APRS and Search and Rescue

Jeff Lehman, KD6DHB
San Bernardino County Sheriff's Cave Rescue Team
4755 Maple Ave.
La Mesa, CA 91941
619-461-6177
jlehman@caverescue.net

[*The APRS team. Tad Gallistel (KG6ANQ), Jeff Lehman (KD6DHB), Mark Kinsey (KG6JZX), and Mark Kern (KE6QXF). All are members of the San Bernardino County Sheriff's Cave Rescue Team*]

I. APRS Introduction

A year or so ago I was on a search as part of a composite team that was sent to assist in the evacuation of some overdue hikers. The hikers were found the previous evening, and had spent a cold night with rescuers. From the outset there was difficulty in locating the proper canyon for our descent. The weather was cloudy so aviation was not flying at the beginning of the mission, and the location reports from those with the rescue subjects were conflicting. Since we were carrying vertical gear (ropes, carabiners, harnesses, etc.) I opted not to bring my GPS or personal radio so as to reduce my load in the steep terrain (I learned many lessons on this rescue. Two of the most important being never leave your radio and GPS). From the outset I realized that our team was having GPS "issues". When I heard the team member with the GPS report our position it didn't correspond to where I thought we were on the map. After a couple of position reports I started to get a bit frustrated with my navigation abilities, when I asked, "What map datum is your GPS set to?" I knew something was amiss when I got a blank stare. It turned out that the GPS's datum was set to "User Datum". While we did accomplish our mission that day, it began the search for a better way to monitor a SAR team's location.

Later, when relating this story to my teammates, most of them hams, we decided that it would be nice to reduce the likelihood of user error in the use of these technologies. After all, unless you use radios and GPS's regularly, their effective use can be daunting. A few of us had been talking about the use of the Automatic Position Reporting System(tm) in SAR, but we hadn't pursued it aggressively.

APRS was developed by amateur radio operator, Bob Bruninga, more than 10 years ago, and hams have been using APRS to track things such as floats in the Tournament of Roses Parade, runners on the Olympic Torch Relay, high-altitude balloons, and their personal vehicles. APRS encoders take the position output of a GPS and use a radio to transmit a "packet" of this information that can be decoded by another station and plotted on a map. Depending on the rate at which one reports his position, the receiving station gets real-time locations for each station.

The reception of a packet can be improved with the use of digipeaters. Like radio repeaters that are used with voice communications, digipeaters can sit on mountain-tops and repeat position packets. The difference with digipeater use is that it is transparent to the end-user. Since there are no input and output frequency off-sets, or PL's to set there is nothing that the user in the field must do. They just go about their primary job which is searching and rescuing. In addition, portable digipeaters can be set up very easily that can help fill in areas of poor coverage. No large duplexing "cans", controllers, or other equipment associated with voice communication repeaters are required. A digipeater consists of a terminal node controller (TNC) and a radio.

The Mountain Rescue Association (MRA) offers a grant to further research in search and rescue operations each year. We wrote a proposal to the MRA (www.mra.org) to study the use of APRS in search and rescue (SAR) environments. We proposed to study the optimum enclosure for the trackers, the optimum reporting interval, the use of digipeaters, and the use of high-quality topographic map software to display position reports. In addition, we sought to use equipment (radios and GPS's) that our team already owned. To our delight our proposal was funded and we began, in earnest, the construction and purchase of the necessary hardware and software to build six tracking encoders and a base station to receive the reports and display them on a map.

II. Hardware and Software

A. Encoders

When designing the device that is to accompany rescuers in the field there are a number of requirements for effective SAR use. The device must be weatherproof to some degree, it must be relatively lightweight and not bulky; the device should not encumber the rescuer to such a degree that their ability to perform their primary function is compromised. Finally, the device should be "rescuer proof". That is, there should be minimal maintenance required once deployed. The greater the number of buttons, and user intervention that is required, the greater the likelihood that the device will fail due to user error.

After investigating numerous options for encoders which included the TinyTrakII encoder (www.byonics.com), Paccomm PicoPacket (www.paccomm.com), and the Tigertronics TigerTrak TM-1 (www.gpstracker.com), we decided upon the TigerTrak TM-1. We initially purchased and built two TinyTrak's, but we were not able to get past an RF interference issue that would lock the encoder into transmit. Our packaging requirements necessitated close proximity of encoder and radio, and we were not able to provide adequate shielding. The TigerTrak did not seem to have the same problems, so we decided to use this device.

