzerland and the DR even if this adds to the overall budget. No amount of testing in Switzerland can recreate the weather conditions of the Caribbean. Due to this, WeRobotics attempted several techniques to achieve autonomous landings, for example. As such, field testing cargo drones in-country prior to commencing official deliveries is a must.

As expected, deliveries were often delayed during rainy weather since the M600 is not fully waterproof. It was also discovered during the customization of the drone that newer models of the M600 have an altitude lock, which limits the drone to an altitude of 500 meters above ground level. DJI, the manufacturer of the M600, confirmed this constraint when contacted by WeRobotics. Furthermore, DJI made clear that this constraint could not be unlocked. As such, WeRobotics plans to explore other drones that are less constrained by weather or landscape.

Of keen interest to both Pfizer and WeRobotics moving forward is the possibility of handing over local cargo drone operations to local hospital staff in the future and thus do away with the need for dedicated drone pilots. Given that high frequency deliveries are rarely needed in highly rural environments, the personnel costs of drone operations quickly becomes the largest cost driver for drone deliveries to rural communities. In other words, staff costs can make drone deliveries uncompetitive on price. For example, if only 1 delivery per day is made, then that delivery must factor in the cost of an entire day of wages even if the staff time required for said delivery is less than 30 minutes. In sum, the personnel cost per delivery is very dependent on the number of per day deliveries. The 6 weeks of deliveries in the DR demonstrate that this handoff is possible pending further testing and development.

While no major incidents were encountered during the course of 101 flights, there were flight cancelations due to rain and once due to a technical concern. That being said, it is important to manage expectations. The M600 platform is an early prototype when it comes to cargo applications. As such, further development of the electronics and software is necessary before the platform can be handed off to hospital staff. In addition, WeRobotics recommends exploring weatherproof drones.

In closing, it is important that medical cargo drone projects (even those at the pilot stage) respond to the logistics needs of the local health care system. To be sure, the local health care system is obviously critical to generating both local and national demand for new logistics solutions. This process is often the most time-consuming element of a cargo drone project but it is also the most essential element.

This pilot project was funded by Pfizer Inc. to better understand the use of drone technology in health care. The data and opinions expressed in this report have not been validated by Pfizer, nor do they relate to Pfizer's opinions. The results and conclusions shared in this report are not based on Pfizer's hands-on experience. They are based instead on findings from WeRobotics and Dominican Republic Flying Labs based on the information available in September 2019. Note that Pfizer was not involved in any of the other cargo drone projects included in this report.

2. Introduction

Local communities in the remote mountains of the Dominican Republic do not have regular access to healthcare services. This is not due to the lack of paved roads connecting their villages and local clinics to regional hospitals. Rather, it is the cost of local transportation that serves as the biggest impediment. This is particularly problematic when local clinics run out of medicines, or when they cannot test patient samples locally. When this happens, patients have to travel to the hospital in person. If the patient can afford the cost of local transportation, then getting to the hospital often requires a full day of travel due to the limited number of local transportation options. Taking a full day away from paid work and/or from supporting family is often not an option. What’s more, some patients are too frail to travel on the back of motorbikes on bumpy and windy roads. Several have noted that the increasing number of motorbike accidents near their villages is another reason why they won’t make the trip to the hospital. This explains why some nurses at remote clinics have had to make the journey to the local hospital themselves when patient samples needed to be dropped of and/or medicines picked up.

M600 cargo drone landing autonomously at the local hospital after delivery at El Coco Clinic.

2.1 Cargo Drones at Flying Labs

WeRobotics first partnered with Flying Labs in 2016 to field test cargo drones for medical deliveries. Flying Labs are local knowledge hubs run entirely by local experts who are trained, equipped and supported by WeRobotics as needed. Flying Labs are currently operational in 25+ countries across Africa, Asia, Latin America and Oceania. Flying Labs and similar local organizations are indispensable to ensuring the sustainable and ethical transfer of knowledge and emerging technologies for social good. Flying Labs strengthen local capacities, build local markets and incubate local businesses that support local drone projects, they coordinate efforts among key stakeholders, facilitate regulatory permissions and provide invaluable logistical support. They have local knowledge, partnerships and technologies already in place. They also enable long-term implementation beyond pilot projects. Without local organizations like DR Flying Labs and the other 25+ Flying Labs in Latin America, Asia, Africa and Oceania, drone projects like this one would be unsustainable and would require considerably more time and significantly more resources to implement.

DR Flying Labs drone pilot introduces the cargo drone to local doctors at Bohechio Hospital.

The first cargo drone field tests with Flying Labs took place in Peru between 2016-2017 and in the Dominican Republic from 2017 to present day. In addition, WeRobotics has partnered on cargo drone projects with Flying Labs in Nepal, Fiji and Papua New Guinea. While the first field tests were carried out over 3 years ago, there is still an important gap in terms of cargo drone technologies: it is still nearly impossible to find an affordable, commercially available, reliable and locally-repairable platform that can be locally owned and locally operated.

This explains why WeRobotics teamed up Dominican Republic Flying Labs in 2017. Together, we field tested the use of multi-rotor cargo drones and hybrid-drones for the delivery of essential medicines and patient samples between remote clinics and local hospitals in the DR. As part of these tests, WeRobotics began training local drone pilots on how to use cargo drones safely, responsibly and effectively for supply chain. Over 30 flights were logged in varying environmental conditions in 2017. The tests demonstrated that the multirotor drones proved more reliable than the prototype hybrid drones. To this end, WeRobotics ran additional hands-on training for local drone pilots and government officials in May 2018. More than a dozen participants were trained on the operation of multirotor drones for cargo delivery, covering topics such as multi-operator flights, payload considerations and route planning. This served to initiate the process of building local capacity, which is key to future cargo drone deployments in the DR.

2.2 Cargo Drones with Pfizer

Bohechio Hospital on lower right, El Coco clinic on lower left, Montacitos care upper middle.
Blue path corresponds to the Bohechio-El Coco flight route.
Red path corresponds to the Bohechio-Montacitos flight path.

In November 2018, Pfizer partnered with WeRobotics and DR Flying Labs to carry out autonomous cargo drone deliveries over a 6-week period in 2019. As noted by the Ministry of Health Director for the El Valle Region, “This project is important in rural areas. With this project, people would have access to pharmaceuticals, lab tests and other data in an expedited way because of the drone. This is an opportunity to extend to our people a service at the right time at the right quality, warmth and quickly as well.” The purpose of the joint Pfizer-WeRobotics project was to determine whether affordable, locally-operated and locally-repairable cargo drones could reliably and consistently deliver medicines on demand. As such, an important objective of the project was to collect performance data on aerial deliveries and compare this with data on ground deliveries. This comparative analysis would provide a better understanding of the cost-benefit analysis of using drones for medical deliveries. WeRobotics therefore repurposed and customized the DJI M600 mapping drone into a fully autonomous cargo drone solution by developing dedicated Android software, onboard autopilot extension with dedicated electronics and a precision landing solution.

DR Flying Labs “droneport” on the rooftop of the Municipal Hospital in Bohechio.

The M600 industrial drone was selected because it is highly reliable, relatively affordable and locally-repairable. What's more, the M600 can continue to be used for mapping in-between cargo delivery projects.

WeRobotics provided DR Flying Labs drone pilots with in-person training on the customized system and relevant standard operating procedures in May 2019. The initial plan had been to immediately follow this training with 6 weeks of locally-led deliveries. However, the original precision landing solution was not particularly effective. As such, deliveries were placed on hold while WeRobotics created a completely new solution. Flights resumed in San Juan at the end of June and continued uninterrupted for 6 consecutive weeks. These flights were carried out entirely by local drone pilots trained by WeRobotics. A total of 101 autonomous flights were carried out to two separate health facilities, traveling a total of 994 kilometers. Of the 51 outbound flights, 40 carried medicines totalling 21.25 kilos and included the following: Cefalexina, Ciprofloxina, Calcio Carbonato, Vitamina D3, Dolorgesic, Nistatina, Metronidazol, Fluimucil, Espadrapo Base, Azitromicina, Salbutamol, Diclofenac, Aguadestiada, Ketoconazol, Naproxen, Sulfadiazina and Getamicina.. To reach one of the two facilities in the mountains, the drone had to gain an altitude of 784 meters above ground level.

Takeoff and landing location at Bohechio hospital with 360 views of skyline for drone operations.

The base of operations was the Municipal Hospital of Bohechio (Hospital Municipal Bohechio). More specifically, the “droneport” was placed on the rooftop of the hospital to have a safe operating environment by allowing drone pilots to have a 360 view of the skyline and by avoiding crowds. From Bohechio, the droneport serviced two health facilities: Clinica Rural El Coco and Centro de Atencion Primaria Los Montacitos. The rural clinic in El Coco is 13.1 kilometers away by car, 10.3 kilometers by drone. At El Coco, the drone landed in the fenced-in lawn of the rural clinic. The altitude difference between the takeoff and landing sites is 77 meters. In addition to El Coco, the droneport serviced a primary care facility in Montacitos 18.0 kilometers away by car, 10.2 kilometers by drone. There the drone landed on the rooftop of the primary care facility. The altitude difference between the takeoff and landing sites is 784 meters.

2.3 Public Health Stakeholders

The National Health Service (Servicio Nacional de Salud (SNS) public entity under the Ministry of Public Health and Social Assistance of The Dominican Republic, that has the role of promoting and coordinating the strengthening and development of regional health services, gave written authorization to execute the deployments and cargo tests.

At the local level, we coordinated our activities with the collaboration of the Regional Health Directorate No. VI (El Valle), that oversees operations in the provinces of San Juan, Azua and Elias Pina, located on the south-west portion on the Dominican Republic. The Strategic Management Team of El Valle suggested 10 locations within the San Juan province that fit the description of presenting some challenges of access, either due to long distances between clinics and hospitals, or with roads that had poor conditions. From there we agreed with them that the most challenging case would be the Bohechio Hospital - El Coco / Montacitos Clinics routes.

The Bohechio Municipal Hospital administrative leadership provided full support as far as providing access to all areas of the hospital, at all hours and any day of the week. In addition, healthworkers, laboratory and diagnostics personnel as well as the hospital pharmacy staff were instructed to collaborate.

DR Flying Labs introducing the cargo drone system to local nurse at Clinica Rural El Coco.

2.4 Peer-to-Peer Deliveries

Cargo drones that deliver medical supplies always follow predetermined routes. They transport medicines from one fixed point to another—regional hospitals to remote clinics, for example. But what if Community Health Workers (CHWs) need additional medicines while visiting remote communities? They may not know exactly what they need ahead of time or may be unable to carry a wide range of medicines with them across rough terrain. Worse, what if CHWs aren't available and patients have difficulty getting to the clinic or to the pharmacy? Discussions around the last mile typically focus on the challenge of delivering medicines to local healthcare facilities rather than caring for the patient directly.

So what would totally agile, peer-to-peer cargo drone delivery look like? To explore this question further, WeRobotics field-tested a new drone that seeks to enable agile, peer-to-peer deliveries at short range. The people-centered drone (pictured below) is built by the Swiss start-up Dronistics, a technology partner of WeRobotics. The purpose of the 2-day field test in Montacitos in May 2019 was into introduce the drone to local communities in Montacitos and to explore local use-cases for last mile deliveries made to people rather than places.

Sofia unloading medicines from the Dronistics cargo drone after it landed in front of her house.

2.5 Flight Permissions and Community Engagement

Since DR Flying Labs has been operating cargo drones in the region of San Juan since 2017, they did not have to start from square one with respect to community engagement and applying for flights permissions from IDAC, the country's Civil Aviation Authority. IDAC simply renewed their flight permissions for the same areas with respect to this project with Pfizer. DR Flying Labs Coordinator Orlando Perez has been coordinating cargo drone deliveries in the region since 2017. As such, he has worked especially hard to get buy-in from local health professionals and has also done his best to raise awareness amongst local communities and their representatives over the past 2 years.

3. Capacity Building

Foreign-led, top-down, techno-centric solutions often create more harm than good. Furthermore, transferring expensive, foreign-owned and overly sophisticated emerging technologies to the Global South is rarely sustainable, effective or ethical. This explains why WeRobotics has co-created Flying Labs in 25+ countries across Africa, Asia, Latin America and Oceania. Flying Labs are local knowledge hubs run entirely by local professionals who are trained, equipped and supported by WeRobotics as needed. Flying Labs also train each other directly and partner on joint projects. As such, capacity building is central to the work of WeRobotics and Flying Labs. This capacity building enables Flying Labs to operate independently and to offer a range of services across multiple sectors, which enable the labs to become increasingly self-sustaining.

Advanced and introductory online courses on the use of cargo drones in public health

WeRobotics has already partnered with Flying Labs in Peru, Nepal, Fiji and Papua New Guinea to build local expertise in the use of cargo drones for public health. In addition, WeRobotics offers an advanced online course[1] on the use of cargo drones for public health. Combining hands-on, in-person training and technology transfer with professional online courses is an effective way to build the capacity of Flying Labs.

WeRobotics has also developed and implemented a Business Incubation Program (BIP) to incubate locally-owned, locally-managed businesses that offer drones as a service. To date, WeRobotics has partnered with select Flying Labs to incubate 6 successful, locally owned drone

[1] https://werobotics.org/healthrobotics-course-medical-cargo-drones-public-health

business in Africa and Asia. WeRobotics is currently training one of these local businesses (DroNepal) in Nepal to expand their services beyond mapping to include cargo drone services. This explains why DroNepal is now taking the lead on cargo drone deliveries in Southern Nepal that focus on the collection of patient samples for more rapid TB testing.

Local drone pilot Juan Almonte learning to operate the customized M600 cargo drone.

In the context of the Dominican Republic (DR), WeRobotics organized three professional, hands-on training for local drone pilots and government officials between 2017 and 2019. This explains why local drone pilots with DR Flying Labs are able to operate cargo drones independently of WeRobotics. In July 2019, drone pilots with DR Flying Labs subsequently began to introduce the cargo drone system to local health professionals.

WeRobotics provided hands-on training to these local drone pilots in the DR in May 2019. The training was important to introduce the local team to the considerably more customized version of the M600 drone. DR Flying Labs recruited these local drone pilots by reached out to leading governmental and non-governmental agencies and programs that had some experience in drone operations, particularly in the context of humanitarian, emergency and environmental applications. DR Flying Labs drone pilots were thus recruited from the Dominican Republic Red

Cross, the National Emergency Assistance and Security System (911), the National Institute of Hydraulic Resources (INDRHI), The Dominican Republic Navy and the National Office of Seismic Evaluation and Infrastructure and Building Vulnerability (ONESVIE).

The 2019 capacity building started with two days of training at Parque Cibernetico in Santo Domingo. The local pilots were introduced to the opportunities and challenges of cargo drones and to the customized cargo system, including the DJI M600, the ground station app, the hardware extension, the communication network and protocol, the control modes and emergency behaviours, the standard operating procedures and the material preparation and checklists. This initial training was complemented by practical, hands-on workshops on M600 maintenance and repair as well as mission planning and route preparation.

