Astral Automation

Business Outline

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Executive Summary

Astral is trying to solve the problem of accessibility in remote regions, which is a major hurdle for effectively transporting items. In Sub-Saharan Africa for example, 85% of the roads are inaccessible during the rainy season, which cuts off huge swathes of the population and hinders the transport of essential supplies. This presents a problem for time-sensitive transportation. For example, in Peru, local doctors report an average of 45 snake bites per month with no rapid access to anti-venom. The typical route via car takes over 6 hours, but can be done by a drone within 35 minutes. In situations like this, the difference is between life and death.

Astral provides an end-to-end solution to deliver critical supplies in remote areas. Users can easily send or request items through a web-interface or text message, and the delivery is fulfilled by an autonomous network of drones. The use of fully autonomous vehicles allows us to deliver items faster and with increased reliability across large distances. Through the simple user interface of our system, users such as hospitals, clinics, or disaster relief workers can request a delivery of supplies they don't have on hand or send supplies to other locations.

The purpose of this document is to outline our business objectives, market analysis, and technological capabilities.

Astral is still in its early stages, yet within a few short months we have accomplished many of the objectives that we set out for. We started our planning phase by identifying the key logistical and engineering constraints after which we built a quadcopter capable of navigating between GPS waypoints, and created a preliminary web-app and cloud server for optimizing orders.

Since then, we have secured funding and mentorship through MIT Sandbox, which has enabled us to develop our market research, refine our engineering solution. We intend to continue our Sandbox partnership through the summer and will receive additional funding during these months. Through the Sandbox program, we have had the opportunity to receive feedback on our business plan and engineering solution with influential mentors such as Prof. Ian Waitz who is the vice-chancellor of the MIT Aero/Astro Department and with Mick Mountz, founder of Kiva Systems (now acquired by Amazon Robotics).

Requirements

We have five areas of focus illustrated below which will be broken down into various sub-factors to ensure that different areas of our business are accounted for. These boxes represent important factors relative to the logistical and business baseline which will help us determine our initial requirements.

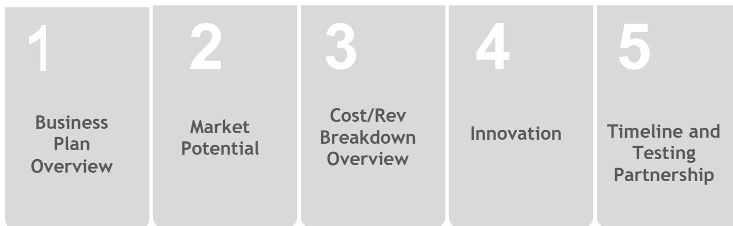


Figure 1

Each of these factors will be broken down further to assess the details and technologies by assessing market feasibility barriers, vehicle considerations, economics, infrastructure challenges, operations, and user experience amongst other details. On the engineering side, detailed logistics and engineering requirements have been planned to facilitate a holistic engineering solution that caters to all necessary requirements needed by all stakeholders of the project while establishing a process of quality gates at each stage of the project phases.

Business Plan Overview

Astral is not reinventing the wheel, rather improving existing capacities. This is done by analyzing existing capabilities, partnerships, and business models that are presently in place by our competitors and applying our research, ideas, designs, logistical networks, and affiliations to further optimize this industry.

Initially, during our testing and implementation phase, Astral will partner with governments and NGO's primarily focused on hospitals and disaster relief deliveries. Upon completion of the testing phase, a subscription based model which accounts for distance, time required, and cargo weight will be considered for regular fast-moving consumer goods.

We provide users with affordable, accessible, and convenient delivery options which add value by expanding networks that were previously out of reach and if in reach, achieving much shorter travel times at a fraction of the cost per delivery. Specifically, in the short-term we are focusing our efforts on improving distribution of vaccines and medicines by restructuring the cold-chain. Instead of relying on old and expensive storage facilities at every location, health service providers can utilize our drone network to receive just-in-time delivery of vaccines – minimizing transports losses, storage costs, and large capital investments.

