COLORADO

Center of Excellence for Advanced Technology Aerial Firefighting

Department of Public Safety

Report on April 2019 TAK Use for Search and Rescue

CoE-19-002.1

Purpose

This report describes Team Awareness Kit (TAK) support provided by the Colorado Division of Fire Prevention and Control (DFPC) Center of Excellence for Advanced Technology Aerial Firefighting (CoE) to the Mesa County, CO Search and Rescue Ground Team during the spring of 2019. This support was provided to assess the suitability of the TAK app as an operational tool for search and rescue (SAR) purposes.

TAK Use Cases Discussed
Training Mission—April 5, 2019
Actual SAR Call—April 14, 2019
Actual SAR Call—April 21, 2019

Operational Summary

Section I: Training Mission

CoE and Mesa County Search and Rescue personnel conducted a field test of TAK during a SAR training mission on April 5, 2019, from 1830 hours to April 6 at 1000 hours. CoE staff brought a cache of six Android smartphones, two tablets, and charging accessories to deploy with search and rescue personnel. This equipment was purchased by the CoE to support TAK deployments with first responders. This cache also includes a goTenna Pro radio for each mobile device; the goTenna Pro is a tactical mesh-networking radio operating on UHF frequencies that integrates with the Android version of TAK—known as ATAK—and facilitates limited communication when responders are operating in cellular-denied environments. This scenario was the largest physical area tested by the CoE over which the goTenna Pro communication platform was intended to be the primary connectivity mode. The terrain in the area of operations was largely cellular-service denied. In a few isolated locales connectivity was available, such as on ridgetops or at the command post—where a Cradlepoint router provided limited connectivity. However, in the ravines and drainages where much of the search activity took place, cellular service was unavailable.

Figure 1— Area of Operations During Training Exercise

The training exercise took place in an area about 30 miles southeast of Grand Junction, Colorado, in the remote terrain near the Dominguez-Escalante National Conservation Area known locally as Cactus Park. Piñon -juniper vegetation dominates this area as it is relatively arid at an elevation of about 6,000 feet. Trail access is normally by high-clearance vehicles or all-terrain vehicles (ATVs). The primary attraction in this area is the Tabeguache Trail on the shoulder of the Uncompahgre Plateau, a "mega, epic-length cross-county trail" extending 142 miles through Western Colorado.

The training mission was for prospective search and rescue members. It was a field exercise, serving as the culmination of several months of training and was formatted as a long-distance tracking exercise (approximately 10 miles) finishing with a low-angle rope element and litter-carry of an (simulated) injured party. It was the final test in which prospective members are chaperoned and evaluated by team members throughout the evolution. Two groups totaling five individuals, who were role-playing "victims" were given assignments on generally where to hike and where to simulate their injury. Although this was a training mission, participants did not know the final outcome nor did operations (OPS) personnel that were also training.

Figure 2— Providing goTenna Pros to Field Teams

Six search teams were outfitted with the TAK/goTenna Pro package. Field teams received no training on using the TAK/goTenna Pro package. They were instructed to secure the items in their backpacks and not to touch them as the utilization was intended only as a demonstration for personnel at the command post, thus vastly limiting the utility of the TAK platform but minimizing any erroneous user input.

Figure 3— Search Teams and Trail Data Displayed in TAK

The teams deployed at approximately sunset and began tracking their subjects at dark. The traditional method for OPS oversight and position reporting was for field teams to use voice radios to read their UTM (Universal Transverse Mercator) coordinates to a communications unit located at the command post, who then hand-plotted the coordinates on a paper or digital map. After an hour or so, OPS was given an Android tablet running TAK with a satellite image as their map and team locations represented as dots on the map. It was evident right away that OPS found the TAK/goTenna Pro location tracking platform very useful. OPS would note and comment frequently when teams would go "stale" (i.e., Ops not receiving a goTenna Pro location report for more than 2 minutes) and interpret the possible cause as terrain interference or other reasonable explanations. This is significant as OPS intuitively understood the limitations of the goTenna Pro system and correctly predicted when location reports would "reappear." OPS was able to view the location data and cross-

reference with their common platform (i.e., topo maps) to create a more complete operational picture of the teams' performance.

