THERMAL UAS USE DURING A NIGHTTIME SEARCH AT VAIL PASS, COLORADO

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ABSTRACT: Summit County Rescue Group (SCRG) deployed an unmanned aircraft system (UAS) equipped with a thermal camera during an overnight response for a missing individual near Vail Pass, Colorado, on 7–8 March 2026. The subject was overdue in avalanche terrain during Considerable hazard, and nighttime field searching quickly reached limits where further travel would have exposed rescuers to unacceptable risk. SCRG's UAS team used thermal imagery to identify a recent avalanche, with two ski tracks entering the start zone and only one visible exit track. That finding shifted the mission from a broad overdue search to a focused avalanche response, reduced rescuer exposure to hazardous terrain in the dark, and helped align incoming resources.

Here, we present the incident timeline, key operational decision points, and lessons learned from using a DJI Matrice platform with a thermal camera as a nighttime avalanche search tool. The case highlights how UAS observations changed the search problem and provides practical lessons for UAS tasking, sensor use, deployment, staffing, and mission coordination during nighttime winter searches.

KEYWORDS: Search and Rescue, Instrumentation and Remote Sensing, Avalanche Response, Case Studies, Unmanned Aircraft System, Thermal Imaging.

1. INTRODUCTION

At 23:35 MST on 7 March 2026, Summit County Rescue Group (SCRG), a Mountain Rescue Association-accredited volunteer search and rescue (SAR) team based in Frisco, Colorado, United States, responded to a report of an overdue snowmobile-assisted skier near Vail Pass, Colorado. The search area included a large network of winter trails and avalanche terrain during Considerable (Level 3 of 5) danger rating near and above treeline. SCRG recently developed a UAS program to provide rapid overhead observation where ground access is slow or hazardous. However, UAS effectiveness in mountain rescue can often be limited by weather, limited range, terrain, and search conditions. This SAR incident tested multiple aspects of UAS employment in a complicated winter search in avalanche terrain.

This case study reconstructs the events from field notes, UAS flight records, the Colorado Avalanche Information Center (CAIC) accident report, and observations from pilots and rescuers, along with weather data from the nearby United States Geological Survey (USGS) Boss Basin automated meteorological station. This paper focuses on how UAS information changed the search problem, what was and was not visible in longwave infrared (LWIR) imagery, and practical lessons for UAS deployment during nighttime winter searches.

2. INCIDENT SETTING

2.1 <u>Location</u>

Vail Pass is a 3,250 m highway pass on the Interstate 70 corridor near the western boundary of Summit County, approximately 130 km west of Denver. Interstate 70 between Vail and the Vail Pass summit sees approximately 22,000 vehicles per day (CDOT, 2023). At the summit is the primary entrance to the Vail Pass Winter Recreation Area (VPWRA), a roughly 220 km² federally managed zone containing designated motorized, non-motorized, and motorized-assisted ski areas ranging from 2,800 to 3,870 m (USFS, 2026). The missing subject was recreating as a snowmobile-assisted backcountry skier, meaning the initial search area encompassed over 13 km² accessed by over 108 km of motorized trails.

The avalanche occurred in the South Fork of Resolution Creek, an area locally known as Boss Basin (CAIC, 2026). Situated roughly 14 km from the Vail Pass summit parking lot, this drainage features motorized trail access to slopes designated for non-motorized use only. The

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VPWRA trail guide outlines the designated motorized path within this motorized-assisted ski zone as the “Boss Basin - Hybrid Route” (Vail Pass Alliance, 2026). Approximately 1.8 km long with a “Most Difficult” rating, this low-use trail developed dangerous ice formations during the low-snowfall winter, which impacted the search operation by prompting an experienced team to restrict further travel along this route.

2.2 Terrain, Snow, and Weather

The topography of Boss Basin comprises a blend of simple and challenging terrain. According to the CAIC accident report, the zone features “a series of northeast-facing slopes with low-angle terrain at the top that rolls into steeper slopes. The slope ends in a flat bench” (CAIC, 2026). Situated at the transition between near treeline and above treeline, sparse tree cover in this area increased the probability of detecting surface features with the UAS.