The TigerTrak is a small, robust tracking encoder that will interface to just about any GPS or radio. Jason Yilek manager of CJ Products, the distributors of the TigerTrak, worked hard with us to make sure that this device would fit our design requirements. For example, when he found out that we were going to use the popular Garmin eTrex GPS with the device, they made a modification to the board to make sure that the voltage levels provided by the eTrex would indeed work with the TigerTrak. It turns out that some eTrex GPS's don't provide enough voltage at the serial port to successfully pass the data with the TigerTrak. A modification to the board, and a diode in the cable (they even gave us the diode so that we could include it in our cable) took care of any potential problems with the GPS interface.

B. Radios

Being hams, our team has a cache of the popular Yaesu VX-150 handheld VHF radio. This radio is well-suited for rugged treatment, and they have performed admirably in the field for a number of years. The trick to interfacing this radio to the encoder was finding a source for the 4-conductor microphone plug now popular on Yaesu radios. One suggestion from a local amateur radio store was to buy the cloning cable and cut it in half, but this was an expensive option, and it did not allow for a 90 degree bend in the connector. A call to the Yaesu parts department and their technical folks yielded no leads. Finally, we happened upon a terrific source. Bux Comm Co. (www.buxcommco.com) has the 4-conductor right-angle plug molded onto a spiral microphone cord. What a find! This enabled us to make a robust connection to the encoder for only a few dollars.

C. Base Station

For the command post station we purchased a Kantronics KPC-3+ TNC and connected it to a Yaesu FT-50R HT that we had in the team cache. The TNC was connected to a team member's personal laptop computer, and the radio fed a "James Pole" copper j-pole purchased from James Pole Antennas (www.jamespole.net).

Software

The mapping software is a crucial part to APRS. After all, the whole point is to show where things are. The trouble with APRS software and SAR is that most of the mapping packages for use with APRS are street-level maps, and not topographic maps for wilderness use. To compound the difficulties, the USGS topographic maps used for wilderness travel use the North American Datum of 1927 (NAD27) and the maps with packages such as DeLorme StreetAtlas, Microsoft Mappoint, or WinAPRS use WGS84 or NAD83 as their datum. Also, most wilderness SAR uses the Universal Transverse Mercator (UTM) coordinate system. UTM coordinates are much easier to decipher when trying to plot a position on a map. With the UTM system, finding your position on the map is much like playing the game of "Battleship". Your position is a series of numbers that correspond to so many units over and so many units up in a particular grid shown on the map. The position reports available via APRS use the NMEA sentence which is given in latitude and longitude. The ability to translate between coordinate systems and datums is an important feature.

We tried three software packages: WinAPRS, APRSPoint, and APRS+SA. Another package, XASTIR, which has topographic map support, was not actually used in the field due to the fact that it only runs under LINUX (The source code for a Windows version is available at the time of this writing), and we did not have a laptop configured to run LINUX at the time. While Mappoint was the most user-friendly in terms of the integration of maps with APRS software, the ability of APRS+SA to translate position reports between coordinate systems and datums made it the favorite.

Why is this an important feature? First, since APRS positions are reported in latitude and longitude it is helpful to convert these positions to UTM so that they can periodically be plotted by hand on the master command post map somewhere in the command post. Also, remember that the positions are being reported relative to the WGS84 or NAD83 map datum so that they correctly appear on the real-time APRS map. That master map in the command post, however, uses the NAD27 datum so in order to correctly plot a position on this map, the position reports need to be translated to the correct datum. To be honest, for most work the difference between NAD27 and NAD83/WGS84 is negligible, but in the example given at the beginning of this article, the difference between these was significant. Finally, this conversion is handy because the GPS's in the aircraft in our county are set to read NAD83/WGS84 and latitude and longitude. Often positions of teams on the ground (who are using NAD27 and UTM) are routed through the command post so that the appropriate conversion can be made in the case where a helicopter needs to meet a team on the ground.