Local drone pilot with DR Flying Labs introducing the cargo drone system to local nurse.

A dedicated pilot operations handbook was developed to provide pilots with standard operating procedures, checklists, flight log sheets and a failure handling guide during field operations. This handbook was published in both Spanish and English. After the initial training, supervised field operations took place in order to equip the pilots with all the necessary practical knowledge to operate the system safely and reliably. They were trained on using different drone controls in case of emergency (DJI remote control, gamepad, virtual gamepad), they learned how to autonomously prepare a new route, plan a new mission and setup a new ground station, they developed the vital habit of practicing the safety checks. Finally, they practiced test missions and real missions under the supervision of WeRobotics staff until ready to operate on their own.

WeRobotics and Emprende are looking to replicate the success of the Business Incubation Program in the DR. Ultimately, the role of WeRobotics and Flying Labs is to sustainably transfer knowledge, technologies and opportunities to local experts. As such, Flying Labs are ideally placed to serve a first-movers vis-a-vis new projects and technologies such as the use of cargo drones in public health. Flying Labs like the one in the Dominican Republic are not meant to provide any and all services at scale, however. Instead, Flying Labs are meant to be a driver. This is why the Business Incubation Program exists. DR Flying Labs, WeRobotics and the accelerator Emprende are together exploring a range of options to help incubate a locally owned and locally managed drone business that can offer long term deliveries as a service.

Local doctor watches cargo drone landing on the rooftop of primary care center at Montacitos.

4. Cargo Drone Selection and Customization

The vast majority of cargo drones are still early prototypes. The few cargo drone companies that have been in regular operation since 2016 are Zipline and Matternet. Zipline offers 1-way deliveries only while Matternet offers 2-way delivery and collection. Neither of these companies make their drones available commercially. What's more, Zipline currently operates in 2 countries (Rwanda and Ghana, and soon India) and focuses exclusively on areas of very high demand to ensure they can make a profit. Matternet has been operating in Switzerland with SwissPost to deliver patient samples between nearby hospitals in Lugano and Zurich. While no longer a prototype, Matternet drones have nevertheless crashed twice in Zurich in early 2019.

Doctor removes medicines from the drone on the rooftop the primary care facility at Montacitos

Every year sees new cargo drone startups launching (and failing). Some of these newer startups include Wingcopter, a German company that is developing a hybrid cargo drone; Swoop Aero, an Australian company that is also developing hybrid cargo drones; Dronistics, a Swiss startup that focuses on peer-to-peer cargo drone deliveries; and Animal Dynamics, a British company that has created an autonomous paraglider. While Wingcopter is further ahead than Dronistics and Animal Dynamics, the Wingcopter drone costs around Euros 75,000 and is relatively less easy to repair locally in terms of required skills and parts. The pricing model for Swoop is unclear. The Dronistics platform is still an early prototype and currently limited to a

1-2km range. The autonomous paraglider from Animal Dynamics is more rugged but still an early prototype and the price point still unclear.

WeRobotics is exploring possible partnership opportunities with these companies to keep all options open for Flying Labs. There are of course several other startups entering this space but it is clear that many of these are not going to be a good fit for locally-operated, rural drone deliveries. Don't be fooled by new startups that are winning awards. Many of them haven't even run a cargo drone project let alone a pilot with their prototypes. What's more, some co-founders of new cargo drone startups already have the reputation of being highly unethical. Some have even been accused of stealing intellectual property. As such, when selecting a cargo drone technology, one must not only evaluate the performance of a given drone but also evaluate the company and the human team behind the cargo drone company. If these co-founders already have a negative reputation, partnering with them becomes a serious liability, even if their cargo drone works as advertised.

In sum, there is still an important gap in terms of cargo drone technologies. It is still nearly impossible to find an affordable, commercially available, reliable and locally-repairable platform that can be locally owned and locally operated. This has been true since Flying Labs began working on cargo drone projects in 2016. Equally importantly, there is still an important gap in terms of easy-to-use, easy-to-setup and easy-to-deploy cargo drones. It is also important to emphasize that an overall cargo drone *system* is still lacking, not just the drone itself. A full cargo drone system includes ground station software, communication links to multiple ground stations, safety features for Beyond Visual Line of Sight flights, precision landing and preventive maintenance component, for example.

This explains why WeRobotics began testing the DJI M600 with DR Flying Labs in 2017. After these tests and further analysis, WeRobotics decided to continue repurposing the M600 industrial drone into a cargo drone for 10 specific reasons. Namely, the M600:

1. Is a very robust and reliable industrial drone.

2. Remains more affordable than existing cargo drones.

3. Is already widely used and thus familiar to and trusted by aviation authorities.

4. Is locally repairable and operable.

5. Can be locally owned, i.e., there are no issues around intellectual property.

6. Has an open SDK for further development and modification

7. Is already widely used, which means that many local drone pilots already know how to operate the drone, which reduces training costs.

8. Is already owned by some local drone companies, which they use to offer video and mapping services, for example. As such, by using the add-on we've developed, they can easily repurpose their drone into a cargo drone and offer a new set of services as a result. The cost of the add-on is the same price as a good laptop.

9. Can be used as a first cargo drone to gain experience and credibility in cargo drone projects. As such, the M600 can enable local companies to become first-movers in offering cargo drone services in their countries. This allows them to gain hands on experience, demonstrate impact and to create demand. They can then invest in longer range drones and grow their company.

10. Has already been used by Flying Labs in the Dominican Republic, Nepal and Fiji. These labs have completed some 400+ autonomous flights over the past 10 months. This explains why we are now making the solution available to others for purchase.

4.1 Cargo Drone Platform

The DJI M600 is a very robust, well-tested industrial drone with superior flight performance. It's a hexacopter with 6 propellers and also 6 batteries. The M600 is simple and easy-to-use, ready to fly in a matter of minutes. The M600 is designed to carry large cameras for videography and mapping. The heavy-lift multicopter can carry up to 6kg of payload. It's hovering flight time without payload is up to 38min, and 18min with a 5.5kg load. The maximum flight speed of the drone is 18m/s, which results in a theoretical distance range of up to 40km without payload, and

19km with payload. In practice however, taking into account forward flight, maneuvers, wind, altitude differences, and safety margins, distances up to 15km with payload are reasonable.

The airframe is equipped with the latest DJI technologies, including the A3 Pro flight controller. It has triple modular redundancy and diagnostic algorithms that compare sensor sets from three GPS, compasses, IMU's and also motors. The system's modular design makes it easy to mount additional modules. Dustproof propulsion systems simplify maintenance and active cooling motors ensure that operation is reliable for extended periods of time.[2]

Intelligent Batteries and Battery Management system means that if any of its six Intelligent Batteries are turned on or off, the rest will follow suit. The battery management system monitors every battery during flight, ensuring safe landing in the event of single battery failure. Compared to traditional non-intelligent batteries, the M600 Pro's battery management system simplifies maintenance while enhancing security.

The M600 can be extended with third party software/hardware by using the DJI Onboard Software Development Kit. This allows direct interfacing with the autopilot for navigation, telemetry data and more. The M600 is an industrial platform sold at roughly USD 6,000 and distributed all around the globe via DJI resellers. For this project, purchasing an M600 in the Dominican Republic via the local DJI reseller was simple, straightforward and fast.

Main limitations of DJI M600 for Cargo Operations

Cargo operations require certain features that are not available using an off-the-shelf DJI drone. Moreover, some safety behaviours are implemented with a circular mission in mind and can lower the safety of a cargo mission if left untouched. The M600 can only be controlled by one operator using the designated paired remote control and it has limited communication capabilities. Safety features such as a limit on the altitude from the take-off point, the impossibility to go lower than the take-off point in an autonomous mission and an automated return-to-home when going too far prevent the M600 to be used for cargo operations without modifications.

Access to the flight controller is limited, so it had to be significantly modified using a second on-board computer, additional radio and a custom flight-planning application in order to perform cargo operations. The drone has been modified to deliver cargo, and can be connected to using multiple separate remote control radios - on sending and receiving sides.

- **Communication link:** the RF communication link provided by DJI is limited to one single downlink, which means controlling the drone is limited to one user per default. Hence, 2-way cargo flights with take-off and landing from point A to B and vice-versa are not enabled. A workaround is to take-off and land at the same place, and do drop-offs without landing a the

[2] https://www.dji.com/matrice600-pro

destination (see Flytrex). That means however, that the distance range of the system is cut by half (same batteries used for flying to destination and back). Moreover the range of DJI radio link is limited to 4km line of sight. The M600 can fly up to 16km which make this link unreliable for cargo operations.

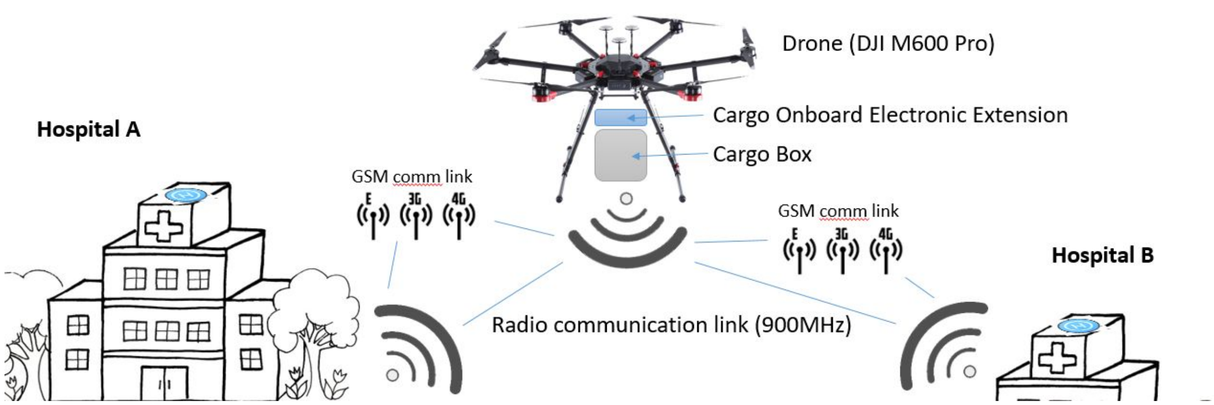
- **Distance limits:** the DJI M600 has a number of features built into their platform that does not allow the drone to fly as far as it could. For instance, standard distance limit is set to 5km. In case of RC signal lost (which is often the case in mountains or for BVLOS operations), the drone returns home. Furthermore, it calculates how much battery it still needs to return home, and triggers a return to home if the battery level falls below that limit.

- **Height limits:** per default, the M600 is limited to not fly higher than 500m above the take-off altitude. This safety feature makes sense to prevent a drone from flying to high into the commercial airspace. However, it is very limiting in mountainous terrain when the drone needs to gain a lot of altitude to reach a destination (e.g. Bohechio-Montacitos is more than 700m in altitude difference).

- **Negative waypoints:** with the default software provided by DJI, it is not possible to set waypoints with negative altitude referring to takeoff altitude. This means per default a DJI drone cannot fly from an elevated location to a less elevated location.

- **GPS accumulated error over long distances:** the DJI autopilot calculates the global position of the drone by fusing measurements from GPS, IMU and compass. This leads to a very accurate position estimation close to the take-off location, however, an accumulated error when flying long distances. We measured estimation errors up to 10m when doing missions of more than 10km.

- **Rainproof:** the DJI M600 is not rain- or snow-proof. Although we aware of flights performed in rain, electronics are not shielded enough to fly continuously in rainy conditions. This puts a serious weather limitation on cargo missions, and requires challenging flight planning by taking into account local weather conditions (which even with the greatest forecast may change within minutes).



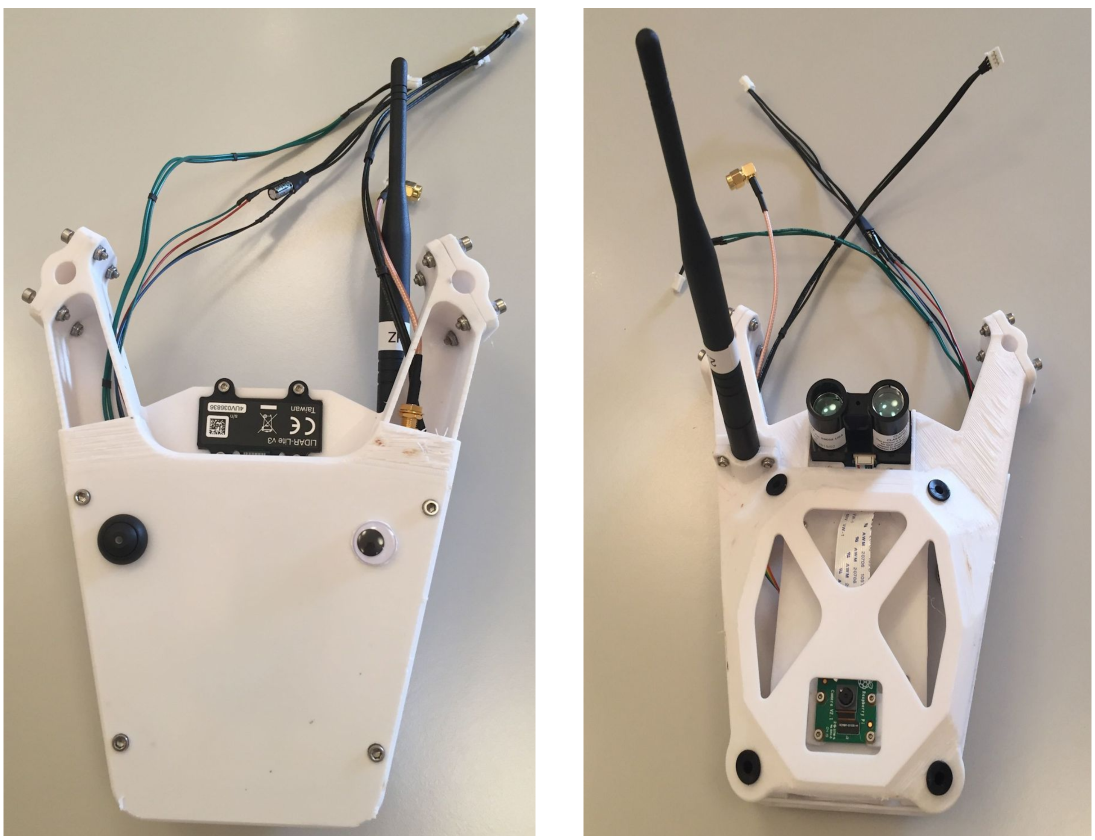
Cargo system allowing to transport up to 5.5 kg from Hospital A to Hospital B. The Drone features a Cargo Onboard Electronic Extension as well as the Cargo Box for medicines.

Except for the limitation on the M600 not being rainproof, we managed to circumvent all the other limitations mentioned above. However, many of the limitations were not known at the start of this project, and overcoming them was not always an easy task.