For 7 March 2026, the CAIC forecast rated avalanche danger as Considerable (Level 3) near and above treeline, and Moderate (Level 2) below treeline. The primary hazard was Large to Very Large (D3) Persistent Slab avalanches on NW-N-SE aspects. Secondary hazards included Small to Large (D2) Wind Slabs on N-E-SW aspects near and above treeline. Entering March 2026, the snowpack was shallow with weak faceted layers that formed during historically low snowfall and dry periods through January. These weak layers were buried by February storms. On 7 March, 23 cm of new snow fell, creating a critical soft layer over these persistent weak layers. This fresh snow caused ski tracks to stand out clearly in thermal imagery (CAIC, 2026).

Weather data were collected from the automated USGS Boss Basin Meteorological Station less than 500 m from the avalanche site. From 08:00 MST on 7 March to 08:00 MDT on 8 March, air temperature increased from −15.4 °C to an afternoon maximum of −6.9 °C before decreasing to −10.1 °C the following morning. Snow surface temperature warmed from −26.1 °C to −8.2 °C near midday, then fell to −21.2 °C as net radiation became negative overnight. Relative humidity declined to 61 % during the afternoon before recovering to 88 %, while winds shifted from southerly to northwesterly and remained generally light, with a maximum sustained speed of 3.3 m s^{-1} and a gust of 5.8 m s^{-1} (USGS, 2026).

3. UAS AND SEARCH PROCEDURE

3.1 Aircraft and Sensors

The UAS operation utilized a DJI Matrice 4T and a 4TD. These aircraft have multiple visible-light cameras ranging from wide-angle to telephoto, laser range finders, and LWIR sensors. The thermal camera has a 640 × 512 native resolution and a 30 Hz frame rate, operating within the 8–14 μm spectral range. Operating temperature limits depend on the Matrice model. The Matrice 4T is rated for operations at temperatures as low as −10 °C, while the 4TD is rated to −20 °C. Temperatures during the search approached the minimum threshold for the Matrice 4T, which contributed to reduced flight duration per battery (DJI, 2026a, b).

Search teams utilized both visible and LWIR cameras during the initial deployment phase. Visible-light searching supported by an onboard spotlight yielded no results, but the thermal imagery revealed the avalanche during a search of the drainage near the subject’s snowmobile. The decisive observation from the UAS was not a human heat signature, but rather indirect evidence of avalanche activity and ski tracks. In similar nighttime winter searches, tasking for UAS teams should specifically include other identifying signs besides human detections.

3.2 Mobile Deployment

The SCRG UAS team deployed from a tracked utility task vehicle (UTV) carrying spare aircraft batteries and a portable charging system. This UTV traveled along motorized trails to high points to deploy the aircraft. The power supply and spare batteries supported repeated flights, while repositioning between launch points became one of the primary interruptions to flight operations. Repositioning was necessary as flights from the Vail Pass parking lot would not have been possible due to terrain obstructing line of sight and radio signal transmission. SCRG had not previously deployed a UAS team out of this tracked UTV. When the UAS team operates from a command vehicle at a trailhead, the video feed is displayed on a large screen with direct observation possible by incident command. The UTV forward deployment did not support streaming live video from the UAS to the Incident Command Post at the trailhead. The UAS team was able to upload photos and tracks to the CalTopo mapping system through intermittent cellular service to keep Incident Commanders (ICs) informed. Forward deployment improved aircraft access and flight effectiveness but reduced ICs' access to a real-time common operating picture.

4. INCIDENT TIMELINE AND RESULTS

The subject was reported overdue by a family member who located the subject's vehicle and trailer at the trailhead. The SCRG Mission Coordinator, the IC, also notified a nearby SAR team because the search area extended across response areas.

At approximately 00:30 MST on 8 March, SCRG deployed three two-person snowmobile teams to begin searching the groomed trail network. Associating off-trail tracks with the subject was not possible due to a snowmobile gathering that heavily tracked the area. Concurrently, the UAS team deployed to the top of Ptarmigan Hill (Launch Point A) with a tracked UTV and two DJI Matrice UAS (Figure 1). This launch point was chosen due to the central location in the search area and higher elevation. Without any indication of where the subject was last seen, the initial UAS tasking was general to the entire area. Meanwhile, ground search teams contacted and interviewed people at three separate backcountry huts. Interviewees reported seeing someone generally matching the description of the subject headed toward the Boss Basin area around 13:15 MST on 7 March. Travel conditions on groomed trails were treacherous at times due to ground hazards and exposed ice formations.

