PROJECT REPORT

Implementation of blood sample transports with autonomous drone in Jämtland within the Green Flyway project

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Background

Green Flyway has commissioned Aviant AS to carry out blood test transports with autonomous drones in Jämtland between Funäsdalen and Östersund. The Aviant project is a sub-project within Green Flyway that receives support from the Interreg Sweden-Norway program and Region Jämtland's 1: 1 Regional Growth Fund.

Objective

The objective of this project is to investigate if drone transport is possible between Funäsdalen and Östersund, with blood samples onboard. Included in the objective are all operating concerned factors, such as 4G coverage, weather, CTR operations, communication, airspaces, blood sample insulation and more.

Project timeline

In the initial stage of the project it was made clear that flights had to be conducted in a Restricted Area to assure separation from other traffic in uncontrolled airspace. As this limited other operators in the area, Aviant decided to reapply for R-area during official night.

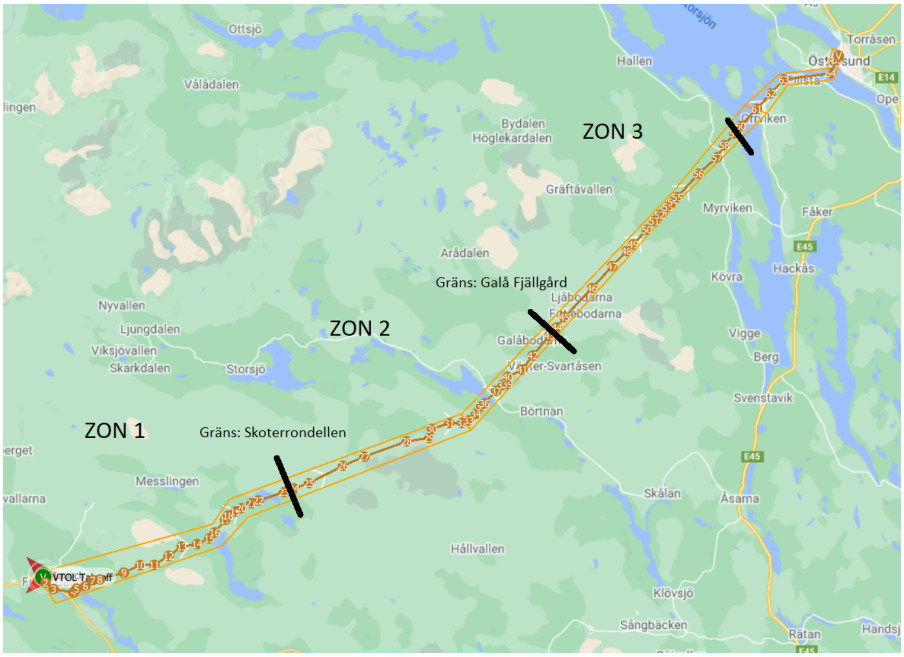
The lead time for an application to Transportstyrelsen of R-areas is more than 4 weeks, therefore beyond line-of-sight (BVLOS) flights could not be initiated until the 11th of October 2021. This delay in time was however beneficial to prepare both crew, test flights and other formalities. Test period has been between 2021-11- 10 to 2021-12-

Routing

The routing between Funäsdalen and Orrlanda was challenging due to remote and variable terrain. Inaccessible terrain is a challenge due to the possibilities of landing far away from openroads, where a drone recovery would consume a lot of time, even days. Therefore, Aviant included the Swedish Mountain Rescue team to help us with unplanned landing in remote terrain and mountainous areas.The cooperation with the Swedish Mountain Rescue team was not closed, as there was not enough time to rule out all uncertainties, such as insurance and responsibility. However for the future it would be beneficial to utilize their ability to use terrain vehicles in the concerned areas.

The terrain has furthermore been a slight concern when crossing valleys, where terrain elevation changes are rapid. This means that in the worst case, an unplanned landing by the drone could happen when the drone is very high above the ground, so that the multirotor descent would consume a lot of battery to land. Path planning was hence focused on ensuring sufficient time to descend, which consumed a large amount of planning time.

