

Medical **DRONES**

Bradley Steffens



WORLD OF
DRONES



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For more information, contact:

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Delivering Medical Supplies

On December 18, 2018, Joy Nowai, a one-month-old baby in the island nation of Vanuatu, became the first person in history to be given a vaccine delivered by drone. The drone flew almost 25 miles (40 km) to deliver the vaccine to Cook's Bay, a remote area usually accessible only by foot or locally operated boats. A total of thirteen children and five pregnant women were vaccinated that day. "Today's first-of-a-kind vaccine delivery has enormous potential not only for Vanuatu, but also for the thousands of children who are missing out on vaccines across the world," said Henrietta H. Fore, executive director of the United Nations Children's Fund, an organization that provides food and health care to children around the world. "This is innovation at its best."²²

Delivering vaccines, medications, and blood for emergency transfusions is currently the most common use for medical drones. In part this is because drones can reach places that land vehicles cannot—zipping over water, rough terrain, and dense jungle. It is also a matter of cost. Treating patients in place can be a lot less expensive than moving them to a hospital. Ryan Oksenhorn, a software developer with Zipline, says:

It makes perfect sense to use this technology very cheaply and very quickly to travel long distances. Right now it costs \$10,000 to emergency lift someone in a helicopter to go to the hospital if they need

blood. For [much] less money and less time you can deliver the blood with a drone. There's no need to send several humans in a helicopter. You can send the blood directly to the person who needs it.²³

The First Large-Scale Medical Drone Network

Blood delivery is the first large-scale use of medical drones. Since 2016 a fleet of drones owned and operated by Zipline has been delivering whole blood, plasma, and platelets to hospitals and clinics in Rwanda, which has about the same area as the US state of Massachusetts. Due to the traffic and Rwanda's large number of unpaved roads, it can take up to five hours to deliver blood to a rural hospital by driving. That kind of wait can mean death to a patient who has lost a large amount of blood. "Patients frequently die because of lack of access to a basic medical product that exists in a central warehouse 75 kilometers away but can't make it out that final mile to the person who needs it,"²⁴ says Zipline CEO Keller Rinaudo. Zipline drones can reach almost any part of Rwanda in just forty-five minutes.

Zipline maintains 60 percent of Rwanda's blood products in two fulfillment centers, known as "nests." From there, the drones fan out across the country as needed. About half of the blood supply goes to treat mothers who are suffering from postpartum hemorrhaging, bleeding that sometimes occurs after giving birth. According to the Rwandan government, maternal mortality rates are declining thanks to the delivery of blood by drones.

Most Rwandan hospitals do not stock large supplies of blood, because the vital fluid has a short shelf life. It is also difficult to predict how much blood of each type will be needed over any given period. Holding large supplies of blood under ideal conditions and sending it to the hospitals by drone overcomes these problems. In its two years of operating at a national scale, Zipline's data show that it has helped Rwanda reduce its blood waste from about 7 percent to 0 percent. At an estimated cost of \$80 to collect, test,

and store a unit of blood, the reduction in wasted blood saves the Rwandan government more than \$1 million per year.

Ground Operation

The Zipline nests receive shipments of blood by truck several times a week. When a shipment arrives, the workers quickly move the blood, plasma, and platelets into refrigerators. Hospitals can order the blood products by phone, text message, WhatsApp, or the company website. When an order is received, a staff member removes the blood products from the refrigerator, wraps them with padding, and places the bundle into a box with a wax-paper parachute attached. The box is loaded into the belly of the drone, known as a “Zip,” and launched. The entire process takes about ten minutes.

Zipline’s engineers believe the order fulfillment time can be much shorter. Israel Bimpe, Zipline’s head of national implementation, says that changes in the procedure will eventually allow the company to fulfill orders in less than sixty seconds.



Blood supplies are loaded onto a Zipline drone for delivery to a remote Rwandan clinic. The company's drones have been making these deliveries in Rwanda since 2016.

