Avalanche Rescue Technology

Dale Atkins
Avon, Colorado 81620 USA

INTRODUCTION

Technology: A device, thing, method or knowledge used to accomplish a task.

Avalanche rescue requires a holistic approach that combines people, processes and technology to be ready and capable to handle all types of situations that may arise from an avalanche accident. It is the combination of the three that makes up the *rescue system* and produces the best opportunity for favorable outcomes. While Mike Rheam's presentation will focus on *people* and *process* this paper and presentation will focus on *technology*—the stuff, methods and knowledge to help rescuers become more efficient and effective.

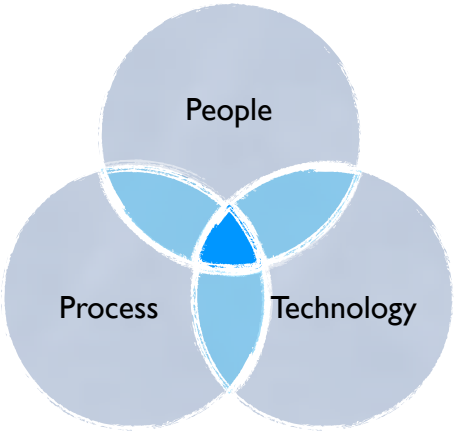


Figure 1. A rescue system is the combinations of people, process and technology.

Technology aids and facilitates avalanche rescue and can make a difference for survival for some avalanche victims. However, technology is not Superman's cape nor Captain America's shield and should not be relied upon to guarantee survival. Surviving an avalanche is luck. Technology can only position one to be in a better place to be lucky. Technology does not make one lucky.

This paper reviews briefly technologies used in the search and rescue/recovery of avalanche victims. Avalanche rescue technologies should be considered on their effect on the different phases of the general rescue and as they relate within a systems approach to avalanche rescue. Today avalanche rescue is less often defined by distinct steps, but rather as a structure of different classes and subsystems working together. Also, traditionally, emphasis on technology has focused on tools the locate a buried avalanche victim. While important, especially for a buried victim, such emphasis ignores other vexing problems—including locating the accident, accessing the avalanche, caring for injured victims, and transporting victims and rescuers. An avalanche rescue is actually a process rather than an event. The best opportunity to save a life starts with the actions of the individuals and companions and then continues on to the efforts of professional rescuers on the mountain, to pre-hospital medical providers and eventually to hospital providers in the emergency departments and later to other hospital specialties.

SYSTEMS: A NEW WAY OF THINKING

A systems approach to avalanche rescue is a new way to think about avalanche rescue and wilderness search and rescue in general, but it is not new to other related fields like industrial and mine rescue, military search and rescue, and medicine. Efforts in these fields focus not

only on finding someone, but also on saving lives. Traditionally, avalanche rescue has focused only on finding someone. This narrow view has led to inflexibility and blindness to adopting new practices and technologies, and reinforces the faulty attitude held by many American avalanche rescuers who feel that professional rescue does not save lives. (Imagine how effective search and rescue would become if ambulance medics, fire fighters, or the US Coast Guard held the same attitude.) Professional rescue in the United States does save lives! Though the numbers are small, the numbers are growing every winter. Table 1 shows how 282 buried avalanche victims were found during a recent 10-year period.

Method	*Found Alive*	*Found Dead*	*Total*
Attached object or body part	31	29	60
Spot probe	4	9	13
Coarse or fine probe	3	32	35
Rescue Transceiver	43	82	125
Avalanche dog	1	18	19
Voice	8	0	8
Other (digging, RECCO)	1	7	8
Found after a long time span	–	10	10
Not found, not recovered	–	4	4
Inside vehicle	1	–	1
Inside structure	–	–	0
Totals	91	191	282

Table 1. Rescue method by type of rescue for buried avalanche victims, 2003/04–2012/13.

GENERAL PHASES OF SEARCH AND RESCUE

To resolve an avalanche rescue in the favor of the buried or injured victim requires not just technology (and luck), but that all rescuers—companions and organized—know and be prepared for the five phases (N-LAST) of rescue. Within each phase technology plays key roles.