As an additional note, there are a number of topographical map packages available that would make an excellent platform for APRS. The author contacted National Geographic Topo Maps (formerly TOPO!) and MapTech and both of these companies said they had no plans to offer APRS support. This is unfortunate, because either of these would be an excellent SAR tool.

D. Roving Digipeater

Since most SAR missions occur in sparsely populated areas we were not certain how well the existing APRS network would be accessible to digipeat our field stations. We did consider using full-fledged TNC's (encoders and decoders) for each of the field stations so that each could serve as a digipeater, and forward position reports along, but this option was beyond our budget, and form factor requirements. We decided that one or more roving digipeaters may be the best way to ensure that the position reports of those teams in the field would be heard by the command post.

Small, portable digipeaters have been constructed by a number of folks to support APRS activities. Deployment of man-portable digipeaters would be very helpful in remote locations, but they could not be fielded as quickly as a vehicle-based digipeater. For most operations, however, a digipeater with a relatively high-power radio (>10 watts) in a vehicle is the most useful. This digipeater can move as teams move, or quickly be placed in a location where it can hear the stations in the field and be heard by the command post. So far, we have used one roving digipeater and it has been sufficient in a number of different kinds of terrain.

The use of existing digipeater infrastructure greatly simplifies the problem of getting the position reports back to the command post. If the command post can hear one or more existing hill-top (WIDE) digipeaters then chances are the roving digipeater can as well. In this manner, the hill-top digipeater can forward packets even if the roving digipeater is out of range for direct contact with the command post. More on this topic later.

III. The Field Tests

After a few months of building and research we were able to field our six tracking devices, base station, and a roving digipeater on three different occasions.

A. Mountain Terrain with Rolling Hills

The first operation was part of a San Bernardino County Sheriff's West Valley SAR Team search scenario in the local San Bernardino Mountains.

The plan was the "overdue hiker scenario" where the team rolls on site, interviews the reporting person, sketches any shoe prints, makes team assignments, and searches for the lost person. Mark Kinsey (KG6JZX), a fellow Cave Team member, and I were to attach our tracking devices to one member of each of the six search teams, set up a base station for map display, and deploy our roving digipeater if necessary. The search scenario occurred in Holcomb Valley which is well-suited for a first-time test. For the most part, radio coverage is not greatly complicated by the terrain, but as with any search, communication can always be problematic.

Mark Kinsey and I were prepared to operate out of the front seat of a vehicle, but Bill Maclay (KD6HFY) member of both the San Bernardino County Sheriff's Search Dog Team and Communications Team, showed up with his nifty trailer with well-appointed radio/computer workspace. This freed our team vehicle for use as the roving digipeater. We maintained a position lock on every team throughout the duration of the eight hour scenario. When we began to not get position reports from teams at each two-minute interval, the roving digipeater was deployed to fill the gaps. This digipeater was the Cave Rescue Team truck with a TNC attached to its VHF radio (Kenwood TM-733A). I drove the roads in the area finding a high spot, and coordinated with Mark back at the command post to confirm that he was getting position reports. When the teams moved to an area no longer covered by the digipeater, I moved along as well. A few times we "lost" teams for 10 or 15 minutes, but this could have been due to poor GPS coverage, as the encoder will not send a packet unless the GPS has a position lock. In one case it was due to a team member's pack covering the GPS during a lunch break.

Since this was new technology, the APRS information was not relied upon heavily early in the search. One of the issues was the location of the mapping display with respect to the master search map. It would be more effective if they were right next to each other. Also, one of the current difficulties with SAR use is that the maps provided with the APRS software are street-level maps, and not topographic maps. We could see relative locations and locations with respect to roads, but not directly on a topographic map.

At one point three teams were waiting for instructions at a road intersection when one of the teams "caught sign" and began tracking. Right away their departure from the area was noticed on the APRS plot and the command post called to ask why they were leaving, and why the command post wasn't notified. As it turned out, one of the other teams at the intersection had suggested to the tracking team that they should notify the command post of their departure, and the tracking team was about to do that when the command post called. This same day we were able to notify two teams that they were actually following each other, and to spread out to make a more effective search.

