AVALANCHE CONTROL WITH UNMANNED AERIAL SYSTEMS ON NORWEGIAN ROADS

Jens Tveit[1]*, Jarle Bøckman[2]

[1] *Norwegian Public Roads Administration (NPRA), Norway*
[2] *AF Decom, Norway*

ABSTRACT: The demolition company AF Decom started developing a concept for UAS based avalanche control in 2019. The Norwegian Public Roads Administration (NPRA) got involved after a request from AF Decom and two field tests were carried out in 2019 on the winter closed county road 613 Gaularfjellet. The field tests gave valuable experience both for AF Decom and the NPRA and the goal for the future was to have UAS based avalanche control as an alternative to Daisybell, hand charges and in some cases RACS. After some years with development and working with permissions, the system was ready to test as an operational method on highway 15 Strynefjellet in the winter of 2024. As of March 2024, NPRA and AF Decom have carried out two rounds of avalanche control. The UAS based system is remote controlled and can carry various types of explosive charges. The system can either detonate a charge above the snow cover while hanging below the drone, or multiple charges can be deployed in the terrain by dropping them at suitable spots. With the use of electronic igniters and nodes, the charges can be programmed to explode simultaneously or in a preferred pattern. The system shows great potential for operational use, however further development is necessary to ensure the stability and flexibility that is needed. Examples of further development are site scanning with lidar to gather information about snow depth distribution and autonomous deployment to a site as well as a more stable UAS platform to carry the explosives.

KEYWORDS: Avalanche control, Avalanche mitigation, UAS, Road operations.

1. INTRODUCTION

The demolition company AF Decom started testing a concept with unmanned aerial system (UAS)-based avalanche control in 2018. The Norwegian Public Roads Administration (NPRA) got involved after a request from AF Decom to contribute to the testing at a suitable site with avalanche prone terrain. Since the first full scale field tests in 2019, the method was further refined. The NPRA implemented avalanche control with UAS as an operational measure on highway 15 “Strynefjellet” in the winter of 2024.

2. AVALANCHE CONTROL ON NORWEGIAN ROADS

Avalanche control for avalanche mitigation has been used for decades on Norwegian roads. However, the extent of use is not as widespread as in the Alps or in North America. This is mainly due to low traffic density on many of the avalanche prone roads. Tveit (2023) described the implementation of new methods for avalanche control on roads in Norway. The introduction of modern Remote Control Avalanche Systems (RACS) started in 2014, and as of 2024, modern RACS are in use at five different sites (NVDB, 2024). In addition to RACS there are a total of 6 DaisyBell systems available for avalanche mitigation.

3. AVALANCHE CONTROL WITH UAS

The introduction of UAS in our daily work has opened many opportunities for avalanche mitigation operations. The NPRA are one of the largest UAS-operators in Norway, with applications ranging from simply taking pictures and videos, to surveying, mapping, and photogrammetry. It was thus a logical step for us to also investigate UAS-borne avalanche mitigation.

3.1 Description of the system

Over several years, AF Decom has developed a concept for triggering avalanches using UAS, with large emphasis on flexibility and mobility. Their UAS-borne concept therefore includes the deployment of explosives by drone (UAV) and a remote-controlled firing system.

The control units, which are self-developed, can be easily moved from one UAV platform to another. We therefore have the option of using several UAV configurations, from the DJI 300 to the DJI FlyCart 30 with a lifting capacity of up to 40kg.

Combined with a remote-controlled launch system, this concept provides a technical operational radius of around 20km. Practical range is limited by permits and security restrictions set by public

* *Corresponding author address:*
Jens Tveit, Norwegian Public Roads Administration, Hahaugvegen 39, N-3550 Gol, Norway;
tel: +47 576 55 949; tel: +47 970 13 790;
email: jens.tveit@vegvesen.no

authorities and physical operational risks in the relevant operational area.

The system provides the option of placing explosive units in the terrain and then detonating them remotely. There are no technical restrictions on the number of charges deployed beyond the range of the communication. The communication goes from the control unit (PC), via the UAV, to the igniter unit (Figure 1) in the explosive charges. With the use of electronic igniters, it is possible to deploy all charges at the same time or have an interval between the detonations, see Figure 2.

Figure 1: Electronic igniter and communication unit. Photo: AF Decom

Figure 2: Deployment of multiple charges in the terrain with simultaneously detonations. Photo: AF Decom

There are several challenges with placing explosives. The snow is often hard and the terrain very steep. It can therefore be difficult to place the explosives in the terrain. The snow can also be very loose, so that the charge disappears into the snow. This can cause either the effect to deteriorate and/or the communication with the igniter unit can be broken. The same challenges are further amplified when mitigating vertical ice areas. AF Decom has therefore also developed a method where the explosives can be detonated while still being attached to the drone (Figure 3). The contact with the igniter right up to detonation reduces operational and environmental risk.

