Operation Last-Mile:
Critical Drone Delivery Testing

April 7-9 2020
Lawrenceville, Virginia

160 Newtown Road, Suite 302 | Virginia Beach, VA 23462 | 877-601-1860 | droneup.com

Table of Contents

About DroneUp

DroneUp provides complete drone solutions that include FAA compliant consulting services, Part 107 pilot flight services, aerial data collection & processing, data delivery & analysis, training, program integration, and equipment sales to commercial industries and public sector organizations. DroneUp operates globally with more than 10,000 certified drone pilots. DroneUp is headquartered in Virginia Beach, Virginia, and a SWaM or Small, Women-owned, and Minority-owned Business certified as a small business by the Commonwealth of Virginia. For more information: droneup.com.

1 Overview

In response to the COVID-19 Pandemic of 2020, various government agencies began inquiring about the capabilities of drones to deliver critical medical and other supplies to quarantined areas in the event the pandemic forced the physical quarantining of entire towns and cities. In particular, the White House and the Commercial Drone Alliance asked members of the commercial drone community to document their capabilities through surveys of drone manufacturers and drone service providers. Based on previous experience delivering payloads with the DJI Inspire 2 drone, DroneUp LLC, a leading drone service provider in the United States, responded that it could assemble a team of 50 drones and pilots who could provide delivery capability in the Eastern half of the United States. At the same time, DroneUp proposed conducting a test of these capabilities through an exercise to be held at an outdoor test environment. The purpose of the test would be to determine the limits of drone delivery for small packages in a quarantine environment.

Representatives of the Commonwealth of Virginia's Center for Innovative Technology (CIT) were intrigued by DroneUp's proposed exercise and conducted a search for an appropriate location to perform such an exercise. Of three viable locations, the former campus of Saint Paul's College in Lawrenceville, Virginia was selected. The 55-acre campus was under the stewardship of Brunswick County, Virginia. Various local, regional, and state entities believed it was an appropriate location to perform such testing because of its rural location, variety of terrain, buildings, mature trees, and the ability to be secured for the protection of the general public during the testing. Once funding from the Commonwealth was approved and it was concluded that the operation could be held safely by following recognized virus protocol, the exercise was scheduled. It was called, *Operation Last-Mile: Critical Drone Delivery Testing.*

DroneUp scripted a 2 ½ day test plan to utilize the DroneUp pilot network and readily available, industry-standard drones to simulate the delivery of 1.5-pound payloads of medical and other critical supplies in city-like conditions. This exercise sought to test the capabilities, capacity, and scalability of small package drone delivery while establishing a baseline of performance for multiple drones operated under FAA Part 107 rules. Testing variables included delivery over buildings, trees, and power lines over varying terrain. Tests were designed for both single aircraft and simultaneous multiple aircraft operations. Also tested were semi-autonomous flights versus manual flights, aircraft deconfliction using command center drone visibility software versus visual command only, and night operations.

2 Executive Summary

This exercise proved that Part 107 pilots using commercially available drones could successfully and repeatedly deliver 1.275-pound payload packages to 10-foot diameter targets on 1500-foot round trips under FAA Part 107 flight rules. Over 200 total flights were flown during the day and at night. Test plans called for 90 successively more difficult delivery test flights. Those 90 delivery flights were recorded in rich detail. Of the 90 delivery flights, 90 payloads were dropped inside a 10-foot diameter, predetermined target. One delivery attempt was safely aborted when the wind caused instability, that flight was then reflown successfully.

Four delivery teams operated during the operation. Three DroneUp teams operated the DJI Inspire 2 drone. Each DroneUp team consisted of a Remote Pilot in Command (RPIC), a LoadMaster, and a Visual Observer (VO). The RPIC manned the sticks on the controller. The LoadMaster was adjacent to the RPIC and operated the radio and managed the payload. The VO was positioned in the target area to ensure a visual line of sight was maintained on the aircraft at all times. A fourth pilot team from UPS/Workhorse also participated in Operation Last-Mile. They flew tests independent of DroneUp and also flew alongside DroneUp in Test 5, which tested airspace deconfliction. The flight statistics reported include only the 90 DroneUp flights flown with the Inspire 2 drone.

The average round-trip flight distance to the 19 different targets ranged between 452 feet and 1501 feet, averaging 924 feet. The average delivery elapsed time was 4.24 minutes, which consumed 20.2% of the aircraft's battery power. Most of the targets for the payload deliveries were purposely placed close to obstacles such as trees, buildings, and power lines because the purpose of the testing was to find the limits of safe and efficient drone delivery. In the real world, wide-open targets would be selected, which would take an estimated 42 seconds off the average round trip delivery times. Taking into account delivering to wide-open targets, we estimate that 2000-foot round trip flights would, on average, take 5.4 minutes (including payload handling and battery swap-outs) and consume 30% battery.

DroneUp estimates that 3 flight crews of 3 members each could deliver between 150 and 300 packages in an 8-hour shift depending on the distance of the take-off spot to the target. Based on actual recorded performance, here are the projections we make for round trip deliveries at target distances between 500 feet and 2500 feet.

Summary of Delivery Capacity								
1.275-pound Payload on Inspire 2 Drone								
3-Person Delivery Team (RPIC, LoadMaster, VO)								
Target Distance One Way (feet)	Round Trip Distance (miles)	Payload / Batt Time (min)	Take-Off, Landing, Drop Time (min)	Time to Target @ 8mph (min)	Time From Target @ 15mph (min)	Total Time Per Del (min)	Del per Team Per 8 (Net 7) Hour Shift	Del per 3 Teams Per 8 (Net 7) Hour Shift
500	0.2	1.0	2.2	0.7	0.4	4.3	98	294
1000	0.4	1.0	2.2	1.4	0.8	5.4	78	234
1500	0.6	1.0	2.2	2.1	1.1	6.5	65	195
2000	0.8	1.0	2.2	2.8	1.5	7.6	56	167
2500	0.9	1.0	2.2	3.6	1.9	8.6	49	146

In addition to 90 recorded deliveries, successful demonstration tests included using drone thermal imagery to see humans and drones at night, using a drone as a public address system, showing that drone noise is not harmful to hearing and delivering a package to an automated drone package mailbox.

Important lessons learned include:

- The operating procedures for handing off the line-of-site responsibility between the RPIC and the VO can be better defined.
- The operating procedures for the use of radios can be better defined.
- The terminology used by the VO to instruct the pilot on how to reposition the drone in the target area can be better defined.
- The use of checklists before and between flights can be refined and enforced.
- Providing lighting of some kind on drop targets at night might improve speed.
- Pre-programmed flights help ensure consistent flight parameters but take longer than manual flights.
- Providing the mission commander with a dashboard showing locations and video feeds from all active drones is helpful.

DroneUp is encouraged by the success of this operation. Not only did the pilots hit obscured and obstacle-ridden targets 100% of the time, but over 50 significant lessons

learned were recorded which will help improve the safety and efficiency of drone deliveries. We look forward to taking what we've learned from Operation Last-Mile and testing delivery of potentially heavier payloads over potentially long distances.

3 Location

All tests were performed on the property of the former St. Paul's College, located at 115 College Dr, Lawrenceville, VA 23868.

4 Aircraft and Camera

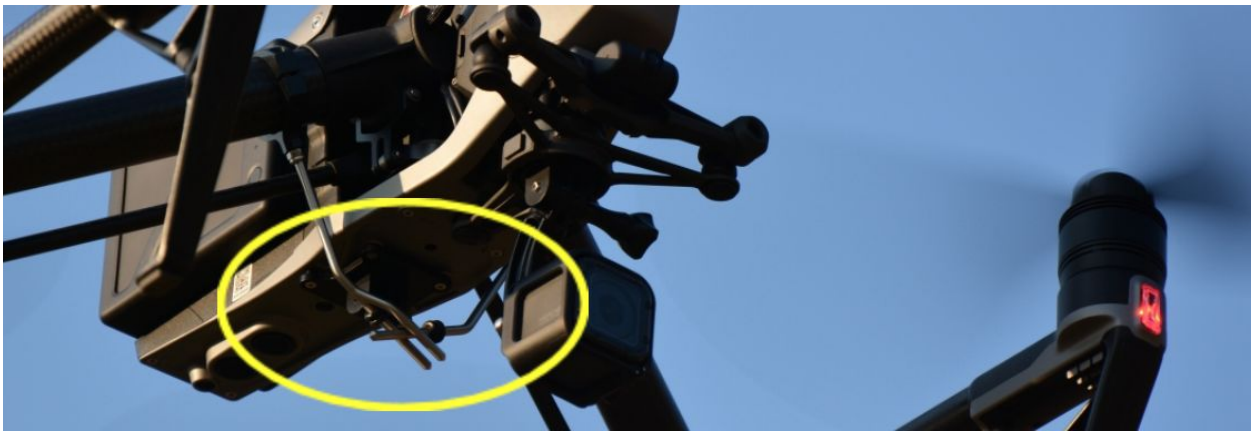
The aircraft DroneUp chose for Operation Last-Mile was the DJI Inspire 2 outfitted with the Zenmuse X5S camera. This model was released in 2017 and is often used for cinematography. It features a retractable landing gear system that lends itself to reliable delivery when paired with the Skyzimir Stork 2 drop mechanism.

The baseline Inspire 2 retails for $3299 and comes with a low-resolution first-person view camera. For this operation, we added the optional Zenmuse X5S (including gimbal) which retails for $2049. This high-quality camera ensured the pilots a good view of the drop areas to assess the area for safety before dropping the payload. This camera weighs 461g (1.01 lb). Another camera option for this aircraft is the Zenmuse X4S camera at 253g (.56 lb), but it had been discontinued by the manufacturer so it was not chosen for this test.

5 Payload and Drop Mechanism

The payload for each delivery totaled 20.4oz (578g or 1.275lb) consisting of a lightweight GSM bag, a ziplock bag of sand, a medicine bottle, a small cardboard box, an 8-foot-long paracord tether, and 2 S-carabiner clips.

The assembled payload bag was connected to a DJI Inspire 2—a popular consumer drone—using an S-carabiner clip attached to a Skyzimir Stork 2 drop mechanism. The Stork 2 features a set of stainless steel bars that interlock when the Inspire 2 landing gear is in the down position. The drop mechanism on the drone allows the release of the payload when the pilot uses a manual switch on his controller to raise the landing gear. For each drop, the bag with a tether was left at the drop site.



6 Aircraft Payload Capacity

The DJI Inspire 2's (4) motors (model 3512) produce a combined thrust of 8500 grams. A general rule of thumb is that a drone should ideally hover at 50% throttle, therefore the manufacturer recommends an Inspire 2 maximum takeoff weight of 4250g. Each of the (4) Inspire 2's in this exercise weighed 3957g, which included the aircraft, batteries, props, X5S camera, and drop mechanism.

The aircraft weight at 3957g plus the payload at 578g (1.275 lb) created a total weight of 4535g. This weight represented 53.3% of the total thrust of the motor/propeller system. DroneUp deemed that this 3.3% overage over the general rule of thumb was acceptable considering the nature of the flights (straight flights with little maneuvering), the supervision

being provided (more than a dozen Part 107 pilots participating and observing) and the short-range of the flights (average 924 feet round trip). During the 2 ½ days of flying this drone with this payload, there was no indication of payload weight being a problem. There was one incident when the wind seemed to be an issue and that resulted in a safely aborted delivery shortly after takeoff.

The Inspire 2 drone, having been in production for 3 years, is readily available across the United States. Within 300 miles of Washington, DC, DroneUp identified over (50) Part 107 commercial pilots within its network who indicated they owned this drone. DroneUp also received a commitment from its sister company in Norfolk, VA that committed to manufacturing 200 compatible drop mechanisms within 2 weeks of placing an order. For critical packages of up to 1.275 pounds, the Inspire 2 as outfitted for this operation would be ideal.

If the X5S camera were replaced with the X4S at a savings of 208g, the resulting total weight as flown in these tests would represent 50.9% of the rated thrust of the motors/propellers. If the large camera were to be removed altogether and the pilot relied solely on the permanent low-resolution First Person View (FPV) camera, the 4250g of recommended payload capacity would allow an increase in the payload to 1.66 lb while staying at the "50% hover throttle" general rule of thumb.

7 Team Participants

DroneUp queried its database of 10,000 Part 107 pilots to find the pilots within 100 miles of Lawrenceville, VA, and sent them each an email describing Operation Last-Mile and seeking their participation if they met the criteria below. All the candidates were located in either Virginia or North Carolina. They were paid a flat rate per day plus a meal and lodging per diem to participate. Interested pilots were instructed to respond to our email describing their relevant experience. These are the criteria we asked the candidates to meet.