At 04:19 MDT, after traveling 15.3 km along the motorized access trails, a team found the subject's snowmobile parked on a ridgeline above the Boss Basin drainage. The team noted a skin track leaving the end of the groomed trail heading further up the ridge. Due to terrain complexity, avalanche hazard, and darkness, the team did not feel comfortable continuing onward with snowmobiles. This team was unfamiliar with the area below the ridgeline and was not carrying skis.

Upon discovery of the missing subject's snowmobile, the UAS team moved their launch location closer to this last known point. They did not fly any additional flights in the direction of the snowmobile. The UTV was forced to turn around at a hazardous section of the Boss Basin trail after helping snowmobiles with the UTV winch. At this farthest forward point (Launch Point B), the team conducted one visible optic flight using the mounted spotlight across Boss Basin with no results. The pilot reported some clouds and line-of-sight concerns that prompted them to not launch another flight from this location. The UTV then turned around and climbed the ridge to get to a better line-of-sight position from an area known locally as Machine Gun Ridge (Launch Point C).

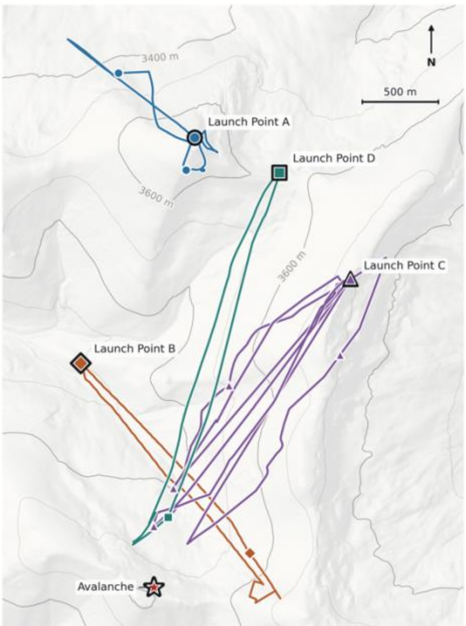

Figure 1: UAS launch points A–D, recorded aircraft flight tracks, and the avalanche site in Boss Basin. Launch points are labeled in chronological order.

From Launch Point C, the pilot utilized the LWIR camera and found the avalanche quickly. The pilot noted two tracks in and one track out of the avalanche at 06:16 MDT (Figure 2a). A skin track that ascended back to the snowmobile on the ridgeline was located to the climber's right of the avalanche. The track pattern was interpreted as two ski laps. The team made multiple flights trying to determine if they could find the subject in the area. It took some time to confirm that the tracks showed an initial ski descent, a transition point, an uphill skin track that overlapped some of the downhill ski track before continuing to the ridgeline, and then a second ski descent into the avalanche.

The LWIR imagery narrowed the mission focus to an avalanche rescue. At first light, the response transitioned from UAS operations to a helicopter-supported avalanche search. The SCRG UAS team suspended flights before a helicopter operated by Flight For Life Colorado transported an avalanche-rescue dog team to the site. The dog team was on the scene at approximately 08:00 MDT. The dog alerted shortly after landing, and a rescuer obtained a probe strike on the first attempt. The subject was found buried near the toe with no signs of life. The helicopter evacuated the subject and rescue personnel from the site. After helicopter operations ceased, Launch Point D was used to collect additional daylight documentation. This location provided a sheltered launch area and clear line of sight to the avalanche. The successful documentation of the avalanche from Launch Point D indicates that the movement from A to B to C may have been excessive, as flights from Launch Point A might have sufficed.