Not only improving delivery service, we can provide an easier solution to inventory management and tracking by limiting the number of storage facilities needed to facilitate vaccinations across a wide geographic area. Overall, just-in-time delivery provides a streamlined approach to large-scale medicine distribution, and saves health providers money in terms of efficiency and time. For governments, we provide the opportunity to facilitate progress towards improving health care.

In terms of growth, we determined a feasible approach of selecting regions surrounding larger cities where our flight networks could instantly connect remote villages through our bases. These bases would be close enough to the cities to bring supplies to central locations before transportation.

In each of the countries selected, our primary parameters constitute government regulations and partnership availability, civilian impact, and strategic business development. Noting where existing partnerships have been made, we selected areas where new agreements could materialize, enabling Astral to grow without initial competition.

Within the transport sphere there are less than five large scale businesses which share the global market. In Rwanda for example, a newer startup called Zipline controls complete market dominance, which allowed it to quickly expand into neighboring Tanzania within a couple years of ground testing. Vayu is another such company that aims to begin testing in Senegal within the next year. Matternet has also conducted a few ground tests in the DR, Malawi, and Bhutan.

As a business, we intend to complete our initial testing phase after which expanding the company, setting up office spaces, and hiring more engineers will be our growth focus which is outlined in more detail. During this phase, we will require increased investments to grow and sustain ourselves as we build and grow Astral.

Market Potential

There are 3 tiers to our market, each contained within the one before it: the drone delivery market, the healthcare delivery market, and the cold chain delivery market. These tiers are in order of decreasing size, but *increasing* potential for immediate impact. For example, the consumer drone delivery market is the largest of these markets, but current U.S drone regulations present a substantial barrier to entering the consumer delivery market immediately. The cold chain delivery market in remote regions, on the other hand, is smaller, but presents an opportunity for immediate disruption using autonomous drone technology. We intend to enter the cold-chain delivery market first, and expand to higher tier markets as regulatory barriers are inevitably reduced.

Global Drone Market

The drone market is projected to see growth across multiple categories over the next several years. A comprehensive study on drone technology and global markets in 2014 by BCC Research projected a growth for the global drone market to over $1.2B total by 2020. Specifically, our first trials will be the healthcare sector, which as a market is projected to $151.8 MM by 2020, at a rate of 12.1% a year.[1]

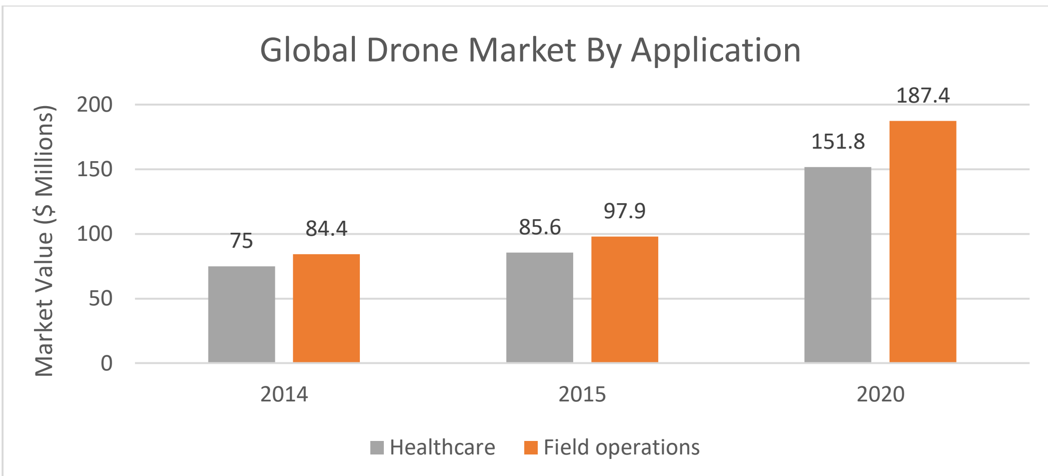


Figure 2: Source BCC Research[1]

Seeing promise in the technology, governments across the globe have increased funding for emerging drone technologies. In 2013, the U.K. Minister for Universities and Science approved a grant of $51.5 million for Robotics and Autonomous Systems.[1]

Geographically, nearly every region on the globe has large growth potential. We have originally focused our efforts in the Asia-Pacific region, though as we expand into consumer oriented deliveries, North America will likely be a large part of our operations.

