CovidTestDrone

CovidTestDrone is an end-to-end drone delivery system optimised for the delivery of COVID-19 tests and materials to patients' homes.

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Project Paper

This paper is designed to present an overview of the project

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Abstract

It is undeniable that our world was turned upside down with the coming of the COVID-19 virus. Over the past three years, people from everywhere in the world had to adapt to countless quarantines and surging cases. In moments of crisis such as this, opportunities arise for individuals and businesses to develop solutions to help us navigate uncharted waters.

One of the innovations that helped us the most in the pandemic, was the release of the COVID test. Over time, we iterated over our protocols for administering tests, each country going about a procedure they deem suitable for testing the population. With time, the number of pharmaceutical companies offering testing solutions to patients increased; arguably it is now easier than ever for people to get tested for the virus. Many countries offer walk-in testing centres where patients can get a PCR test and receive the results in 24 hours and companies have developed cheap, over the counter, rapid antigen tests that offer patients a result in minutes.

There is still plenty innovation to be done in this space though. Firstly, most options for getting a COVID test involve physically leaving the premise of your home to get tested. This inevitably means that a potentially infected person will interact with others on the way to get a test or at the location of the testing centre or store.

It may also be challenging for individuals with symptoms to get to a testing centre or acquire a test. Some people may be living too far away from a centre to get there safely while having symptoms. Other people may live too far away from a centre and opt to not bother getting tested as a result - the inconvenience of getting to a testing centre may deter some people from getting tested.

CovidTestDrone enables self-administered COVID-19 tests and other medical equipment to be delivered to patient's homes via drone delivery and returned to the lab to be analysed within minutes. There is no need for patients to leave their homes nor get into contact with other individuals to get tested and individuals that would not have had access to a test can now rapidly secure one.

This project offers the most convenient and safe way to get tested for the virus: a

patient can simply order a test online, select a convenient time slot and provide a location for the drone to land. They will then receive a COVID-19 test at their doorstep, provide a specimen, and send it back for analysis via the same drone.

The drones used in the delivery and return of tests are semi-autonomous: take-offs and landings are manual whereas flying from one destination to another is autonomous. Figure 1 illustrates a typical implementation of the system.

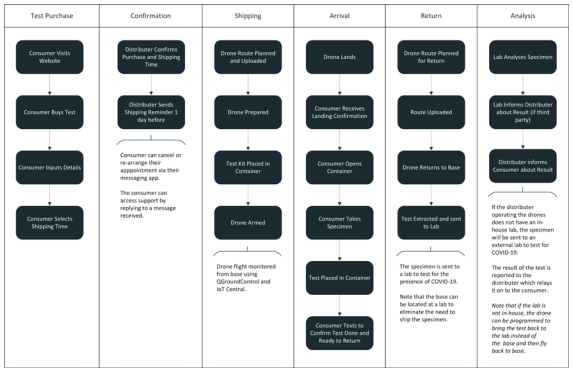

Figure 1: Application Implementation Diagram

For the purpose of this walk-through, the solution will be implemented by a private company. The first step in the process is the purchase of a test; in a private company model, the test will be sold to individuals online. The consumer can purchase the test via the provider's website and then input their details (address, phone number, etc.). The consumer will then be required to select a time when the test can be shipped to them.

The confirmation stage involves the company introducing the consumer in their consumer messaging client and sending them a confirmation text to let them know that their order was placed and confirm the details with them.

The provider should also send out another text a day and an hour before the shipment respectively to remind the consumer of the delivery.

The next step is shipping the test kit; this is where the drone comes in. The drone base is an NXP Hovergames Drone Kit. This is a reference kit that is highly customisable, easy to assemble and maintain, and runs on Dronecode firmware allowing for advanced autopilot deliveries to be executed.

The drone can be monitored live at the base using Azure IoT Central and QGroundControl, the latter being an open-source application used to plan routes for drones to execute and monitor them during flight.