4.2 Cargo Drone System

We designed a “Cargo Onboard Electronic Extension” to turn the DJI M600 into a cargo drone. Specifically, we added the following features:

- Separate onboard computer for handling cargo missions and interfacing with autopilot
- Separate communication links for long-range operations (RF 900MHz, GSM, Satellite)
- Ground distance sensor for smooth landing
- Precision landing module for accurate landing



Top view (left) and bottom view (right) of the “Cargo Onboard Electronic Extension” to adapt the DJI M600 for cargo drone deliveries. (a) Push button (user interface), (b) LIDAR: ground distance sensor, (c) high-gain antenna for long-range *communication, (d) camera for precision landing.*

The red arrow points to the "Cargo Onboard Electronic Extension" mounted on the DJI M600.

4.3 Cargo Drone Software

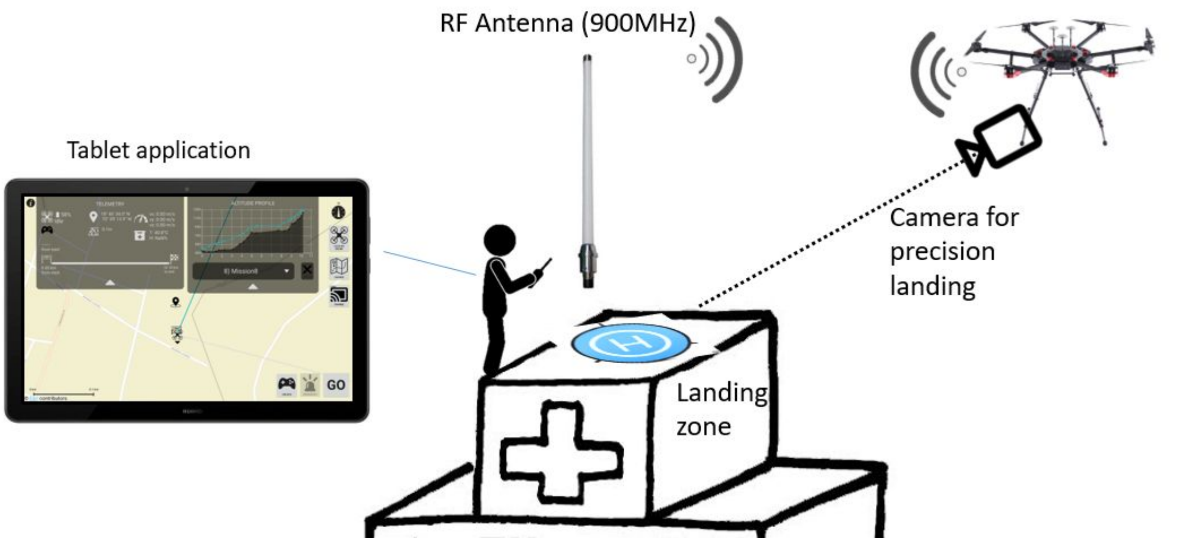
We designed and developed custom software that runs on the onboard computer. The main features include:

- Cargo mission loading and execution
- Safety features such as going to safe landing spot when reaching low battery
- Ground level distance estimation
- Communication management with RF(900MHz) and GSM(3G/4G)
- Control mode management (mission execution, navigation, manual control)
- Flight logging
- Autopilot interface
- Precision landing (target estimation and control)

4.4 Cargo Drone Communications

A big challenge in BVLOS drone operations is to keep communications with the drone during a long route, beyond the range of a standard radio. This problem is compounded in mountainous areas such as the Dominican Republic where line-of-sight is quickly lost. Mobile data communications is still not available throughout the country, so we had to rely on a combination of local telemetry radio combined with high gain antennas, Remote-control (RC) radio, 3G/4G modems and satellite modems to keep track of the drones. All separate communication links are coming together on an online server, where data is collected.

An important feature of our communication architecture is that one drone can communicate with multiple ground stations, and groundstations are also directly linked to each other and can exchange information (for instance, agree on sending/receiving cargo).



At every ground station, the user can monitor the drone via tablet application. Each ground station also features a high-gain antenna to send and receive data to the drone, as well as a designated landing area where the drone lands autonomously (precision landing).

4.5 Precision Landing

Drone positioning using GPS location and altitude is typically not very accurate (up to 5m error horizontally and up to 20 meters vertically). In order to land on hospital rooftops or other confined spaces, we implemented a precision landing feature that allows the drone to land in a 2x2m field (see image below).

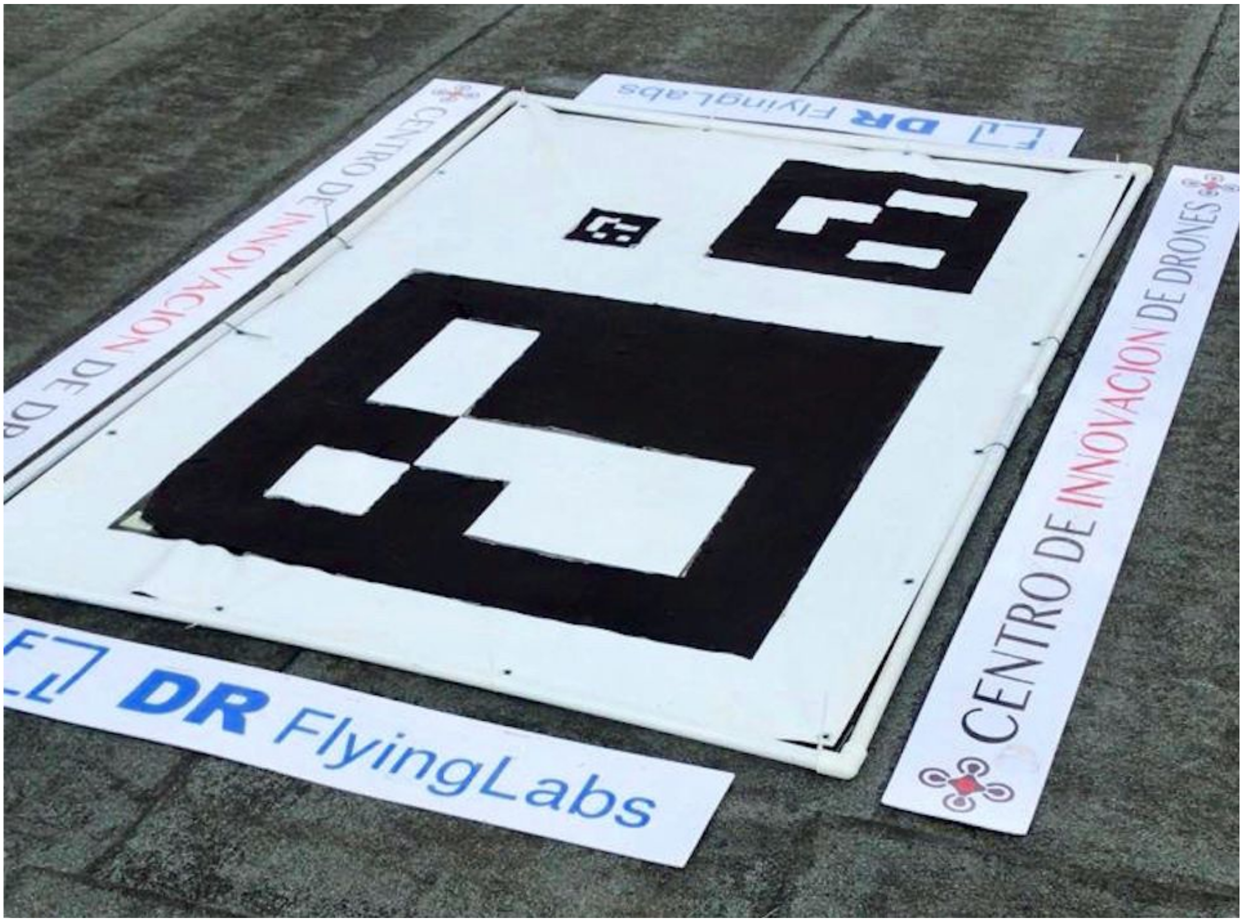
The precision landing system is composed of the following:

- A LIDAR, i.e. a laser based sensor that measures distance in a fixed direction (in our case towards the bottom of the drone). The one we use has about 40m range, and an accuracy in the order of 10cm (depending on ground).

- A RGB camera, that enables to detect a pattern on the ground, and therefore the angle between the pattern and the drone.
- Predefined ArUco tags on the ground. AruCo patterns are similar to QR codes with only 6*6 pixels, which makes them easy to detect from far away. Three ArUco tags with different sizes are used enabling the drone to keep at least one tag in its field of view during the landing maneuver.

Photo sequence of a fully autonomous precision landing approach in Bohechio.

Based on this, we implemented a feedback-control strategy to land the drone safely and precisely on designated landing tags.



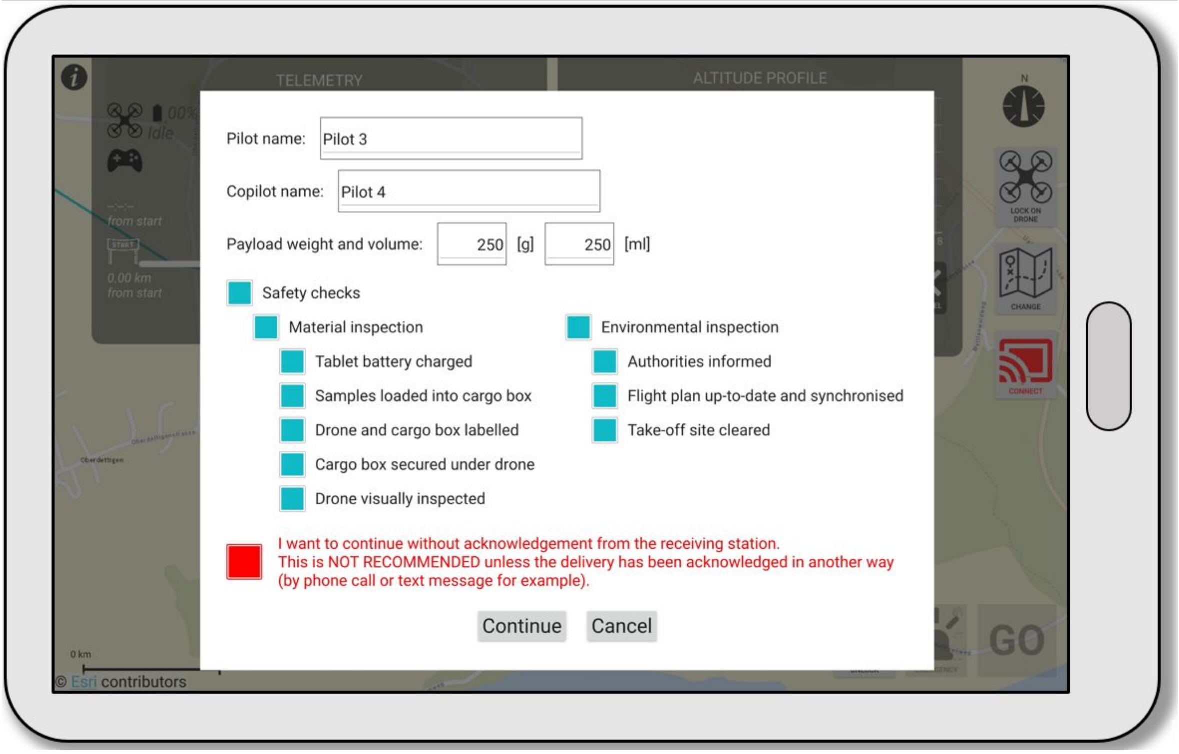
ArUco marker solution enables the cargo drone to land reliably at very precise locations such as hospital rooftops or other confined spaces.

4.6 User-Interface and Ground station

Cargo missions are launched and supervised using a custom Android ground control station application. The application features a simple user-interface that allows loading and executing predefined routes (missions). It displays the drone position and its route on a map (with a selection of map providers) as well as useful telemetry information for remote monitoring of missions (speed, altitude, state, etc). See image below for screenshot.

Custom Android ground station application interface. Telemetry and route information is displayed on the top while the drone and its route are displayed on the background map.

Before any mission, the interface guides the user through safety checks and procedures using an integrated pre-flight checklist and automated weather checks. This checklist can be customized but currently includes pilot and cargo information, tablet and drone battery levels, cargo box and drone hardware checks, flight plan confirmation and take off site preparation as well as the IDAC (Aviation Authorities) clearance and confirmation with the receiving health post, as can be seen in the second image below. It also allows interventions in case of emergency with safety commands such as “Go to safe landing location” or “Emergency landing” and a virtual gamepad for manual control. Finally, the application performs data logging and is connected to a remote server.



Custom Android ground station integrated pre-flight checklist including logging information, drone, cargo and site inspection as well as authorities clearance and confirmation from the receiving station.

4.7 Data Logging and Remote Support

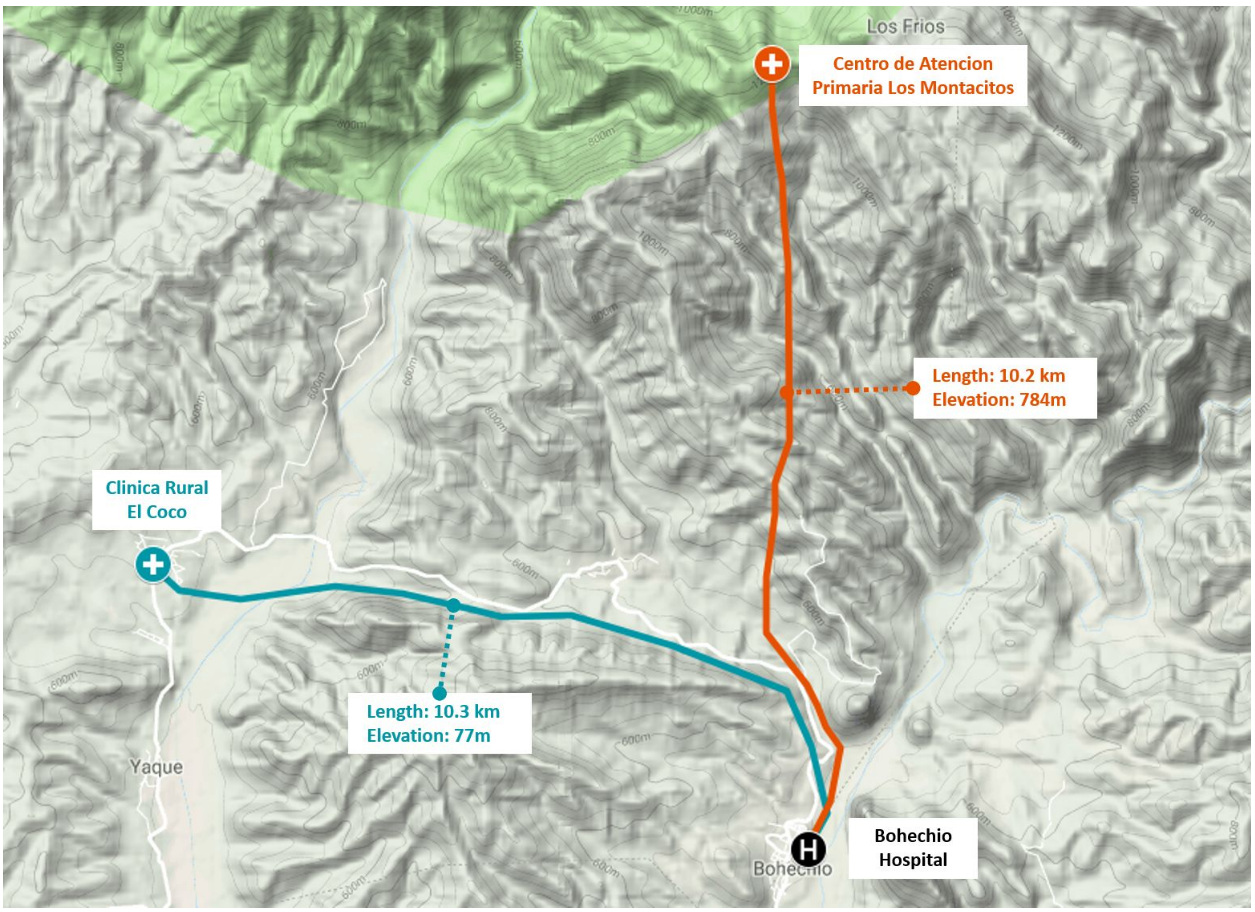
Continuous logging of flights and data collection is of paramount importance to analyze flight behavior and optimize system performance. In addition, when handing over a newly designed system to a local team, it is indispensable to have ways to remotely access flight data and to remote support operations.