[1] (G.)

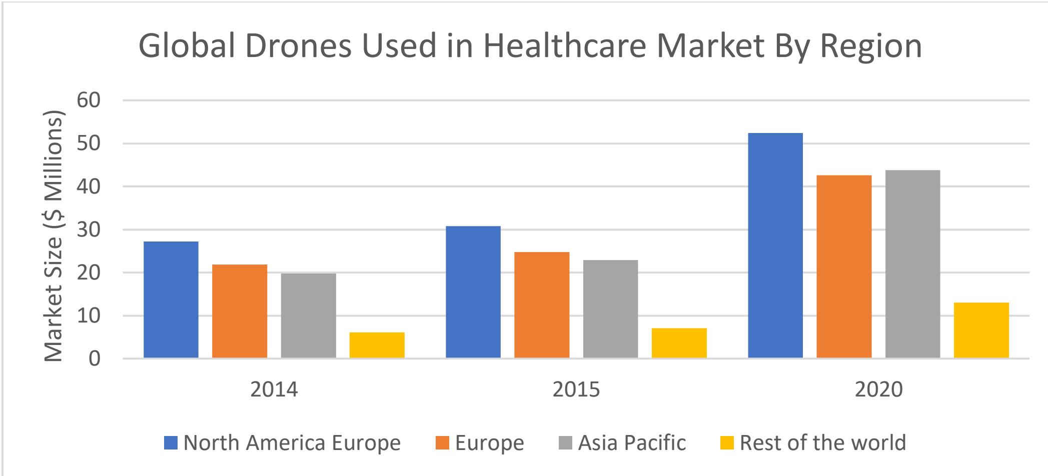


Figure 3: Source BCC Research[1]

In terms of specific sectors, drones have the potential to improve work in dangerous areas, including disaster response and accidents - such as moving medical supplies and foods to critical areas or location missing persons. As the regulatory landscape shifts to be friendlier toward UAVs, the delivery of consumer goods has tremendous growth prospects for years to come.

As a company, our long-term vision is to incorporate a variety of autonomous systems and delivery mechanisms into our platform, which increases our large-scale potential. Looking at the combination of UGVs, USVs, and UAVs, we see that just by 2020 the combined market in Field Operations and Healthcare for UGVs and UAVs will be over $290 million.[1] The fusion of numerous technologies into a single platform helps us expand the reach of our service geographically and use-wise.

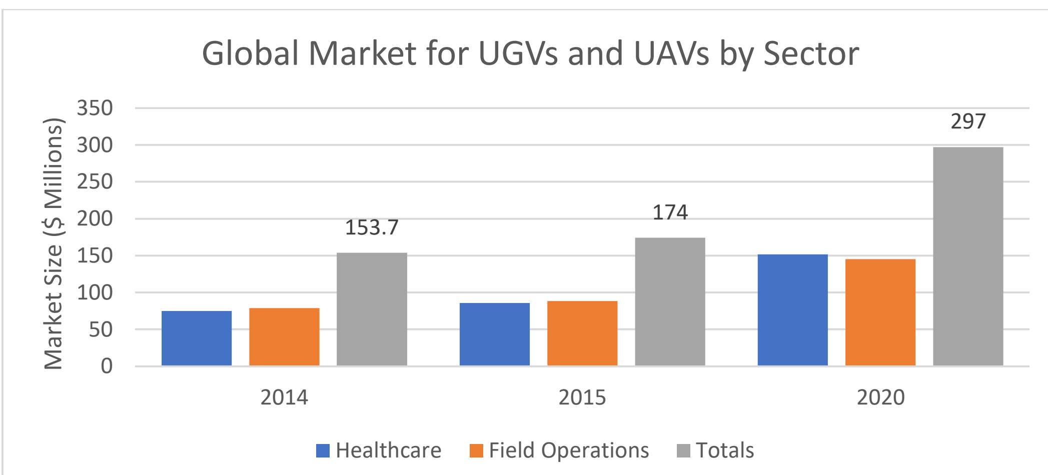


Figure 4: Source BCC Research[1]