Figure 3: Detonation of 4 kg mix of TNT and RDX hanging on a detonating wire underneath the UAV. Photo: AF Decom

4. FIELD TESTING OF UAS BASED AVALANCHE CONTROL

The winter closed county road 613 over Gaularfjellet was selected as a suitable location for testing in 2019. Gaularfjellet is a mountain pass in western Norway connecting the Sogn region to the Fjordane region. The test site was situated at lake Nystølsvatnet at 715 m asl. The road runs along the northern shore of the lake, prone to avalanches from south facing mountainsides around 1200 m asl.

On both tests, the field base where we deployed the UAS was on the west side of the lake. Map overview is shown in Figure 4.

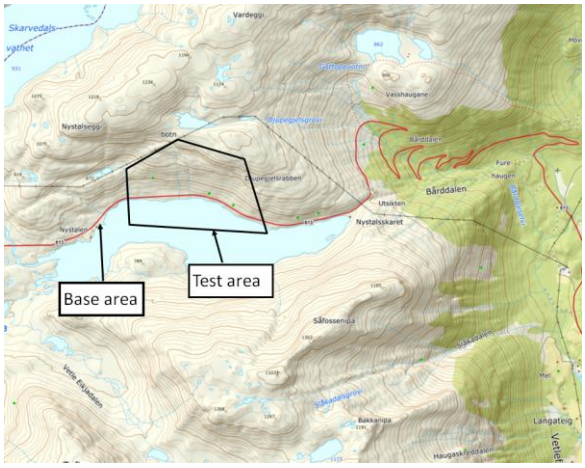

Figure 4: Map over Gaularfjellet. From: Farestveit 2019.

4.1 Details from test 03.27.2019

The test area was around 500-700 meters away from the field base and roughly 150-200 m higher in elevation. The snow cover was considered stable on the test day, we had therefore low expectations of releasing slab avalanches. The weather was snowy, with around 5 m/s wind, creating poor visibility.

On this first test a total of 4 charges were detonated. The first one was dropped and detonated on the snow cover. The next two were dropped and detonated simultaneously. The last two charges were detonated in a longline while hanging from the UAV. All charges weighed 5,1 kg.

4.2 Details from test 04.10.2019

The base area for this test was situated at the same location as the last test, but the test area was around 1600 m in distance and 230 m in elevation away from the field base. The snow cover consisted more or less of melt forms, and the stability was rated good. The weather was significantly better than at the last test with no wind and good visibility.

The plan was to test deployment from greater distances than in the first test, however only one charge was detonated this day. The UAV carried 5,1 kg with explosive hanging on a long line underneath. When the charge detonated, the shock from the detonation threw the rope up and into the propellers causing the drone to crash. The drone was recovered, but no further tests were carried out that day.

4.3 Results from the tests

On the first test one of the detonations released a size 1 avalanche. No further avalanches were released, but that was as expected due to the stable snow conditions. The test verified that the UAS-system were able to carry charges up to the release area and detonate them while hanging on a longline underneath the drone or being dropped onto the snow surface. The system performed in conditions with precipitation and poor visibility, but improvements would be necessary in an operational phase. As a result from the crash on the last test, the rope was replaced with a detonating wire for future operations.

5. OPERATIONAL AVALANCHE CONTROL WITH UAS

For the winter season of 2023/2024 the NPRA decided to perform avalanche control with UAS on an operational level. The avalanche prone highway 15 over Strynefjellet was selected as a suitable location. Two campaigns were performed and both the NPRA and AF Decom gained valuable experiences after this winter.

5.1 Strynefjellet

The mountain pass over Strynefjellet is an important east-west connection between the Nordfjord and the Sjåk area. The old road opened in 1895 but was closed during the winter. In 1978 the new road opened and made it possible to drive east-west in the wintertime. The area is known for its steep topography and mountain tops around 1700 m asl. Due to the steep terrain a large portion of the road is inside tunnels.

Avalanche mitigation measures in use on highway 15 today are a gallery, avalanche cones, avalanche control as well as a site-specific avalanche forecast (NVDB, 2024)

5.2 Sætreskarsfjellet

The avalanche site of Sætreskarsfjellet was chosen as the site for testing UAS-based avalanche control on an operational level for the season 2023/2024. The road in Grasdalen leads through the valley bottom at approximately 870 m asl. The top of Sætreskarsfjellet is at 1606 m asl, containing two main avalanche paths that deposit snow on the road (Jacobsen and Dahle, 2022). These areas are mainly orientated to the east thus collecting snow from westerly winds. There is a good line of sight from the tunnel entrance to the release areas. Map of the area is shown in Figure 5.