(1) DroneUp Call Sign
(2) If not already submitted via the DroneUp app — your part 107 number
(3) Number of hours as PIC (looking for pilots with 75-100 hours as a PIC)
(4) Number of hours piloting an Inspire 2 or Matrice 210 (looking for 25 hours in at least one of those drones)
(5) Experience with night operations — yes or no. If yes, please verify your training as well as whether or not you possess a Part 107.29 waiver.
(6) Any public safety background?
(7) Any commercial UAV background?
(8) Any scheduling conflicts being in Lawrenceville, VA the week of April 6
(9) Your current city of residence

A total of 103 pilots were contacted via email and invited to respond. Thirteen pilots who responded met the criteria and provided sufficient detail to be considered viable candidates. The top 10 candidates were invited to be interviewed via a video call with the DroneUp Flight Operations team. In the end, 8 applicants were chosen. Here is a summary of the qualifications of DroneUp's Operation Last-Mile pilot team.

- All pilots had Part 107 certificates and were experienced, commercial drone pilots.
- Almost all had been pilots prior to the establishment of the Part 107 rules in late 2016.
- The average number of hours logged as a drone pilot was 1193. The mean was 165.
- Four of 8 had logged flight hours on the Inspire 2 or Matrice 200 drones.
- 2 pilots were current and 3 pilots were former public safety members, particularly with fire departments. At least one of the pilots not involved in public safety had a military background. So at least six of the eight pilots had either public safety or military background.
- Four of the pilots had Part 107.29 waivers to operate at night.
- The pilots ranged in age from 39 to 67 with the average being 50.

DroneUp has a Part 107.29 waiver allowing it to operate outside the daylight operating period of between 30 minutes prior to sunrise until 30 minutes after sunset. In order for our pilot teams to operate under DroneUp's FAA waiver, each had to pass a training course in night operations. While four of our Operation Last-Mile pilots had their own Part 107.29 waivers, all 8 pilots attended a 2-hour night operations training course provided by the DroneUp Airboss on Monday, April 6. The course was held via webinar and all 8 pilots passed the 25 question test with an average score of 92% - allowing all participating pilots the opportunity to fly nighttime delivery flights on April 8.

The pilots were divided into three teams (Yellow, Blue, and Green) with three members each. DroneUp provided a Part 107 pilot as a VO for the Blue team. For every given flight, the team roles were RPIC, LoadMaster, and VO. The RPIC piloted the aircraft and made the final decision on fly/no-fly, drop/no-drop, and abort/continue the flight. The LoadMaster was responsible for examining the payload, attaching the payload to the aircraft, ensuring the tether did not foul the propellers upon takeoff, and relaying radio communication to and from the RPIC. The VO was responsible for keeping the drone within line of sight once the RPIC lost line of sight and directing the RPIC during the descent and drop of the payload over the target.

Because of the COVID-19 virus epidemic, DroneUp adhered to guidance from the Commonwealth of Virginia on social distancing and best practices in mitigating virus risk. A registered nurse was hired to screen all participants each day, (taking temperatures and interviewing) and the participants were given labels to wear indicating they had been screened. The Deputy Sheriffs assigned to provide security at the exercise entrance were instructed not to allow anyone entry who had not been screened.

DroneUp issued masks to every participant who didn't bring one and made hand sanitizer readily available. The nurse monitored all activities and reminded participants and observers to observe social distancing. Every known precaution was implemented to ensure the safety of the exercise participants.

8 Communications

Push to Talk (PTT) radios were provided to each member of the participating flight teams. This allowed communication with the Airboss, communication between RPIC, LoadMaster, and VO, and communication with other flight teams.

Channel 1 was assigned to the Airboss, the DroneUp Operations Manager, and the DroneUp CEO. Channel 3 was assigned to flight operations, particularly the communications between piloting teams and their VO's in the field. Channel 5 was dedicated to facility logistics. Even channels were available to allow teams to have conversations without stepping on the communications of other teams. This convention was especially useful during Test 3 when multiple teams were flying and delivering at the same time.

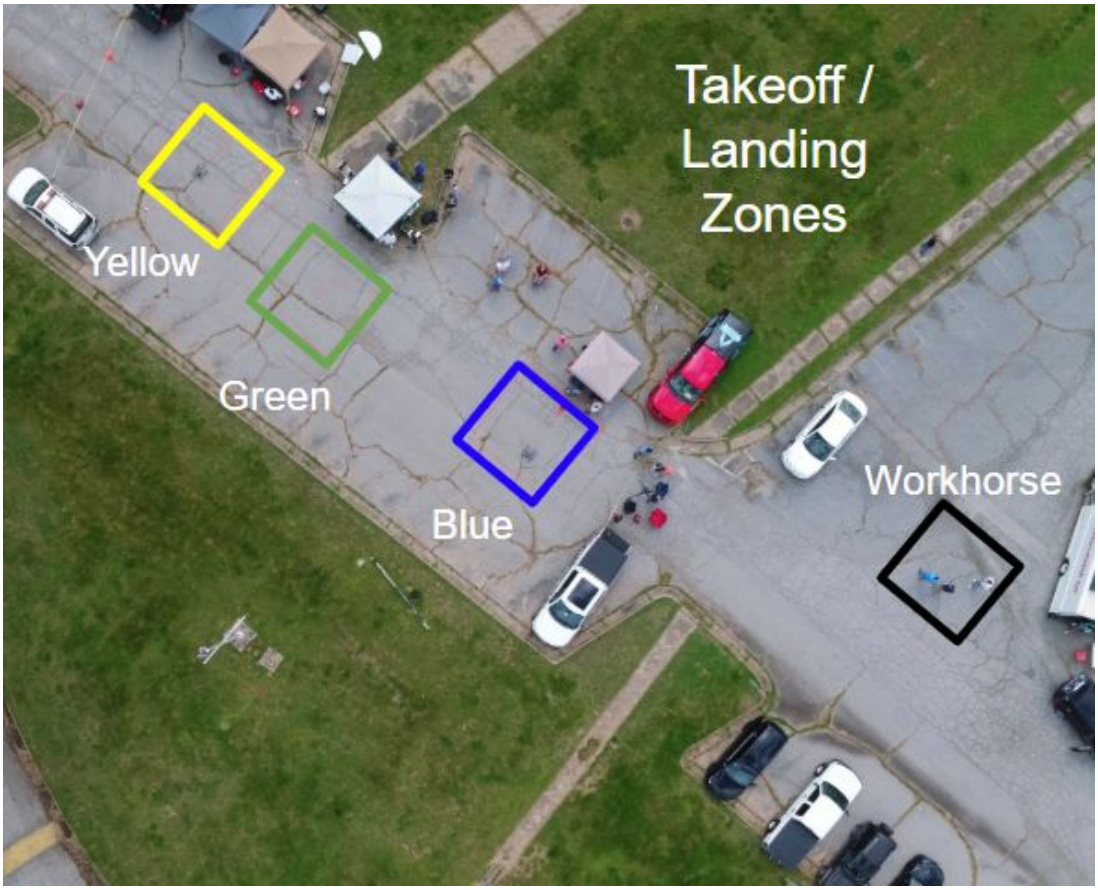
The radio communication protocol was discussed during the project briefing and in each flight session briefing. The directions included the following:

- Identify the party you want to talk to and then identify yourself prior to speaking your message. Example: "Green Team, Green VO. I'm in a position at target 2-1".
- Keep radio messages concise. Think about what you're going to say before you say it. Remember that while you are holding down the PTT button, only you can be heard across all the radios on that channel.
- Deliveries, take-offs, and landings take precedence on the radio. If you have a question or comment about something else, wait until the important communication has finished to key the PTT button.
- Under Part 107 rules, the RPIC cannot allow the drone to leave his visual line of sight until he receives confirmation that the VO has obtained a visual line of sight of the drone. So we established that the VO was to announce his visual acquisition of the drone as soon as he had acquired it and the RPIC was not to fly further until he had that confirmation.
- Methods used by the VO for directing the RPIC to the correct location above the target were varied. Some said, "Go forward 5 feet." Others said "Slide right." and then "Hold." if the correction was more than a few feet and "Bump right." if the correction was slight.

Role of the Airboss and Communications

DroneUp provided the Airboss for Operation Last-Mile. The Airboss was in charge of directing all flight takeoffs and landings and overall direction regarding weather, wind, which tests were to be run, when to break for meals, etc. Delivery drops were managed by the flight teams and their VOs without Airboss intervention. The directions from the Airboss came generally from the radio so that all personnel involved in the operation knew what was happening.

The flight teams were adjacent to one another, which made verbal communication possible between the teams. DroneUp's (3) teams were about 20 feet from one another and each had a landing/takeoff square of 20 by 20 feet. The Workhorse team was located approximately 50 feet to the Northwest and down a slight hill from the DroneUp teams. All teams requested permission from the Airboss to take off or land and permission had to be granted before that action was taken.



9 Test Plan

The following section describes the plan, objectives, and scoring criteria of each test the delivery teams performed. In all the tests, the following scoring criteria and demerit system, if applicable, were followed.

Scoring Criteria: The test began when the pre-test briefing was complete. DroneUp Flight Crews were tasked with pre-flighting their aircraft, loading the packages, delivering the packages, and returning safely. Human Data Recorders recorded the following during the operation:

- The number of successful deliveries. A successful delivery was defined as a package that came to rest within a 10-foot diameter around an 18-inch cross marking the exact center of the delivery location.
- Time to complete each delivery. Time recording started when the package was loaded and stopped when the aircraft landed after returning.
- Time to complete all deliveries. Time recording started as the preflight inspection was performed, and ended after the final landing.
- Fuel consumption. Each delivery battery level was recorded at each takeoff, each delivery, and each landing.

Demerit Points: Demerit points were recorded for incidents that would gravely impact safety or operational efficiency in live operations performed outside of the testing environment. The occurrence of a single demerit point indicates an expected real-world emergency or catastrophic failure. Any of the following conditions would be recorded for each test as demerits:

- Controlled Flight Into Terrain (CFIT) - Any portion of the aircraft contacts terrain in controlled flight, other than landing
- Takeoff or Landing Damage to Airframe - Any damage to the aircraft occurs during takeoff or landing
- Inadvertent Activation of Emergency Procedures Emergency procedures are activated by another mechanism than the RPIC, such as a C2 link failure
- Failure of Flight Critical Avionics - An avionics component critical to flight safety fails (IMU)
- Failure of Powertrain - A powertrain unit fails
- Drop Mechanism Failure - The drop mechanism fails
- Payload Entanglement - The payload becomes entangled
- Loss of Communications between RPIC and VO
- Near-Miss - A "Near Miss" is defined as 2 aircraft in en route flight passing within 25' horizontally or 10' vertically of one another. Additionally, a "near miss" is any situation where an sUAS pilot must take evasive action to prevent midair collision with another sUAS.
- Viral Contamination - Drone Descends below 8' AGL. The CDC had provided guidance that if an object remained 10 feet above the ground, the chance of COVID-19 aerosol particles infecting the object was very low. We determined that a drone with an 8-foot tether dropping the payload 2-3 feet above the ground would avoid contamination in a simulated quarantine environment. Our targets were unpopulated at the drop times so the risk of infection at any height was near zero. But we wanted to demonstrate that the drone drop height could be successfully controlled using VO's.

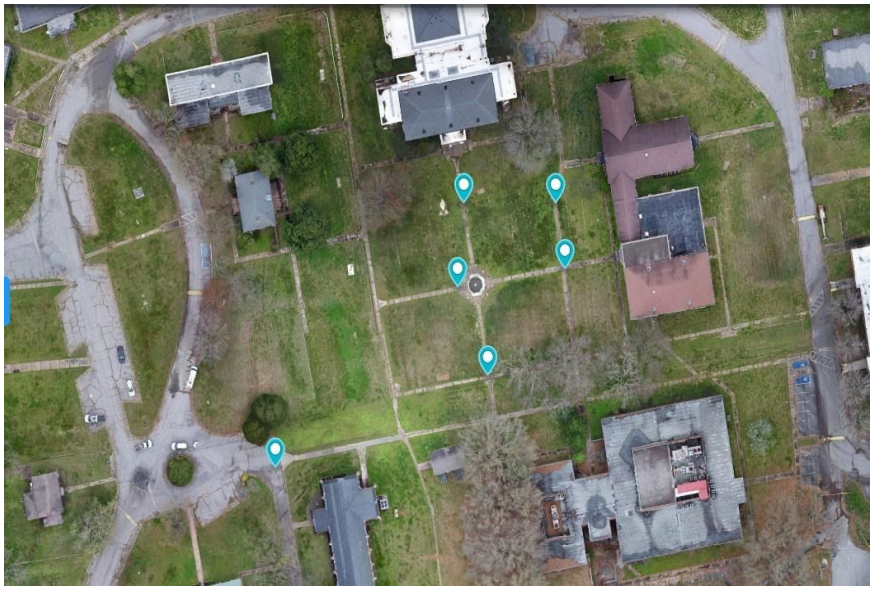
9.1 TEST 1: Control – Establish Performance Baseline

Test 1 Objective: Test 1 established the baseline performance of each drone model in a standardized test of a fixed number of deliveries in a fixed set of locations. This test was designed to control, as much as operationally feasible, the variables of environment, human factors, and objectives. The baseline performance of each drone in an idealized environment was used as the control group to compare the impacts of each on delivery performance on each successive test.