Therefore, a key feature of our system is that flight logs are directly sent to a remote server, so that the engineering team can continuously monitor flights. Whenever needed, we were able to support the local team via remote support, as we had direct access to the logs of the flights. Also, as some parts of the system have been under continuous development, we did several small firmware updates from afar.

5. Cargo Drone Operations

In this section, we present the flight routes, flight descriptions, standard operating procedures and emergency procedures developed to enable the safe and responsible use of cargo drones for medical deliveries.

5.1 Delivery Routes



Bohechio Hospital on lower right, El Coco clinic on middle left, Montacitos care upper middle.
Blue path corresponds to the Bohechio-El Coco flight route.
Red path corresponds to the Bohechio-Montacitos flight path.

The base of operations was the Municipal Hospital of Bohechio (Hospital Municipal Bohechio). More specifically, the "droneport" was placed on the rooftop of the hospital to have a safe operating environment by allowing drone pilots to have a 360 view of the skyline and by avoiding crowds. From Bohechio, the droneport serviced two health facilities: Clinica Rural El

Coco and Centro de Atencion Primaria Los Montacitos. The rural clinic in El Coco is 13.1 kilometers away by car, 10.3 kilometers by drone. At El Coco, the drone landed in the fenced-in lawn of the rural clinic. The altitude difference between the takeoff and landing sites is 77 meters. In addition to El Coco, the droneport serviced a primary care facility in Montacitos 18.0 kilometers away by car, 10.2 kilometers by drone. There the drone landed on the rooftop of the primary care facility. The altitude difference between the takeoff and landing sites is 784 meters.

5.2 Standard Operating Procedures for Medicine Request

It is important that medical cargo drone projects (even those at the pilot stage) respond to the logistics needs of the local health care system. To be sure, the local health care system is obviously critical to generating both local and national demand for new logistics solutions. This process is often the most time-consuming element of a cargo drone project but it is also the most essential element. Once this process is completed, the standard operating procedures for medicine request and delivery can be developed.

In the present case, requests to the pharmacy at Bohechio hospital were to be made by relevant staff at the health facilities in El Coco and Montacitos. It was decided that these requests would be communicated in writing via WhatsApp and follow the standard operating procedures listed below:

1. Health staff at El Coco and Montacitos inform Bohechio that medicine supply is required.
2. Pharmacist at Bohechio Hospital confirms request and prepares medicine for delivery.
3. Pharmacist informs Dominican Republic Flying Labs when medicine is ready for pickup.
4. DR Flying Labs goes to the pharmacy with the empty cargo box.
5. Pharmacist places medicines directly into the cargo box and seals the box.
6. DR Flying Labs takes the cargo box to the takeoff site on the roof of the hospital and attaches the box securely to the drone.
7. DR Flying Labs informs requesting staff at El Coco or Montacitos that delivery is ready.
8. Health staff at El Coco and Montacitos replies that weather is favorable and landing area is clear, and thus gives go-ahead for delivery.
9. DR Flying Labs launches drone delivery via designated tablet application.
10. Drone takes off, flies and lands autonomously at requested health facility.
11. Health staff at El Coco or Montacitos confirms landing and removes medicine from box.
12. Health staff at El Coco or Montacitos changes batteries.
13. Health staff at El Coco or Montacitos informs DR Flying Labs at Bohechio Hospital that drone is ready for return.
14. DR Flying Labs replies that weather is favorable and landing area is clear, and thus gives go-ahead for delivery.
15. Health staff at El Coco or Montacitos launches drone return via designated tablet app.
16. Drone takes off, flies and lands autonomously at Bohechio Hospital.
17. DR Flying Labs confirms landing and awaits next request form Bohechio pharmacist.

5.3 Flight Descriptions and Logistics Data

Drone / Car comparison	Bohechio - Montacitos	Bohechio - El Coco
Distance with car/drone	18.0 km by car 10.2 km by drone	13.1 km by car 10.3 km by drone
Travel time with car/drone	40 min by car 12 min by drone	19 min by car 11 min by drone
Average speed car/drone	27 km/h by car 51 km/h by drone	41 km/h by car 56 km/h by drone
Time difference	Drone is 28 min or 70% faster	Drone is 8 min or 42% faster

Flights	
Total number of flights accomplished	101
Total number of flights accomplished autonomously	97
Number of flights with pilot assistance during landing	4
Total kilometers flown autonomously	993.8
Number of flights delayed/canceled due to technical issue	2
Number of flights delayed/canceled due to weather	13
Number of flights carrying medical cargo	40
Average weight of medicines carried [kg]	0.53
Total weight of medicines carried [kg]	21.25

Timing	Minutes
Setup time of cargo drone until ready for take-off	25
Time to load cargo until take-off (pilot receiving medicine, loading cargo box, weighing, loading to drone, starting mission)	15
Typical flight time Bohechio - El Coco	12
Typical flight time Bohechio - Montacitos	12
Time until cargo reaches doctor (after medicine request has been made)	35
Pack-up time after flights (pack-up drone and other equipment, transfer to car)	30

5.4 Peer-to-Peer Delivery

The Dronistics drone is a new cargo drone built by Swiss startup Dronistics. The drone has a range of approximately 1 mile (or 1,500 meters) and can carry up to 1/2 kilogram in terms of payload. The drone is designed as a people-centered drone, which explains why the protective exoskeleton is directly integrated into the drone itself. This safety feature explains why Dronistics potentially can provide direct, peer-to-peer deliveries; enabling deliveries to people rather than places.

DR Flying Labs Coordinator Orlando Perez adds medicines to the Dronistics carbo box (left), and folds the Dronistics drone for hand-carry (right).

In addition, the exoskeleton folds up into 10% of its original size, which makes the drone highly portable. In May 2019, WeRobotics, DR Flying Labs and Dronistics teamed up to demo the new drone in the Dominican Republic. While the drone was flown over a 2 day period, no formal deliveries were made since the main purpose of the joint project was to explore possible use-cases in person with local communities and stakeholders.

Dronistics is an official technology partner of WeRobotics. As such, will the demo is now over, WeRobotics, Dronistics and select Flying Labs including DR Flying Labs are exploring further project opportunities in 2019 and 2020

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5.5 Standard Operating Procedures

The concept of operations for the cargo drone deliveries operated by DR Flying Labs comprised the following steps:

1. Setup ground station and check hardware (antenna and cabling, tablet app).
2. Bring drone and medicines in cargo box on rooftop.
3. Select route on app and perform safety checks (weather, batteries, take-off site, …).
4. Get drone ready (unfold, load batteries, insert cargo box, check everything).
5. Confirm delivery with receiving station (via app).
6. Turn drone on and wait for ready state.
7. Start mission and monitor drone all along.
8. *Drone takes off from the hospital's rooftop and follows flight plan autonomously.*
9. *Drone lands on the clinic's rooftop autonomously.*
10. Retrieve cargo box and deliver medicine.
11. Send drone and box back following the same steps.

After all flights have been completed:

12. Turn off onboard computer and drone, remove batteries, fold and pack away for storage.
13. Stop app, uninstall ground station (antenna and cabling).
14. Charge tablet, drone batteries, remote control.

5.5 Emergency Procedures

The following features and procedures are set in place in case of emergencies:

- Pre-defined safe landing spots (rally points): large flat unoccupied areas where the drone can land safely without a precision landing mechanism in case the destination is unreachable (battery too low due to unforeseen circumstances such as strong winds) or the battery is critically low (<20%).

- Emergency landing: on-the-spot landing in case of emergency battery level (<10%).
- Satellite tracking: tracker on the drone linked to an online interface for the pilot to monitor the drone position in case the communication is lost between the drone and the ground station.

6. Medical Cargo

Cargo drone projects often consider medical cargo boxes as an after-thougth. This is a mistake. Selecting an appropriate cargo box for a given cargo drone project is an important process, which must be done with care and attention. Naturally, the weight and dimensions of the cargo to be transported must factor in selecting an appropriate cargo box. In addition, the type of cargo to be transported has an important impact on the selection of the cargo box. If the cargo is potentially biohazardous or a particularly expensive or strong medicine, then the cargo box must be secure and follow appropriate medical regulations for the transportation of such cargo. Some patient samples and medicines have temperature requirements. As such, an appropriate cargo box will have reliable cold chain capability and a temperature logger, for example.

One of the cargo boxes designed for the M600 cargo drone along with examples of the types of medicines delivered to remote clinics by drone.

6.1 Medicines

The cargo drones delivered a range of medicines to the two local health facilities over the course of 6 weeks. These medicines included Cefalexina, Ciprofloxina, Calcio Carbonato, Vitamina D3, Dolorgesic, Nistatina, Metronidazol, Fluimucil, Espadrapo Base, Azitromicina, Salbutamol, Diclofenac, Aguadestiada, Ketoconazol, Naproxen, Sulfadiazina and Getamicina.

While Pfizer and DR Flying Labs spent the better part of half-a-year to identify the most pressing needs for demand-driven medicine deliveries in the province, recent findings suggest that more investments are required in terms of human resources, laboratory services and in the procurement of medicines before demand-driven drone deliveries can add significant value for the delivery of standard medicines in San Juan. This explains the limited amount of patient impact data connected to this project. To this end, the medicine deliveries operated by DR Flying Labs were supply driven. More specifically, DR Flying Labs submitted requests to the pharmacy at Bohechio Hospital for as many different types of medicines (size, liquid, pills, etc.) that could fit in the cargo box.

One of the cargo boxes filled with medicines and ready for cargo drone transportation.

6.2 Cargo Box

We developed a customized cargo box for medicine deliveries in the Dominican Republic. This cargo box is:

- Easy-to-open and close
- Easy-to-mount and unmount from drone (20 seconds)
- Max volume of 10x11x20cm (2.2L)
- Max payload of 5.5 kg
- Insulated to keep cold chain / prevent from heating up

6.3 Cold Chain

For this project, it was not necessary to control either temperature or humidity given the types of medicines being delivered. Nevertheless, we added insulation to the cargo box to keep environmental conditions somewhat stable within the cargo box. This ensured that the medicines were not exposed to direct sunlight and outside temperatures. In other cargo drone projects, WeRobotics has actively controlled and monitored temperature/humidity by using ice packs and silica gel as well as controlled air flows. Having an actively controlled environment necessarily requires adding small amounts of weight for ice/silica gel, controlled fans/air flows and a power source (small battery).

In order to monitor the temperature and humidity in the cargo box for cargo drone projects that require cold chain, we used an off-the-shelf data logger that can be easily added (and removed) to/from the cargo box. The temperature output of the data logger is available in the Appendix.

REED R6020 Temp/RH logger

7. Cost Benefit Analysis

Carrying out detailed cost benefit analyses of cargo drones is a significant undertaking. Supply chain management experts like Llamasoft will typically spend many months developing sophisticated supply chain models to estimate the cost benefit analyses of drones. The InSupply tool for determining use cases for cargo drones, which Llamasoft contributed to, requires 39 data points and makes over 100 assumptions related to drones, land transportation, product group and facility density to determine the total cost per kilometer for drone transportation compared to land transportation. Carrying out this detailed level of analysis is beyond the scope of this project. Furthermore, for such a study to be more credible, it should ultimately be carried out by an independent group. This explains why DR Flying Labs contracted VillageReach.

In the section below, we first summarize best practices around cost benefit estimates for the use of cargo drones. We then review the preliminary findings produced by VillageReach.

7.1 Best Practices in Cost Estimates

There is growing consensus that cost benefit analyses of cargo drones must extend well beyond any possible cost savings enabled by the introduction of cargo drones. We already know that cost savings can come from decreased operation and personnel costs. Cargo drones can also reduce inventory holding time and cost, for example. Furthermore, additional cost savings are possible when combining drone deliveries with existing ground delivery options, and when drones are used to carry cargo on both outbound and inbound flights. In addition, studies have found that drones can still provide cost-savings if weather conditions have a 50% probability of delaying flights by up to one week. If drone deliveries enable capacities that save significant costs in the health system by, for instance, averting unnecessary hospitalizations given that front-line medications are made more easily available — then for sure those cost savings need to be factored into the equation.

But cost is never the only criterion used by shippers to select the “right” transportation. Cost benefit analysis must also seek to quantify performance improvements including greater speed of delivery, increased flexibility given that drones do not depend on the availability of ground transportation infrastructure, and higher frequency deliveries, which can decrease stock-out. As such, even if the introduction of drones increases transportation costs at the outset, these costs may be recouped thanks to the reduced inventory cost of capital and the reduced inventory storage cost, for example.

That being said, we contend that additional benefits must also be factored in. For example, the long term benefits that come with local capacity building and business incubation such as local sustainability, local ownership, trust, professional development, local employment, shared prosperity, equal opportunity and locally-driven innovation. These factors almost never appear in any cargo drone case studies. This is a gross error and the result of a largely top-down, techno- centric, foreign-company driven model of cargo drone deliveries in the Global South.