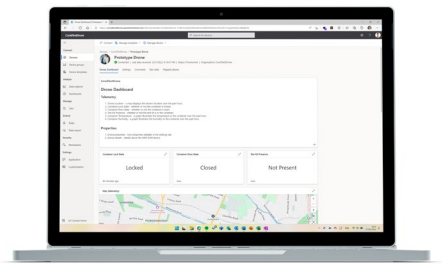

Figure 2: IoT Central Dashboard

The drone will send telemetry data to the base through two data streams: using radio communication to send basic flight data such as pitch, speed, and location of the drone to QGroundControl, and GSM to send over information about the test kit, container, and status of the shipment to IoT Central.

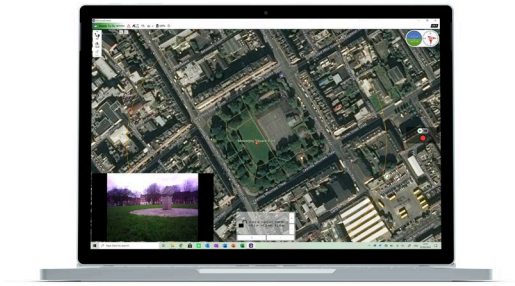

Figure 3: QGroundControl View

The drone can also be controlled remotely via QGroundControl and IoT Central: the flight plan can be changed, and manual control can be regained over the drone at any time. This allows full control over the functionality of the drone remotely if an unexpected occurrence happened.

The operator can also control the drone through IoT Central: the container holding the test kit can be locked and unlocked remotely and the PIN to unlock the container can be changed.

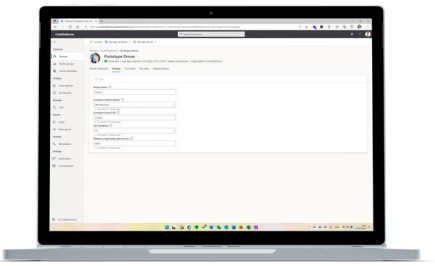

Figure 4: IoT Central Settings

The drone will stream live footage back to the base station via the Nav-Q onboard computer. This device will stream a video feed from a camera mounted on the drone live to the QGroundControl application.

The drone has been customised to carry a COVID-19 self-administered testing kit with it. A container has been attached to the drone to securely ship the test in a climatically controlled environment. There are specific guidelines for the transport of specimens to ensure that they do not get damaged; according to the CDC, samples must be shipped to the lab for analysis within 72 hours. During this time, they must be stored between 2-8 degrees Celsius on dry ice.

The container has a locking mechanism that requires the consumer to input a PIN to open the container and extract the test. This ensures that only authorised individuals have access to the test kit and specimen. The device is also equipped with a helpful LED to indicate if the

container is locked or unlocked and signalise any errors with the shipment.

The device uses GSM connectivity to transmit key data back to the base. The device gathers information such as its geolocation, as well as if the container is open or closed, locked or unlocked, etc. This data is displayed live in IoT Central.

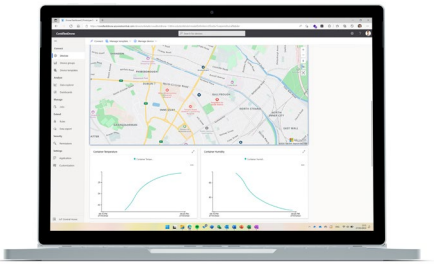

Figure 5: IoT Central Device Dashboard Scrolled

The container is also equipped with a variety of sensors that collect crucial data while in operation and report it live to the backend, for example, the device is equipped with a temperature and humidity sensor allowing the temperature and humidity of the container to be streamed live to IoT Central ensuring that the kit is held in appropriate conditions.

The container is also equipped with an IR breakbeam sensor which checks if the test kit is in the container and reports this live to the backend. This allows the operator to always know if the test kit is in the container. A photoresistor detects whether or not the container is open.