N-LAST

In all search and rescue (SAR) actions, including avalanches, there are five fundamental elements, or phases that must be accomplished to solve the SAR problem whether it is inside a ski area or far into the backcountry. Each phase must be solved sequentially, and any problems or mistakes during one phase will result in delays that can lead to mortality.

Technologies applied during each individual phase saves time, which increases the possibility of saving lives. These elements are defined as follows:

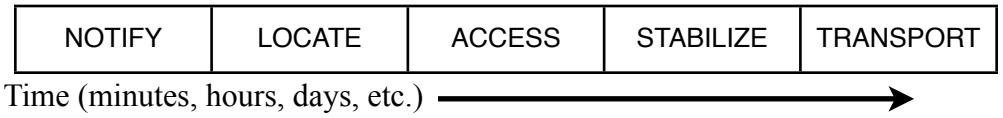
1. NOTIFY rescuers. No help can be provided until rescuers are notified of an incident. In avalanche rescue new notification technologies save rescuers (and victims) tremendous amounts of time — hours to even days. Thanks to cell phones and satellite emergency notification devices (also known generically as SEND and for example include satellite phones, SPOT, Garmin/InReach, and PLBs) rescuers can be notified immediately of an

emergency. (When using SEND products the call for help can be made immediately, but the notification of the local rescue team can take at least an hour.) Therefore, when an avalanche accident happens and serious consequences are known or suspected, the companions should not wait to call for help. According to the International Commission for Alpine Rescue (ICAR), an avalanche burial is a medical emergency.

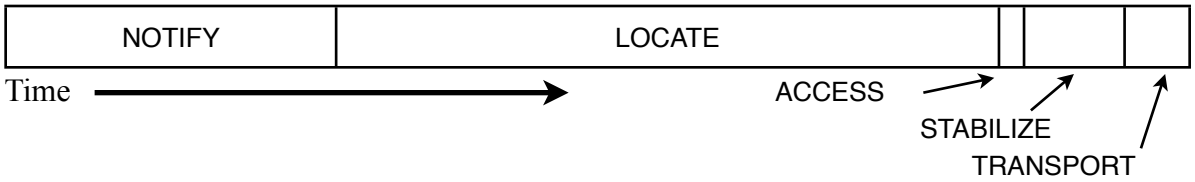
> "An aim of all rescuers is to identify and adopt technologies that can reduce the time or effort spent within each phase of a SAR response."

2. LOCATE the victim. Special technologies and methodologies increase speed and effectiveness of rescuers. Electronic technologies—transceivers and RECCO—save time. Trained and experienced rescue dogs and handlers save time. Probe poles work but are extraordinarily slow and inefficient.
3. ACCESS the victim. Specialized shoveling techniques save time, which is critical in companion rescue. Knowing how to properly use a shovel can sometimes be the difference between life or death.
4. STABILIZE the victim. Whether buried or not buried, people suffer critical injuries in avalanches. First aid can can improve physical comfort, reduce injuries, and save a life. Both companions and organized rescuers should be ready to treat and care for potential injuries (hypothermia and shock) and actual injuries (airway, bleeding, fractures, etc.).
5. TRANSPORT the victim. This may be as simple as escorting an uninjured person back to the trailhead or hoisting an injured skier into a helicopter. Or, it may be as complicated as moving an injured person across rugged terrain during atrocious weather.

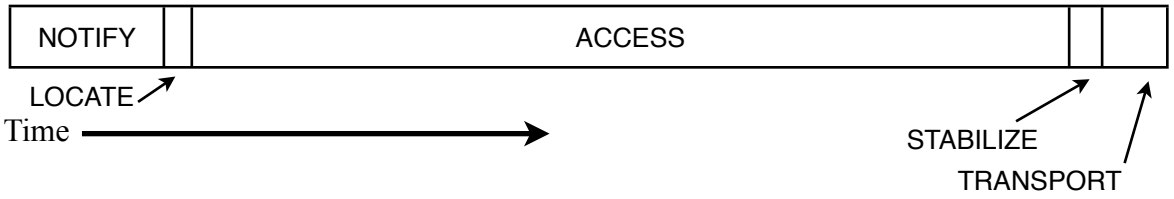
When put into chronological order the phases reveal the basic structure of any SAR operation. The SAR response—whether companions or rescue teams—starts the second the avalanche stops moving. An aim of all rescuers is to identify and adopt technologies that can reduce the time or effort spent within each phase of a SAR response.