Prior to the commencement of the training exercise, CoE personnel and students deployed a communications repeater/bridge to improve goTenna Pro connectivity in the search area. This unit was an in-house-conceived data bridge between the goTenna Pro and an LTE hotspot (see Section II). The intent was to pipe the location data provided by the goTenna Pros in areas of limited connectivity to a cellular network and cloud-based TeamConnect server so others could remotely view the location information via the TAK platform. This was accomplished by locating a site that had LTE coverage as well as a reasonable overview of the search area. The CoE intended the bridging box to provide dual-platform coverage in case of LTE or goTenna Pro failure during the training mission. We appreciate the efforts of several first-year engineering students at Colorado Mesa University for designing a backcountry platform in which these components could function.

The goTenna Pros communicated across an area of approximately 10 square miles. Although the maximum effective distances were not tested, it was discovered that ridge and canyon features limited connectivity as would be expected based on known UHF radio propagation characteristics. One particular search team lost contact via the TAK/goTenna Pro package early in the exercise, though they were still in contact with communications personnel via VHF voice radio. As terrestrial goTenna Pros on the team members and at the bridging box could not contact this team, CoE personnel were interested in testing the possibility of an aerially deployed goTenna Pro acting as a meshing repeater to re-establish contact with them. A single goTenna Pro was affixed to a DJI Mavic Two unmanned aerial system with plastic cable ties and flown toward the area of operations in accordance with the CoE's night waiver for part 107 UAS operations. The goTenna Pro was attached to the drone in upside-down vertical orientation and hand-launched. A connection with the missing team was reestablished once the aircraft was launched, leading personnel to believe that the aerial goTenna Pro had successfully functioned as a repeater to broadcast location data from the team back to the command post. However, the dot for the team that reappeared in TAK was in a dubious location, which CoE personnel attribute to the fact that the team's phone was not in an optimal position to support GPS connectivity (i.e., buried in a backpack) and thus produced an inaccurate GPS location. Nonetheless, this application of an aerially deployed goTenna Pro appeared superior to the terrestrial repeater during this exercise and, as such, merits further development as an option for connecting challenging environments.

Figure 4— Affixing a goTenna Pro to a UAS

It is common for field teams to go 30 minutes or more without reporting a current location via voice radio since the reporting procedure is an inconvenience and distraction during an actual search. In the case of the goTenna Pro/TAK pairing, OPS would receive automated position reports every 60 seconds. In at least one case, OPS communicated to a team to recheck their direction of travel as it appeared they had become disoriented in the dark and were traveling opposite of their intended path, likely saving the team wasted

effort. TAK eased the workload of OPS personnel that were trying to evaluate and update their search strategy by removing the distraction of manually inputting team locations.

After conducting brief interviews with field teams, it is the author's opinion that field teams felt assurance that OPS was attentive to their progress and could be of assistance if immediate terrain necessitated rerouting. The search effort was physically and mentally demanding and TAK provided a check on field-team awareness as the hours wore on. OPS personnel were pleased with the demonstration deployment and would like to use TAK/goTenna Pro further to determine its utility. During the duration of the operational phase, CoE staff utilized a small projector connected to a Motorola phone (model Z2 Play with an Insta-Share Projector) to project the search area onto the side of a white pickup truck. Other methods of display were considered, but this seemed to work adequately as a briefing tool.

Figure 5— TAK Projected onto Side of Pickup Truck

It may be useful to create a local network in the physical area of the Operations base so that many users are able to view TAK information. In this case (due to minimal cell connectivity), each device user who wanted to view data needed an attached goTenna Pro, necessitating 4–5 goTenna Pros at the mission base when one would have been adequate with a better-constructed local network. CoE personnel are currently working on an economical solution to this issue.

Section II: Data Bridge

To enhance the effectiveness of the TAK and goTenna Pro system, CoE staff believed it would be useful to incorporate a goTenna-to-cellular data bridge, with the purpose being to place the bridging unit at a high point to both repeat goTenna Pro UHF radio traffic and channel the location data into the cellular LTE network—allowing mission managers to access the data over a cellular connection through TAK even if goTenna Pro users were not capable of sending or receiving over cellular data networks.