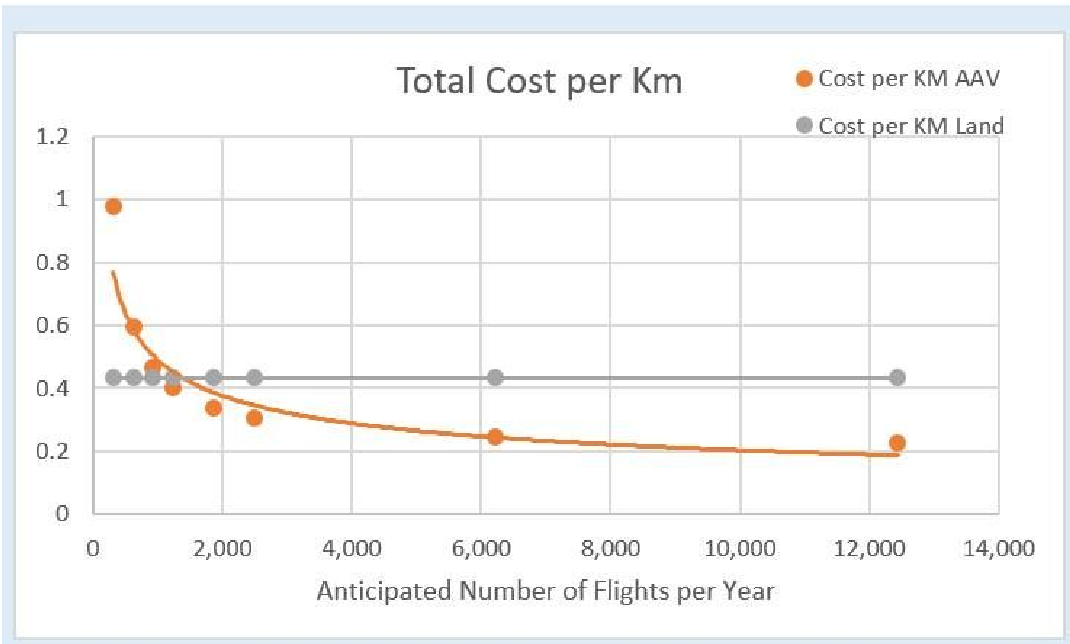
What's more, enabling local employment is not enough. International donors, governments and drone companies in the Global South must enable local entrepreneurs to create their own locally-owned, locally-managed drone delivery businesses. Otherwise, governments in the Global South run the risk of becoming entirely reliant on cargo drone monpolies from Silicon Valley and having these companies displace local entrepreneurs and local innovation, thus exacerbating inequality and the digital divide even further. These very real opportunity costs must be factored into cost-benefit analyses of cargo drones. In sum, we acknowledge the accounting cost dilemma but recommend that accounting cost may not sufficiently account for the true economic and health benefits to the system and the society overall.

7.2 Review of Preliminary Findings

The initial findings below were kindly provided by VillageReach and focus specifically on the Province of San Juan. As such, the analysis considers the Province's 69 health facilities serving a population of 317,293 over an area of 3,569 km2. The analytical tool used for the analysis is the InSupply Tool developed by InSupply, JSI and Llamasoft. The tool was developed to help organizations make informed decisions on whether there are potential benefits based on the cargo drone use cases they want to implement. The analytical tool is an excel spreadsheet, which allows the user to select the geography, product or demand and cargo drone specs to be compared with land transport in terms of cost savings. The spreadsheet comprises well over 100 inputs and variables to calculate the cost-benefit of introducing a specific type of cargo drone for a specific use-case in a specific region.

The analytical tool estimated 1,243 drone flights per year (or around 5 per day, every day) based on estimated demand for essential medicines, and found that the cost was approximately $0.40 per km for 5 flights per day with M600 drones, and $0.43 per km for land transport (a 7% cost savings per km). Further cost savings may be achieved if the number of flights per day increases from 5 to 8 ($0.33/km drone vs. $0.43/km land), resulting in 23% cost savings per km. With 26 flights per day, cost savings per km decreases to $0.25/km by M600 vs. $0.43/km by land, which represents a cost savings of 42%. That being said, there are only 69 health facilities in San Juan, so that frequency may not be logical without diversifying the cargo being transported.

Note that all these figures assume that the assumptions in the analytical tool are accurate. This tool comprises well over 100 inputs and parameters. As such, it is critically important that the 42% cost savings figure *not* be taken as a fact or guarantee as many parameters feed into this analysis. Furthermore, the analytical tool only compares transport cost and no other logistics objectives such as speed and responsiveness, which must be considered in the overall analysis. As such, VillageReach strongly cautions against fixating on the cost savings figures alone. To this end, it is important to emphasize that the M600 drone deliveries saved 50+ hours of driving time and 1,000km of driving. The drone deliveries were also 42% to 70% faster than road deliveries.



Total cost estimate per KM for cargo drone deliveries in San Juan Province

Instead, VillageReach urges donors and other relevant stakeholders to focus on the following 3 learnings from the logistics analysis for San Juan Province :

1. The cost simulation of introducing one M600 drone in comparison to the use of 3 Hilux-type vehicles to deliver essential medicines to the 69 health facilities in San Juan province found potential to at least maintain and potentially decrease the financial cost of transport per kilometer traveled.

2. As the frequency of use of drone flights increases, the potential for cost-efficiency also increases. Estimated demand for essential medicines is assumed to require 5 flights per day, but if the number of drone flights per day increases further, then additional costs could be saved. This could be done by transporting both medicines and patient samples.

3. It is important to consider the costs of introducing drones relative to the potential benefits, which may include time saved, maintenance of product quality, and/or more environmentally-friendly transport. An analysis of time saved when traveling by M600 in

comparison to Hilux found that travel by drone saved transport time from the regional warehouse to the health facility in 97% of sites in San Juan Province, cutting travel time by half or more in 30% of sites.

8. Discussion

These are still early days for the cargo drone space, particularly for projects that seek to genuinely localize cargo drone deliveries by fully transferring local ownership to local stakeholders. These projects typically require that cargo drones be affordable, locally-repairable and that they be operated by local stakeholders. Such projects are still far and few between. What's more, lessons learned from these projects are rarely made public. This has already led others in the cargo drone space to make the same mistakes. This leads to a waste of time and a considerable waste of resources. As such, it is imperative that cargo drone projects be transparent when reporting their shortcomings and lessons learned. Equally importantly, those coordinating local cargo drone projects should be sure to offer concrete recommendations to overcome the challenges they have documented.

8.1 Lessons Learned

WeRobotics and DR Flying Labs have identified a series of important lessons learned during this joint project with Pfizer. These have to do with demand-driven use-cases, proprietary technology, weather conditions, field testing, timeline and available resources.

Flying Labs. The strong dedication, local presence, expertise and connections of DR Flying Labs were absolutely essential to the success of this project. To be sure, Flying Labs and similar local organizations are indispensable to ensuring the sustainable and ethical transfer of knowledge and emerging technologies for social good. Flying Labs strengthen local capacities, build local markets and incubate local businesses that support local drone projects, they coordinate efforts among key stakeholders, facilitate regulatory permissions and provide invaluable logistical support. They have local knowledge, partnerships and technologies already in place. They also enable long-term implementation beyond pilot projects. Flying Labs in the DR, Peru, Nepal and Fiji are each gaining the knowledge and the technology to carry out their own cargo drone projects independently of WeRobotics. Without local organizations like DR Flying Labs and the other 25+ Flying Labs in Latin America, Asia, Africa and Oceania, drone projects like this one with Pfizer would be unsustainable and would require considerably more time and significantly more resources to implement.

Demand. The province in which cargo drone deliveries have been facilitated by Emprende and Cyberpark since 2017, San Juan de la Maguana, may not be a geographic priority for the introduction of drones. While Pfizer and DR Flying Labs spent the better part of half-a-year to identify the most pressing needs for demand-driven medicine deliveries in the province, recent findings suggest that more investments are required in terms of human resources, laboratory services and medicines availability before demand driven drone deliveries can add significant value for the delivery of standard medicines in San Juan. This explains the limited amount of patient impact data connected to this project. As such, future cargo drone projects in the Dominican Republic should also consider other provinces such as Azua and Elias Pina. Alternatively, Pfizer should consider the use of cargo drones in San Juan for products that also require cold chain as there may be greater demand for these higher value products than standard medicines. That being said, and despite the relatively low level of demand for the delivery of standard medicines along the 2 flight routes from Bohechio Hospital, it was abundantly clear that the public health needs of these local communities are very real. These communities should not be discriminated against regardless of the level of demand.

Drone Technology. Repurposing DJI's M600 drone into a cargo drone proved challenging. The M600 was originally selected because it is one of the most reliable and affordable industrial drones on the market. That being said, the M600 is a proprietary platform and thus not fully open. What's more, the M600 was not designed for cargo delivery but rather videography and mapping. This explains why numerous work-arounds were required to repurpose the drone for cargo delivery. Upon completion of this Phase 1 project with Pfizer, WeRobotics learned that newer models of the M600 have an altitude lock that cannot be disabled. Unless another workaround is found, this means missions are limited to 500 meters above ground w.r.t. to take-off location. That limits operation in mountainous regions considerably.

System performance and reliability: Within this project, we achieved more than a hundred fully autonomous deliveries carried-out by local end-users (see Appendix). On our way to this result, we were continuously confronted with the requirement of highest reliability. This stringent requirement could only be met by integrating the most-suited parts and components. This explains why for some of the technical challenges multiple solutions as well as redundant solutions needed to be investigated and integrated (e.g. precision landing, communication).

Remote support: While the local team in the DR was almost fully autonomous, it was key to have means to remotely support the local team. Flights logs synchronized with our remote server enabled us to assist the local team almost in real-time.

Weather. Several M600 cargo drone deliveries were delayed due to heavy rains since the M600 is not waterproof. Strong winds in the afternoons occasionally delayed some deliveries as well.

Testing. The original precision landing system developed by WeRobotics was not as reliable as expected when first used in the Dominican Republic. The system, which used infrared light and a beacon to guide the drone to a specific landing spot, had been tested extensively in Switzerland prior to deployment. However, it is impossible to recreate all the environmental conditions of the Caribbean in Switzerland. As such, when the precision landing system was first used in the DR, it became clear that the infrared sensor was simply not strong enough to work effectively given the strong Caribbean sun. As such, cargo drone deliveries had to be put on hold for 6 weeks until WeRobotics developed a completely different and more versatile landing system.

Time. Another important lesson learned has to do with timeline and resources. The timeline for the project was ultimately unrealistic given the additional amount of work that went into preparing the cargo drone project and in repurposing the cargo drone itself. DR Flying Labs Coordinator Orlando Perez had to spend a significant amount of time to lay the groundwork for the project and to coordinate the local drone pilots. Likewise, the WeRobotics engineering team spent more time on the engineering side than initially anticipated. As such, the budget was also unrealistic given that more preparation and engineering time was required, which required multiple trips to the DR and San Juan as a result. These dual constraints meant that there was less time for other important priorities such as the development of training materials and community engagement were not given enough time to be completed.

Hand-off. A final key lesson learned during the project was that handing off drone deliveries to public health professionals may in some cases be unrealistic and at times ill-advised. Fact is, doctors and nurses at local hospitals tend to be extremely busy. This is less an issue for doctors and nurses at remote clinics as they tend to serve a smaller population. Hospitals doctor and nurses should not be distracted by the need to operate drone deliveries even if these deliveries are largely autonomous. As such, training pharmacy staff (clerks) to operate autonomous cargo drones may provide more advantages. This would enable real-time turnaround of the medicine request, depend only on existing hospital/pharmacy staff and those make the economics more favorable than traditional modes of delivery.

8.2 Recommendations

Demand. More time and resources need to be allocated to identifying existing supply chains that can be readily augmented through the use of cargo drone deliveries. This is currently the case for a WeRobotics project in southern Nepal with Nepal Flying Labs and a Nepali health organization. Said organization was already collecting TB samples from remote clinics and driving them back to a regional hospital for testing before Nepal Flying Labs rolled out a cargo drone delivery option. WeRobotics and Nepal Flying Labs are now enabling this NGO to collect some samples far more rapidly than is possible with ground transportation alone. This ensures that the cargo drone project in Nepal is fully demand driven by local health professionals. A similar opportunity needs to be identified in the DR to ensure that future deliveries are entirely demand-driven.

Technology and Weather. WeRobotics plan to explore the DJI M200 platform due to the altitude constraints imposed on the newer M600 drones. DJI has already confirmed in writing that they would unlock the altitude constraint for M200 drones. They don't have the means to do this with the M600. Furthermore, the M200 is waterproof and can thus fly in the rain. In addition, the M200 has a longer range (up to 25km) than the M600 (15km) and has sense-and-avoid sensors, unlike the M600. This makes the M200 a safer platform. Finally, the M200 only requires two batteries rather than the 6 batteries required by the M600. This may ultimately offset the higher cost of the M200 drone given that reduced battery costs. The electronics, software and precision landing system developed for the M600 can be readily integrated into the M200. Like the M600, the M200 is also a proprietary platform, and thus not fully open. This means that some unexpected limitations may arise.

Additional system features. A number of additional system features are required. *Smart route planning:* the planning of specific cargo routes is a very time-consuming and challenging task with the current system. WeRobotics recommends the development of software that facilitates route planning by taking into account terrain data, obstacles, houses, roads, etc. to minimize energy consumption while maximizing safety. *Intelligent packages:* when scaling the system to4$ multiple drones, sites, etc., the number of parcels rapidly increases. Recent IoT technology offers simple ways to track parcels and deliveries. *Predictive maintenance:* to enable fully locally-run cargo deliveries, it is important to integrate predictive maintenance to ensure system performance. Specifically, this could be done by alerting the user in the Android app after x flights to check that mechanical screws are still tightly locked, batteries need to be replaced, etc.

Testing. In-country testing is imperative at least 2 months before implementing regular cargo drone deliveries. This enables engineers to test the cargo drone in relevant conditions and to address any surprises that arise from this testing well ahead of the official start of cargo drone deliveries. As such, timelines and budgets should include 2 in-country trips, the first for initial training and extensive testing, and the second for final training and actual deliveries. Enough time (at least 2 months) should be blocked between these two trips to ensure that engineers have sufficient time to address any surprises and test any new solutions ahead of the official deliveries.

Time. It is important that future timelines and budgets be more realistic to ensure that key priorities don't fall behind. Ideally, Pfizer should take the lead in getting formal buy-in from public health stakeholders and in identifying optimal flight routes based on demonstrated need.

Hand-off: DR Flying Labs should explore the possible role of hospital staff other than doctors for the operation of drone deliveries. Nurses based at remote clinics typically have more flexibility regarding their time but this One possible solution in this respect might be to integrate drone delivery responsibilities with general IT responsibilities at individual hospitals. In any event, multiple individuals need to be trained given the regular turnover of hospital staff.