Test 1 Description: Each DroneUp flight crew, consisting of RPIC, LoadMaster, and VO, was tasked with delivering 5 packages, each weighing 1.275lb, to the (5) drop locations identified below. For this test only, the takeoff location was moved to allow visual line of sight to be maintained by the RPIC throughout the flight. The five target locations were all in the area called "the quad". This test was repeated through 3 flight crew rotations, and the scores of each rotation were averaged to eliminate flight crew variance in the result. Only one flight team operated at a time and all 3 teams completed all 5 deliveries.

The test results were recorded by Data Recorders assigned to that task by the Airboss. These Recorders were either trained Part 107 pilots or temporary workers hired locally who were supervised in their recording tasks by DroneUp Part 107 pilots not participating in flight operations. A sample recording sheet is included in the appendix.

Test 1 Location: This test was performed at the 5 drop locations shown in blue near the center of the map. The takeoff and landing area was located at the blue marker on the southeast corner of the map.



Test 1 Resources: 3 Inspire 2, 3 Flight Crews (RPIC/LoadMaster/VO), 15 packages, 5 drop locations, communication radios.

Test 1 Limitations: For the purposes of test integrity, flight crews performed the drop function using only the stock DJI Inspire 2 and supporting hardware plus the Skyzimir Stork 2 drop mechanism. All Inspire 2 batteries were fully charged at the start of each test. No other software than DJI Go 4 was used in flight to complete Test 1. The RPIC, LoadMaster, and VO were all co-located for the duration of the operation and used verbal communication for Crew Resource Management (CRM).

Test 1 End State: The test was complete when each flight crew attempted one delivery (successful or unsuccessful) at each of the 5 defined locations for a total of 15 dropped packages.

9.2 TEST 2 E-VLOS Operations - Determines variables in performance between Visual Line of Sight (VLOS) operations, and flights where terrestrial obstructions prevented VLOS during the package drop/delivery.

Test 2 Objective: The objective of Test 2 was to determine variables in performance between test operations within visual line of sight of the RPIC, and operations where VLOS of the RPIC is occluded by terrestrial obstructions. Additionally, this test validated the performance of the VO coordination with cross-trained RPIC/VO's, and VO's with limited training and experience.

Test 2 Description: Two DroneUp flight crews performed five deliveries to five locations sequentially. Each of the five delivery locations was positioned behind structures and/or obstacles in a manner to intentionally obstruct the visual line of sight of the RPIC. Each flight crew utilized a downrange VO communicating with the RPIC directly by PTT radio to meet the requirements of FAA rule 107.31(b)(2). The first flight crew consisted of (2) cross-trained RPIC/VO's. We intended the second flight crew to consist of one RPIC and one layperson VO with minimal prior training, but that plan did not get executed. Instead, VO's with Part 107 certificates were used.

Test 2 Location: This test took place at the locations indicated in green in the northeast corner of the map. The takeoff and landing area is marked by the green marker on the southwest corner of the map.

Test 2 Resources: 2 Inspire 2, 2 RPIC/LoadMaster/VOs, 1 Layperson VO, 5 drop locations, communications radios

Test 2 Limitations: For the purposes of test integrity, flight crews performed the drop function using only the stock DJI Inspire 2 and supporting hardware, excluding the drop mechanism. All Inspire 2 batteries were fully charged at the start of each test. No other software than DJI Go 4 was used in flight to complete the operation. The RPIC and VO maintained direct 2-way communication at all times during the test.

Test 2 End 2 State: The test was complete when each flight crew attempted one delivery (successful or unsuccessful) at each of the 5 defined locations.

9.3 TEST 3: Deconfliction – Validate the performance of command and control solutions and automated or manual deconfliction procedures.

Test 3 Objective: A total of 30 flights were flown in Test 3. The objective of Test 3 was to compare deconfliction and delivery results when the flight teams utilized pre-programmed flights to reach and return from the drop target versus manually flying to and from the drop target. The stakes were raised during this test because all 3 teams were to fly simultaneously (the two previous tests had only one team flying at a time).

Test 3 Description: Airboss A directed the first half of Test #3. Dronelink software was used to pre-program each of the 3 flight team's 5 flights, for a total of 15 pre-programmed flights. Each team flew their set of flights from beginning to end simultaneously with the other 2 flight teams. The Dronelink pre-programmed flights were used to control the aircraft takeoff and its flight to and from the target. The pre-programmed flights paused automatically over the target to allow the RPIC and VO to coordinate the manual drop of the package. After the package was dropped, the pre-programmed flights were resumed, which brought the drone back to the takeoff area where it hovered until the RPIC manually landed the drone. Airboss A had pre-programmed the Blue team's flights to go out and back at 175 feet. The Green team's operating altitude was 200 feet and the Yellow team's operating altitude was 225 feet. This pre-programmed separation was intended to assist with deconfliction.

Airboss B directed the second half of Test #3. DroneSense software was used to show the pilots the target location on a map. The pilots flew to and from the target manually at an altitude directed by Airboss B and the flight team handled the package drop manually. Return flights were also flown manually. DroneSense allowed the Airboss to see a dashboard showing a map of the real-time location of each drone and the camera view from all 3 drones simultaneously. This provided the Airboss B a central place to view the status of all the flights in addition to his physical proximity to the crews and radio communication. Airboss B manually deconflicted flights for this half of the test.

Test 3 Location: Each flight crew was assigned one set of drop locations. Yellow was assigned targets 1-1 through 1-5. Green was assigned 2-1 through 2-5. Blue was assigned 3-1 through 3-5. Each flight crew took off and landed in their respective landing areas in front of their canopies at the Launch 2 Area. Each team delivered a package to each of their 5 targets under both Airboss A using Dronelink and Airboss B using DroneSense.

Because all 3 crews were operating at the same time and flying all over the campus, this was a test of airspace deconfliction.

Test 3 Resources: 3 Inspire 2, 30 packages, 6 RPIC/LoadMaster/VOs, 15 drop locations, Dronelink software on all iPad controllers for Test 3A, DroneSense software on all iPad controllers for Test 3B, DroneSense software on a PC for Test 3B, communications radios.

Test 3 Limitations: For the purposes of test integrity flight crews performed the drop function using only the stock DJI Inspire 2 and supporting hardware, excluding the drop mechanism. All Inspire 2 batteries were fully charged at the start of each test. No other software than that being tested (Dronelink and DroneSense) were used in flight to complete the operation. The RPIC and VO maintained direct 2-way communication at all times during the test.

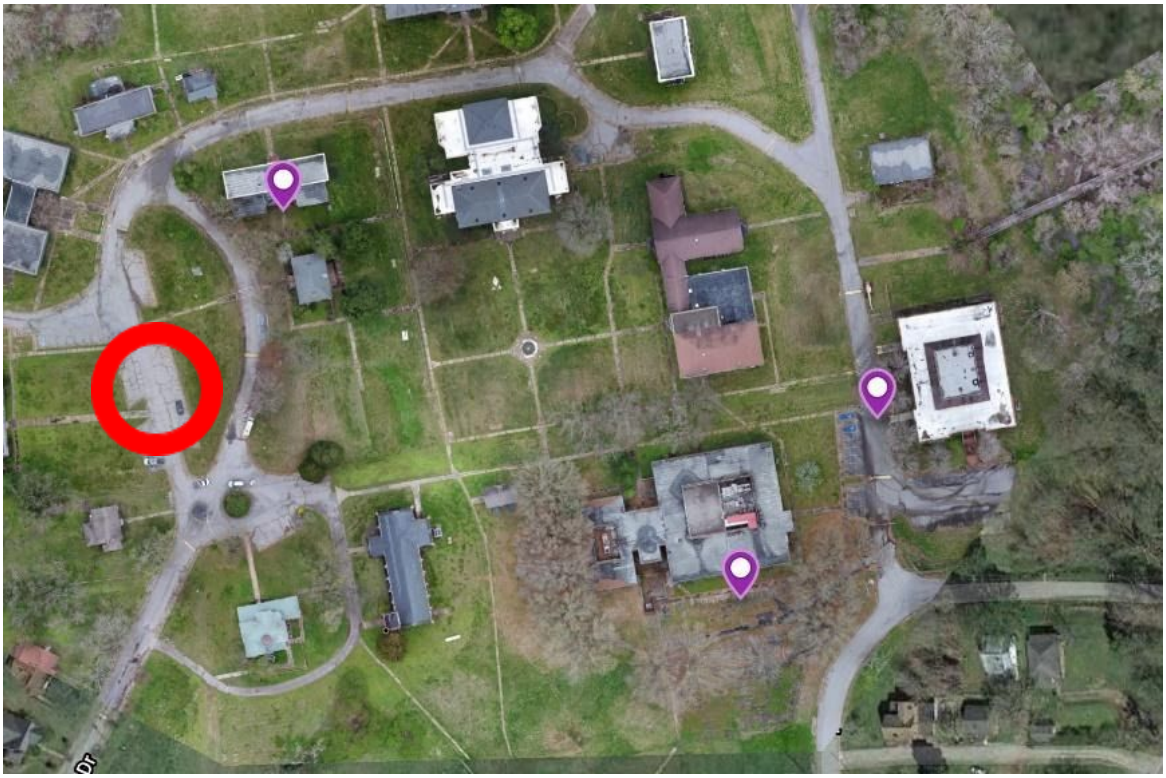
Test 3 End State: The test was complete when each flight crew attempted one delivery (successful or unsuccessful) at each of the 5 defined locations for each half of Test 3, for a total of 15 flights for each team.

9.4 TEST 4: Hazard Scenarios – Determine the performance impact of hazards.

Test 4 Objective: The objective of Test 4 was to validate the adaptability of flight crews in dynamic environments with hazardous and dynamic obstacles.

Test 4 Description: This test challenged the flight crews to deliver in tight spots surrounded by obstacles that were well out of the line of sight, possibly with command and control problems due to buildings. Also, dynamic (moving) hazards were introduced. Each flight crew was required to deliver a package to 3 locations. Pilots were not briefed on what hazards to expect and had to respond to and resolve each hazard in real-time to safely achieve the delivery objective.

Test 4 Location: Each team took off from and landed at Launch Area 2 marked by the red circle and flew to each hazardous target indicated by purple points on the map below (targets 4-1, 4-2, and 4-3).



Test 4 Resources: 3 Inspire 2, 9 Packages, three flight crews (RPIC/LoadMaster/VO), one vehicle, communication radios.

Test 4 Limitations: For the purposes of test integrity flight crews performed the drop function using only the stock DJI Inspire 2 and supporting hardware, excluding the drop mechanism. All

Inspire 2 batteries were fully charged at the start of each test. No other software than DJI Go 4 was used in flight to complete the operation. The RPIC and VO maintained direct 2-way communication at all times during the test.

Test 4 End State: The test was complete when each flight crew attempted one delivery (successful or unsuccessful) at each of the 3 defined locations for a total of 9 flights.

9.5 TEST 5: Cross-Platform Deconfliction

Test 5 Objective: The objective of Test 5 was to identify command and control methods for the deconfliction and management of flight operations of multiple platforms in a confined operating environment.

Test 5 Description: One DroneUp flight crew and one Workhorse flight crew performed deliveries simultaneously to the same locations identified for test 5. As a part of their performance, DroneUp and Workhorse flight crews needed to coordinate with the Airboss to implement tactics to deconflict their operations.

Test 5 Location: Test 5 revisited the yellow and green points from Test 3.

Test 5 Resources: DJI Inspire 2 drone, DroneUp Flight Crew, Workhorse drone, Workhorse Flight Crew, 10 packages, Communications Radios

Test 5 Limitations: For the purposes of test integrity the DroneUp flight crew performed the drop function using only the stock DJI Inspire 2 and supporting hardware, excluding the drop mechanism. All Inspire 2 batteries were fully charged at the start of the test. The Workhorse flight team utilized their standard controller and associated software. No other software was used in flight to complete the operation. The RPIC's, LoadMasters, and VO's all maintained direct 2-way communication with each other and the Air Boss during the test.

Test 5 End State: The test was complete when each flight crew attempted one delivery (successful or unsuccessful) at each of their 5 defined locations, for a total of 5 flights for each of the 2 teams.

9.6 TEST 6: Night Operations – Determine the performance impact of night operations

Test 6 Objective: The objective of Test 6 was to understand the impact of night operations on drone deliveries and determine what different procedures must be implemented to ensure the safety and efficiency of drone deliveries at night.

Test 6 Description: Test 6 was performed identically to Test 2, but flight operations began after evening civil twilight.

Test 6 Location: Test 6 used the same locations identified for Test #2.

Test 6 Resources: 3 Inspire 2, 9 RPIC/Loadmaster/VO's, red night lights for ground vision enhancement, anti-collision lights installed on the drones per FAA regulations, communications radios.