In late January 2019, the CoE made an arrangement with first-year engineering design students at Colorado Mesa University to design a weather-proof device containing a Raspberry Pi running the Android Operating System and TAK, goTenna Pro, Automatic Dependent Surveillance-Broadcast (ADS-B) receiver, GPS, an LTE hotspot, and an internal battery. The preferred container would be something the size of a common "ammo box" or a similar receptacle.

The CoE tested the bridging box during the overnight SAR training mission referenced in Section I since fire

season had not yet begun in Colorado and CoE staff believed the physical size and terrain of the operations area would be a reasonable test deployment (approximately 10 square miles) that would simulate challenges common in Colorado firefighting. Also, the consequences of box failure would be of little significance in terms of personnel safety.

Figure 6— Bridging Box Deployed During SAR Exercise

On April 5, 2019, the box was deployed in a "high" location, but not one that would command a complete view of the search area. The terrain sloped dramatically down to the north, and to the east ridges blocked line-of-sight to SAR teams by approximately 300–500 vertical feet. The goTenna Pro (connected by Bluetooth to the Raspberry Pi) was taped in a vertical orientation to the top step of a 3-foot fiberglass ladder. The goTenna Pro was connected to a Goal Zero 400 by micro USB to provide the radio with a consistent source of electrical power. Additionally, the bridging box was connected to the Goal Zero battery.

The system appeared to work as intended through the night; however, in the early morning hours (after about 11 hours running) the box dropped off the TAK map. Upon retrieval of the equipment about 16 hours after deployment, CoE staff noticed that the goTenna LED light was red, indicating charging status. After unplugging and reconnecting the device, the LED light turned blue, indicating a full charge. We are not certain why this was observed, although the manufacturer informed us afterward that the device does not operate in a "shore power" mode but will recharge if connected to an external battery. The Goal Zero began the operation at 97% charge and after 16 hours read 73%. The bridging box's internal 26,000-milliampere-hour battery was not measured or observed.

Section III: First Actual SAR Mission

On April 14, 2019, at about 1930 hours, Mesa County Search and Rescue was requested to assist National Park Service staff from the Colorado National Monument with a search for a lost hiker. A 30-year-old male reported that he and his 4-year-old daughter had been hiking in the Red Canyon area of the Colorado National Monument near Grand Junction, Colorado. They left the pull-off at about noon on this same date and at about 1830 hours the male called his wife saying he believed they were close to the car but were lost. The pull-off has a scenic view designation but no sanctioned hiking is suggested in this area. Its elevation is approximately 6,200 feet and the terrain is piñon-juniper woodland with surrounding sandstone cliffs and canyons. The temperatures were expected overnight to be in the mid-forties. The subjects were dressed in light hiking clothes.

The ranger informed SAR teams that the wife believed they would hike on the south side of the Rimrock Road, although her husband had only been in the area one time previously. Four of five field search teams were issued data-enabled TAK smartphones with paired goTenna Pros. A data-enabled tablet and goTenna Pro were left for the OPS Chief to use. Neither SAR teams nor OPS personnel had been trained in the functionality of TAK other than to view team locations on digital maps and to view team GPS coordinates. One member of Search Team 2 was a CoE employee and utilized TAK as his mapping platform for the team's navigation.