The BCC Research report also noted that, “the rapid delivery of medications, vaccines and supplies right can prevent outbreaks of life-threatening contagious diseases.” The clear potential to save lives and improve the capabilities of existing non-profits and health organizations is a major driver in our vision for the future, and is also an indicator of our business strategy. In terms of benefits over existing delivery methods, UAVs offer a more custom solution to specific regions that would otherwise require extensive infrastructure for low-volume deliveries (i.e. it's not feasible to build a road just for one major disaster).

Cold Chain Delivery

The vaccine supply chain, also known as the "cold chain," involves a complex sequence of deliveries. Vaccines are transported from manufacturers, to central stores, to regional stores, and finally to health centers, where vaccination occurs. During each stage of transportation, vaccines must be kept at a strict temperature range, requiring specialized and expensive refrigerated vehicles.

In remote areas, the final stage of transportation from regional stores to health clinics has the highest potential for vaccine wastage, and the highest cost per dose of vaccine delivered. It is economically infeasible to use refrigerated vehicles for delivery to remote areas, so motorbikes or small trucks with small ice-cooled containers are used instead.[2] Over long distances, these deliveries are slow and costly. Rural communities must also maintain their own cold storage for vaccines, which presents another economic barrier to widespread vaccination.

By extending vaccine delivery analysis performed by the PATH organization**Error! Bookmark not defined.**, we find that autonomous drone delivery can cut down the cost-per-dose of final stage vaccine delivery by a truck by a **factor of 22**, from 26.5 cents to 1.2 cents. This is primarily due to two facts: (1) a drone can fully utilize its payload when visiting smaller remote regions, and (2) fully autonomous electric vehicles incur a substantially lower human operation and energy usage cost per flight. We provide detailed calculations in Appendix I.

	4WD Truck	Astral Drone
Capital Cost	$35,749.00	$5,450.00
Cost Per Trip	$132.64	$6.01
Cost Per Dose Delivered	$0.2653	$0.012

Table 1: A summary of total capital cost, cost-per-trip, and cost-per-dose of vaccine delivered for traditional delivery via a four-wheel drive truck and by our drone system.

These values are obtained by comparing the vehicles over a 50km delivery route, each transporting enough vaccine for 500 people. Although the truck has capacity for much more vaccine, remote areas cannot take full advantage of this.

Because autonomous drones can deliver vaccines to remote areas more rapidly and at a reduced cost, they create the possibility for "on-demand" vaccine delivery. Vaccines can be delivered very close to the time that they will be administered, reducing wastage and eliminating the need for remote communities to purchase a long-term storage solution.

[2] (WHO)

Cost Breakdowns

Here, our aim is to list important items that will help us in consolidating our business plan. Listed below are a few cost breakdowns that we should consider.