Test 6 Limitations: For the purposes of test integrity flight crews performed the drop function using only the stock DJI Inspire 2 and supporting hardware, excluding the drop mechanism. All Inspire 2 batteries were fully charged at the start of the test. No other software was used in flight to complete the operation. The RPIC and VO maintained direct 2-way communication at all times during the test.

Test 6 End State: The test was complete when each flight crew attempted one delivery (successful or unsuccessful) at each of their 5 defined locations, for a total of 15 flights.

9.7 Proof of Concept 1: Thermal Imagery

Proof of Concept 1 determined how aerial thermography might be used to identify groups of persons who may be in violation of certain state-sponsored quarantine and distancing orders. An Inspire 1 drone outfitted with a FLIR XT thermal camera was used.

Not only was the XT thermal camera able to identify the heat signatures of people at night, but drones themselves were discovered to emit a heat signature that could be readily detected by a pilot viewing the first-person view of what the XT camera was capturing. This is an actual photograph of the Inspire 1 controller viewing the XT camera output.

9.8 Proof of Concept 2: Aerial Broadcast

Proof of Concept 2 determined how aerial broadcasting might be used to warn groups of people of potentially hazardous events without the need for public address system infrastructure, radios, or a functioning communications grid. A Mavic 2 Pro drone was outfitted with its broadcast speaker option and recorded messages were broadcast to the test teams gathered outdoors. The recordings were clearly audible by all attending with the drone at approximately 70 feet of altitude.

9.9 Proof of Concept 3: How loud in Decibels (dB) are Inspire 2 Drones?

Proof of Concept 3 tested how loud the Inspire 2 drones were in delivery operations to ensure that they can operate safely in an emergency delivery environment without damaging the hearing of people nearby. Normal conversation is about 60 dB, a lawnmower is about 90 dB, and a loud rock concert is about 120 dB. The National Institute of Occupational Safety and Health (NIOSH) has established the Recommended Exposure Limit to avoid hearing damage as 85 dB averaged over an 8 hour period. A decibel meter was used to measure the decibels present when the Inspire 2 drone was at various altitudes. Here are the results of the test:

Inspire 2 Drone Sound in Decibels			
	Altitude	Sound	Net Added
Description	(feet)	(dB)	(dB)
Ambient Noise (no drone)	0	42	0
Drone motors idling	0	62	20
Drone hovering	10	68	26
Drone hovering	25	62	20
Drone hovering	50	57	15
Drone hovering	100	50	8
Drone hovering	200	47	5
Drone hovering	250	45	3

Our flight altitudes generally stayed between 150 and 200 feet, so the decibel level of those deliveries was probably in the 47 to 50 dB range. The most decibels anyone would hear were upon landing when the levels reached 68. That is slightly louder than a normal conversation and well below the NIOSH standards for preventing hearing loss.

9.10 Proof of Concept 4: Delivering a package to a Drone Mailbox

Proof of Concept 4 demonstrated the AirBox Technologies solar-powered, secure, Internet-connected delivery receipt box. A signal was sent from the authorized drone operator to open the box, and the package was dropped into it using a controlled magnet at the end of a tether connected to a winch.

10 Schedule of Operations

10.1 Day 1 Tuesday DroneUp Only

0900-1200 DroneUp Set Up	9:00-12:00PM
1200-1300 DroneUp Lunch	12:00-1:00PM
1230-1300 Pilot and VO Registration and Check-In	12:30-1:00PM
1300-1500 Partner Registration and Check-In	1:00-3:00PM
1300-1500 Pilot Briefings	1:00-3:00PM
1500-2100 Orientation Flights	3:00-9:00PM

10.2 Day 2 Wednesday

0800-0930 Day 2 Briefing	8:00-9:30AM
0930-1100 Test 1 (DroneUp)	9:30-11:00AM
1100-1200 Test 1 (Workhorse)	11:00-12:00PM
1200-1300 Lunch	12:00-1:00PM
1300-1430 Test 2 (DroneUp)	1:00-2:30PM
1430-1600 Test 2 (Workhorse)	2:30-4:00PM
1600-1800 Test 3 (DroneUp)	4:00-6:00PM
1800 - 1900 Test 4 (DroneUp)	6:00-7:00PM
1900 - 2000 Dinner	7:00-8:00PM
2100 -2300 Test 6 (DroneUp)	8:00-9:30PM

10.3 Day 3 Thursday

0800-0930 Day 3 Briefing	8:00-9:30AM
0930-1030 Test 4 (Workhorse)	9:30-10:30AM
1030-1230 Test 5 (DroneUp & Workhorse)	10:30-12:30PM
1230-1330 Lunch	12:30-1:30PM
1330-1530 Partner Demos	1:30-3:30PM
1530 -1800 Pack Out and Depart	3:30-6:00PM

11 Testing Results

Forty-five people attended the event, half of whom were Part 107 certified sUAS pilots. The weather was great for an outdoor drone exercise. There were a few periods of rain where flight operations were suspended. Day 3 had windy conditions with gusts over 20 mph.

April 7 (day): 80°, wind 6mph, humidity 40%, visibility 10 miles
April 8 (day): 80°, wind 10mph, humidity 40%, visibility 10 miles
April 8 (night): 65°, wind 5mph, humidity 75%, visibility 10 miles
April 9: (morning): 65°, wind 10mph, humidity 70%, visibility 10 miles
April 9: (afternoon): 75°, wind 15mph, humidity 45%, visibility 10 miles

Over 200 flights were flown and the 90 DroneUp team delivery flights were recorded in detail in the Inspire 2 log files analyzed by AirData software and by human Data Recorders. During the 90 delivery flights, one flight was aborted due to wind instability. The pilot during the one aborted flight dropped the payload near the takeoff area in a controlled drop. Of the 90 delivery flights, the DroneUp pilots successfully dropped the payload within a 10-foot diameter target 90 times for a 100% success rate. Successful demonstration tests included using drone thermal imagery to see humans and drones at night, using a drone as a public address system, measuring drone noise at different altitudes, and delivering a package to an automated drone package mailbox.

Test 1 Results

Test 1 was the baseline with 3 teams each delivering 5 packages for a total of 15 flights, all within VLOS. All 15 drops were within the 10-foot target circle. No demerits were scored. Here are the distance, time, and speed results for the baseline. Test 1 Results will be compared to the more complicated tests to follow.

(All times in minutes)	Test 1	Test 1	
Baseline	Results	Control	Difference
Number of Flights	15	15	0
Distance (total feet)	580.6	580.6	0
Time Ascending (Takeoff)	0.25	0.25	0
Time to Target	0.79	0.79	0
Time on Target	0.68	0.68	0
Time Returning	0.25	0.25	0
Time Descending (Landing)	0.31	0.31	0

Total Elapsed Time	2.28	2.28	0
Speed to Target (mph)	4.8	4.8	0
Speed Returning	15.2	15.2	0
Battery Consumption	10.7%	10.7%	0.0%

This set of flights was easy for the pilots. At this short distance (round trip 581 feet on average) a crew could potentially deliver 4 packages on a set of batteries and 20 deliveries per hour.

Test 2 Results

Test 2 moved the flight crews to the top of the hill and moved the targets to Beyond Visual Line of Sight (BVLOS). The distance was increased by 81% to a 1052 foot round trip (about three times the length of a typical city block). All 15 drops were within the 10-foot target circle. No demerits were scored. Here are the results compared to the baseline of Test 1.

(All times in minutes)	Test 2	Test 1	
BVLOS	Results	Control	Difference
Number of Flights	15	15	0
Distance (total feet)	1052.4	580.6	471.8
Time Ascending (Takeoff)	0.49	0.25	0.24
Time to Target	0.91	0.79	0.12
Time on Target	1.75	0.68	1.07
Time Returning	0.47	0.25	0.22
Time Descending (Landing)	0.38	0.31	0.07
Total Elapsed Time	4.00	2.28	1.72
Speed to Target (mph)	7.5	4.8	2.7
Speed Returning	14.5	15.2	-0.7
Battery Consumption	19.3%	10.7%	8.6%

For Test 2, the increased distance of 81% combined with the introduction of a VO guiding the drop increased the elapsed time by 75%. The speed to and from the target actually increased, possibly due to practice. However, because the target was BVLOS, the time on target, as expected, more than doubled to almost 2 minutes. Under these conditions, a crew could potentially deliver 4 packages on a set of batteries and an estimated 13 to 15 deliveries per hour.

Test 3A Results

Test 3A introduced pre-programmed flights to and from the target and remained BVLOS. This was the first test where all 3 crews flew at the same time. Deconfliction was accomplished in the pre-programmed flights by having each team fly at pre-set altitudes 25 feet vertically apart (175, 200, and 225). The distance for the 15 flights was increased on average by 54% over Test 1. All drops were within the 10-foot target circle. No demerits were scored. Here are the Test 3A (Pre-programmed) results compared to the baseline of Test 1.

(All times in minutes)	Test 3A	Test 1	
Pre-Programmed	Results	Control	Difference
Number of Flights	15	15	0
Distance (total feet)	893.2	580.6	312.6
Time Ascending (Takeoff)	0.43	0.25	0.18
Time to Target	0.88	0.79	0.09
Time on Target	2.58	0.68	1.9
Time Returning	0.42	0.25	0.17
Time Descending (Landing)	0.79	0.31	0.48
Total Elapsed Time	5.10	2.28	2.82
Speed to Target (mph)	5.8	4.8	1
Speed Returning	12.8	15.2	-2.4
Battery Consumption	24.2%	10.7%	13.5%

Test 3A, on average, took over twice as long to complete than Test 1. The battery consumption went up as the speeds that were programmed to be conservative were slower than what the pilots flew manually. The elapsed time per flight went up 28% compared to test 2 even though the distance was shorter. Under these conditions, a crew could potentially deliver 3 packages on a set of batteries and an estimated 10 to 11 deliveries per hour.

Test 3B Results

Test 3B eliminated pre-programmed flights and remained BVLOS. The targets were the same as in Test 3A. This test used DroneSense software, which identified the target on the flight controller map with a pin, which helped the pilots find it faster than a pure manual flight. DroneSense also provided the Airboss with a dashboard to view the location of each drone on a map and the video feed from each drone. This was the second test where all 3 crews flew at the same time. Deconfliction was accomplished by the Airboss setting flight altitudes on the fly.

The distance for the 15 flights was increased on average by 54% over Test 1 and the same as Test 3A. All drops were within the 10-foot target circle. No demerits were scored. Here are the results compared to the baseline of Test 1.

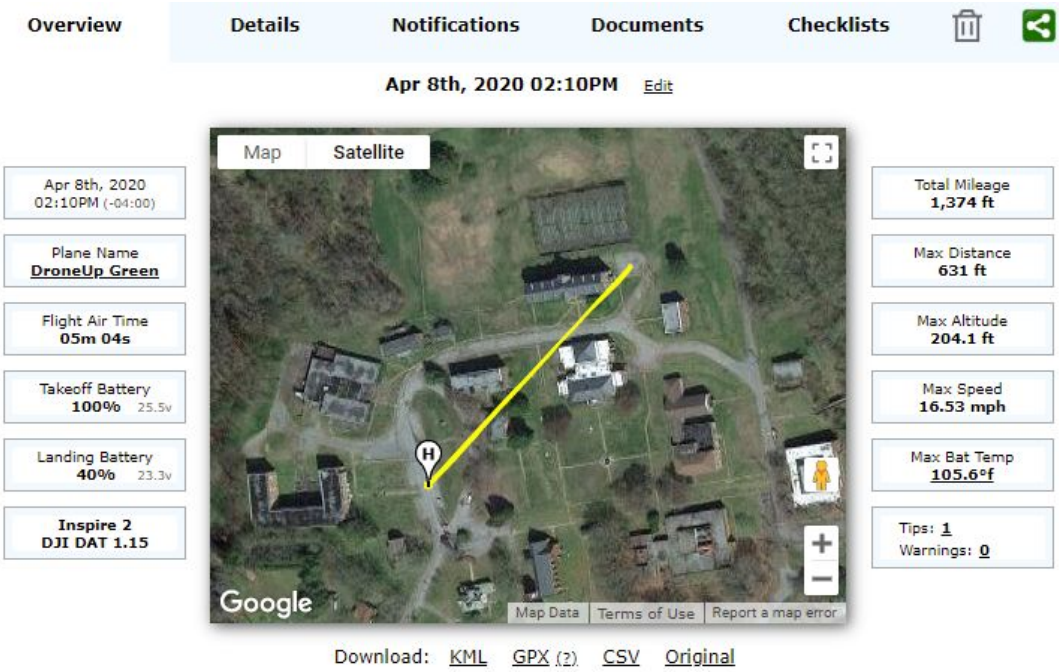
(All times in minutes)	Test 3B	Test 1	
Manual with Dashboard	Results	Control	Difference
Number of Flights	15	15	0
Distance (total feet)	893.2	580.6	312.6
Time Ascending (Takeoff)	0.85	0.25	0.6
Time to Target	1.14	0.79	0.35
Time on Target	2.13	0.68	1.45
Time Returning	0.42	0.25	0.17
Time Descending (Landing)	0.5	0.31	0.19
Total Elapsed Time	5.04	2.28	2.76
Speed to Target (mph)	6.6	4.8	1.8
Speed Returning	14.9	15.2	-0.3
Battery Consumption	22.0%	10.7%	11.3%