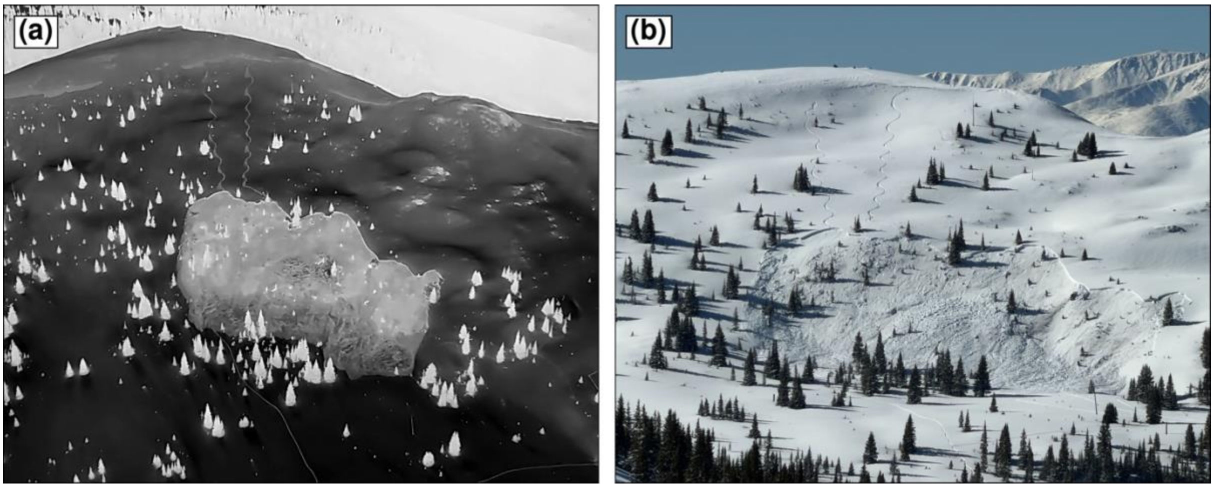

Figure 2: (a) LWIR frame captured at 06:16 MDT from a DJI Matrice 4T. (b) Daylight view from Ptarmigan Pass on 8 March; the subject's first descent is left of center, and the second descent is near the center. Thermal image courtesy SCRG; daylight image courtesy CAIC.

5. OPERATIONAL EFFECTS

Shortly after the discovery of the subject's snowmobile and skin track, teams halted their search due to avalanche hazard and darkness. The mobility of the UAS team proved invaluable for remote assessment and for maintaining a continuous, safe search in a hazardous environment compounded by darkness. The LWIR image of the avalanche site provided by the UAS team presented a clear chain of evidence to rescuers: most importantly, two tracks into the path and only one track out. That finding triggered a transition in the mission to focus on an avalanche burial. Additionally, it greatly reduced the uncertainty of the rescuers flying into the site with respect to both tasking and conditions at the avalanche. The UAS reconnaissance provided answers about the size of the avalanche, the response needed, hangfire hazard, and safety margins. Overall, it helped teams determine whether the risk was acceptable.

6. THERMAL SIGNATURE OF AVALANCHES

Under cold temperatures and fresh-snow conditions, the avalanche and accompanying track pattern remained visible in LWIR imagery several hours after the subject had traveled in the area. Data from the Boss Basin station indicated that net radiative cooling was taking place, though the precise surface conditions at the avalanche were not documented until the subsequent accident investigation. Although the exact thermodynamic mechanisms behind these temperature variations are not analyzed here, the operational implication is that UAS crews should be trained to identify these indicators. Silvagni et al. (2017) reported that a shallow snow burial of 10–20 cm is sufficient to obscure a person's thermal signature. Consequently, searching solely for people or warm equipment can cause operators to miss critical terrain anomalies or fail to report them to incident command. As thermal imaging becomes standard in mountain search and rescue operations, pilots need training to identify and report thermal signs of snow disturbance and avalanche activity with the same level of care applied during daytime operations.

7. LESSONS LEARNED

7.1 Search Tasking

The initial instruction to search the broader region did not provide priority features, preferred sensors, or defined search boundaries. A large search area may be appropriate at the incident level, but individual UAS flights are more effective when assigned a specific question or geographic objective. In this incident, the usefulness of the UAS increased as ground information narrowed the search problem. Discovery of the subject's snowmobile changed the task from searching a large area to determining where the subject had traveled from the snowmobile. Identification of the avalanche and ski-track pattern narrowed the problem further and shifted the mission into an avalanche response.

UAS crews should therefore treat search tasking as an iterative process. Each flight should have a defined objective, its results should be reported to command, and those results should inform the next assignment. Pilots should develop more specific internal tasking when incident-level direction remains broad. In hindsight, the team's decision to reposition after the snowmobile was located, without first attempting a flight toward that new clue, illustrates how repositioning can interrupt this cycle.

7.2 Sensor Use

The lesson for pilots should not be that thermal imagery is inherently superior to visible imagery. The more defensible conclusion is that LWIR was the most productive search sensor given the cold, nighttime, fresh-snow conditions during this incident. California Aerial Incident Response (CalAIR) guidance similarly supports using thermal when environmental contrast is favorable, then using visible imagery and a spotlight at night to identify, confirm, or reject a possible signature (CalAIR, 2026).