9. Conclusion

Unlike mapping or video drones, cargo drones are not yet available as reliable, mass-produced and affordable off-the-shelf solutions. The commercial case for cargo drones for some public health use-cases in very rural environments may begin when the costs drop well below USD 10,000, and ideally down to USD 3,000 — the cost of a motorcycle. This is especially true for very rural areas since these require lower frequency deliveries. The point here is not to replace motorbike delivery with drone delivery but rather to complement the former with the latter. As such, the commercial case for drones in very rural environments must also take into account the required infrastructure along with the human resources necessary for cargo drone deliveries. For example, if cargo drones require a dedicated droneport with a full-time crew for just a handful of deliveries per day, then the costs inevitably increase relative to medicine delivery by motorbike since motorbikes don't require "droneports" or full-time drivers. As such, cargo drones must operate with minimal infrastructure and without a dedicated drone crew to enable the sustainable use of cargo drones for rural medicine delivery.

While dedicated droneports and drone crews are vital for very high frequency, long-range, cargo deliveries, this is not the case for provincial-level, rural medicine deliveries. In these cases, the overall demand for medicines is lower given the smaller and more dispersed rural populations, particularly those that live in hard-to-reach areas. This explains why large cargo drone companies focus on areas with very high demand (to make a profit). As such, companies like Zipline will never have an incentive to operate a 15-kilometer delivery route in the Dominican Republic, let alone routes that require no more than 50 deliveries per week. The required investment would be too significant for these foreign companies and the financial loss too significant. To be sure, a recent study concluded that some 3,000 cargo drone deliveries per year are required if profit-driven drone companies want to be more competitive than motorbikes.

Even if profitable, large scale cargo drone deliveries of 3,000+ flights per year (or even per month) doesn't mean that every clinic or health care facility in a country is directly or even indirectly served. Large scale drone delivery simply means that drones are delivering to a country's main health facilities. Could a cargo drone company operating large scale deliveries also deliver to more remote and lower level health facilities in hard-to-reach areas with small, dispersed populations? Yes, but again the financial incentive may not exist for cargo drone companies to operate routes that have considerably lower levels of demand.

The fact of the matter is that reaching the most dispersed and hard-to-reach communities is expensive, and will continue to be more expensive than reaching the closest and largest populations. The level of demand for medicine delivery in the rural mountains of San Juan Province in the Dominican Republic is necessarily limited given the small, dispersed populations in the area. But the need is great. This is why a different model is required for the lower frequency drone deliveries that serve rural communities. To be sure, the financial bias that drives cargo drone companies towards serving large scale demand may unintentionally discriminate against rural and more vulnerable communities in harder-to-reach areas. This unintended consequence may run the risk of exacerbating the “medicine deserts” that exist in rural environments. Furthermore, governments that have already invested tens of millions of dollars into large scale cargo drone deliveries may not have the incentive to subsequently invest in provincial-level drone deliveries.

This is problematic since many hard-to-reach communities face greater health risks and don’t necessarily benefit from large scale drone delivery routes. This explains why non-governmental organizations need to be directly engaged in the cargo drone delivery space. NGOs like WeRobotics, for example, are developing a different business model to ensure that remote, hard-to-reach communities can gain access to cargo drone services. This model focuses on using affordable, locally-repairable, locally-owned and locally operated cargo drones.

By locally operated, we don’t only mean operated by local drone pilots. We also mean operated by local hospital and pharmacy staff. Given that high frequency deliveries are rarely needed in highly rural environments, the personnel costs of drone operations quickly becomes the largest cost driver for drone deliveries to rural communities. In other words, staff costs can make drone deliveries uncompetitive on price. For example, if only 1 delivery per day is made, then that delivery must factor in the cost of an entire day of wages even if the staff time required for said delivery is less than 30 minutes. In sum, the personnel cost per delivery is very dependent on the number of per day deliveries.

Obviously, drone delivery cost is not the only factor that negatively impacts rural communities. In the case of San Juan Province, the main hurdle that local communities face when seeking to access healthcare is not the lack of paved roads connecting their villages and local clinics to regional hospitals. San Juan has strong ground transportation infrastructure. Rather, it is the cost of local transportation that serves as the biggest impediment vis-a-vis local access to healthcare. As such, countries need to think through the broad problem of meeting health equity needs within the framework of the available operating budget for the system, and in turn to raise new resources wherever necessary in order to provide quality, affordable care.

Drone delivery is one piece of that re-thinking, along with telemedicine consultations, point of care diagnostics, travel subsidization and medical waiting homes and hyper-localized manufacturing for medical supplies, for example. The point is not to suggest that one model (large scale) or the other (small scale) is preferable, let alone a silver bullet. Rather, it is our strong conviction that both models in addition to many of the other solutions listed above are essential to ensure equal access to medicines and healthcare services.

This explains why Pfizer and WeRobotics partnered on the cargo drone project documented in this report. As noted by the Ministry of Health Director for the El Valle Region, “This project is important in rural areas. With this project, people would have access to pharma-ceuticals, lab tests and other data in an expedited way because of the drone. This is an opportunity to extend to our people a service at the right time at the right quality, warmth and quickly as well."

WeRobotics and Flying Labs are keen to leverage affordable and locally repairable drones that can be locally owned and operated locally by existing hospital staff using existing hospital infrastructure including electricity and rooftops, for example. This means that cargo drones must be especially easy and safe to use by non-experts. They must of course be reliable and robust as well. In terms of hospital staff, we recommend that critical medical staff (doctors and nurses) not be made responsible for drone deliveries for obvious reasons—their priorities are patients. Local organizations like Flying Labs can train appropriate staff to operate these cargo drones at lower cost, thus minimizing the exposure of the clinical staff to drone operations.

The purpose of the joint Pfizer-WeRobotics project, which comprised 6-weeks of continuous deliveries, was to determine whether affordable, locally-operated and locally-repairable cargo drones could reliably deliver medicines on demand. As such, an important objective of the project was to collect performance data on aerial deliveries and compare this with data on ground deliveries. This comparative analysis would provide a better understanding of the cost-benefit analysis of using drones for medical deliveries. WeRobotics therefore repurposed and customized the DJI M600 mapping drone into a fully autonomous cargo drone solution by developing dedicated Android software, electronics and a precision landing solution.

Results of the Pfizer-WeRobotics Cargo Drone Project

DR Flying Labs drone pilots, who were all trained by WeRobotics, subsequently carried out 6 weeks of consecutive deliveries in San Juan de la Maguana Province between June and July 2019. A total of 101 autonomous flights were carried out to two separate health facilities, traveling a total of 994 kilometers. Of the 51 outbound flights, 40 carried cargo medicines totally 21.25 kilos including Cefalexina, Ciprofloxina, Calcio Carbonato, Vitamina D3, Dolorgesic, Nistatina, Metronidazol, Fluimucil, Espadrapo Base, Azitromicina, Salbutamol, Diclofenac, Aguadestiada, Ketoconazol, Naproxen, Sulfadiazina and Getamicina. To reach one of the two facilities in the mountains, the drone had to gain an altitude of 784 meters above ground level.

While these accomplishments are certainly encouraging, more work needs to be done on both the selection of use-cases and the further development of the technology. In terms of use-cases, either different medical cargo should be considered to respond to demonstrated demand, and/or other provinces should be considered where demonstrated demand is more evident. In terms of the technology, the repurposed M600 drone is an early cargo drone prototype rather than a "Minimum Viable Product". What's more, the M600 has important constraints including altitude locks and the fact that it can't fly through rain. As such, any further technical development should pivot to the M200 drone so that the latter can be made available as a Minimum Viable Product for broader use. This includes the localization of the user-interface with built-in checklists and standard operating procedures.

An independent cost-benefit analyses carried out by VillageReach for drone deliveries in San Juan Province after the completion of this project found that the cost of delivery was approximately \$0.40 per km for 5 flights per day with M600 drones compared to \$0.43 per km for land transport (a 7% cost savings per km). While this cost savings estimate seems relatively modest, one must consider that essential medicines are already relatively easy to transport by road given that strong infrastructure in San Juan Province. Further cost savings may be achieved if the number of flights per day increases from 5 to 8 (\$0.33/km drone vs. \$0.43/km land), resulting in 23% cost savings per km. With 26 flights per day, cost savings per km decreases to \$0.25/km by M600 vs. \$0.43/km by land, which represents a cost savings of 42%. That being said, there are only 69 health facilities in San Juan, so the frequency of 26 flights may not be feasible without diversifying the cargo being transported.

Note that all these figures are estimates and depend on the assumptions built into the analytical tool. Furthermore, the cost simulation uses proxy supply chain data to derive the estimates. As such, it is critically important that these estimates are *not* taken as guaranteed cost savings. Furthermore, cost-estimates alone are insufficient when analyzing the benefits of cargo drones. To this end, it is important to emphasize that the M600 drone deliveries saved 50+ hours of driving time and 1,000km of driving. Furthermore, the drone deliveries were also 42% to 70% faster than road deliveries, which is significant since San Juan Province already has relatively strong ground transportation infrastructure. Furthermore, knowledge transfer, drone technology transfer and opportunity transfer to local experts also generate direct benefits as demonstrated by the Flying Labs network.

Drone Delivery Models

Cargo drone delivery is still in its early days but insights from the past 3 years of medical cargo drone projects in 12 countries are already pointing to 2 different albeit complementary models.[3] The first model is state-centered while the second is community-centered. Both are vital to ensure equal access, duty of care, patient impact, cost-savings and resource optimization. In fact, when combined, these models provide the holistic approach that is necessary to improve healthcare outcomes for all populations. To be sure, the future of medical drone delivery will encompass a number of different solutions. As such, the opportunity for Pfizer is to understand how those complementarities will play out earlier rather than later. To this end, the goal of the Pfizer-WeRobotics partnership is to demonstrate the existence of a vibrant drone logistics market which can solve many different problems, rather than pre-determining the best outcome.

The state model is being developed by the American for-profit company Zipline. This centralized model requires dedicated droneports and professional drone crews to operate high-frequency, high-volume deliveries. The reason for this is Zipline's business model, which depends on large

[3] https://werobotics.org/healthrobotics-course-medical-cargo-drones-public-health

scale demand to return a profit. As such, the state model delivers medical supplies to larger health facilities that serve relatively large populations. This necessarily means that smaller remote health facilities with less demand are not directly included in the state model. In addition, drone deliveries based on the state model are one-way deliveries: the medical cargo is dropped by parachute. This means that return flights do not carry cargo. In order for the state model to work, a relatively high level of investment is required up-front to set up multiple droneports with a large fleet of drones. In addition, the need for dedicated drone crews represents additional costs for the state model.

The community model is being developed by NGOs like WeRobotics. This decentralized model focuses on reaching the most remote and vulnerable communities. These hard-to-reach communities have smaller populations and tend to be widely dispersed, making them more costly to reach. The fact that these are smaller populations means that there is a lower frequency and volume of demand. WeRobotics' business model thus focuses on using locally affordable and repairable cargo drones that can be locally operated by hospital and/or pharmacy staff without the need for a dedicated droneport or drone crews. This significantly reduces both fixed and variable costs. In addition, the model prioritizes local ownership of the drones and also enables two-way cargo deliveries when required, with outbound deliveries to remote clinics carrying medicines and in-bound deliveries to regional hospitals carrying patient samples. As such, the model can offer a dual service and thus creates two possible revenue streams.

The state and community models are necessarily complementary and can be combined into one holistic approach. This can be compared to "highways" versus "country roads". Zipline builds highways with their delivery model, while WeRobotics builds the "back roads". In any event, a company like Zipline will not operate low-frequency, low-volume deliveries, while an NGO like WeRobotics will not focus on high-frequency, high-volume deliveries. The business models for the state and community models have to be different.

Together, however, the state and community models are complementary and can ensure the speed and geographical coverage necessary to ensure equal access, duty of care, patient impact, cost-savings, resource optimization and to improve healthcare outcomes at a truly national scale. To be sure, Zipline drones could deliver medicines from a droneport to a regional hospital where a WeRobotics drone could then deliver those same medicines to a more remote health facility. The latter drone would then pick up patient samples from the remote facility and return them to the regional hospital for rapid testing.

One might think of the state model as more of a "corporate" approach, while the community-centered model could be described as more "philanthropic". In both cases, however, each approach does have its own specific business model. But unlike the state model, more data is needed to fully validate the community model operationally, especially within the context of hospital staff operating the drone deliveries. In addition, more data is needed to test and refine the business model of the community-centered approach.

Recommendations and Next Steps

WeRobotics advocates for a holistic approach to cargo drone services, one that combines both models to ensure duty of care, equal access, patient impact, cost-savings, resource optimization and positive healthcare outcomes. The two models are very much complementary in exactly the same way that these models are complementary in manned aviation. And just like “manned” aviation, these combined models are about creating a market. WeRobotics recommends that more operational data be generated to fully validate the community model and corresponding business model. In addition, WeRobotics recommends testing the use of both the state and community models in one country to evaluate overall impact since the implications of drone delivery should not be focused narrowly on specific technical models but broadly on the transformation of health care logistics. This requires a commitment of time, attention and resources to see through.

As such, the economic data alone while a requisite is only one piece of the larger puzzle. The analysis must be more comprehensive and extended to include performance improvements, access, equity, patient outcomes and of course the transformation of health care logistics. The best way to get to that larger puzzle is by unpacking what is contained within the cost benefit discussion. Are we sure we are accounting properly for costs? What are the costs of systems which can be locally sustained? How will we determine those costs if markets are only minimally functional in this space? And more importantly, the benefits have to be understood broadly, systematically and comparatively. What is the value of improved speed in critical logistics? How do we make sure that improved health is both understood in these projects and properly accounted for in our understanding of financial benefit?

In sum, the end point is not to test these models or systems for their own sake but precisely as a way to build a market. And for this, more data and learning is required.