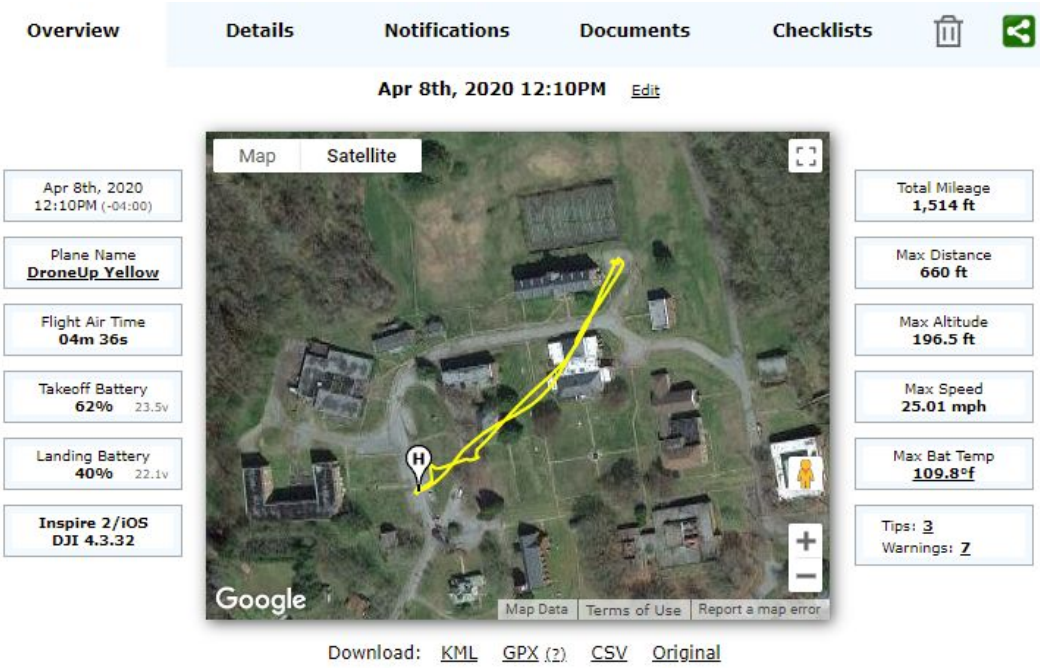
It is interesting to compare tests 3A and 3B, which shared the same targets. The flights during 3A used pre-programmed flights and the 3B flights were manual. Here is the comparison.

(All times in minutes)	Test 3A	Test 3B	
Pre-Programmed v Manual	Results	Results	Difference
Number of Flights	15	15	0
Distance (total feet)	893.2	893.2	0
Time Ascending (Takeoff)	0.43	0.85	-0.42
Time to Target	0.88	1.14	-0.26
Time on Target	2.58	2.13	0.45
Time Returning	0.42	0.42	0
Time Descending (Landing)	0.79	0.5	0.29
Total Elapsed Time	5.10	5.04	0.06
Speed to Target (mph)	5.8	6.6	-0.8
Speed Returning	12.8	14.9	-2.1
Battery Consumption	24.2%	22.0%	2.2%

The total elapsed times are similar for both tests but there are significant differences in the components that make up the total times. For example, ascent time in Test 3B was slower than 3A due to at least one pause to deconflict air traffic at the takeoff and landing zone. The time to target was slower in 3B than the pre-programmed flights in 3A. But, the Time on Target for 3B was 21% less than 3A. Under these conditions, a crew could also potentially deliver 3 packages on a set of batteries and an estimated 10 to 11 deliveries per hour.

Here are two flight recaps from the AirData software we employed to analyze the flights. The first image shows a flight to target 2-3 using Dronelink and the second shows a flight to the same target flown manually. Both flights are at approximately 200 feet altitude but the manual flight wandered a bit along the way and back, adding 30 feet to the overall trip. The pilot flew manually at a maximum speed of 25 mph while the pre-programmed flight was set to a maximum of 16 mph.





Test 4 Results

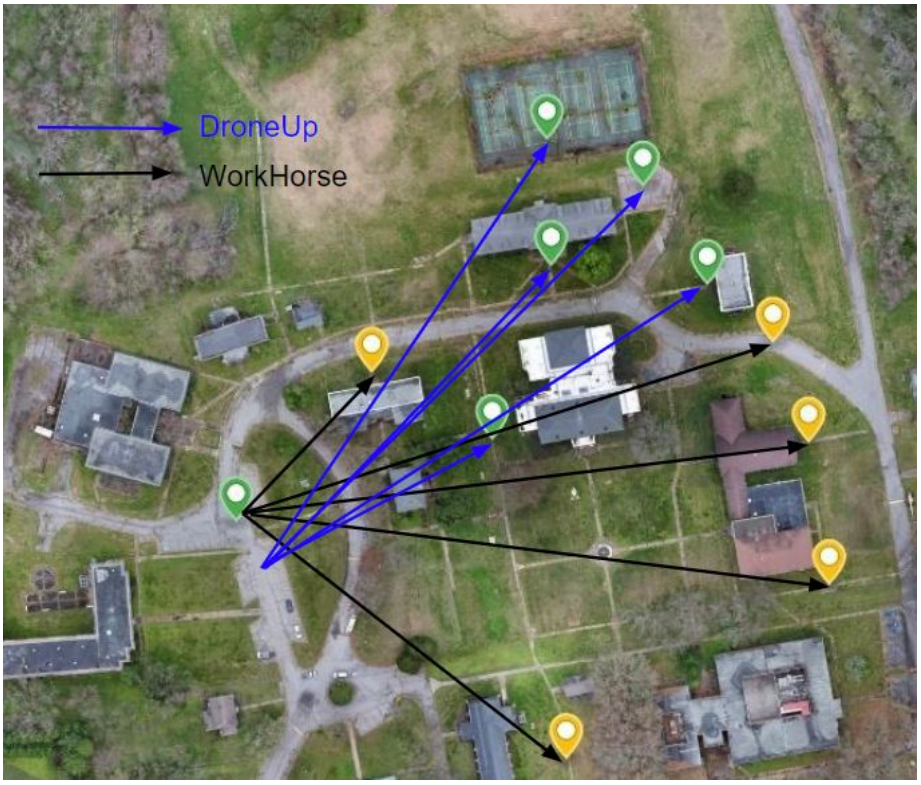
Test 4 was designed to add tight and dynamic obstacles to the delivery target areas to see if the pilots and VO's could successfully navigate over and around the obstacles. Each team delivered to 3 targets (4-1, 4-2 and 4-3) for a total of 9 deliveries. All drops were within the 10-foot target circle. No demerits were scored. It was anticipated that the time on target would increase, especially when a dynamic obstacle (a car) blocked the target.

(All times in minutes)	Test 4	Test 1	
Difficult with Obstacles	Results	Control	Difference
Number of Flights	9	15	-6
Distance (total feet)	1094.7	580.6	514.1
Time Ascending (Takeoff)	0.57	0.25	0.32
Time to Target	0.85	0.79	0.06
Time on Target	2.36	0.68	1.68
Time Returning	0.36	0.25	0.11
Time Descending (Landing)	0.36	0.31	0.05
Total Elapsed Time	4.50	2.28	2.22
Speed to Target (mph)	8.4	4.8	3.6
Speed Returning	17.5	15.2	2.3
Battery Consumption	20.8%	10.7%	10.1%

As expected, the Time on Target for Test 2 was 2.5 times greater than for Test 1 and almost as long as Test 3A. Speeds to and from the target by the pilots flying manually continued to increase over the previous tests. Battery consumption, on average, was twice that of Test 1. Under these conditions of tight and dynamic obstacles, a crew could also potentially deliver 4 packages on a set of batteries and an estimated 13 to 14 deliveries per hour.

Test 5 Results

Test 5 tested deconfliction between a single DroneUp flight crew and the Workhorse flight crew operating in adjacent and potentially conflicting airspace. Each team delivered to their own set of 5 targets at the same time for a total of 10 deliveries (the granular results below include only the DroneUp flights). The average elapsed time per delivery was 4.8 minutes for Workhorse during this test versus 4.5 minutes for DroneUp. There were no deconfliction problems. The Airboss was successfully able to deconflict the airspace with both teams being on radio communications. Both flight teams operated in the adjacent and overlapping airspace together for 21 minutes. All drops were within the 10-foot target circle. No demerits were scored. Here is a diagram showing the launch and target areas for this deconfliction test.



(All times in minutes)	Test 5	Test 1	
Deconfliction	Results	Control	Difference
Number of Flights	5	15	-10
Distance (total feet)	1052.4	580.6	471.8
Time Ascending (Takeoff)	0.58	0.25	0.33
Time to Target	0.71	0.79	-0.08
Time on Target	2.3	0.68	1.62
Time Returning	0.31	0.25	0.06
Time Descending (Landing)	0.59	0.31	0.28
Total Elapsed Time	4.49	2.28	2.21
Speed to Target (mph)	8.9	4.8	4.1
Speed Returning	19.5	15.2	4.3
Battery Consumption	21.3%	10.7%	10.5%

This test replicated the target locations that a DroneUp team delivered to test 3B. In Test 5, the DroneUp team was slower getting to the target, faster on the target, and the same speed returning. DroneUp's total elapsed time per flight was 24 seconds slower in this set of flights versus the same flights in 3B. The Airboss for this test noted that there were times he had to ask the DroneUp team to "climb and hold" because the Workhorse team was slow to respond to radio requests. Additional or more comprehensive training on radio operations may have mitigated this problem. In any case, having disparate teams operating in the same airspace did slow down the delivery pace.

Test 6 Results

Test 6 was night operations. Four of the 8 members of the pilot teams had FAA Part 107.29 Daylight Waivers and previous night flying experience. All members had passed a night operations training webinar put on by the DroneUp Airboss on April 6 (average score 92%). Flights were flown with anti-collision lights and down-pointing searchlights. The target locations for the 15 deliveries in Test 6 were locations 3-1 through 3-5. All 15 payloads were delivered within the 10-foot target circle. No demerits were scored. The average statistics for Test 6, which are all-night flights, are presented below and compared to the average of all-day flights

(All times in minutes)	Test 6	All Day	
Night	Results	Flights	Difference
Number of Flights	15	75	-60
Distance (total feet)	1046.6	898	148.6
Time Ascending (Takeoff)	0.53	0.52	0.01
Time to Target	0.55	0.90	-0.35
Time on Target	2.59	1.89	0.7
Time Returning	0.38	0.38	0
Time Descending (Landing)	0.55	0.48	0.07
Total Elapsed Time	4.60	4.17	0.43
Speed to Target (mph)	11.4	6.6	4.8
Speed Returning	16.6	15.1	1.5
Battery Consumption	24.3%	19.4%	4.9%

Comparing night flights to daily flights, the night flights were, on average, 26 seconds or 10% longer than the day flights. This was due to an extra 43 seconds spent on target at night. The pilots reported not being able to see the drop zone target until they were close to the ground while flying at night. Interestingly, the speeds to target and back to base were faster at night. This may be explained by pilots not being able to judge their speed against the stationary terrain which they cannot see at night. In DroneUp's training of pilots new to night operations, flying faster than usual has been consistently observed. We suspect this demonstrates a general weakness in instrument proficiency, which is required at night when there are fewer visual cues.

Test 7 Results

Test 7 was one flight conceived by the CEO of DroneUp to be an extremely difficult challenge. It was night. It was in extremely tight spaces with multiple obstacles. The VO was a layperson on a cell phone and there was an imposed deadline due to the scenario of delivering snake antivenom to a clinic under quarantine.

The Blue team executed Test 7 with flying colors. The layperson, a Brunswick County Deputy Sheriff, was escorted to a building and told it was a clinic and he had to direct an incoming drone that was delivering snake antivenom and it had to be there within 10 minutes. Aided by his public safety background, the LoadMaster was able to direct the Deputy to shine his flashlight first up in the air to locate the clinic and then down on the landing spot to provide

the target. The Deputy spoke to the LoadMaster on the phone and the LoadMaster relayed instructions to the RPIC. The team was able to successfully avoid the very tight tree and building obstacles and the package was delivered in less than 4 minutes. The night emergency drop zone was in this courtyard next to the doors.