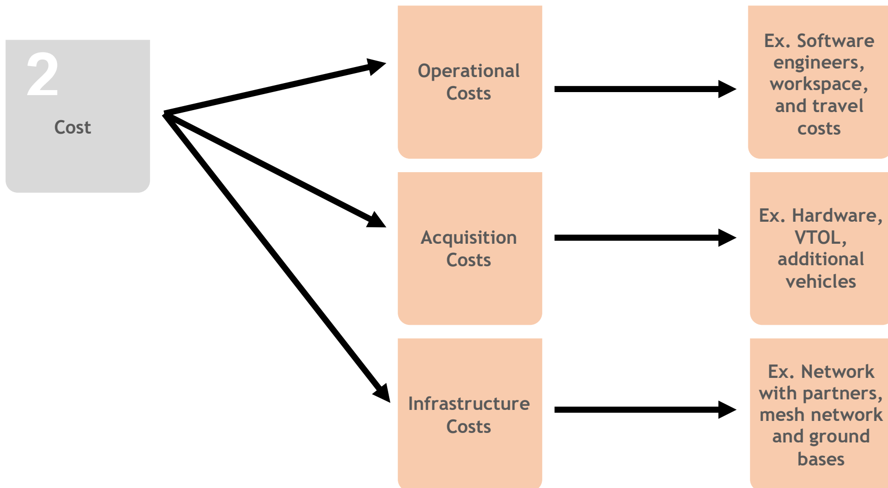


Figure 5

Currently our initial costs are covered by the MIT Sandbox Fund for preliminary testing but we will need funding to grow this company as outlined in the chart above. Precise cost estimations are being conducted.

Innovation and Engineering

Our drone delivery platform is designed with two main goals in mind: (1), making the user-experience as simple as possible, and (2), maximizing the level of autonomy and safety at which our drones operate. The first goal is critical towards developing a service that users and organizations will adopt and use frequently. The second goal allows us substantially reduce delivery costs associated with human operation, and ensure a high-level of flight safety.

User-Interface

Users and organizations interact with our service through either a web-application or text message in areas where Internet access is limited. Through either method, the user can request a delivery or send an item by specifying a source location, destination location, and item to transport. The web application displays real-time updates on the status, location, and ETA of an order. These updates can also be received through SMS.

For our short-term vision, we have a simple system in place which is illustrated below. During the flight we will receive drone data pertaining to location, altitude, speed, flight path, and battery levels.

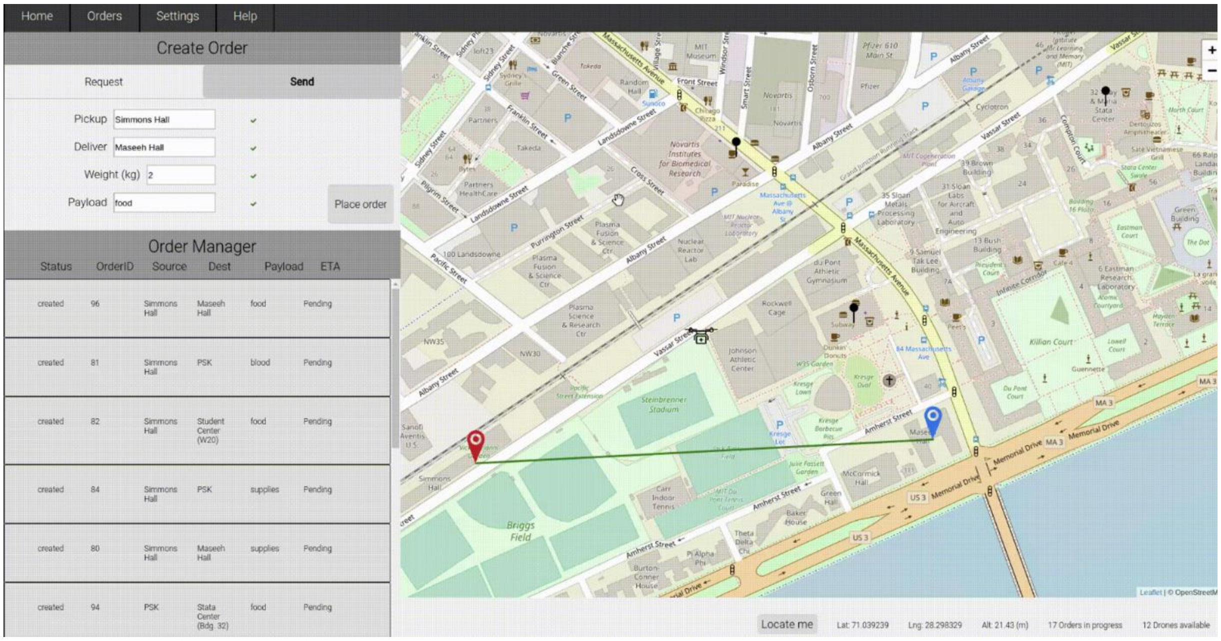


Figure 6

Autonomous Capabilities

We have designed our platform to fulfill an order fully-autonomously. To accomplish this, we have a centralized system that assigns vehicles from our fleet to a delivery, creates a flight plan based on current weather, geographic, and aircraft control data, and continuously monitor vehicles for any necessary changes to their plan.