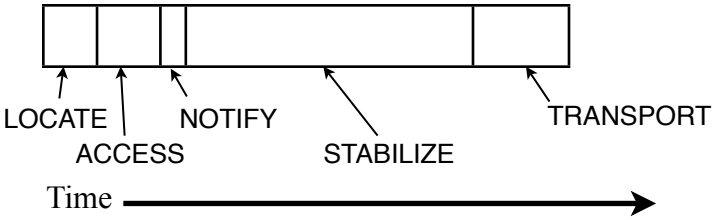
If the size of a block is made to reflect the length of time devoted to a phase, the search and rescue of a buried backcountry skier whose group had to sent out a skier to get help for a friend not equipped with a transceiver (or RECCO) and rescuers who responded by helicopter but had to use a probe line to find the victim might look like this.

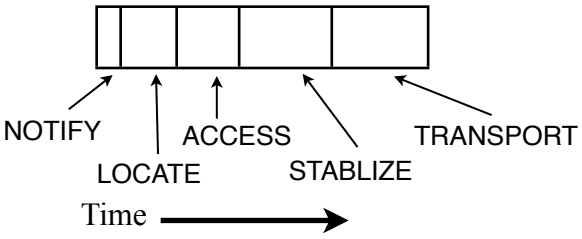


A buried snowmobiler with a transceiver but whose companions don't have a shovel might look something like this:

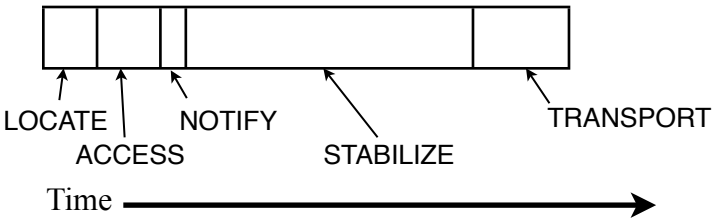


Here might be a fast, textbook rescue of a critically injured snowboarder inside or just outside the ski area:





In any incident, if the *notification* phase is performed out of sequence, significant time delays will result. Take the above example for the same critically injured snowboarder (say outside a ski area) but this time the companions wait until after *accessing* their friend before calling for help. To call after finding a friend delays rescuers considerably, which can have potential serious, life-threatening affect to an injured person.



When a search is unsuccessful it may be presented as:

NOTIFY	LOCATE . . . ?

To take maximum advantage of technologies, recreationalists and professionals like ski patrollers must understand the interrelationships of these fundamental elements of search and rescue. How one approaches these phases will be covered by the Operational Avalanche Rescue lecture and materials. What specialized technology one applies in each phase will be covered below.

MODERN AVALANCHE RESCUE — A SYSTEMS APPROACH

Avalanche accidents are changing and so too is rescue. Today, in many rescues, especially in and near ski areas, the so-called companion and organized phases often blur together. And even in the backcountry the phases are blurring, too. A generation ago, it was uncommon in the backcountry for another group to be close by when an avalanche accident happened. Today, it is common for other nearby groups to come to the aid of the stricken group and assist in or even direct companion rescue efforts. Near and in ski areas, many guests (compared to a generation ago) have avalanche training, including rescue training.

Modern avalanche rescue is the arrangement of and relationships of different classes and subsystems working together. The rescue classes are: *individual*, *small-group*, and *professional*, and the subsystems are: *protection*, *notification*, *rescue*, *medical* and *transportation*. Technologies are considered within each subsystem. Figure 2 shows this integrated systems approach to avalanche rescue. Note that the subsystem common to all three classes is *rescue*. Compared to the outdated sequential approach (i.e. three stage rescue) that focused on finding a buried person, the integrated holistic approach focuses on saving all people caught in avalanches, whether buried or not.