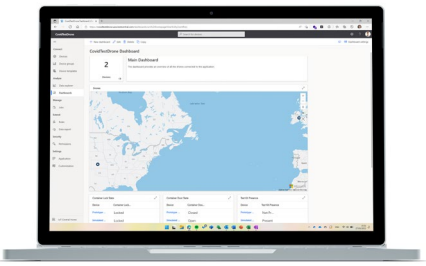

Figure 6: Central Dashboard

As seen in figure 6, a central dashboard is accessible via IoT Central which allows for all drones in a fleet to be monitored at a glance.

After receiving confirmation from the consumer, the drone will be loaded with a test at the hospital or base station, a route for the drone to get to its destination will be planned using QGroundControl and the drone will then be instructed to take off. The drone will then autonomously proceed to its destination. When the drone lands, the provider will inform the consumer where the drone landed (e.g. back yard) and will provide the PIN to open the container via a messaging client.

The consumer will then open the container and extract the test. They will then go indoors to administer the swab and place it back in the container according to the guidelines provided. The consumer can let the operator know that the container was put back in the drone and that it is ready to take off. The

operator checks to make sure that the container is closed and locked through the dashboard and that the test kit is present and then instructs the drone to return to base/deliver tests directly to a laboratory (if in range).

Figure 7: CovidTestDrone Drone

The PIN is provided to the individual in charge of handling the test. If the drone returned to base, the operator would open the container and ship the test to a laboratory. If the drone returned to the lab, the container would be opened, and the sample would be analysed there. The drone can take off from the lab after the sample was extracted and return to base, thus completing a journey.

In conclusion, CovidTestDrone combines recent advancements in technology to bring Covid-19 tests to peoples' homes in minutes using drone delivery. This way, anyone can get tested safely from the comfort of their homes in record-time.

Links

All the code and other resources can be found at the project's GitHub Repo.

Market Research

This section will delve into the business and research aspects of the project. It will outline use cases and will analyse the product's place in the market if it were developed and launched. This section will also delve into finances regarding the development and operation of the project.

Target Audience

The main focus of the project is to provide the population with a rapid and innovative solution to getting tested for COVID-19.

Some of us may find it difficult to get to the test centre in the first place, maybe we lack a means of transport or there is not a centre located nearby. There is also the problem of time, we want to get our results back as soon as possible so that we can return to our routines. But it may take days to get an appointment at a testing centre in the first place.

CovidTestDrone was designed to resolve all these issues by shipping tests to consumers via drone delivery.

By delivering the test to the consumer, the consumer does not need to expose themselves to the public and potentially infect others. It is also more comfortable for the test to be administered at home as

the patient does not need to stress about getting to the testing centre and back.

Finally, more healthcare workers can focus on treating cases of COVID-19 in the hospital as opposed to testing the population for the virus.

The product would be targeted at people of any age. The service would be geared towards people in the middle to higher economic backgrounds if it were supplied privately. The test will be priced a bit above other private PCR solutions that offer quick results to account for the drone delivery aspect.

The location of the individual is very important in the case of this project. The drones can only operate 2 to 3 kilometres away from base. Hence, only a zone with a diameter of 6 kilometres can be served by one implementation. Of course, multiple bases can be constructed to cover more areas.

It is important that the individuals who purchase the test have a place for the drone to land. This would ideally be a garden or a back yard.

It would make sense to restrict the areas where the product is provided to suburbs outside the primate city where access to testing may be limited or difficult to arrange, this also allows for greenspace for the drone to land.

A laboratory is needed to analyse the specimen for COVID-19. If the company is operating with a few drones in a limited area, a contract can be signed with a private lab in the area to analyse tests. Under this model, the drone can be programmed to fly the specimen to the lab (after collecting it from the user) and then fly back to base after the specimen was extracted.

Pricing Model

The product is geared towards the premium market. This is done for multiple reasons; primarily, the service provided, drone delivery, is novel in the field and a premium feature unique to CovidTestDrone. It would undermine the market for the test to be cheaper than other competitor options considering this premium feature.