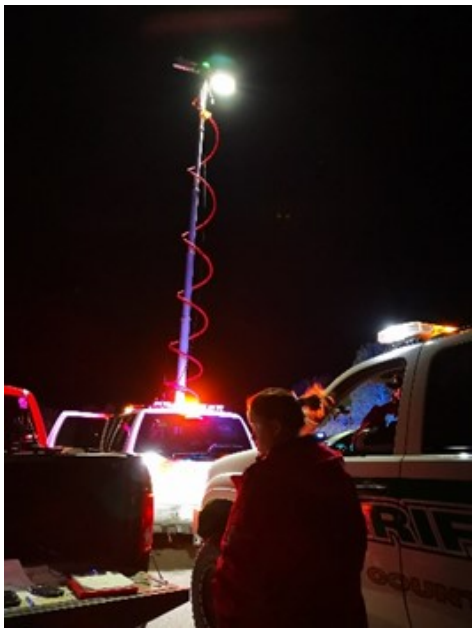

Figure 7— Scene at Command Post During Mission

Teams 1–4 deployed into the field: three teams on the north side of the road and one on the south side. The terrain dictated this allocation of resources since to the north was a large plateau ranging several square miles, while the south was accessible via an approximately 300 foot long human-made tunnel hewn from solid sandstone. Footprints matching the subjects' descriptions (those of an adult alongside a small child) were located in each of the team deployment locations (i.e., all four teams found potential subject tracks). This unfortunate coincidence complicated search efforts.

Team 2 on the south side of the road located footprints at the entry to the tunnel and about 30 feet after the tunnel ended. The terrain turned to a solid sandstone creek-bed and shortly thereafter ended in an extremely exposed cliff edge. SAR personnel believed that the pair did not continue up the drainage due to the extremely hazardous cliff-type terrain. Team 2 left the drainage and cut for sign along the east side of the drainage back north to the road since the west side was a sheer cliff of 15–30 feet and not believed to be a reasonable route. Team 2 discovered no sign of the pair and was reassigned to an area further west of the other three field teams on the north side of the road.

Several times, teams called in to OPS requesting direction as the target footprints seemed to disappear into very large sandstone flats. Utilizing location and breadcrumb-like track data visible in TAK, OPS made team route determinations utilizing terrain features to take advantage of areas that could be "cleared" by audio attraction (calling out/ whistling for the subjects). An audio overlap technique was used in this situation. SAR team members believed the subjects wanted to be found and determined that continuing a hasty-type search was in the best interest of the subjects rather than continuing to search footprint to footprint. For instance, Team 2 was able to quickly measure the distance between its members and Team 1 using TAK. Team 2 made a radio call to OPS indicating

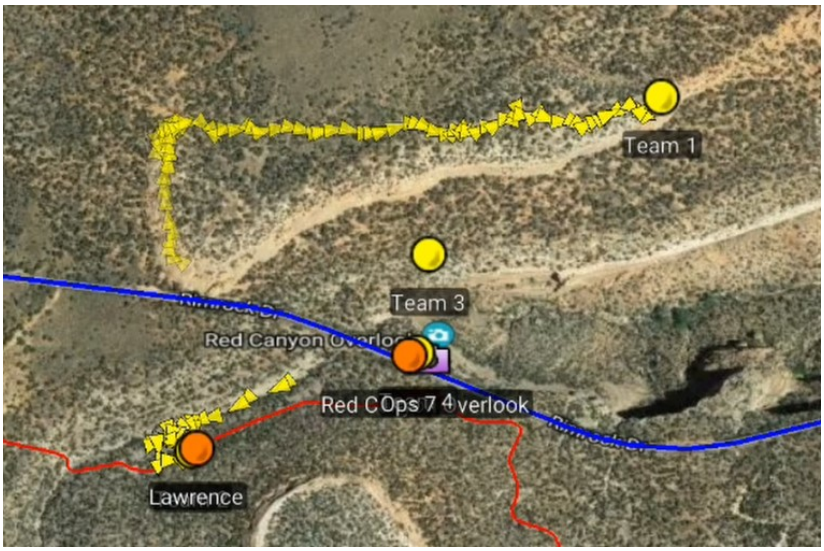

Figure 8— In-Progress Search Operations Viewed in TAK

that they could hear Team 1 from approximately 0.5 mile away. Team 2 requested that OPS make a note of both teams' locations in TAK and call the area between the teams "clear" at that time—enhancing operational effectiveness and efficient use of search teams.