“We just need to improve it a bit more,” he says. “It’s tweaking operational procedures and improving software to reduce that time to 1 minute. We receive an order and as soon as we finish packing, we just put it on the Zip and it’s ready to go.”²⁵

Delivering blood products by drone makes sense in emergencies, when every moment counts. But drones cannot yet compete with motorbikes when it comes to moving large amounts of blood when there is ample time to do so. Right now, Zipline drones can carry a payload of only 2.9 pounds (1.3 kg), which amounts to two units of blood. Motorbikes can carry more than ten times that amount, about 33 pounds (15 kg), for routine deliveries. “Until you get to 6 or more likely 12 kg [for drones], it’s not viable,”²⁶ says Jonathan Ledgard, the former director of African technology at the Swiss Federal Institute of Technology. The only

Launching a Drone

Drones with one propeller and fixed wings are ideal for long-distance medical deliveries because they fly faster and require less battery power. Technical experts Evan Ackerman and Michael Koziol describe the launch of a Zipline fixed-wing drone:

A technician places the box and parachute in the belly of a drone behind a spring-loaded hatch, then snaps a modular battery pack into the drone’s nose. Two people carry the drone to a 13-meter-long electric catapult powered by a bank of supercapacitors [devices that store and discharge electricity], then run through a preflight checklist with the aid of a smartphone app. Zipline confirms the drone’s flight plan with the Rwanda Civil Aviation Authority and requests flight clearance. . . . Finally, with a satisfying zzzing, the catapult flings the drone skyward, accelerating it to 100 kilometers per hour in half a second.

Evan Ackerman and Michael Koziol, “In the Air with Zipline’s Medical Delivery Drones,” *IEEE Spectrum*, April 30, 2019. <https://spectrum.ieee.org>.

reason hospitals can afford Zipline blood products now is that the Rwandan government helps pay for the drone program. Ledgerd says Zipline will have a hard time surviving if those payments end. “The price points they have to charge once the subsidies end are far, far, far too high for developing countries,”²⁷ Ledgerd says.

The Next Generation of Zipline Drones

Zipline is already at work on a new generation of drones to better compete with land delivery. The new drones will have a lighter chassis and a more efficient battery. This will allow them to carry a payload of 3.9 pounds (1.75 kg), or three units of blood, an increase of 33 percent over the current drones. They will also be safer. They will be equipped with a transponder to sense and be located by other aircraft, a backup communication system that uses a satellite link rather than the cellular phone network, and sense-and-avoid equipment that will be able to automatically detect and avoid other aircraft. These will be important features as more drones and other aircraft take to the Rwandan skies.

The Rwandan government is confident that these improvements will make drone deliveries more efficient and economical. In 2019 the government awarded Zipline a three-year contract extension. New provisions call for Zipline to deliver not only blood products but also medicine and vaccines. The company will be adding new routes to its service, so it can deliver to small clinics as well as hospitals.

Zipline is partnering with a public-private global health partnership for the delivery of vaccines to remote areas of Rwanda. The group has been looking into using drones to deliver vaccines for several years, because the speed of the delivery can mean the difference between life and death. For example, a child who is bitten by a rabid animal must receive the rabies vaccine as quickly as possible. Drones can deliver the vaccine in a fraction



transponder

A device for receiving a radio signal and automatically transmitting a response signal

of the time it takes a motor vehicle. “The global health community is looking for new ways to deliver vaccines, increase coverage and protect children against various diseases,” says the group’s spokesperson Frédérique Tissandier. “With all the mountains in Rwanda it’s hard to get to remote villages. Some places can only be reached by boat. We’re using this partnership to save kids’ lives and protect them from vaccine-preventable disease.”²⁸

Medical Delivery in Ghana

Rwanda is not the only country using drones to improve its health care. At the end of 2018, the government of Ghana approved a four-year contract with Zipline to deliver medical supplies by drone. The drones will carry not only blood products, but also vaccines, antivenom, birth control pills, and condoms.