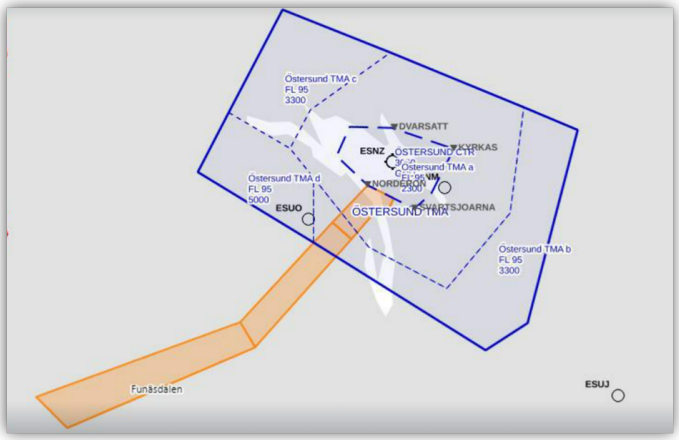
4G Coverage



Evaluation of 4G coverage was the focus of the initial tests. The full path was divided into 3 different zones that were tested individually. Surprisingly, there was only one area that was beyond the tolerance, near Grundsjön, Härjedalen. As 4G reception increases with altitude in proximity to mountains, increasing the altitude by 80 meters was sufficient to solve this problem.

Normally there were short disconnections 2-3 times per flight but no longer than 10 seconds each.

Restricted area



Flying in a restricted area is a solution that allows for Aviant to fly BVLOS within uncontrolled airspace. It is however limiting for the other operators to use the airspace freely. As the other operators normally fly during daylight hours only, Aviant decided to operate at night time.

For future drone operations the restriction of airspace could be avoided by using Danger areas, or only the “Notice to Airmen” system (NOTAM), as it does not limit other operators in the same way, but raise awareness of drone operations. Good communication with other operators in the area could also be a solution to simultaneous operation in danger areas, or even if using only NOTAM in the future.

Weather

Jämtland and Härjedalen are known to have severe weather conditions during the transition between fall and winter. Snow, icing and freezing rain are examples of concerns apparent at the start of the project. However after several flights in aggressive weather it became less of a problem. Freezing rain accumulated some icing but it did not severely affect the performance of the drone. Freezing rain could potentially make the drone aerodynamically unflyable, but this was not an issue for the flights in this project. The last flight was in snowfall all the way to Orrviken from Funäsdalen, 128 km, without problems.

Windy conditions, especially headwind, made flights back to Funäsdalen a hassle in terms of endurance. Most of the time the drone was landed in Övre Särvsjön after 88 km of flight from Orrviken, towards Funäsdalen.

Weather limitations

Based on the flights conducted in this project, including both nominal and experimental flights, the following weather limitations were identified.

Takeoff/landing limit: 10 m/s, gusts cannot exceed 50% of the mean wind speed
Cruise: 12 m/s, gust cannot exceed 40% of the mean wind speed
Maximum headwind to fly Orrviken - Särvsjön: 8 m/s (limited by endurance)

Cooling of the batteries was an issue when flying in temperatures below -20 degrees celsius, but the problem was solved by insulating the batteries and limiting the airflow through the fuselage.

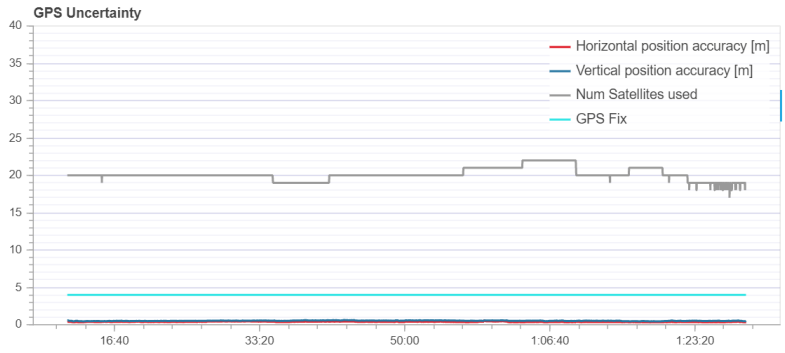
Western headwinds made it hard to return to Funäsdalen. However a good landing spot near Särvsjön made it possible to return the drone safely towards Funäsdalen.

Ice accumulation on the airframe and aerofoil reduced the endurance of the drone but not to the extent that the drone could not fly.

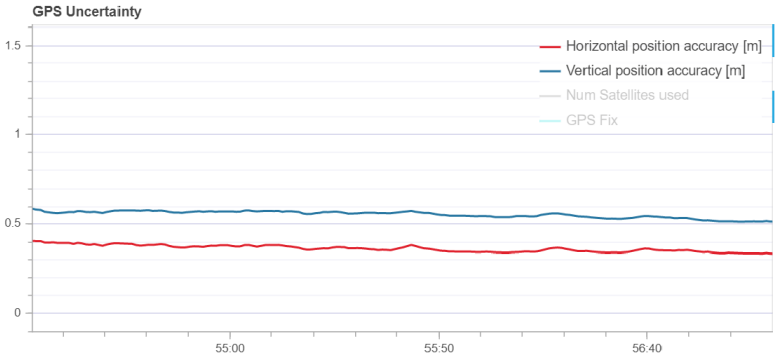
Ground frost was an issue during high humidity during temperatures below freezing, but it was solved by alcohol liquid before takeoff, as ground frost is mostly present in ground proximity.