Team 2 was directed to proceed to the northwestern-most point on the plateau before it ended in a cliff. Team 2 created and sent a point in TAK to OPS noting the furthest north they traveled in case OPS needed to revisit the search area. TAK functioned, albeit in a small way, as a field documentation tool. OPS was later able to communicate that this point would have been valuable if the search had continued without success. Additionally, using TAK, Team 2 observed Team 3 making a turn back toward the south, so Team 2 adjusted their search path to avoid overlap and maximize the effective search area. Reliable cell service was present in the area of operations and field team locations were updated every few seconds. After reviewing the breadcrumb tracks of teams on the plateau, OPS believed the area had been covered well and began to divert resources back to south of the road.

At about 2200 hours, Team 5 (with no TAK/goTenna) was given an assignment to go back through the tunnel and simply explore the area. They didn't locate tracks or any other indication that the subjects traveled in the area, but eventually decided to turn east out of the drainage approximately 1,000 feet south of where Team 2 left the drainage. Team 5 then contoured back to the north-northeast along the bottom of an approximately 50-foot-tall cliff band. Coincidentally, at the base of the cliff they discovered a backpack belonging to the adult male (his employee credentials were inside). No tracks were around the backpack and it appeared to have slipped or been thrown off the cliff. Team 5 joined Team 4 (now with TAK/goTenna) and scoured the upper cliff band.

Team 2 created and broadcast a point in TAK indicating the location of the backpack. Teams continued south utilizing a search dog to speed tracking efforts. Teams 4 and 5 located the uninjured subjects at about 0300 hours. They were transported back to mission base by ATV and vehicles. Using Team 4 and Team 5's locations, Team 2 created a waypoint and designated it as the find location in TAK.

Figure 8— Backpack Belonging to Subject

Figure 9— Subject's Footprint

Several times during this mission, OPS was able to anticipate direction of travel questions teams would ask and had pre-determined which direction they would need to go next using information provided by TAK. Additionally, on at least one occasion while OPS was viewing a team's direction of travel, OPS corrected an error that would have cost the team physical effort and wasted search time. Utilization of TAK enabled OPS personnel to reduce unnecessary communication of GPS coordinates by radio (the benefit of this cannot be overstated) and anticipate terrain challenges teams would encounter and have a plan of action.

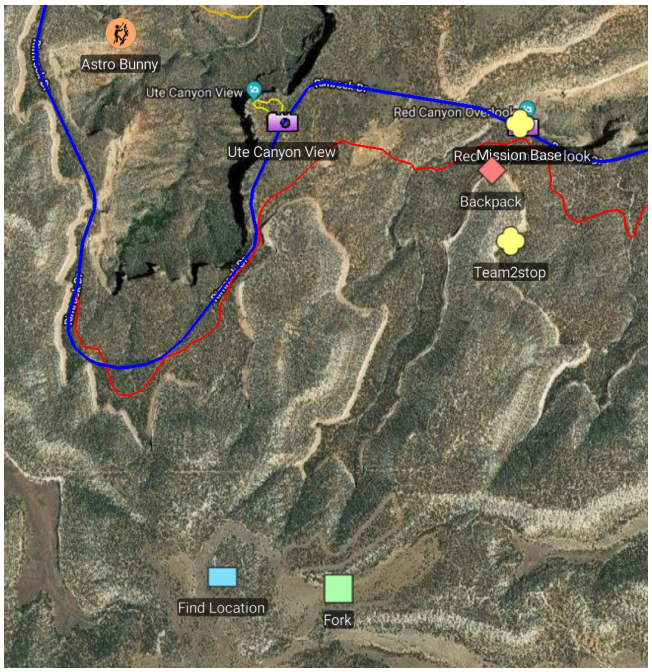

Figure 10— Points Dropped in TAK During First Mission

Section IV: Second Actual SAR Mission

On April 21, 2019, at about 2045 hours, Mesa County Search and Rescue was requested to assist Colorado National Monument rangers with a report of an injured hiker. 911 dispatch received a very brief call from a subject reporting they had injured their pelvis in a fall and had substantial bleeding. The caller gave his name as "Dave" (changed for this purpose) and described his location as something to the effect of "Monument National Canyon"—verbally transposing the title of the general area and thus providing no clues as to his whereabouts. He believed he was going to pass out and the call went dead. Rangers and Sheriff's Deputies scoured local trailheads looking for a vehicle of interest. A rental car with documents in the vehicle appearing to belong to "Dave" was located at the Upper Liberty Cap trailhead along Rimrock Road in the Colorado National Monument.