(All times in minutes)	Test 7	Test 1	
Night Courtyard	Results	Control	Difference
Number of Flights	1	15	-14
Distance (total feet)	1044.0	580.6	463.4
Time Ascending (Takeoff)	0.53	0.25	0.28
Time to Target	0.38	0.79	-0.41
Time on Target	1.95	0.68	1.27
Time Returning	0.27	0.25	0.02
Time Descending (Landing)	0.22	0.31	-0.09
Total Elapsed Time	3.35	2.28	1.07
Speed to Target (mph)	15.5	4.8	10.7
Speed Returning	22.2	15.2	7
Battery Consumption	18.00%	10.7%	7.27%

Combined Test Results

Here are combined statistics and results on the 90 delivery flights completed by DroneUp using the Inspire 2 drone during Operation Last-Mile: Critical Drone Delivery.

(All times in minutes) *Night*	All Flights	Day Flights	Night Flights	Manual Flights	Pre-Programmed Flights	Line of Sight	Beyond Line of Sight
Number of Flights	90	75	15	75	15	15	75
Distance (total feet)	924	898	1046	930	893	581	993
Time Ascending (Takeoff)	0.52	0.52	0.53	0.54	0.43	0.25	0.57
Time to Target	0.84	0.90	0.54	0.83	0.88	0.79	0.85
Time on Target	2.01	1.89	2.55	1.89	2.58	0.68	2.27
Time Returning	0.38	0.38	0.37	0.37	0.42	0.25	0.40
Time Descending (Landing)	0.49	0.49	0.53	0.43	0.79	0.31	0.53
Total Elapsed Time	4.24	4.18	4.52	4.06	5.10	2.28	4.62
Speed to Target (mph)	7.5	6.6	11.7	7.9	5.8	4.8	15.2
Speed Returning	15.4	15.1	17.0	15.9	12.8	15.2	15.5
Battery Consumption	20.20%	19.4%	24.3%	19.5%	24.2%	10.7%	22.1%

As expected, speeds returning without a payload were faster than speeds carrying the payload. Time over the target at night was 37% greater than during the day due to reduced visibility of the target at night. The pre-programmed flights (automatically flying the drone to and from the target) were a full minute (24%) longer than manual flights. This is due to higher programmed altitudes and slower speeds compared to pilots flying manually.

- Battery consumption on the Inspire 2 drone for these 4.2-minute flights averaged 20.2%. That means, on average, a team could complete (3) of these 1000 foot round trip missions before having to change out the batteries.
- Automation can be valuable for drone delivery to ensure that the drone reaches its target and returns to base efficiently. However, the actual drop decision and execution needs to remain with the pilot and VO if the drop area is dynamic and subject to conditions outside of anyone's control, such as people and vehicles being present.
- Radio communication protocols were developed on-the-fly during the exercise. We want to establish operating procedures for radio communication between Pilot, LoadMaster, and VO so that common jargon and procedures are used.

- Maintaining command and control of flight operations is critical. During operations with simultaneous multiple flights, the software can be used to assist the situational awareness of the commander. Consolidated video feeds from active drones are a good start.

12 Lessons Learned

Summary of Lessons Learned

Many participants reported that the exercise was a great experience and success. The consensus is that commercial drones can be used to deliver critical supplies over distances of less than a mile by Part 107 pilots not specifically trained in these types of operations prior to being called into service. But, this first-of-its-kind exercise was intended as a testing and learning opportunity and there were many lessons learned.

One of the common comments was, "we'd never actually deliver to drop zones so close to obstacles". This is absolutely true. In a real-world scenario, drop zones would be chosen that were out in the open, away from power lines, buildings, and trees. DroneUp purposely designed the (7) tests to be more difficult than would be experienced in the real world so we could be confident that our success would carry over into the real world. Another common observation was that we would not be able to rely on highly qualified VO being so close to the drop zones in a quarantine situation. This observation is also valid. But, we performed the most difficult test, a night drop surrounded by tight obstacles, with a layperson VO and it was a success. After observing and listening to the communication for 100 deliveries, we believe that an experienced RPIC or LoadMaster can quickly coach a layperson VO on how to provide valuable directional and altitude feedback during the drop operation. This is especially true if the volunteer VO has a public safety background or another rigorous background such as working in the medical field.

Communications

The most common recommendations came in the area of communication. Feedback was provided on phrases and words used, team communication, and the use of radios. Here, observations and recommendations regarding communication from the Operation Last-Mile participants.

- *Drop Zone Takeover:* To position the drone for a drop, VO's must clearly accept responsibility-for and then take over the process of guiding the drone by providing concise direction to the RPIC. To coordinate this hand-off, the RPIC should say a pre-agreed command, such as, "Green VO, Green Base...Take us in." This lets the VO know that he has control of where the drone goes to line up for and make the drop. It would be good for the flight teams to practice the mission communication via role play

prior to having a drone in the air. Our Director of Training pointed out that the Part 107 pilot certificate is the only one that does not require a demonstration of Crew Resource Management. He suspects that many Part 107 pilots aren't prepared for or comfortable with the idea of delegating some of their authority to another crew member. He believes the drone industry needs to adopt a practical test as part of Part 107 certification so pilots can demonstrate their Crew Resource Management.

- *Drop Zone Position Guidance:* When the pilot tells the VO to "take us in", the VO should start with altitude and obstacles, such as, "80 feet, clear of obstacles". Then the VO should provide short, active direction guidance, such as "descend slowly", "right 10 feet", "hold there", "you have trees on the left". From 100 feet down, the VO should call out altitudes at 10-foot increments. At 20 feet, the VO should start counting down altitude in smaller increments, such as 15, 10, 8, 6, 4, and then 2 feet. The pilot knows to hold at 2 feet and the VO commands, "drop, drop, drop". The pilot raises the landing gear and the package drops. The VO declares, "good drop" and checks airspace surroundings. One pilot suggested referring to obstacles in general as the situation is green (clear of all obstacles), yellow (no obstacles in the immediate vicinity), and red (go slow; close to obstacles). We should discuss that.
- *Return to Home guidance:* When the VO is satisfied the airspace is clear after the drop, he radios, "Green Base, Green VO...you are free of obstacles overhead. Ascend to return altitude". The pilot ascends to return altitude, orients the drone to face home, and begins bringing the aircraft home. The VO continues to monitor the flight until the LoadMaster indicates that he and the pilot have sight of the drone. "Green VO, Green Base...we have visual on the Green drone". At that point, the VO's responsibilities for the flight are over. Our teams were not as consistent on this return handoff as they were on the "to-target" handoff.
- *Drone Orientation:* Everyone agreed that the VO should use the commands "forward", "back", "up", "ascend", "down" and "descend". The pilot teams had differing ideas on how the VO should direct the left and right movements. Some preferred using a convention of pointing the drone due North once over the target and then using the compass directions to direct the pilot. But since the heading is not readily displayed on flight control screens, this would require the pilot to take time to orient the aircraft according to the map, which would take extra time. Some teams preferred having the VO take note of the nose of the aircraft and provide "left, right, forward, back" commands from the same viewpoint as the pilot. Additional field testing and/or consultation with more drone pilots are in order. The author prefers the commands, "roll right", "roll left", "forward", "reverse", "up", "down", "yaw left" and "yaw right" based on the orientation of the nose of the aircraft at the time of the communication, regardless of the heading.
- *Radios:* We had 20 radios on site. Each flight team member had a radio. These radios were a lower end, 15 channel Push to Talk (PTT) radios that did not support listening to 2 channels at a time. When only one flight team was operating, the radios worked

great. However, when 3 teams were operating simultaneously and multiple drops were occurring at the same time, it did not work for everyone to be on channel 3. The Airboss spontaneously allowed teams to move to their own dedicated channel. Since the RPIC and LoadMaster each had a radio, they could tune to both channels and communicate with the Airboss and their VO. This worked OK for 3 teams. A pilot cautioned that bad actors could disrupt radio communications if we used radios without dedicated bandwidth and less expensive radios are not going to work if there is great building density. If a delivery assignment were to be longer-term, a more expensive, and flexible radio system would be good to have.

- *Radio Comms Training:* The public safety and former military personnel were good at radio communication. The less experienced pilots struggled to stay off the mic and make their communication concise. The pilot orientation should include a more thorough discussion of radio protocol and role-playing with radios prior to commencing flight operations. DroneUp also wants to participate in the industry in establishing a common vocabulary and syntax for radio communications during drone operations.
- *Sterile Cockpit:* Manned aircraft guidance is that no extraneous chatter occurs in the cockpit. The same guidance applies to RPIC and LoadMaster operating a drone, particularly when the drone is beyond visual line of sight. This concept was explained in the pilot briefing but a number of pilots noticed that we were lax on this requirement at times. This is especially important during periods of multiple simultaneous drone flights.
- *Building Side Firefighter Jargon:* Firefighters are trained that the wall where the front door is located is called the "alpha" side of the building. Then if you are looking down and going clockwise from there, the walls are called bravo, charlie, and delta. This kind of convention would come in handy as pilots and VO's are discussing drop locations and drone orientation compared to adjacent buildings.

Equipment

The pilots liked flying the Inspire 2 drone and they were familiar with DJI flight controller software. These recommendations were provided by the participants.

- Tether: Test different tether lengths to see how they affect airworthiness (DroneUp has done some testing in this area and for the Inspire 2, the 8-foot tether seems to be the sweet spot to cause the least amount of oscillation). We also should test a break-away tether that would release from the drone if a specific amount of force were exerted on it (i.e., a person grabs it).
- iPads: Provide backup iPads if the weather is warmer. They notoriously overheat in warm conditions.

- Batteries:
    - The Inspire 2 requires 2 batteries to fly and they are set up in pairs that are designed to stay together as pairs for their life cycle.
    - We may want to issue battery hot-swap instructions to the pilots so they do not have to go through a power-down/power-up cycle between battery changes. That could speed up turnaround time when battery changes are required.
    - We noted that a few of the batteries heated up beyond ideal operating temperature (104°F). The batteries will flash specific patterns on the LED charge indicators when there is a high-temperature problem.
    - Charge time on the Inspire 2 batteries is 90 minutes per pair and two batteries can be charged at a time with the charger that comes with the aircraft.
    - Charge time on the remote controller is 3 hours and it can be used for 4 hours after being fully charged.
    - At lower than 59°F, the Inspire 2 batteries will warm themselves up to 68°F before they can be used in flight. It stayed warmer than 59° for this operation but had it been colder, the batteries would have ideally been kept at 68° or warmer.
- Goggles: Test First Person View Goggles since we have a VO on both ends of the flight (LoadMaster on the launch end and VO on the target end).
- Screens: Issue screen hoods for the iPads or provide Crystal Sky controllers to allow better visibility of the flight controls in sunny conditions.
- Spectrum Analyzer: Operate and monitor a radio spectrum analyzer before and during operations to ensure that any radio signal conflicts are identified and mitigated to avoid loss of control to aircraft. At the drop zone 3-2, the target was directly behind 100 feet of a concrete block building in relation to the takeoff zone. When the drone dropped below 20 feet, teams experienced some controller signal drop-out. This did not cause any drop attempts to be aborted, but it did account for extra time on target. A few times the DroneUp Blue team noticed controller signal glitches when the adjacent Workhorse flight team began operating. A spectrum analyzer could help diagnose situations like this and avoid potential problems.
- Multiple Drones: The Inspire 2 operates at either the 2.4 GHz or 5.8GHz bandwidth ranges. One pilot pointed out that DJI recommends limiting the number of their drones operating within the size of a soccer field to 3 at the same time to prevent radio interference. We had very few controller signal problems but we did notice some 1-2 second drop-outs of video signal when more than 3 drones were operating at the same time in the same general area.
- Stripes: The colored stripes on the drones were not discernible unless the drones were close. This did not cause any problems but the stripes helped only when the drones were on the ground, not when they were in the air.

- Controller Settings
    - Gain: Based on our delivery experience with the Inspire 2 drone, we instructed the pilots at orientation to adjust the automatic controller gain to 80% versus 100% so that the aircraft did not overcorrect oscillations caused by the payload tether being attached. A couple of pilots suggested eliminating that adjustment to allow a quicker response to the drone since we were flying near obstacles. It was suggested to use "tripod mode" only when landing as a compromise. A pilot said he tried that on the windiest day and it hampered handling. So this all needs to be tested, possibly with a multiple drop test just staying over the target and dropping multiple times with different settings.
    - Grid: It is recommended that the screen grid be turned on to help pilots know where the center of the screen is.
    - Nadir Lock: It is recommended that the Inspire 2 camera be set to lock its travel to prevent going beyond nadir (straight down). It is also recommended to instruct the pilots to set their C1 or C2 switch at the bottom of the controller to be a preset nadir/horizon toggle. This will allow the pilot to quickly change from looking at the surroundings to looking down at the payload/target and then back again.
- Personal Protection Equipment: VO's near the drop target should be wearing personal protective equipment or PPE (vest and helmet). We didn't fly over people but if the VO's are in proximity of the drop zone, they should be wearing PPE. We had one instance where, for sake of speed, the LoadMaster instructed the pilot to hover to allow connection of the next tether. This was an unwise operating practice that we prohibited from that point forward. We should discuss if the RPIC and LoadMaster should also wear protective gear.
- Chem Lights or Brighter Drone Down-Lights: The targets were difficult for the RPIC to acquire at night. A number of pilots suggested having the VO's drop chemical lights on the targets or using brighter downward-facing lights on the drones.
- Canopies for Pilot Teams: We had a couple of rain squalls that interrupted flight operations and we had windy conditions that threatened to damage the canopies. Future events would include planning for better securing the canopies. It was noted that the Blue Team used surplus delivery bags and sand payload bags to hang weighted bags on their canopy to provide stability in the wind.
- Parabolic Antenna: It was suggested we test antennas that would enhance controllers to aircraft signal integrity.
- Audio Recording in Proximity of Controller: It was suggested we investigate software that records the audio in the immediate vicinity of the aircraft controller. We utilized AirData software to examine the log files to recreate the flights but we did not have audio recordings.