GPS uncertainty

Horizontal uncertainty is consistently within 0.5 meters. Seen in the graph to the right, a flight performed 09.12.2021 in winds estimated to 180 degrees and 11 m/s, gusting 23 m/s in cruise. The red line represents horizontal position uncertainty (m) over time.

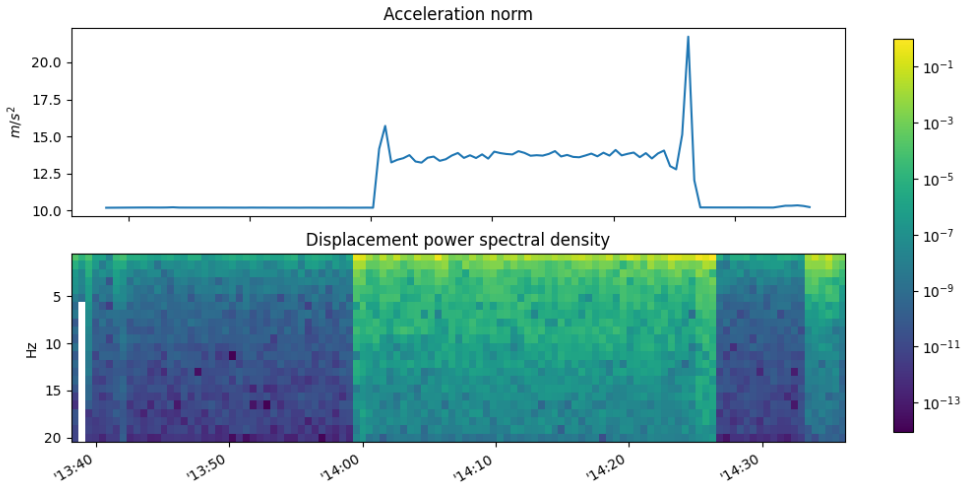


The red line represents vertical position uncertainty. GPS altitude in general, is not as accurate as horizontal position, this is why you see a constant larger value of deviation in altitude. However the onboard computer also measures barometer altitude in addition and fuse the both.

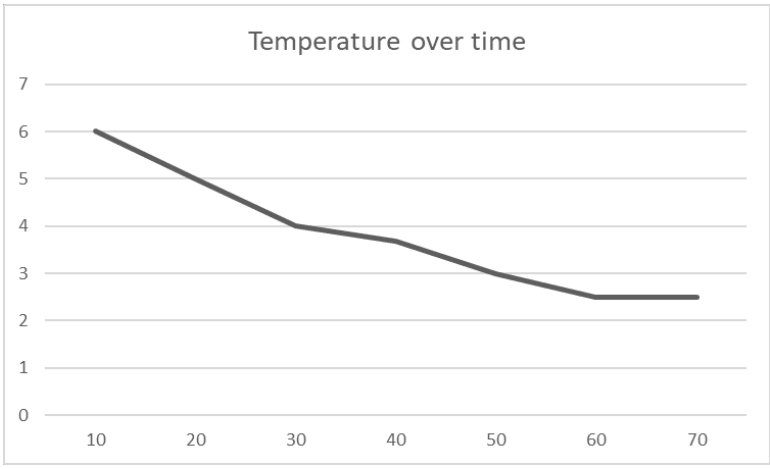


Vibration measurement

The graph shows how much energy is found at each frequency of vibration (0-20Hz) over time. Darker color corresponds to less energy and lighter color to more energy. In general, most of the energy is at low frequencies, and there are no frequencies that stand out in terms of energy during flight.



Payload temperature measurement



Temperature measurement has been recorded inside the styrofoam box next to the transportation tube that holds the blood tube. The lowest temperature measured in 70 min is +2.5 degrees celsius with this kind of insulation. As seen in the graph, the temperature drop decreases with time and eventually becomes insignificant when reaching 60 minutes. Note: Insignificant because the flight time varies between 70-85 min. This measurement was made on the 17th of November 2021.

Blood sample transport

Initially, insulation was difficult due to temperature drops near the payload,but it was solved by using proper materials. A blood cargo box was made for the drone in the lab in Norway, but mostly the blood was transported in simpler styrofoam boxes. A handful of times, one blood tube was additionally transported by the regular road transport, so that the analysis could be compared by the lab in Östersunds Hospital.

The results from the lab was that the samples transported by drone had the same quality as the samples transported by car. This is reassuring, since some samples were flown in outside air temperatures lower than -20 degrees celsius, and still had good analyzing results.