This area is high-desert piñon-juniper landscape with an elevation of approximately 6,300 feet. Sandstone cliffs abound and catastrophic falls are common. The trail from the upper parking lot is approximately 5 miles in length, gently sloping to a major cliff band featuring a narrow-ledge descent of about 1,000 feet. Also of interest was an area known as "Otto's Bathtub," named after the park's first superintendent. This is a narrow sandstone ridge with numerous pothole-type features. Teams collected rappelling gear and planned for a hike of 10 miles and deployed at approximately 2200 hours. Prior to this mission, some of the SAR personnel had received a brief training on the operation of the TAK app during a team meeting. Personnel were trained on basic mapping functions and how to create and share points in the app.

TAK and goTenna Pro "kits" were left at mission base for field teams to pick up and stow to allow their location to be tracked by the OPS Chief. Team 1 deployed and began heading toward Otto's Bathtub. They located a braided survival bracelet along the trail. This was left in place and a point was created and broadcast in TAK. Along the way, they spotted several tracks leaving the main trail that then appeared to return (out and back). Team 1 created a point at the first of these locations and broadcast it to OPS so other teams would have a coordinate reference to ignore the previously "run-out" tracks. Team 1 attempted to create and broadcast 2–3 more of these points, but the personal phone running TAK (Samsung Galaxy S9+)

was having touchscreen issues related to sand debris between the screen face and the screen protector. At that point, it was easier to contact OPS by radio and request that a point be placed at Team 1's location in TAK and broadcast back to Team 1. This enabled the team to continue with a hasty search without having to delay for technical troubleshooting. The OPS Chief is an individual with above-average digital map and technical skills. However, this individual only received a 15-minute informal group training on basic TAK functions just 3 days prior to this operation. This ability to create/broadcast points after such a short training was encouraging for future adoption of this technology.

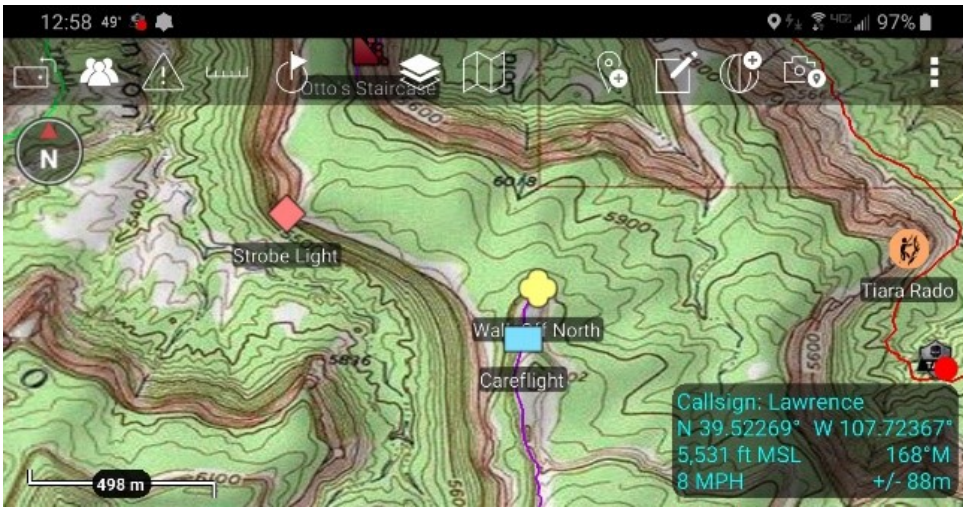

Figure 11— Points Dropped in TAK During Second Mission

A local air-medical helicopter was requested to assist in the search as their use of night vision goggles had previously been helpful in locating subjects in the dark in vast terrain. They were requested to search the prominent 1,000-foot-ledge descent and then search out from there. At approximately 2250 hours, the helicopter crew spotted some glow sticks spread on a cliff band and what was later identified as a cellphone light in strobe mode. They were able to land on a sandstone plateau about 0.5 miles from the light and found a route through sandstone cliff bands to access the patient. He was located to the northwest of Otto's Bathtub. This is an off-trail/ unsanctioned area for foot travel and in an area unlikely to have been searched by foot teams during the first operational period.