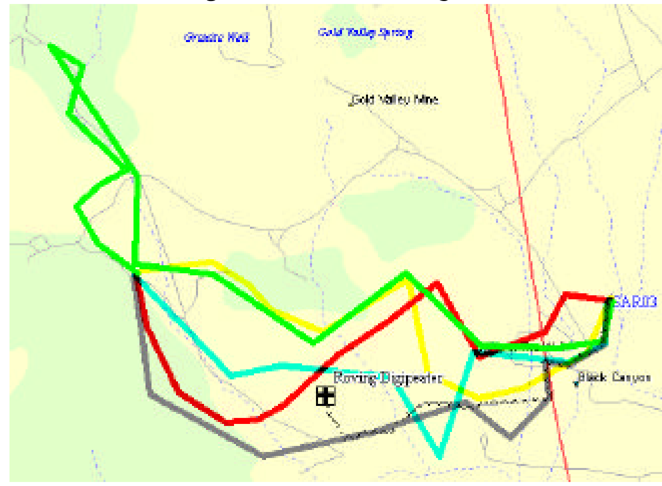
B. Desert Terrain

The following month Mark Kern (KE6QXF) and I were able to accompany West Valley SAR on their annual land navigation exercise. This exercise covers a very large area in the East Mojave Desert that presents some interesting challenges with respect to RF propagation. This particular exercise placed the command post a few miles from the operation in a low spot with a very large hill (mountain for you Easterners) between it and most of the teams. Again, all six trackers were deployed, but there were 11 teams. Therefore, not all teams were tracked throughout the exercise.

Each team was given a series of locations on a map for which they were to travel to and report what they found. They were not allowed to use a GPS and had to rely on their ability to read a topographical map and compass.

The roving digipeater was crucial in that the command post could not hear any stations due to the hill and low position. Also, the terrain allowed for the digipeater to stay in one location throughout the operation.

The APRS triumph of the day occurred relatively early when the command post notified the operations leader that a team was heading in the wrong direction, out of the navigation course area. The position was converted to the correct datum and UTM coordinate system and reported to the ops leader so that he could plot it on a topo map. He couldn't believe that this team was in the position reported by the APRS report and didn't worry about them until the team was no longer within communications range (a portable voice comm repeater was used by the team, so out of commo range meant a long way away). Again our command post showed them a couple of miles in the wrong direction. [*The image below is a screen*



shot of the APRS tracks of these groups, with the green track being the errant team]. We continued to get position reports even though they were no longer within voice comm range. We relayed their last position to the ops leader as he left to try to find them. Lo and behold, they were right where we said they were, and were promptly returned to their original start location so that they could begin again.

During this operation we used an additional item in the roving digipeater. We used a Handspring Visor Deluxe running PocketAPRS to monitor the position reports in the roving digi. This proved to be very helpful in placing the digipeater as the operator can see for him/herself whether reports are being received. This reduces radio traffic in that the command post does not have to tell the digi when and where to move. It was also helpful in making the case that there was a team off-track that needed some guidance. One thing is certain, however. The operator of the digipeater must be intimately familiar with TNC operation since PocketAPRS, depending upon configuration, may change a few TNC settings upon start-up. If a computing device is to be connected to the TNC used as the digipeater, then there must be an experienced operator nearby to tend it, as an inexperienced operator could change the TNC configuration rendering it useless for the task at hand.

C. Steep Alpine Canyons

West Valley SAR agreed for a third test as part of another of their monthly trainings, and Mark Kinsey, Tad Gallistel, and I headed for the mountains for a simulated search and subsequent litter evacuation. The scenario was different from the others in that the team was not told ahead of time where the activity was to be. They were told that they would be paged as they are in an actual call-out, so to play along the APRS team was told to be in a certain metropolitan area and tune to a coordinating radio frequency. Around 6pm the page was sent and team members began coming up on the requested frequency and coordinating their activities. At that time we, the APRS team, were notified of the location and began heading in that direction.

Arriving on scene we found the terrain to be steep canyons with no place to operate a roving digipeater. We issued our tracking packages to the first team out, the hasty team, and the next two teams. Fortunately we had good reception of the teams in the field and didn't need to deploy the digipeater early in the exercise. Also to our relief the lost subject was located within the first hour or so of the operation, and he was within 1.5 miles of the command post. What ensued was a several hour evacuation down a talus slope on a cold evening in November.