The vehicle itself has a suite of sensors that allow it to fly autonomously, even when connected to a ground station is lost. We use a combination of stereo cameras and ultrasonic sensors on the drone to sense and avoid obstacles, even at full cruising speed. Redundant inertial measurement and GPS units provides accurate state estimation on the drone that is robust against the failure of a single sensor.

In addition, using multiple electric motors, controllers, and redundant battery architecture can significantly reduce the chances of full engine failure by having a propulsion system redundancy. Distributed propulsion enables a controlled landing in the event of multiple engine failures.

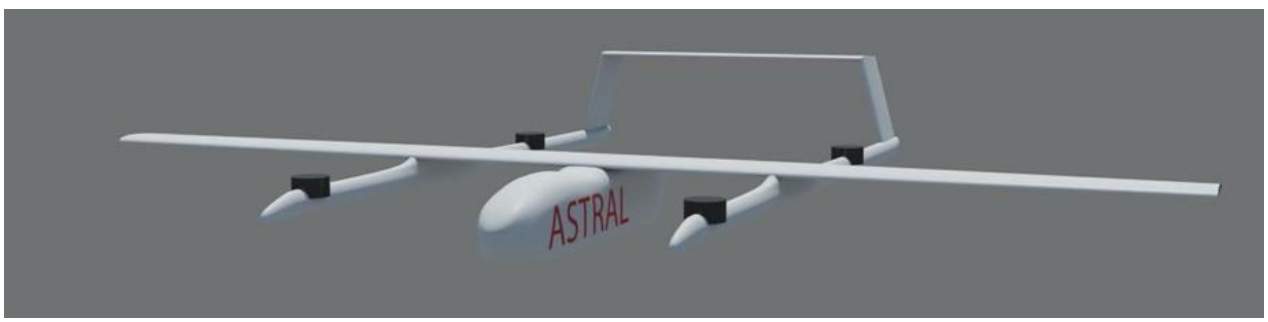
We leverage the open-source Pixhawk flight controller for low-level hardware control. The Pixhawk offers advanced failsafe configurations, such as a return-to-launch if connection to a ground station is lost for too long, or a hardware failure is detected. We have an additional flight computer onboard our drones to handle higher-level planning and vision tasks related to obstacle avoidance. The drone can dynamically re-plan in response to unexpected obstacles, weather patterns, or changes to an order in progress.

Hardware Design

For the short-term we are simply purchasing electric VTOL kits which we will add additional sensors and a flight computer to. In the future, we can consider developing our own vehicles.

We have chosen to use a fully-electric vertical takeoff and landing drone for our deliveries in remote regions. Several models that meet our distance and payload requirements are available as a kit. Electric VTOL drones offer many advantages over fixed wing and multirotor vehicles.

- Vertical takeoff allows our drones to deliver to any location without specialized landing accommodations.
- A fully-electric VTOL system doesn't generate any flight-based carbon emissions and can also further lower emissions by through renewable power sources for charging down the road. Our system has the potential to substantially reduce emissions from delivery vehicles. In addition, electric motors reduce vibrations of the payload.
- We benefit from the efficiency of fixed-wing flight while travelling at cruise speed, increasing our maximum flight distance on a single charge.



Impact

Our services have the potential influence people in all remote regions of the world. Reducing delivery and storage costs, as well as wastage of vaccines can substantially improve the coverage of vaccines in remote regions. After validating our system through medical and disaster relief applications, we can begin transporting fast-moving consumer goods in remote areas. In the long term, we aim to bring our delivery platform to urban areas, where autonomous drones have the potential disrupt existing last-mile delivery services.