Payload

- Shape: Test different payload shapes and containers.
- Winch: Test a winch system for dropping the payload so the payload is closer to the drone during flight for better stability and less drag.
- Bags: Test cinching the bag so it did not catch the downward prop wash.

Drop Zones

- Target Size and Markings: In the real world, larger, wide-open drop zones without exact targets would be used. This would reduce time on target because less time would be spent avoiding obstacles and trying to drop inside an exact 10-foot diameter circle in the wind. Instead, the VO would verify that the drop area is safe, talk the pilot down to a safe drop altitude and declare, "drop, drop, drop". After the rain, some of the targets needed to be repainted. Some of the targets were too close to obstacles to be realistic. However, the pilots and VO's demonstrated their flying and communication skills by successfully dropping on all targets.
- Controller to Aircraft Signal Drop-Out at Drop Zone: We did not have many problems with this, but we did see some second-long video link dropouts when the drop zone was behind a building. We should establish and brief the pilots on proper procedures if dropping in the drop zone is not feasible. For example, they could change the drop zone at the VO's discretion.

Weather

- Wind Limit: We tested in various wind conditions and there were some times when the Airboss briefly suspended flight operations while he tested wind speeds with a hand-held anemometer. We did not establish a firm threshold for steady or gusting winds beyond which we would not fly. We likely would establish that in advance for future exercises. Another option we will consider and test in the future is using data from just-completed flights in the current environment to determine winds aloft.
- Storm Interruption: Just as day 2 was kicking off, a storm blew through and everyone had to shut down, pack up and find shelter. We responded well to the situation but we should have briefed everyone ahead of time on what to do, who was responsible for what and exactly where we would shelter in the event of a storm.

Visual Observers in the Field

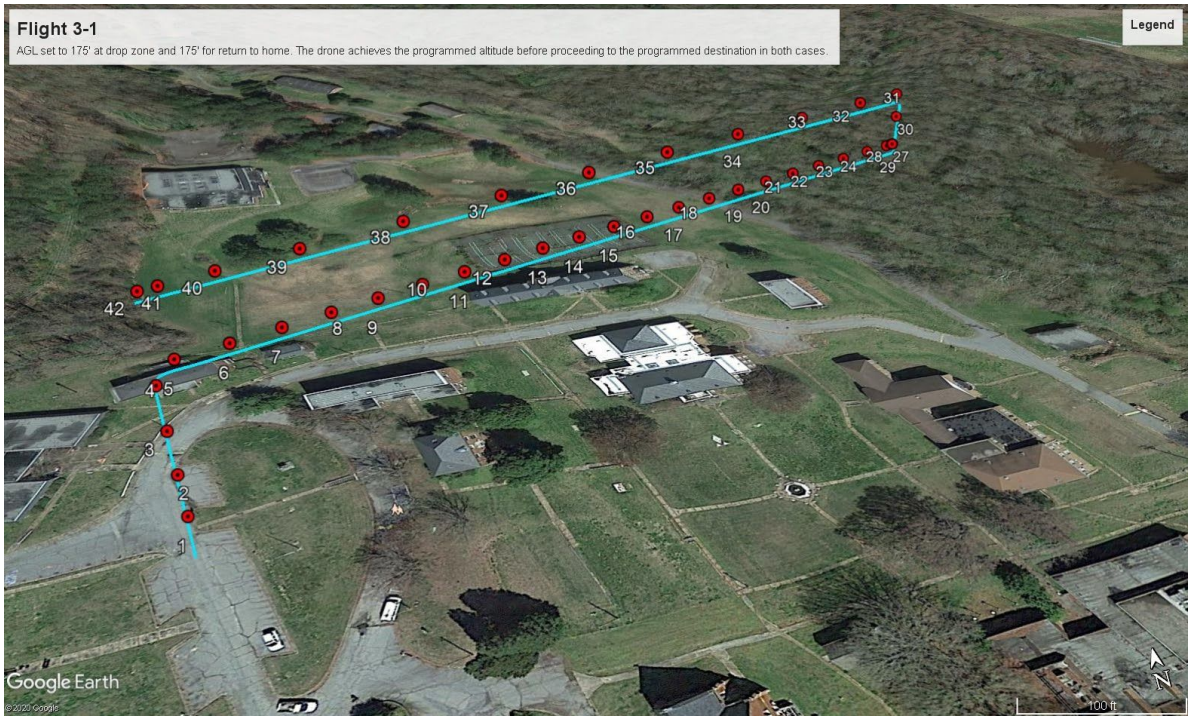
- Team VO's: The pilot teams rotated into the role of VO (the Blue Team utilized DroneUp employees who rotated in as their VO). A pilot suggested that for consistency's sake, we potentially should have trained the VO's on their roles and positioned them centrally in the landing areas rather than have a VO for each team.
- Layperson VO's: We had one exercise where a layperson VO directed the pilots to a night drop. We had intended to use additional laypersons as VO and in a similar exercise in the future, we should do that.

Operating Procedures

- Checklists: The Airboss provided preflight checklists on paper which were taped to the tables under the pilot canopies. However, the pilots stood facing away from the tables and the checklists appeared to go unused. In future exercises, a system must be selected from the myriad of options to ensure that pilots use checklists for preflight, postflight, and maintenance checks during the exercise, and the Airboss must enforce their use.
- TakeOff and Landing Zones: A number of people noted that we did not cordon off the takeoff and landing zones as definitively as we might have to ensure safety and limit pilot distractions.
- "Slow is smooth, smooth is fast": The Blue Team featured two firefighters who were used to high-stress situations. Their flight time to target, time on target, and flight time home were the best among the teams. They attributed their performance to the rigors of firefighter training in communications and operations. They know that repeating processes is the key to consistent performance. Their communications were low key and concise. They talked about and pre-planned their moves before they started the motors. For example, they studied the maps the most before beginning flights. The non-public safety pilots caught on relatively quickly but the training and experience that current or former public safety members lend themselves to successful pilot operations.
- Fly to the Furthest Target First: When the goal is to fly to multiple targets as efficiently as possible, fly to the furthest targets first. Let's say that consumes 25% of your battery. Then you fly to a closer target and it consumes 20%. You're at 45% when you go to the third, even closer target. You might be at 30% and be able to get that 4th flight in on that battery. If you went in the other order, you'd never attempt that furthest drop on less than 40% battery, so you'd change out with a lot of battery left.
- Cheating on the Takeoff/Return Altitude: For most flights, the Airboss directed the pilots to take off and achieve a certain altitude before proceeding to their targets. The Airboss also directed pilots to return to base at a certain altitude and then descend straight down to their takeoff/landing pad. It was observed that on manual flights the pilots sometimes cheated on both the takeoff altitude and the return altitude. In other words, they flew toward their targets before achieving the specified altitude and started descending upon return before being directly over the takeoff/landing pad. This was highlighted in the pilot briefings but may need to be reinforced more strongly and frequently to ensure altitude deconfliction in all cases.

Pre-Programmed Flights

- Aeropoint Ground Control Points (GCP's): Test 3A was the first test that called for all 3 drones to be operating at the same time. We established latitude and longitude coordinates for all 19 targets by placing Aeropoint Ground Control Points (GCP's) on all the targets on April 6. We supplied the GCP data for all the targets to Workhorse to use in their autonomous flight planning software. We also plugged the coordinates into Dronelink autonomous flight planning software for Test 3A.
- Dronelink Software: For Test 3A, we used Dronelink flight controller software to pre-program each team's 5 flights for a total of 15 flights. As mentioned in the test description, each team had an operating altitude of 175, 200, and 225 feet respectively. The flights to the target and back to base were pre-programmed. The pilots were to descend over the target and drop the payload manually and land the drone back at the base manually. Lessons learned from the use of Dronelink:
    - Only one of the 8 pilots had used Dronelink before so a brief orientation was held. More time might have been allocated for this training.
    - The Airboss for this Test was familiar with Dronelink and had programmed all the flights. However, he had set the target altitude to "AGL" (above ground level). The way the software works, the drone takes off and ascends to an altitude that allows a level flight to the desired target altitude. In this case, the target AGL was programmed at 175 feet. The takeoff area was 35 feet higher than the target area. So at takeoff, the drone ascended to 140 feet and then started flying to the target. By the time the drone would reach the target with level flight, it would be at the programmed 175 feet AGL. The pilot, watching his altitude, saw that the drone started flying "too early", at an altitude of 140 feet, which was lower than the 175-foot operating altitude directed by the Airboss. So the pilot prudently paused the autonomous flight and reported the error in altitude. The other flight teams reported similar "errors" in their initial pre-programmed flights. But it turned out the problem was the Airboss misunderstanding how the software worked rather than an error in the software. Because the altitudes were set substantially higher than required to miss obstacles, all flights resulted in successful drops. In hindsight, the Airboss should have suspended Test 3A until the software problem was understood rather than wait to see how things went. This image shows the path for the pre-programmed mission when the target altitude and return altitude are set to 175' AGL but the target is 35 feet below the takeoff point.



- All pre-programmed flights went directly to the appropriate target. Once resumed above the target, the pre-programmed flights all returned directly to the takeoff point.
- The pre-programmed flights were, on average, 52 seconds longer than the manual flights. Thirty-four of those extra seconds occurred over the target because the arrival altitude was higher on average than manual flights and there was a learning curve navigating the "pause for landing" and resume features. The remaining 18 seconds came from pilots manually flying faster to and from the targets than the pre-programmed flights were programmed to fly.
- Conclusion on Pre-programmed Flights: The jury is out on whether pre-programming the flights brings value. The flight paths were certainly straighter but the battery consumption and overall flight times were also greater. It is possible that tuning the altitudes and flight speeds, especially if there are not potential conflicting flights involved, would make this model more attractive than manual flights due to the consistency of path and speed and elimination of pilot error.

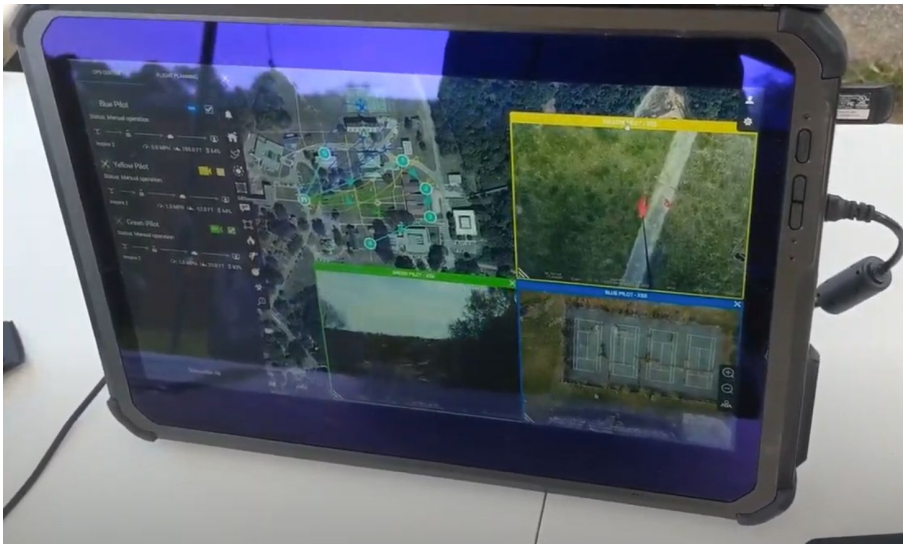
- Interruption of Pre-programmed flights. The Airboss for Test 3A told the flight teams that just like there is no crying in baseball, there is no, "I hit the tree because the pre-programmed flight flew into it." He cautioned them to have their finger on the P-mode switch at all times to pause the pre-programmed flight if necessary. This happened one time and the Blue Team handled the situation well. More time should be

spent briefing the flight teams on how the pre-programmed flights work, how to pause them, and when it is appropriate to pause them.