Real blood tests for patients were never flown by drone, as this was never approved by the persons in charge of transport at Östesund Hospital due to privacy concerns.

Flights in CTR

In total, six flights were conducted within Östersund CTR. These flights landed and took off in Orrviken in UAS sector “N”. Out of these flights, three were made with blood onboard. It was not possible to fly in the CTR on a more regular basis due to the operating hours of the ATS, and the policy that no other IFR traffic was allowed within CTR at the same time as the drone. However, at the times at which it was possible to conduct flights within the CTR, the cooperation and routines worked well with the ATC controllers.

Every flight into the CTR had to be carefully planned in order to match the drone landing time with the IFR landings and takeoffs from Åre Östersund Airport. Any delay in the drone departing from Funäsdalen, or taking off at Orrviken, closed the CTR flight window. After such an event the drone needs a new flight route uploaded, which delays the flight and can cause damage to the blood samples due to freezing air temperature.

Canceled flights

As the number of BVLOS flights was increasing with time, we started testing more and more adverse weather conditions too. We started to test windy departures and landings, and later on, mechanical turbulence and precipitation (snowfall). These tests were carefully executed with continuous risk evaluation.

Due to taking extra care early in the project, that period also had more cancelled flights. An estimation of total cancellations is 20-25% throughout the project time, meaning that we have an uptime of 75-80%

Total flight data in the project

Flights:	More than 45
Kilometers:	2 725 km
Time in air:	35 hours

GPS route and Swedish distance record

The longest distance flown was 128 km from Funäsdalen to Svedjesjön, Orrviken. This flight was performed 10.12.2021 in snowy conditions and low level clouds. The total flight time was 1 h 37 min. This is the longest autonomous flight flown in Sweden as far as we know. The white line represents road transport.

Current transport of blood samples

The Region Jämtland Härjedalen has recently updated the agreement with JPS Åkeri (Schenker) which carries out the task of collecting blood samples in Funäsdalen to the laboratory in Östersund.

JPS picks up and leaves 1 sample box and 1 portfolio of internal post at 15.30 at Hälsocentralen in Funäsdalen and leaves this at the laboratory at the hospital in Östersund between 21.00-23.00 if nothing unforeseen happens.The mission is performed on weekdays at a cost of 750 kr per day..

In addition to the daily transports with samples and internal post, there is also at least 1 cage with storage goods and aids every week. This is also transported by JPS Frakt.

There is an agreement but the transportes are not procured and can be terminated with a 1 month notice.

At other places in Jämtland the Region collaborates with Linjegods and PostNord but most of the transports are done with the Regions own transports. The region Jämtland Härjedalen has 4 cars and 4 employees that transport the blood samples normally.

Drone compared to road transport concerning time, environment and work environment

Drone transport reduces the transportation time by more than half compared to road transport. Hence it will be possible to transport blood more frequently throughout the day and would ease the workload at the lab.

Some tests can not be taken in Funäsdalen as it needs to be analyzed within four hours. These tests can be immediately sent off with the drone and reach Östersund within two hours, meaning that the patient does not need to be transported 480 km.

All road transports arrive in the afternoon and evening to the lab in Östersund. Drone transport will result in a more steady flow of samples throughout the day. This is good for the work environment in the laboratory.

PCR covid samples are sent to Uppsala laboratory today. Sending them with drone transport to Östersund Hospital would decrease the response time, hence shorter isolation time for patients not infected with Covid.

The drone has 99% less CO2 emissions compared to a petrol vehicle and 95% less emissions than an electrical vehicle according to an environmental analysis made by Aviant.

Economic aspect

The cost of drone transportation today between Funäsdalen and Östersund is higher than road transports today because the road transports are coordinated, but drone transport would solve other transportation costs as the patient is transported a large distance. Drone transport in the future can be a more economical option in means of transportation. The drone flies empty on the return flight to Funäsdalen and this would be an opportunity to transport medication saving more costs.

Summary conclusions

The project has been very successful and demonstrates that drone transport of blood has many advantages compared to current transportation methods, as the transportation time is reduced to 50% and increased frequency of transport availability. This also reduces the environmental footprint of transportation in general.

The increased delivery frequency at the laboratory will reduce the quantity of blood tests per delivery as the drone could deliver many times throughout the day.

Drone transport of tests would enhance more complex testing to be made in Funäsdalen instead of sending the patient to Östersund to be tested. This is because some blood samples must be analyzed within four hours.

There were challenges with the airspace as Aviant could only fly in restricted airspace. In the future a danger area would make operations easier and less restrictive to other operators in the area.

The planned duration of the project was too short to fly real patient blood tests, but if the project is extended, danger area and real blood tests are a goal.