Team and Mentors

The founding partners of Astral all have a passion for aerospace, drones, and taking on ambitious projects. Alykhan has earned degree in Mechanical Engineering from Queens, and he has worked on several start-ups in the past, including a hybrid quadcopter drone company focused on extending range via gas turbines. Isaac has extensive experience with prototyping methods, learning from his lifelong passion for making. Both in work and school, he has shown strong management and planning skills, and he has experience in numerous aspects of business, technology, and research. Studying computer science and aeronautical engineering, Milo has hands-on experience developing perception, estimation, and control software for autonomous drones.

Our mentors provide a range of technical experience to our project. We have gathered a few strong advisers with diverse background to assist with company needs. One of our advisers is currently teaching at the Harvard Kennedy School and was previously a financial controller for Nokia who will be assisting us in maintaining budgets, our second advisor completed engineering at MIT and is currently at Harvard Medical School. His medical experience in developing countries is valuable to understand market needs combined with his engineering expertise is a strong asset to our team. Our last advisor is pursuing his PhD at MIT and has experience in machine learning that we can leverage as we expand our software capabilities.

Project Description/Feasibility

Our goal is to develop our software platform and integrate a VTOL drone with it this semester and over the summer at MIT. Within our team, Milo is working on our software capabilities and route optimization goals. Isaac and Alykhan are focused on hardware integration, including the failsafe measures in our flight software and reliable telemetry.

Appendix I

We assume a 50km out and back trip to a remote clinic. The drone flies 100km exactly, and the car drives 150km due to winds in the road. The car averages 30km/hr. (15mph), while the drone averages 60km/hr. (30mph). Both vehicles have an unload time of 20 minutes. The truck can fit 12 Domestic RCW25 cold boxes, and our drone uses a custom cold box that fits our payload bay. We assume the 4WD truck has a fuel efficiency of 25.6 km/gallon (16mpg), and gasoline costs $4.00 per gallon. The drone uses two 4S 22AH LiPo batteries, requiring 0.651 kilowatt-hours of energy used for the whole flight (we round to 1 kilowatt-hour to account for charging inefficiencies). The average price for one kilowatt hour of electricity in the US is 12 cents. We assume that one drone operator is paid $17/hour (based on a 50k yearly salary in the US), and they are monitoring a fleet of 10 drones, so the hourly cost to monitor a single cost is $1.70. We also assume that a truck driver is paid $13.78/hr. based on a 2017 U.S median salary of $40,260.

	4WD Truck Carrying Domestic RCW25 Cold Box	**Astral Drone**	**Ratio (truck/drone)**
Trip Requirements			
Distance (km)	150.00	100.00	1.5
Transport Time (hrs.)	5.00	1.67	3.0
Unload Time (hrs.)	0.33	0.33	1.0
Trips Per Year (12-hour days)	821.30	2191.10	0.4
Capital Costs			
Containers	$9,499.00	$200.00	47.5
Vehicle	$25,000.00	$5,000.00	5.0
Vehicle Replacement and Repair (1yr)	$1,250.00	$250.00	5.0
Total	$35,749.00	$5,450.00	6.6
Transport Costs (1 trip)			
Operator wages	$73.49	$3.40	21.6
Fuel/Electricity for Trip	$15.63	$0.12	130.2
Capital Amortization	43.5	2.5	17.5
Total	$132.64	$6.01	22.1
Payload Capabilities (1 trip)			
Max. Volume (Liters of vaccine)	240.00	1.10	218.3
Max. Doses in Payload	34347.05	514.66	66.7
Conclusions on next page.			

Conclusions			
When Using Entire Vehicle Payload			
Hourly Operating Cost (including capital)	$24.87	$3.00	8.3
Cost Per Dose Delivered	.0039	.0117	.3333
Cost Per Liter Delivered	$0.55	$5.46	0.1
When Delivering for 500 People			
Hourly Operating Cost (including capital)	$24.87	$3.00	8.3
Cost Per Dose Delivered	.2653	.0120	22.1
Cost Per Liter Delivered	.0380	.0017	22.4

References

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