Manual Flights

Pilots expressed a preference for manual flights. Part of that comes from resistance to the "black box" effect where pilots don't know what the software is doing and don't trust it. Part of it is an ego thing where their skill is only on display if they are flying. Here are some observations and lessons learned about manual flights

- Speed: Pilot flew to the target .5 mph faster than pre-programmed flights and 2.7 mph faster on the return trips. This did not cause any issues but if the payload were heavier or the wind was stronger, speeding may have become a factor. It was recommended that we set speed limits on manual flights.
- Finding the targets: with only the benefit of a map, the pilots sometimes found it difficult to find the target. Sometimes they were familiar with the map but were confused about which target was actually the right target. For Test 3B, DroneSense software was used to assist the pilots in finding the right target. The targets were dropped on their controller map as waypoints and they simply had to fly to the waypoint. This seemed to be the perfect combination for the pilots as they were able to fly manually but see their target and the path they had been taking right on their flight controller screen. This can be done with DJI Go flight controller software too, but the added benefit of DroneSense is a central dashboard to monitor multiple flights.
- DroneSense Dashboard: In Test 3B, multiple teams flew to multiple targets at the same time. The Airboss manually directed takeoff, landing, altitude going out, and altitude coming back. With the DroneSense dashboard, he was able to monitor the locations of the drones on the map and all (3) flight cameras on one screen. This gave him ideal situational awareness. The following image is a picture of the DroneSense dashboard.



Night Flights

- Equipment: All drones were outfitted with FAA-required anti-collision lighting and battery-powered down lighting. Pilots had been trained to avert their eyes when dealing with the lighting and most let their LoadMasters handle the aircraft and lighting to allow their eyes to stay accustomed to the darkness.
- Time on Target: Time on target for night flights was 40 seconds more which was 25% slower than day flights. Pilots reported difficulty seeing the painted target markings and VO's reported difficulty judging the position of the aircraft both vertically and horizontally at night. A suggestion was made to light up the target area with car headlights. Another suggestion was dropping chemical lights on the target. The flight times to and from the target were equivalent for day and night, with the night being slightly faster.
- VO Direction: The pilots seemed to want more and/or sooner direction from their VO's for night flights. Comments such as "talk to me, Goose", or, "gimme some direction" were overheard in the pilot area.
- Two drones: A recommendation was made for a future test to deploy 2 drones to the same night drop- one with the payload and one (such as the DJI Mavic 2 Enterprise) with either a PA system or a powerful searchlight. This would require an FAA waiver or a public safety COA but could be a good test in a future exercise.

13 Flight Data Analysis

All drone flight logs were loaded into AirData web-based analysis software. This software takes flight logs which are generally unreadable to humans and converts them to reports and graphic flight paths that can reconstruct a flight in great detail. Here are examples of data provided by AirData which we used to analyze the flights, particularly the flight times, time over target, speeds, etc. Had there been a serious incident, we would have used this toolset to reconstruct what happened.

GENERAL

POWER

SENSORS

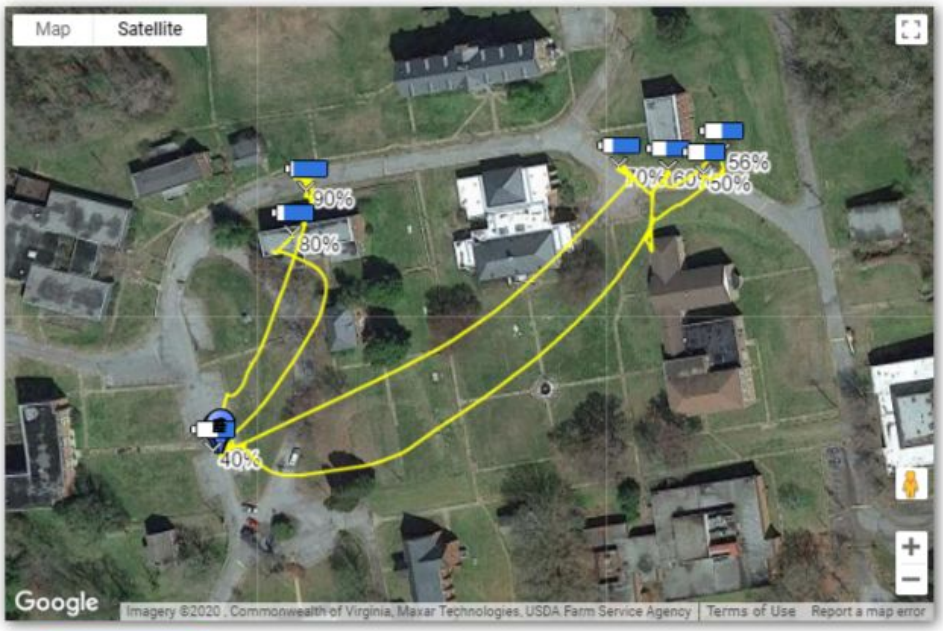
CONTROLS

WEATHER

MEDIA

HD Flight Player

Review notification highlights from the flight.
NEW Click "HD Flight Player" to view detailed flight info.



HD Flight Player NEW!

Download notifications KML

	Flight time	Altitude	Home Dist	Type	Notification
A	00m 00s	0.0 ft	0 ft	Mode	Mode changed to Motors_Started
B	00m 00s	0.0 ft	0 ft	Tip	Log filename: FLY043.DAT
C	00m 01s	0.0 ft	0 ft	Mode	Mode changed to Assisted_Takeoff
D	00m 02s	0.0 ft	0 ft	Mode	Mode changed to P-GPS
	01m 34s	142.1 ft	320 ft		90% Battery
	03m 47s	106.0 ft	266 ft		80% Battery
E	04m 51s	0.0 ft	3 ft	Mode	Mode changed to Motors_Started
F	04m 53s	0.0 ft	3 ft	Mode	Mode changed to Assisted_Takeoff
G	05m 10s	0.0 ft	4 ft	Mode	Mode changed to P-GPS
	06m 14s	-7.5 ft	565 ft		70% Battery
	08m 08s	101.7 ft	611 ft		60% Battery
	09m 03s	2.0 ft	674 ft		56% Battery at maximum distance
	10m 07s	-27.9 ft	644 ft		50% Battery
	12m 27s	6.6 ft	6 ft		40% Battery

14 Recommendations for Staging a Real Life Delivery Operation

In keeping with the manufacturer guidelines of no more than 3 drones operating in the same "soccer field" space, we have analyzed the delivery pace attainable by 3 crews of 3 people each doing round trip deliveries over distances between 500 and 2500 feet in increments of 500 feet. Here are the assumptions from which our estimates are derived.

- The Inspire 2 batteries, used and recharged in pairs, take 90 minutes to charge.
- The Inspire 2 remote controller takes 3 hours to charge and can operate 4 hours on a full charge.
- If operating temperatures are below 59°F, the flight times will be reduced. The lower the ambient temperature, the less the flight time.
- All 3 team members of each team would be Part 107 certificate holders so they can rotate between the roles of RPIC, LoadMaster, and VO.
- The operating altitude will be between 150 feet and 200 feet. Pilots will ascend to operating altitude at takeoff, fly to the delivery target at altitude, descend down to the target, drop the payload, ascend up to the operating altitude, fly back to the base at altitude, descend to the landing area and reload the payload.
- Flight teams will operate in 8-hour shifts with (2)-15 minute breaks and (1)-30 minute breaks for a total of 7 hours of flight time.
- No flights will begin if the battery charge level is below 35%.
- Ascent time from takeoff to reaching operating altitude is .5 minutes and descent time from operating altitude to landing is .5 minutes (based on average across 90 flights). So the total time reaching and descending-from operating altitude at takeoff and landing combined is 1 minute.
- Average speed to target is 8mph. Average speed returning is 15mph (based on the average of all BVLOS flights of 8.1mph and 15.5mph respectively)
- Average time on target to descend, make a drop, and ascend back to altitude is 1.2 minutes. This is .7 minutes faster than the teams achieved when they were trying to hit the cross in the circle. It allows .5 minutes for the descent, .2 minutes for a drop, and .5 minutes for the ascent over the target.
- Time spent between flights to set up the new payload, check the systems, and change batteries if necessary is assumed to be 1 minute per flight.

Here is a summary of the resources needed for (3) teams operating over the same 8-hour shift.

- (9) pilots
- (4) Inspire 2 drones (1 for each team plus a spare)
- (6) Inspire 2 controllers (2 needed per shift)
- (42) Inspire 2 batteries (12 for each team plus 6 spares)
- (15) Push-to-talk radios

Here is a table representing the estimated number of flights the 3 delivery teams could achieve at the various one-way distances from the takeoff to the target.

	Summary of Delivery Capacity							
	1.275-pound Payload on Inspire 2 Drone							
	3-Person Delivery Team (RPIC, LoadMaster, VO)							
Target Distance One Way (feet)	Round Trip Distance (miles)	Payload / Batt Time (min)	Take-Off, Landing, Drop Time (min)	Time to Target @ 8mph (min)	Time From Target @ 15mph (min)	Total Time Per Del (min)	Del per Team Per 8 (Net 7) Hour Shift	Del per 3 Teams Per 8 (Net 7) Hour Shift
500	0.2	1.0	2.2	0.7	0.4	4.3	98	294
1000	0.4	1.0	2.2	1.4	0.8	5.4	78	234
1500	0.6	1.0	2.2	2.1	1.1	6.5	65	195
2000	0.8	1.0	2.2	2.8	1.5	7.6	56	167
2500	0.9	1.0	2.2	3.6	1.9	8.6	49	146

15 Appendix

A sample Score Sheet is attached. Human recorders were asked to capture pertinent data for each flight in addition to the data captured in the log files. On the front page, we recorded the team name, test number, flight times, and battery percentages, etc. On the back, we detailed any out-of-the-ordinary events. In this example from Test 3A, the pilots reported the pre-programmed software was not flying at the Above Ground Level (AGL) altitude that had been programmed. This turned out to be a failure of the Air Boss to understand how Dronelink executed the program when a specific AGL was specified at the landing site. An explanation of this situation is described in detail on page 44. About 25% of the recommendations from pilots were taken from the "hot wash" debrief topics captured on the backside of these Score Sheets.

droneUp

Operation Last Mile - Score Sheet

Test #	Participant:(Check)	Crew Rotation	Test Start Date/Time
3	DroneUp ✓ Workhorse	Green	1:51 4/8
RPIC	**VO**	**Airboss**	**Test End Date/Time**
Ray	Tommy	Joe	2:29 4/8

Flights

Flight #	Takeoff Time	Takeoff Battery (%)	Delivery (Y/N)	Delivery Battery (%)	Landing Time	Landing Battery (%)
1	1:54	98	Y	82	1:59	72
2	2:00	72	Y	48	2:07	36
3	2:10	100	Y	0%/[illegible]	2:15	0%/75%
4	2:18	99	Y	84	2:23	75
5	2:24	73	Y	58	2:29	50

Demerits (Check if Any)

CFIT	☐ Describe:
Takeoff/Landing Damage	☐ Describe:
Activation of Emergency Procedures	☐ Describe:
Avionics Failure	☐ Describe:
Powertrain Failure	☐ Describe:
Drop Mechanism Failure	☐ Describe:
Payload Entanglement	☐ Describe:
Loss of Communications (Pilot and VO)	☐ Describe:
Near-Miss	☐ Describe:
Viral Contamination	☐ Describe:

Incorrect AGL - 164 (2-3) 180 (2-4) 200 (2-4b) 160 (2-5)
Auto Landed on mission 2-2d 2-5

Out mission AGL Error

Battery needs to be checked on the batt not charger

160 Newtown Road, Suite 302 | Virginia Beach, VA 23462 | 877-601-1860 | droneup.com

droneUp

HOTWASH: (Short Debrief Discussion with Crew)

What Happened:

- Altitude Errors
-

Why Did it Happen:

Program / Attitude difference.

What Should Be Done Differently in the Future:

- Check battery instead of Charger / User error
- cool down on battery before Charge.
- Have PIC verify that the pre-programmed mission parameter (altitude, RTH, etc.) match the known intention of the mission (J.F.)

Attestation of Record

I the undersigned, hereby attest that the Information recorded on this form is true and correct to the best of my ability

Data Specialist (Print name)	Signed	Airboss (Print name)	Signed
[illegible]	[illegible]		

160 Newtown Road, Suite 302 | Virginia Beach, VA 23462 | 877-601-1860 | droneup.com

Author:
Joe Fuller, Chief Information Officer
info@droneup.com

Joe Fuller has over 21 years of Information Technology experience and was the CIO of Dominion Enterprises, which had annual revenues of over $1B. Growing the technology team from 5 on staff to 270 employees; Joe oversaw building and maintaining the company's websites and mobile apps that served 30 million unique visitors per month. Joe integrated the IT and technology teams from 13, multi-million dollar business acquisitions. Joe also owned and operated his own business for four years after having graduated from Georgia Tech.

160 Newtown Road, Suite 302 | Virginia Beach, VA 23462 | 877-601-1860 | droneup.com