While this was a good test of the operation in steep alpine canyons, the search area was relatively well-defined by the terrain, and teams did not get spread out too far such that management of resources was an issue. One helpful aspect to the operation was managing and planning additional resources. For example, once the patient was located and it was determined that a litter and additional equipment was necessary for a safe evacuation, a team waiting in reserve was sent with the needed equipment. They received a tracker and it was helpful to monitor their progress to relay to the teams waiting for the materiel. It was dark, so they could not see each other except for the occasional flash of a headlamp.

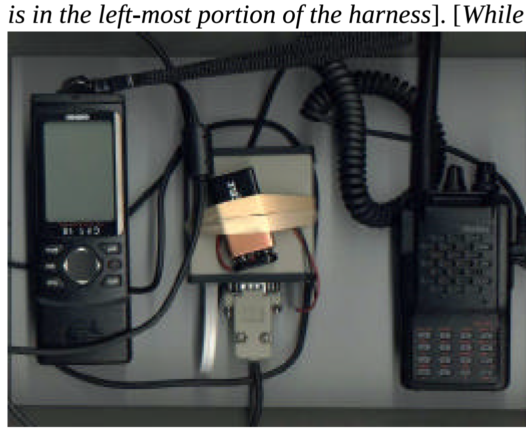
IV. Results and Recommendations

A. In-Field Tracking Package

For our tests, one member from each team was designated the beacon mule, and a radio harness and tracker complement was entrusted to their care for the duration of the event. Periodically they checked on the GPS and radio to make sure that they were still powered up. The TigerTrak will not report a position if the GPS does not have a lock, so it is important to make sure that the GPS is receiving a sufficient number of satellites. One handy thing with the use of APRS in SAR is that the whole set-up does not have to be in operation when teams enter the field; the teams can be issued trackers, but the command post station and any digipeaters can be set-up later in the operation.

There have been a number of interesting and clever packaging ideas for APRS trackers presented in *QST* and other locations. We found, however, that the best packaging for a system that uses off-the-shelf radios and GPS's is the standard radio harness. The antenna stays in the correct orientation and the radio and encoder are out of the way of the rescuer. This set-up could also be placed on a pack, and this configuration was also used.

[*In the image, Steve Elliott, KG6OPJ, is wearing a Conterra radio chest harness. The TigerTrak encoder box and GPS are in the large pocket in the center-right, and the radio is in the left-most portion of the harness*]. [*While we didn't use*



the Garmin GPS 12 in our work, it is shown in the image above for scale].

Tracker Configuration

The TigerTrak is configured via the serial port on a PC. A number of sets of settings are available with the TigerTrak. In this manner one can select a different icon or path for each mode (setting). The call sign and any comments are the same regardless of the mode. The comment can be disabled or enabled between modes, however. Also, the TM-1 can operate in continuous or Mic-E modes. To change modes the mode button is pressed a number of times corresponding to the mode number. For instance, if you would like to use mode 6 then you would press the mode button 6 times in succession and an LED would blink 6 times confirming your change to mode 6. The other button on the TM-1 is the power button; it is a toggle where a press of the button toggles between on and off.

One of my teammates, Tad KG6ANQ, summed it up best when he stated that the TigerTrak has two too many buttons (it only has two buttons.). The configuration program allows for the disabling of both the power and mode buttons, and this is a requirement when sending these devices into the field. The push-button switch is easily bumped which could turn the unit off or change modes inadvertently. This could effectively render the tracker unusable while in the field. A helpful remedy would be some sort of heavily detented switch that shows the mode number easily and is not easily actuated with rough handling. This would allow the user to actually make use of the different modes. For us, the mode feature is unusable since it is not practical to make continuous changes in the field.

Our configuration of the TM-1 used a path of RELAY, WIDE3-3 and we used the call sign field for a tactical call sign (SAR01-SAR06). In this manner the tactical call sign appears on the map which is much more useful than a ham call sign. A piece of tape with the tactical call sign enables quick identification of each encoder so that it can go with the correct team. To keep things legal we identified our stations by putting the ham call sign in the “comment” of the APRS report. Our reporting interval was once per minute. While this is far more resolution than is required for SAR work, where folks are travelling relatively slowly in difficult terrain, it was determined to be optimum since the GPS regularly looses lock, and the terrain limits RF communication, making a higher reporting interval necessary to increase the likelihood that a position report will be heard by the command post.