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10. Acknowledgements

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11. Appendix

- All Flight Logs, Data and Results
- Flights Including Cargo
- Medicines Carried
- Temperature and Humidity Tests

11.1 All flights

flightNumber	name	flightDate	flightTime (local)	droneBra	droneMo
1	Bohechio - El Coco	26/06/2019	18:39:28	DJI	Matrice 600
2	El Coco - Bohechio	26/06/2019	12:00:00	DJI	Matrice 600
5	Bohechio - El Coco	27/06/2019	12:03:00	DJI	Matrice 600
6	Bohechio - El Coco	27/06/2019	13:18:00	DJI	Matrice 600
7	Bohechio - El Coco	27/06/2019	14:12:00	DJI	Matrice 600
8	El Coco - Bohechio	27/06/2019	12:35:00	DJI	Matrice 600
9	El Coco - Bohechio	27/06/2019	13:34:00	DJI	Matrice 600
10	El Coco - Bohechio	27/06/2019	14:35:00	DJI	Matrice 600
11	Bohechio - Montacito	28/06/2019	10:58:00	DJI	Matrice 600
12	Bohechio - Montacito	28/06/2019	12:17:00	DJI	Matrice 600
13	Bohechio - Montacito	28/06/2019	13:27:00	DJI	Matrice 600
14	Bohechio - Montacito	28/06/2019	14:10:00	DJI	Matrice 600
16	Montacito - Bohechio	28/06/2019	11:39:00	DJI	Matrice 600
17	Montacito - Bohechio	28/06/2019	12:54:00	DJI	Matrice 600
19	Montacito - Bohechio	28/06/2019	14:27:00	DJI	Matrice 600
20	Montacito - Bohechio	28/06/2019	13:46:00	DJI	Matrice 600
21	Bohechio - Montacito	04/07/2019	12:01:00	DJI	Matrice 600
22	Bohechio - Montacito	04/07/2019	12:56:00	DJI	Matrice 600
23	Bohechio - Montacito	04/07/2019	14:13:00	DJI	Matrice 600
24	Montacito - Bohechio	04/07/2019	12:26:00	DJI	Matrice 600
25	Montacito - Bohechio	04/07/2019	13:15:00	DJI	Matrice 600
26	Montacito - Bohechio	04/07/2019	14:31:00	DJI	Matrice 600
27	Bohechio - Montacito	09/07/2019	12:22:00	DJI	Matrice 600
28	Bohechio - Montacito	09/07/2019	13:13:00	DJI	Matrice 600
29	Montacito - Bohechio	09/07/2019	12:44:00	DJI	Matrice 600
30	Montacito - Bohechio	09/07/2019	13:32:00	DJI	Matrice 600
31	Bohechio - Montacito	10/07/2019	10:52:00	DJI	Matrice 600
32	Bohechio - Montacito	10/07/2019	11:32:00	DJI	Matrice 600
33	Bohechio - Montacito	10/07/2019	12:10:00	DJI	Matrice 600
35	Bohechio - El Coco	10/07/2019	15:35:00	DJI	Matrice 600
36	Bohechio - El Coco	10/07/2019	16:15:00	DJI	Matrice 600
37	Montacito - Bohechio	10/07/2019	11:11:00	DJI	Matrice 600
38	Montacito - Bohechio	10/07/2019	11:52:00	DJI	Matrice 600
39	Montacito - Bohechio	10/07/2019	12:28:00	DJI	Matrice 600
40	El Coco - Bohechio	10/07/2019	15:57:00	DJI	Matrice 600
41	El Coco - Bohechio	10/07/2019	16:32:00	DJI	Matrice 600
42	Bohechio - El Coco	11/07/2019	09:11:00	DJI	Matrice 600
43	Bohechio - El Coco	11/07/2019	10:03:00	DJI	Matrice 600
44	Bohechio - El Coco	11/07/2019	11:00:00	DJI	Matrice 600
45	Bohechio - El Coco	11/07/2019	11:47:00	DJI	Matrice 600
46	Bohechio - El Coco	11/07/2019	12:32:00	DJI	Matrice 600
47	El Coco - Bohechio	11/07/2019	09:35:00	DJI	Matrice 600
48	El Coco - Bohechio	11/07/2019	10:33:00	DJI	Matrice 600
49	El Coco - Bohechio	11/07/2019	11:26:00	DJI	Matrice 600

50	El Coco - Bohechio	11/07/2019	12:07:00	DJI	Matrice 600
51	El Coco - Bohechio	11/07/2019	12:53:00	DJI	Matrice 600
52	Bohechio - El Coco	16/07/2019	15:36:00	DJI	Matrice 600
53	El Coco - Bohechio	16/07/2019	15:58:00	DJI	Matrice 600
54	Bohechio - El Coco	17/07/2019	09:27:00	DJI	Matrice 600
55	Bohechio - El Coco	17/07/2019	10:47:00	DJI	Matrice 600
56	Bohechio - El Coco	17/07/2019	11:58:00	DJI	Matrice 600
57	Bohechio - El Coco	17/07/2019	12:59:00	DJI	Matrice 600
58	Bohechio - El Coco	17/07/2019	13:53:00	DJI	Matrice 600
59	El Coco - Bohechio	17/07/2019	10:08:00	DJI	Matrice 600
60	El Coco - Bohechio	17/07/2019	11:29:00	DJI	Matrice 600
61	El Coco - Bohechio	17/07/2019	12:32:00	DJI	Matrice 600
62	El Coco - Bohechio	17/07/2019	13:28:00	DJI	Matrice 600
63	El Coco - Bohechio	17/07/2019	14:14:00	DJI	Matrice 600
64	Bohechio - Montacito	18/07/2019	10:01:00	DJI	Matrice 600
65	Bohechio - Montacito	18/07/2019	11:15:00	DJI	Matrice 600
66	Montacito - Bohechio	18/07/2019	10:31:00	DJI	Matrice 600
67	Bohechio - Montacito	18/07/2019	12:32:00	DJI	Matrice 600
68	Montacito - Bohechio	18/07/2019	11:32:00	DJI	Matrice 600
69	Bohechio - Montacito	18/07/2019	13:33:00	DJI	Matrice 600
70	Montacito - Bohechio	18/07/2019	13:00:00	DJI	Matrice 600
71	Montacito - Bohechio	18/07/2019	13:55:00	DJI	Matrice 600
72	Bohechio - El Coco	23/07/2019	10:56:00	DJI	Matrice 600
73	Bohechio - El Coco	23/07/2019	11:46:00	DJI	Matrice 600
74	Bohechio - El Coco	23/07/2019	12:39:00	DJI	Matrice 600
75	Bohechio - El Coco	23/07/2019	13:41:00	DJI	Matrice 600
76	El Coco - Bohechio	23/07/2019	11:22:00	DJI	Matrice 600
77	El Coco - Bohechio	23/07/2019	12:15:00	DJI	Matrice 600
78	El Coco - Bohechio	23/07/2019	13:11:00	DJI	Matrice 600
79	El Coco - Bohechio	23/07/2019	14:07:00	DJI	Matrice 600
80	Bohechio - El Coco	24/07/2019	10:10:00	DJI	Matrice 600
81	El Coco - Bohechio	24/07/2019	10:33:00	DJI	Matrice 600
82	El Coco - Bohechio	24/07/2019	12:30:00	DJI	Matrice 600
83	Bohechio - El Coco	24/07/2019	12:05:00	DJI	Matrice 600
84	El Coco - Bohechio	24/07/2019	13:20:00	DJI	Matrice 600
85	Bohechio - El Coco	24/07/2019	12:58:00	DJI	Matrice 600
86	Bohechio - Montacito	25/07/2019	11:22:00	DJI	Matrice 600
87	Bohechio - Montacito	25/07/2019	12:17:00	DJI	Matrice 600
88	Bohechio - Montacito	25/07/2019	13:15:00	DJI	Matrice 600
89	Bohechio - Montacito	25/07/2019	14:28:00	DJI	Matrice 600
92	Montacito - Bohechio	25/07/2019	11:48:00	DJI	Matrice 600
93	Montacito - Bohechio	25/07/2019	12:38:00	DJI	Matrice 600
94	Montacito - Bohechio	25/07/2019	13:43:00	DJI	Matrice 600
95	Montacito - Bohechio	25/07/2019	14:59:00	DJI	Matrice 600
96	El Coco - Bohechio	31/07/2019	11:22:00	DJI	Matrice 600
97	Bohechio - El Coco	31/07/2019	10:55:00	DJI	Matrice 600
98	El Coco - Bohechio	31/07/2019	12:22:00	DJI	Matrice 600
99	El Coco - Bohechio	31/07/2019	13:15:00	DJI	Matrice 600
100	Bohechio - El Coco	31/07/2019	11:53:00	DJI	Matrice 600
101	Bohechio - El Coco	31/07/2019	12:47:00	DJI	Matrice 600
102	Bohechio - Montacito	01/08/2019	09:07:00	DJI	Matrice 600
103	Bohechio - Montacito	01/08/2019	09:57:00	DJI	Matrice 600
104	Bohechio - Montacito	01/08/2019	10:52:00	DJI	Matrice 600
105	Montacito - Bohechio	01/08/2019	10:25:00	DJI	Matrice 600
106	Montacito - Bohechio	01/08/2019	11:20:00	DJI	Matrice 600
107	Montacito - Bohechio	01/08/2019	09:30:00	DJI	Matrice 600

11.2 Flights including cargo

Fecha	Número de Vuelo	Peso de Carga *(250g)*	Cantidad	Fecha Solicitado	Hora Solicitado	Fecha Enviado	Hora enviado	Solicitado por *(Nombre y Apellido)*	Centro de Salud que Solicita	Gestionado por *(Nombre y Apellido)*
July 09, 2019	1	793,4	6	July 09, 2019	9:00 AM	July 09, 2019	12:10 PM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 10, 2019	2	765,6	6	July 10, 2019	10:00 AM	July 10, 2019	3:30 PM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 10, 2019	3	520,55	4	July 10, 2019	7:40 AM	July 10, 2019	9:12 AM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 10, 2019	4	211,9	2	July 10, 2019	9:00 AM	July 10, 2019	9:35 AM	Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 10, 2019	5	429,45	5	July 10, 2019	10:52 AM	July 10, 2019		Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 10, 2019	6	474,2	4	July 10, 2019	12:20 PM	July 10, 2019		Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 11, 2019	7	262,3	3	July 11, 2019	9:55 AM	July 11, 2019	10:15 AM	Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 11, 2019	8	440,6	1	July 11, 2019	10:00 AM	July 11, 2019		Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 11, 2019	9	474,2	4	July 11, 2019	11:00 AM	July 11, 2019		Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 11, 2019	10	845,1	5	July 11, 2019	11:30 AM	July 11, 2019		Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 11, 2019	11	432,3	4	July 11, 2019	11:30 AM	July 11, 2019		Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 11, 2019	12	165,65	3	July 11, 2019	11:47 AM	July 11, 2019		Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 11, 2019	13	845,1	5	July 11, 2019	11:47 AM	July 11, 2019	1:00 PM	Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 17, 2019	14	696,05	26	July 17, 2019	7:00 AM	July 17, 2019	9:15 AM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 17, 2019	15	441,9	13	July 17, 2019	9:00 AM	July 17, 2019	10:10 AM	Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 17, 2019	16	1050,1	8	July 17, 2019		July 17, 2019		Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 17, 2019	17	197	11	July 17, 2019		July 17, 2019		Rafaela Sanchez	Hospital de Bohechio	Florinda Araujo
July 18, 2019	18	976,35	28	July 18, 2019	7:00 AM	July 18, 2019		Dr. Wander	Centro de Atencion Primaria Montacito	Rafaela Sanchez
July 18, 2019	19	414,9	4	July 18, 2019	9:00 AM	July 18, 2019	10:44 AM	Dr. Wander	Centro de Atencion Primaria Montacito	Rafaela Sanchez
July 18, 2019	20	629,65	5	July 18, 2019	12:00 PM	July 18, 2019	1:30 PM	Dr. Wander	Centro de Atencion Primaria Montacito	Rafaela Sanchez
July 18, 2019	21	525,05	4	July 18, 2019		July 18, 2019		Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 23, 2019	22	905	3	July 23, 2019	7:00 AM	July 23, 2019	10:51 AM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 23, 2019	23	842	2	July 23, 2019		July 23, 2019		Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 23, 2019	24	623	42	July 23, 2019	11:00 AM	July 23, 2019	12:39 PM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 23, 2019	25	223	41	July 23, 2019		July 23, 2019	1:39 PM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 23, 2019	26	678	42	July 23, 2019	9:00 AM	July 23, 2019	11:40 AM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 23, 2019	27	741	43	July 23, 2019		July 23, 2019		Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 23, 2019	28	579	2	July 23, 2019	10:00 AM	July 23, 2019	11:31 AM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 24, 2019	29	225	3	July 24, 2019	9:30 AM	July 24, 2019	10:00 AM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 24, 2019	30	162	2	July 24, 2019		July 24, 2019		Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 24, 2019	31	179	40	July 24, 2019	11:30 AM	July 24, 2019	12:53 PM	Florinda Araujo	Centro de Atencion Primaria Buena Vista del Yaque	Rafaela Sanchez
July 24, 2019	32	642	3	July 24, 2019		July 24, 2019		Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 25, 2019	33	623	42	July 25, 2019	9:30 AM	July 25, 2019	11:34 AM	Dr. Wander	Centro de Atencion Primaria Montacito	Rafaela Sanchez
July 25, 2019	34	242	41	July 25, 2019	10:00 AM	July 25, 2019	12:00 PM	Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 25, 2019	35	181	2	July 25, 2019	10:30 AM	July 25, 2019	12:10 PM	Dr. Wander	Centro de Atencion Primaria Montacito	Rafaela Sanchez
July 25, 2019	36	562	3	July 25, 2019	11:00 AM	July 25, 2019	12:53 PM	Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 25, 2019	37	905	3	July 25, 2019	12:00 PM	July 25, 2019	1:05 PM	Dr. Wander	Centro de Atencion Primaria Montacito	Rafaela Sanchez
July 25, 2019	38	842	2	July 25, 2019	12:30 PM	July 25, 2019	1:29 PM	Rafaela Sanchez	Hospital de Bohechio	Dr. Wander
July 25, 2019	39	223	42	July 25, 2019	12:30 PM	July 25, 2019	2:00 PM	Dr. Wander	Centro de Atencion Primaria Montacito	Rafaela Sanchez
July 25, 2019	40	286	42	July 25, 2019	1:05 PM	July 25, 2019	2:41 PM	Rafaela Sanchez	Hospital de Bohechio	Dr. Wander

11.3 Medicine carried

Fecha	Número de Vuelo	Carga Total *(gramos)*	Cantidad	Unidad	Descripcion	Peso (Gramos)
July 09, 2019	1	**793,4**	**6**			
			2	UN	Cefalexina - 250	143,5
			2	UN	Ciprofloxina	429,5
			1	UN	Calcio Carbonato 600 mg +Vitamina D3 400 U.I.	126,5
			1	UN	Dolorgesic 60 mg	93,9
July 10, 2019	2	**765,6**	**6**			
			2	UN	Nistatina	95,1
			2	UN	Metronidazol 100 ml ALFA 500	280,3
			1	UN	Fluimucil	43,5
			1	UN	GDP - Medical	346,7
July 10, 2019	3	**520,55**	**4**			
			1	UN	Ciprofloxina	214,75
			1	UN	Dolorgesic 60 mg	93,9
			1	UN	Cefalexina - 250	71,75
			1	UN	Metronidazol 100 ml ALFA 500	140,15
July 10, 2019	4	**211,9**	**2**			
			1	UN	Cefalexina - 250	71,75
			1	UN	Metronidazol 100 ml ALFA 500	140,15

July 10, 2019	5	**429,45**	**5**			
			1	UN	Calcio Carbonato 600 mg +Vitamina D3 400 U.I.	126,5
			1	UN	Cefalexina - 250	71,75
			1	UN	Fluimucil 5 ampollas 3ml	43,5
			1	UN	Metronidazol 100 ml ALFA 500	140,15
			1	UN	Nistatina 30 ml	47,55
July 10, 2019	6	**474,2**	**4**			
			1	UN	Metronidazol 100 ml ALFA 500	140,15
			1	UN	Cefalexina - 250	71,75
			1	UN	Nistatina	47,55
			1	UN	Ciprofloxina 200 mg	214,75
July 11, 2019	7	**262,3**	**3**			
			1	UN	Ciprofloxina 200 mg	214,75
			1	CJ	6 rollos, Espadrapo Base	
			1	UN	Nistatina	47,55
July 11, 2019	8	**440,6**	**2**			
			1	UN	Dolorgesic 60 mg	93,9
			1	UN	GDP - Medical	346,7