Cost Analysis

Component	Provider	Cost	
Drone			
XP HoverGames drone kit	NXP	€	377.00
Telemetry Radio	Holybro	€	32.00
Drone Battery	HRB (5,000mAh, 3S, XT60)	€	40.00
Subtotal		**€**	**449.00**
Container			
Arduino MKR GSM 1400	Arduino	€	72.00
Keypad	Kitronik	€	4.50
Electromagnet	Heschen	€	7.00
Adafruit Beam Brake	Adafruit	€	3.00
Other (LED, button, wires, GY21, photore	Generic	€	5.00
Enclosure	3D Print	€	15.00
Subtotal		**€**	**106.50**
Nav-Q Computer			
Nav-Q Computer	EMCraft	€	327.00
Subtotal		**€**	**327.00**
Total per Unit		**€**	**882.50**

Table 1: Fixed Cost per Drone

Table 1 shows the fixed cost incurred for adding one drone to the fleet. This would be around €882.50.

Component	Provider	Cost	
Repairs and Replacements			
Maintenance for Container	Generic	€	10.00
Maintenance for Drone	Generic	€	100.00
Cost of Operation			
Communications	Hologram	€	391.50
IoT Central	Azure	€	3.40
Total per month per drone		**€**	**504.90**

Table 2: Variable Costs of Operating per Drone

As shown in table 2, IoT costs for communicating with the backend amount to around €395 a month per drone. This was calculated considering the device being online for 10 hours a day, 6 days a week. Repairs and replacements average to around €110 a month.

Case Study: Product Deployment in Dun Laoghaire

I created a case study to simulate the deployment of the product in the Dalkey-Killiney area in Dublin, Ireland.

The total population in this area is estimated to be around 61,000. This area was chosen due to most people fitting in the target market of a developed country. The area is also within range of the drone. The predominant housing type in this area is detached and semi-detached which means that there is room for the drone to land.

Details	Description	Gross	Net	
Expenses				
Capital Expenses				
Drones	5 drones	€	4,412.50	
Office Arrangement	Office Equipment (not IT)	€	10,000.00	
IT Equipment	Office Computer Setup	€	15,000.00	
Total Capital Expenses			**€**	**29,412.50**
Recurring Expenses (monthly)				
Rent for premises	small office (1 room)	€	2,500.00	
Drone Maintenance	Repairs and Replacements	€	550.00	
Drone Operation Costs	IoT Costs	€	1,974.50	
Electricity	Charging, light and heat	€	1,000.00	
Other Office Expenses	cleaning, accounting, etc.	€	2,000.00	
COVID-19 Tests	purchase tests	€	22,500.00	
Test Lab Partnership	send tests for analysis	€	22,500.00	
Drone Insurance (€1,000,000 claims)	5 drones @ €700/drone/year	€	291.67	
Wages	4 employees	€	20,880.00	
Total Recurring Expenses			**€**	**74,196.17**
Income (1 test is €200)				
Tests Delivered at 100% Capacity (12% market share)	tests sold monthly (1500 tests)	€	300,000.00	€ 262,500.00
Tests Delivered at 42% Capacity (5% market share)	tests sold monthly (630 tests)	€	126,000.00	€ 110,250.00
Profit Margin				
Tests Delivered at 100% Capacity (12% market share)	**tests sold monthly (1500 tests)**	**€**	**188,303.83**	**63%**
Tests Delivered at 42% Capacity (5% market share)	**tests sold monthly (630 tests)**	**€**	**36,053.83**	**29%**

Table 3: Case Study Cost Analysis

Table 3 shows all the expenses and profits generated by the product over the period of one month as well as capital expenses needed to set the business up in this area.

As can be seen, capital expenses amount to around €29,500. This includes the purchase of 5 drones (each drone operating 10 hours a day with 1 test cycle complete every hour for a month to cover the population). An office has to also be arranged as the base of operations, this should be a small, 1 or 2 room office. IT equipment including computers needed to operate the drones remotely, a strong antenna and charging stations for the batteries are included in the analysis.