Medical personnel contacted OPS on an air-to-ground radio frequency and relayed the GPS coordinates to OPS. OPS then created a point in TAK called "Strobe Light" and broadcast it to all teams. OPS contacted all teams by radio indicating that a new point had been created and that it was likely the injured subject. Teams were advised that the helicopter crew believed from the aerial survey of the scene that numerous SAR personnel would be needed.

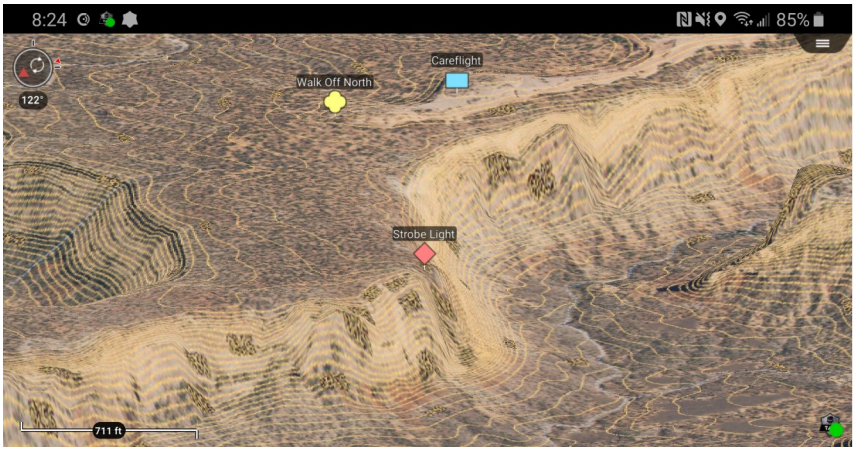

Figure 12— Rugged Terrain of Second Mission Viewed in 3D Using TAK

At about 2315 hours, medics on the helicopter reached the patient and indicated that they were attempting to stabilize him for transport but would be waiting for SAR to do so. OPS sent an additional point in TAK noting the location of the helicopter landing zone just north of Otto's Bathtub. This was used as a spatial reference to enable SAR teams to locate the only reasonable descent from the plateau to the subject's lower elevation. Team 1 then communicated by radio that they had turned off the main trail to the north onto the "Otto's Bathtub" trail—OPS replied that they could see the team's progress and to

continue as quickly as was safe.

Team 1 contacted OPS at the site where they located a descent route and requested that OPS create/send a point titled “Walk Off North” so other teams wouldn’t have to search the cliff band for this spot. Team 1 rendezvoused with the helicopter medics and planned a method to transport the patient to the helicopter. Team 1 sent two members back to the cliff band to set up a low-angle haul system for the rescue litter as it was far too steep to carry the patient up the cliff. A handline was fixed as well.

At about 0100 hours on April 22, 2019, Team 3 arrived with the collapsible litter. The patient was packaged and transported along about 0.5 mile of rough terrain back to the cliff band. The litter was secured to the rope system and the subject was hauled slowly up the cliff using a modified “caterpillar” method. That is, SAR personnel would climb up above the patient and move the patient short distances from locations where team members could scramble, but didn’t need a true vertical rope system for safety. The total raise was about 20–25 vertical feet. The patient was loaded into the helicopter at about 0200 and SAR personnel returned to base at about 0345. The overall travel distance for foot SAR teams was approximately 10 miles.

During the second mission Team 1 observed that the TAK app seemed to “close” when the screen was locked; they noticed this at least four times during the mission. Team 2 also noticed that the TAK app appeared to “close.” Finally, Team 2 had a goTenna “lose” its pair with the phone and they hadn’t received training yet on how to troubleshoot that problem. CoE personnel are currently evaluating the phone and TAK configuration to better understand why these issues occurred and how to mitigate them on future deployments. The CoE is also working on future deployment plans to facilitate TAK usage with Mesa County Search and Rescue personnel.