According to the World Health Organization, there were about 270 cases of malaria per 1,000 people in Ghana in 2017. The malaria rate in rural areas, where 45 percent of Ghanaians live, is even higher than the national average. Malaria is preventable and curable, but getting supplies such as medications and blood to rural Ghanaians is difficult. Most of Ghana’s remote communities are connected to cities and towns by dirt roads. In the rainy season, many of these roads are flooded, and some are impassable. But drones, which can fly in by day or night and in all kinds of weather, can reach such communities easily. “During the rainy season, we have a lot more malaria cases. We tend to use a lot of blood,” says George Appiah Boadu, a medical laboratory scientist at the New Tafo Government Hospital. “Now we are not going to have to rely on the roads. It’s a huge relief to us and our patients.”²⁹

Not everyone supports Ghana’s drone program. Critics say that the money the government is spending on drones would be better spent on health infrastructure. The Ghana Medical Association, a network of health professionals, believes staffing is a more critical need than drones. It says that some of the hospitals receiving drone deliveries do not have enough trained staff to administer the medical supplies once they arrive. “The use of drones without the necessary improvement in the human resource ca-

capacity will not [be of benefit to] the country,”³⁰ says the Ghana Medical Association in a statement.

Ghanaian president Nana Akufo-Addo admits that the country lacks critical medical infrastructure. For example, it now has only fifty-five ambulances serving the entire country. But he defends the use of drones as a way to save lives now. “No one in Ghana should die because they can’t access the medicine they need in an emergency,” says Akufo-Addo. “That’s why Ghana is launching the world’s largest drone delivery service . . . a major step towards giving everyone in this country universal access to lifesaving medicine.”³¹

Treating Heart Attacks

Currently, drones are mainly used to carry lightweight medical payloads, including blood, vaccines, snakebite antivenom, and other medications. Some medical drone experts are building drones to carry heavier payloads. Mark Head, foreign crisis coordinator for RAM, a nonprofit organization that provides medical care to remote areas, is especially interested in using drones to deliver automated external defibrillators (AEDs) to remote areas.



In a 2017 demonstration in Reno, Nevada, the drone manufacturer Flirtey flies a defibrillator (a device that can restore normal heart beat in a person who has experienced cardiac arrest) to a waiting medical team.

AEDs are portable devices that deliver an electric shock through the chest to the heart to normalize an irregular heartbeat after a heart attack. “If you can get a drone to a downed person having a heart attack quicker than an ambulance, you can save lives,” Head says. “The thing about a defibrillator is it doesn’t matter how you use it as long as you can get to the patient quickly. It’s the time after the event that’s critical.”³²

Cardiac arrest, an abrupt loss of heart function, is the third-leading natural cause of death in the United States behind cancer and other heart disease, according to the Health and Medicine Division (HMD) of the National Academies of Sciences, Engineering, and Medicine. Treating cardiac arrest quickly is vital. According to the HMD, for every minute that passes until a cardiac arrest victim receives defibrillation, his or her odds of survival decrease by about 10 percent. Deploying AEDs via drones can increase the average survival rate for cardiac arrests

Capturing a Drone

Drones equipped with vertical rotors can descend straight down and land softly, but fixed-wing drones cannot do this. A fixed wing drone—the type used for delivering medical supplies—could land on a runway like an airplane, but landing gear is heavy and limits how much cargo a drone can carry. Instead of landing, fixed-wing drones are snatched out of the air as they fly over a landing area.

To capture its fixed-wing drones, Zipline uses a system nicknamed Tall Bob. It consists of two 33-foot-high (10 m) towers, each with a rotating arm attached to it. A cable is strung between the two arms. Each drone has a small metal hook attached to the underside of its tail, similar to the tail hook on military jets that land on aircraft carriers. As the drone flies between the towers, Tall Bob’s arms swing up, raising the cable until it snags on the drone’s tail hook. The cable pulls the drone to a stop, and the rotating arms allow it to drop onto a large cushion. The entire process takes less than a second. The workers unhook the drone and reset the arms so Tall Bob is ready to capture the next drone.

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