July 11, 2019	9	**474,2**	**4**			
			1	UN	Nistatina	47,55
			1	UN	Ciprofloxina 200 mg	214,75
			1	UN	Metronidazol 100 ml ALFA 500	140,15
			1	UN	Cefalexina - 250	71,75
July 11, 2019	10	**845,1**	**5**			
			1	UN	Metronidazol 100 ml ALFA 500	140,15
			1	UN	GDP - Medical	346,7
			2	UN	Cefalexina - 250	143,5
			1	UN	Ciprofloxina 200 mg	214,75
July 11, 2019	11	**432,3**	**4**			
			1	UN	Fluimucil	43,5
			1	UN	Nistatina	47,55
			1	UN	Calcio Carbonato 600 mg +Vitamina D3 400 U.I.	126,5
			1	UN	Ciprofloxina 200 mg	214,75
July 11, 2019	12	**165,65**	**3**			
			1	UN	Cefalexina - 250	71,75
			1	CJ	6 rollos, Espadrapo Base	
			1	UN	Dolorgesic 60 mg	93,9

July 11, 2019	13	**845,1**	**5**			
			1	UN	GDP - Medical	346,7
			1	UN	Ciprofloxina 200 mg	214,75
			1	UN	Metronidazol 100 ml ALFA 500	140,15
			2	UN	Cefalexina - 250	143,5
July 17, 2019	14	**696,05**	**26**			
			2	UN	Metronidazol 100 ml ALFA 500	280,3
			1	UN	Ciprofloxina 200 mg	214,75
			1	UN	Azitromicina	30
			2	ampolla	Salbutamol 50 mg	70
			10	ampolla	Diclofenac 25 mg	57
			10	ampolla	Getamicina 2ml	44
July 17, 2019	15	**441,9**	**13**			
			10	ampolla	Diclofenac 25 mg	57
			1	UN	Metronidazol ALFA 500	140,15
			1	UN	Azitromicina	30
			1	UN	Ciprofloxina 200 mg	214,75
July 17, 2019	16	**1050,1**	**8**			
			4	UN	Metronidazol 100 ml ALFA 500	560,6
			2	UN	Ciprofloxina 200 mg	429,5
			2	UN	Azitromicina	60

July 17, 2019	17	**197**	**11**			
			1	UN	Metronidazol 100 ml ALFA 500	140,15
			10	ampolla	Diclofenac 25 mg	57
July 18, 2019	18	**976,35**	**28**			
			4	UN	Metronidazol 100 ml ALFA 500	560,6
			2	ampolla	Salbutamol 50 mg	70
			1	UN	Azitromicina	30
			10	ampolla	Diclofenac 25 mg	57
			10	ampolla	Getamicina 2ml	44
			1	UN	Ciprofloxina 200 mg	214,75
July 18, 2019	19	**414,9**	**4**			
			1	UN	Ciprofloxina 200 mg	214,75
			1	UN	Metronidazol ALFA 500	140,15
			2	UN	Azitromicina	60
July 18, 2019	20	**629,65**	**5**			
			2	UN	Ciprofloxina 200 mg	429,5
			2	UN	Azitromicina	60
			1	UN	Metronidazol 100 ml ALFA 500	140,15

July 18, 2019	21	**525,05**	**4**			
			2	UN	Metronidazol 100 ml ALFA 500	280,3
			1	UN	Ciprofloxina 200 mg	214,75
			1	UN	Azitromicina	30
July 23, 2019	22	**905**	**3**			
			1	CJ	Aguadestilada	381
			1	CJ	Ketoconazol	63
			1	pote	Sulfadiazina	461
July 23, 2019	23	**842**	**2**			
			1	CJ	Aguadestilada	381
			1	pote	Sulfadiazina	461
July 23, 2019	24	**623**	**42**			
			1	CJ	Aguadestilada	381
			40	ampolla	Getamicina 2ml	179
			1	CJ	Ketoconazol	63

July 23, 2019	25	**223**	**41**			
			1	CJ	Fluimucil	44
			40	ampolla	Getamicina 2ml	179
July 23, 2019	26	**678**	**42**			
			1	CJ	Aguadestilada	381
			40	ampolla	Getamicina 2ml	179
			1	CJ	Naproxen 550 mg	118
July 23, 2019	27	**741**	**43**			
			1	CJ	Aguadestilada	381
			40	ampolla	Getamicina 2ml	179
			1	CJ	Ketoconazol	63
			1	CJ	Naproxen 550 mg	118
July 24, 2019	28	**579**	**2**			
			1	CJ	Naproxen 550 mg	118
			1	pote	Sulfadiazina	461

July 24, 2019	29	**225**	**3**			
			1	CJ	Fluimucil	44
			1	CJ	Ketoconazol	63
			1	CJ	Naproxen 550 mg	118
July 24, 2019	30	**162**	**2**			
			1	CJ	Fluimucil	44
			1	CJ	Naproxen 550 mg	118
July 24, 2019	31	**179**	**40**			
			40	ampolla	Getamicina 2ml	179
July 24, 2019	32	**642**	**3**			
			1	CJ	Ketoconazol	63
			1	CJ	Naproxen 550 mg	118
			1	pote	Sulfadiazina	461

July 25, 2019	33	**623**	**42**			
			1	CJ	Ketoconazol	63
			1	CJ	Aguadestilada	381
			40	ampolla	Getamicina 2ml	179
July 25, 2019	34	**242**	**41**			
			1	CJ	Ketoconazol	63
			40	ampolla	Getamicina 2ml	179
July 25, 2019	35	**181**	**2**			
			1	CJ	Ketoconazol	63
			1	CJ	Naproxen 550 mg	118
July 25, 2019	36	**562**	**3**			
			1	CJ	Ketoconazol	63
			1	CJ	Naproxen 550 mg	118
			1	CJ	Aguadestilada	381

July 25, 2019	37	**905**	**3**			
			1	CJ	Ketoconazol	63
			1	pote	Sulfadiazina	461
			1	CJ	Aguadestilada	381
July 25, 2019	38	**842**	**2**			
			1	pote	Sulfadiazina	461
			1	CJ	Aguadestilada	381
July 25, 2019	39	**223**	**41**			
			40	ampolla	Getamicina 2ml	179
			1	CJ	Fluimucil	44
July 25, 2019	40	**286**	**42**			
			40	ampolla	Getamicina 2ml	179
			1	CJ	Fluimucil	44
			1	CJ	Ketoconazol	63

11.4 Temperature and Humidity Log Tests

		Reading Number	Temp(°C)	Hum(%RH)	Date / Time	Location	Variation Temp	Variation Hum
Montacitos	Flight 1	12	26,2	55,4	12/12/2018 10:43	Pharmacy	0	0
		13	26,2	50,1	12/12/2018 10:44			
		14	26	48,4	12/12/2018 10:45	Take-off	-0,2	-7
		15	25,3	49,3	12/12/2018 10:46			
		16	24,5	52,4	12/12/2018 10:47			
		17	24	55,5	12/12/2018 10:48			
		18	24	58,4	12/12/2018 10:49	Landing	-2,2	3
		19	24,1	59,1	12/12/2018 10:50	Pharmacy	-2,1	3,7
	Flight 2	21	24,8	58,6	12/12/2018 10:52	Pharmacy	0	0
		22	24,9	55,7	12/12/2018 10:53	Take-off	0,1	-2,9
		23	24,9	54	12/12/2018 10:54			
		24	24,7	53,3	12/12/2018 10:55			
		25	24,6	53,9	12/12/2018 10:56			
		26	24,6	55,7	12/12/2018 10:57			
		27	24,4	55,9	12/12/2018 10:58	Landing	-0,4	-2,7
		28	24,1	57,1	12/12/2018 10:59			
		29	23,7	58	12/12/2018 11:00	Pharmacy	-1,1	-0,6
	Flight 3	31	23,7	58,4	12/12/2018 11:02	Pharmacy	0	0
		32	23,8	56,1	12/12/2018 11:03	Take-off	0,1	-2,3
		33	23,7	55,4	12/12/2018 11:04			
		34	23,7	55,4	12/12/2018 11:05			
		35	23,6	55,4	12/12/2018 11:06			
		36	23,6	56,9	12/12/2018 11:07			
		37	23,7	58,4	12/12/2018 11:08			
		38	23,6	58,9	12/12/2018 11:09	Landing	-0,1	0,5
		39	23,5	60,1	12/12/2018 11:10			
		40	23,8	62,8	12/12/2018 11:11	Pharmacy	0,1	4,4

Bohechio	Flight 4	4	29,3	51,7	12/12/2018 12:40	Pharmacy	0	0
		5	29,4	52,5	12/12/2018 12:41			
		6	29,6	52,4	12/12/2018 12:42	Take-off	0,3	0,7
		7	29,8	51,1	12/12/2018 12:43			
		8	29,9	50	12/12/2018 12:44			
		9	29,9	49,4	12/12/2018 12:45			
		10	29,9	48,9	12/12/2018 12:46			
		11	29,9	49	12/12/2018 12:47			
		12	29,9	49,4	12/12/2018 12:48	Landing	0,6	-2,3
		13	29,9	48	12/12/2018 12:49			
		14	29,8	49,1	12/12/2018 12:50	Pharmacy	0,5	-2,6
	Flight 5	16	29,9	50,4	12/12/2018 12:52	Pharmacy	0	0
		17	30	49,4	12/12/2018 12:53	Take-off	0,1	-1
		18	30,1	48,7	12/12/2018 12:54			
		19	30,2	48,1	12/12/2018 12:55			
		20	30,2	48,1	12/12/2018 12:56			
		21	30,2	48,6	12/12/2018 12:57			
		22	30,2	47,7	12/12/2018 12:58	Landing	0,3	-2,7
		23	30,1	45	12/12/2018 12:59			
		24	29,8	42,7	12/12/2018 13:00	Pharmacy	-0,1	-7,7
	Flight 6	27	29,3	46,4	12/12/2018 13:03	Pharmacy	0	0
		28	29,4	47	12/12/2018 13:04	Take-off	0,1	0,6
		29	29,5	46,9	12/12/2018 13:05			
		30	29,5	46,6	12/12/2018 13:06			
		31	29,4	46,6	12/12/2018 13:07			
		32	29,4	47,1	12/12/2018 13:08			
		33	29,5	48,2	12/12/2018 13:09			
		34	29,7	45,8	12/12/2018 13:10	Landing	0,4	-0,6
		35	29,6	42,6	12/12/2018 13:11	Pharmacy	0,3	-3,8
	Flight 7	45	29,9	51,5	12/12/2018 13:21	Pharmacy	0	0
		46	30,3	50,7	12/12/2018 13:22			
		47	30,7	49,8	12/12/2018 13:23	Take-off	0,8	-1,7
		48	31	45,2	12/12/2018 13:24			
		49	31	44	12/12/2018 13:25			
		50	30,9	43	12/12/2018 13:26			
		51	30,8	42,8	12/12/2018 13:27			
		52	30,6	43,7	12/12/2018 13:28			
		53	30,6	44,8	12/12/2018 13:29	Landing	0,7	-6,7
		54	30,6	41,1	12/12/2018 13:30	Pharmacy	0,7	-10,4

Flight 8	55	30,4	44	12/12/2018 13:31	Pharmacy	0	0
	56	30,3	45,5	12/12/2018 13:32	Take-off	-0,1	1,5
	57	30,4	45,2	12/12/2018 13:33			
	58	30,5	44,4	12/12/2018 13:34			
	59	30,5	43,9	12/12/2018 13:35			
	60	30,5	43,7	12/12/2018 13:36			
	61	30,4	43,8	12/12/2018 13:37			
	62	30,4	44,3	12/12/2018 13:38			
	63	30,4	42,3	12/12/2018 13:39	Landing	0	-1,7
	64	30,2	39,2	12/12/2018 13:40			
	65	29,9	40,3	12/12/2018 13:41	Pharmacy	-0,5	-3,7
Flight 9	66	29,6	42,5	12/12/2018 13:42	Pharmacy	0	0
	67	29,3	43,4	12/12/2018 13:43	Take-off	-0,3	0,9
	68	29,2	43,8	12/12/2018 13:44			
	69	29	44,3	12/12/2018 13:45			
	70	28,8	45,1	12/12/2018 13:46			
	71	28,8	46,2	12/12/2018 13:47			
	72	29	47	12/12/2018 13:48	Landing	-0,6	4,5
	73	29,1	41	12/12/2018 13:49			
	74	28,9	38,8	12/12/2018 13:50	Pharmacy	-0,7	-3,7

El Coco / Buena Vista	Flight 10	18	27,5	49,4	12/12/2018 15:33	Pharmacy	0	0
		19	27,4	49,8	12/12/2018 15:34			
		20	27,5	50,3	12/12/2018 15:35	Take-off	0	0,9
		21	27,7	50,3	12/12/2018 15:36			
		22	28	49,7	12/12/2018 15:37			
		23	28,3	49,1	12/12/2018 15:38			
		24	28,5	48,2	12/12/2018 15:39			
		25	28,7	47,5	12/12/2018 15:40			
		26	28,8	47,3	12/12/2018 15:41			
		27	28,9	47,4	12/12/2018 15:42	Landing	1,4	-2
		28	28,8	47,2	12/12/2018 15:43	Pharmacy	1,3	-2,2
	Flight 11	30	28,4	47,7	12/12/2018 15:45	Pharmacy	0	0
		31	28,5	48	12/12/2018 15:46	Take-off	0,1	0,3
		32	28,6	47,6	12/12/2018 15:47			
		33	28,8	47	12/12/2018 15:48			
		34	28,8	46,7	12/12/2018 15:49			
		35	29	46,6	12/12/2018 15:50			
		36	29	46,6	12/12/2018 15:51		0,6	-1,1
		37	29	46,8	12/12/2018 15:52	Pharmacy	0,6	-0,9
	Flight 12	39	28,7	47,8	12/12/2018 15:54	Pharmacy	0	0
		40	28,7	48,5	12/12/2018 15:55	Take-off	0	0,7
		41	28,9	48	12/12/2018 15:56			
		42	29	47,1	12/12/2018 15:57			
		43	29,1	46,6	12/12/2018 15:58			
		44	29,1	46,4	12/12/2018 15:59			
		45	29,1	46,6	12/12/2018 16:00			
		46	29,1	46,9	12/12/2018 16:01	Landing	0,4	-0,9
		47	28,9	47	12/12/2018 16:02			
		48	28,7	47,4	12/12/2018 16:03	Pharmacy	0	-0,4

Field-Testing Cargo Drones for Medicine Deliveries in Rural Environments of the Dominican Republic