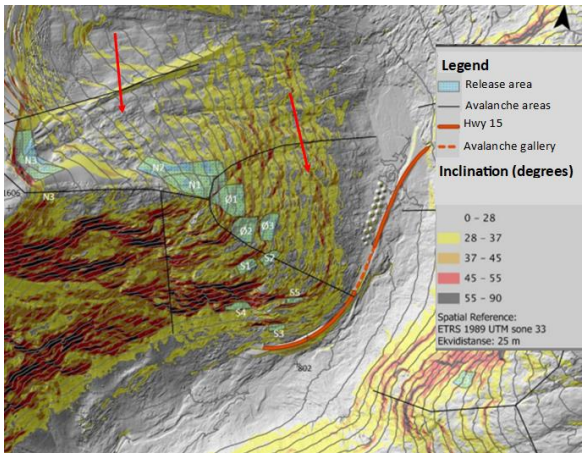

Figure 5: Map of Hwy 15 Grasdalen and Sætreskarsfjellet. Avalanche control was carried out in the areas marked with red arrows. Source: Jacobsen and Dahle, 2022.

5.3 UAS based avalanche control the winter of 2023/2024.

The first round with avalanche control was carried out on January 23 after a storm cycle. The highway had been closed, and avalanche control was considered necessary before opening the road for traffic. Avalanche control was carried out with 1,7 kgs of TNT hanging underneath a DJI Matrice 300 drone. The drone was manually flown up to the starting zone and the charge was detonated approximately two meters above the snow surface. Two rounds of avalanche control were carried out and several size 1 and 2 avalanches were released (Regobs 2024).

The second of avalanche control campaign was carried on February 5. Due to technical issues the drone emergency-landed in the avalanche release area and was unable to detonate the charge. With the help of a more powerful Staker drone, the DJI Matrice was recovered and lifted out together with the charge. No further attempts were made that day.

5.4 Experiences from operational use

Even though only two campaigns of UAS based avalanche control were carried out, useful experience was made.

It is important to have sufficient weight margins on the payload. With snow, wind and icing the real-life weightbearing capacity can be significantly less than the numbers in the manual. When it comes to flying in cold weather, warm batteries are important, otherwise operational flying time is reduced significantly and a sudden loss of power can occur. Even though modern UAV batteries have a self-warming function, experience shows that it is important to ensure that the batteries are warm before deployment.

There are several advantages with having the charge hanging underneath the drone. Knowing the altitude above ground and the length of the longline makes it easier to detonate at an ideal height above the snow surface. Even more important is the control over the charge all the way to detonation as this reduces the risk for duds in the terrain. Experience from this winter have led to further development of the control device which is now updated with a double ignition system.

During all campaigns this winter the drone was controlled manually to a pre-planned position. In situations with poor visibility, automatic deployment would be an advantage. This, however, requires updated information of snow depth distribution in the starting zone to optimize altitude above ground, as well as choosing the best site for detonation.

5.5 Future goals

UAS based avalanche control has several advantages and the future goal is to use it on an operational level in addition to DaisyBell, RACS and other methods. The advantages with UAS based avalanche control are high firepower, a mobile system, and fewer limitations due to weather conditions than the DaisyBell for example. The system is also cheaper than RACS or DaisyBell. The disadvantages, however, are access to approved operators and their response time in addition to the regulations and hazards linked to handling of explosives.

6. FUTURE DEVELOPMENT

We see great potential in UAS based avalanche control and therefore aim to further develop the concept.

When it comes to UAS and the use of explosives, permissions from several agencies must be granted. The Civil Aviation Authority Norway (Luftfartstilsynet) issues permissions regarding the use of UAS based systems and the Norwegian Directorate for Civil Protection (DSB) issues permissions regarding the use of explosives. As a rule it is not permitted to fly with armed explosives in Norway, so it is challenging to get all the permissions to carry out UAS based avalanche control. Further work with the related agencies is crucial to develop this method as an effective way to mitigate avalanche areas.

The newly completed project GEOSFAIR had focus on UAS borne surveying of the snow cover. Detailed information on snow depth distribution in avalanche starting zones helps UAS borne avalanche control in finding the most suitable spots for placing a charge. We have also newly invested in an automatic drone station that will be able to carry out automatic snow cover surveys.

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