In addition to the settings listed above we also used the “To Call” of “SAR” so that we could more easily filter the reports back at the command post.

The following are a number of suggestions for improving the TigerTrak TM-1 for use in SAR:

- Use a detented dial for mode changes.
- Use a more positive button for power such that it cannot be easily switched off with rough handling. The fact that the power switch can be disabled is a big help, however.
- Allow different comments and call signs for each mode. This way the trackers can be more easily repurposed in the field (change icons and tactical call signs).
- Provide some sort of battery “fuel gauge” so that battery condition can be readily assessed in the field without a voltmeter.
- Build a case that will accommodate a 9V battery.
- Have the ability to cycle through the modes alternating with each position report. In this manner different paths can be used without having to reconfigure the tracker if paths are an issue.
- Offer pre-built cables for a number of popular radios. The cables provided are handy, and so is the modular connector, but making the cable and providing sufficient strain relief for those tiny wires is not a trivial exercise.

B. Command Post Station

The biggest issue with the command post station is the software. As discussed earlier APRS+SA was deemed the favorite due to its ability to translate datums and coordinate systems. An interesting finding of our tests, however, was the realization that having topographic software was not an absolute requirement. Often when running an operation the incident commander and command staff will discuss the situation over the hood of a car or in a makeshift command post. It is difficult for many folks to hover over a relatively small computer screen. For this reason, a regularly updated table with the current position of each team that can be translated into any datum or coordinate system is of great utility. With this position data the operations leader can quickly locate each team on a master map, and those positions are easily viewed by everybody around the table. While APRS+SA can do these transformations, it must be done for each team and for each position report. It would be nice to have a table that will toggle all positions between datums and coordinate systems. In fact, PocketAPRS is well-adapted to this since its ability to display high resolution maps is limited, and PalmOS PDA’s can be obtained for small amounts of money compared to a full-fledged PC. The author of PocketAPRS has been contacted in this regard, and he is working on adding these features. If I had to choose between topographic map support and the ability to express position reports in different datums and coordinate systems, I would choose the latter. Granted both are the best situation, however.

C. Roving Digipeater

The roving digipeater has proved to be invaluable in SAR APRS work. The complex terrain requires relay devices, and a mobile radio and TNC provide a great platform for this device. We were continually amazed at the comprehensive coverage of existing amateur APRS networks. Even in the middle of the Mojave Desert we were bouncing in to digipeaters that would forward our positions to the Internet. After each operation we were able to view the locations of all of our teams using findu (www.findu.com). This has tremendous possibilities in resource management.

We set the digipeater to respond to both RELAY and WIDEn-N paths. The reasoning behind this was to accommodate a packet from one of our teams that may have relayed from a nearby amateur station, but was not heard by our digipeater. In practice, however, this concern was not realized.

The use of a PDA and PocketAPRS was a big help in the roving digipeater. Running this software enabled the driver to accurately position the vehicle as well as keep tabs on the teams in the field. In our desert scenario it was nice to be able to show the screen with the relative location of all the teams to the ops leader to show him that there was one team way out of bounds. There is nothing like a picture to get your point across. This did, however, introduce additional training that would be required of the operator. In its simplest form, the digipeater is very easy to operate. Nothing is required as long as the TNC is correctly configured. The operator must only make sure that the digipeater is in a good location.

D. Closing Comments

APRS use in SAR is a perfect fit. We are not the first to have deployed APRS trackers with SAR teams, and we hope that many will continue to refine the packaging and software to better serve those involved in volunteer search and rescue.

I would like to offer a special thanks to my teammates Tad Gallistel, Mark Kern, and Mark Kinsey who are building hardware and working with software as part of this effort. Also, thanks to the Mountain Rescue Association and the San Bernardino County Sheriff's Cave Rescue Team for helping to purchase equipment to make this project a success. We are continuing our efforts, and if you have any questions, comments, or suggestions, we'd enjoy hearing from you at aprs@caverescue.net