There are numerous current expenses that have been calculated on a monthly basis. Rent for the premises is estimated at €2,000, in line with average office prices in the area. Drone maintenance is estimated at €110 a month and operation costs at around €2000 a month. Electricity and other office expenses amount to

about €3,000 a month and drone insurance for the fleet costs around €300.

COVID-19 tests should be purchased from suppliers in large quantities either on a monthly or semesterly basis. I estimated the cost to be around €15 a test kit (including packaging) which is what many companies offer when purchasing in bulk. Because the project is not implemented on a large scale, I included a partnership with a private testing lab in the area that can test a specimen provided and return the result for €15 a sample.

Wages for 5 employees that are needed for various tasks are also included at around €21,000 in total.

Income has been projected at 2 different points. The first (*tests delivered at 100% capacity*) shows the maximum amount of income that can be generated with the system online 10 hours a day, 6 days a week (this assumes that one test is delivered per drone per hour). As of writing this article, this would represent around 12% of the market for COVID tests in the area.

The final category shows the profits generated by the business if it sells to 5% of the market. This is around the predicted market share in the area.

The monthly profit at 5% market share is predicted at around €36,000. All setup expenses would be covered in the first month and the company should be immediately profitable.

Please note that this business model is time-sensitive and can only operate over the duration of the pandemic while tests are in demand. The drone can easily be adapted to deliver other healthcare materials such as vaccines.

Competitor Analysis

There are two categories of competitors; government issued tests and private companies providing self-administered tests in Ireland. The table below shows the services offered by each solution.

Table 4: Services offered by different competitors

Details	CovidTestDrone	Traditional Self-Administered Test	Traditionally Administered Test (test centre)
Swab Test	✓	✓	✓
Accurate Results	✓	✓	✓
Hygiene and Safety	✓	✓	✓
Administered at Home	✓	✓	
Self-Administered	✓	✓	
Results in 1 Day	✓		
Secure Transport	✓		✓

Table 5: CovidTestDrone market analysis

Unique Selling Points

1. Rapid shipping time – less than half an hour to and from consumer
2. Secure shipping – the test is shipped in recommended conditions in a special container
3. Ease of ordering test – the test can be ordered with ease online
4. Non-invasive, lower nasal swab – comfortable swabbing experience
5. Test administered at home – no need to go anywhere, no need to be in contact with anyone
6. Rapid results – results can be received as soon as the day the test was administered

Use of Azure

The project relies heavily on Microsoft Azure's IoT Central solution. The drone sends the following data to IoT Central as telemetry:

- Geolocation
- Container open/close
- Geolocation accuracy
- Temperature and humidity
- Presence of test kit

The container will send details such as its IMEI and firmware version to the backend when it boots up.

The application also makes use of Twin Properties in Azure to allow remote control over the container holding the tests:

- Container Unlock Option (pin unlock or no auth)
- Container Unlock PIN (6-digit pin)

Finally, the container can be locked and unlocked remotely via commands.

Project Team

Hi, I'm Andrei Florian. I am a second level student studying in Dublin, Ireland. I am a dreamer at heart, and I love spending time using the knowledge I gather to create inspiring and impactful products that solve global challenges. I am an avid learner, studying computer science, psychology, philosophy, and entrepreneurship in my spare time.

I started working on CovidTestDrone near the start of the pandemic. I had to get a COVID-19 test and was disappointed by the difficulty of getting one. As a result, I thought of a way to improve the distribution of tests using innovative technology.

This is how CovidTestDrone came to mind. Why not deliver COVID-19 self-administered tests directly to patients' homes using drone delivery. As a result, over the course of a few months, I developed the project by myself and tested it.

CovidTestDrone has won multiple awards as part of BTYSTE (Ireland's National Science Fair) and Microsoft ImagineCup.