The flight from Launch Point B followed the creek line of the drainage with a spotlight and visible sensor from a low altitude. Post-incident review of the thermal video, recorded simultaneously but not displayed on the pilot's controller, showed the sensor recorded two smaller adjacent avalanches of unknown trigger that were not apparent in the visible imagery.

Flying with thermal only can be disorienting, so documenting which sensor was used to search different areas should be on the mind of an operator. Sensor roles and conditions for changing sensors should be explicitly stated before the flight rather than left as an informal decision during UAS flight.

7.3 Crew Structure and Workload

Two aircraft and two pilots provided redundancy but did not necessarily provide two complete search crews. Complex mountain flights can quickly produce task saturation due to the combined demands of terrain avoidance, aircraft control, sensor operation, radio communication, map integration, and CalTopo documentation. Whenever resources permit, each aircraft should have a Remote Pilot in Command (RPIC) and a visual observer (VO) at a minimum. A VO is not a mandatory requirement for a UAS flight per the Federal Aviation Administration (FAA), but is highly encouraged (CalAIR, 2026). A dedicated search technician is also recommended when staffing allows, providing an additional person to monitor imagery without the cognitive burden of flying the aircraft. CalAIR crew resource management guidance similarly recommends that the RPIC not use the radio directly (CalAIR, 2026). This incident suggests that during complex operations, adding personnel to divide aircraft control, visual observation, and image interpretation may provide more operational benefit than adding a second aircraft without the crew needed to fully employ it.

7.4 Integration with Ground Teams and Incident Command

The tracked UTV and portable power supply allowed repeated launches from high points closer to the active search area. These forward launch locations improved line of sight, controller connectivity, and usable flight time. The tradeoff was greater separation from the IC and loss of a continuously shared video feed at command. SCRG now has the capability to deploy mobile Starlink and relay live UAS video using the Eagle Eyes Pilot and Mirada software platforms. Future mobile deployments should preserve the benefits of positioning the UAS team forward in the search area, while maintaining reliable communications and a shared operating picture with command. Non-UAS teams should know what to look for in forward UAS launch sites just as they are trained to select appropriate helicopter landing zones.

8. CONCLUSION

During this search for an overdue subject, thermal UAS imagery did not directly locate the buried subject. Ground teams using traditional search methods first narrowed the search by locating the subject's snowmobile. The UAS then extended observation into terrain that was difficult to assess safely at night and provided information that shifted the mission from a broad search to a focused avalanche response.

This case study illustrates that effective UAS employment in mountain rescue depends on more than aircraft and sensor capability. In this response, the operational value of the UAS depended on task specificity, launch location, viewing geometry, sensor selection, crew workload, and communication with command. These demands were compounded by cold, darkness, avalanche hazard, difficult terrain, and limited access. UAS pilots operating in this environment should train specifically for nighttime winter searches, including the use of multiple sensors, terrain management, and communication with other teams and incident command. ICs should likewise understand the capabilities, limitations, staffing requirements, and information needs of a UAS team so that the aircraft can be integrated effectively into the broader search effort.

This event is unlikely to be the last time SCRG conducts a thermal UAS search during a winter SAR incident. The UAS platform cannot replace knowledgeable and experienced rescuers. Proper UAS employment can only supplement established search skills and methods. The lessons learned from this response provide a practical foundation for continued training, refinement of search procedures, and better integration of UAS into mountain rescue operations.

ACKNOWLEDGEMENTS

The authors acknowledge the SCRG members who participated in the incident and UAS operation and the personnel from Vail Mountain Rescue, the Summit County Sheriff's Office, the Eagle County Sheriff's Office, and Flight For Life Colorado who supported the response and recovery. We thank the CAIC for its investigation and accident documentation, and the U.S. Geological Survey for maintaining the Boss Basin meteorological station and making those observations publicly available. We also acknowledge the California Aerial Incident Response (CalAIR) community whose Drone Operations Manual informed the post-incident evaluation.

This paper describes a fatal avalanche involving a member of our local mountain community. We extend our condolences to the subject's family and friends and recognize the difficult circumstances surrounding the event. We share this case because the response provided important lessons about the emerging use of UAS in nighttime mountain rescue, and we hope those lessons contribute to improved operations in the future.

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