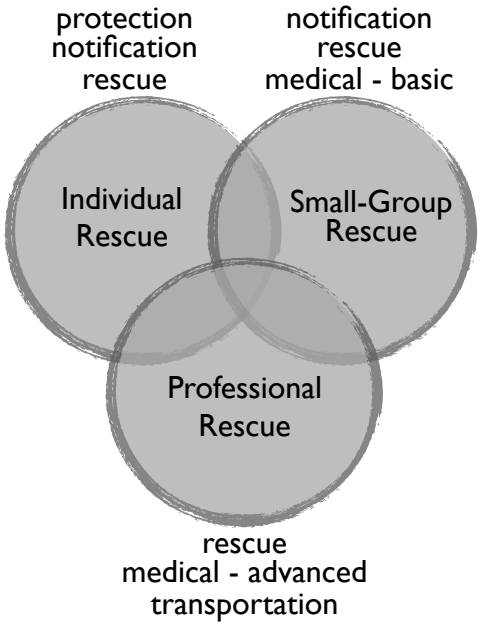


Figure 2. Modern avalanche rescue, an integrated and holistic approach to saving lives.

The settings where technology can be applied varies from such diverse areas as the wilderness, in or adjacent to ski areas, to highways and railways, and to residential to urban areas. While avalanche search and rescue is similar for all settings, each setting may pose unique challenges where some technologies will excel in one setting but fail in another.

Individual Rescue

Rescue starts with the individual, and self rescue is really *individual rescue*. This describes one person and takes into account what one person can do to protect one's self, notify

rescuers, and make themselves easier to be found. If caught, items that provide *protection* like a helmet and body armor protect the body. An AvaLung protects the airway. An airbag might offer protection, but it should not be relied upon to protect a person. *Notification* to outside rescuers can be critical to saving a life. Ski patrollers carry radios, but people in the backcountry should have a means to contact others. A cell phone is the most common and best because it provides two-way communications, but cannot always be relied upon. Other notification devices include satellite emergency notification devices (SEND) like the SPOT or Garmin messengers, or even a PLB. Lastly, the individual needs to be searchable—easy to find—so the rescue can be done quickly. The *rescue* tools for the individual are the transceiver, RECCO reflectors, and an avalanche airbag. Even a whistle can be an invaluable rescue tool. Over the years there have been a number of avalanche victims who were traveling solo who ended up partly buried and injured but lacked the means to call for help or attract rescuers. There also have been groups caught and the not-buried person(s) lacked the means to call for help. Individuals need to protect themselves, notify others, and be equipped with technology that can make their rescue easier.

Small-Group Rescue

Traditionally called companion rescue, today the action is really about *small-group rescue*; it may be friends or others in the immediate area that work together as a team in an organized manner to save a life. Members of the team have to know how to perform avalanche rescue, just as if they were part of a formal rescue team. The subsystems are: *notification*, *rescue*, and *medical-basic*. Each member should have a means for the team to call for help in case of a burial or injured person. Cell phones, radios, SPOT, or other devices can be lifesaving in case of an avalanche accident. The rescue tools of the *small group* are the standard rescue kit: transceiver, shovel, and probe. While not an issue for ski patrollers, in recreational settings each member should have at least basic first aid training and including CPR. People get hurt badly in avalanches, and one needs to be ready to care for an injured friend.

Professional Rescue

When talk turns to organized avalanche rescue, what is really being described is *professional rescue*. (Even volunteers provide professional-level service, and whether or not an accident occurs within a ski area or far into the backcountry, the subject has the same expectation of all rescuers, whether they are paid or not.) *Professional rescue* provides greater capabilities than a small group by offering more rescuers, more expertise, and more rescue tools, such as transceivers, long-range transceivers, dogs, RECCO detectors, and probes. Professionals also can provide two critical capabilities that small groups cannot: enhanced medical care and transportation. To provide a higher level of medical care and faster transportation can make a difference for the critical avalanche victim. Transportation is a key differentiator between smal-group rescue and professional rescue. A small group will not have the ability to move an injured victim quickly and with less harm than performed by professional rescuers.

This new systems approach to avalanche rescue assumes that accidents will happen; therefore, individuals and rescue teams should be ready. The common subsystem that ties the three classes together is rescue. People headed into avalanche terrain need to make themselves

searchable, and electronic means – transceiver and RECCO reflectors – is best and fastest. Transceivers make one searchable to their friends; reflectors make one searchable to the pros. Small groups need to have and know how to use the tools to find a buried victim. Likewise, professionals need to have all the rescue tools to locate someone quickly, and be ready to treat and transport quickly. The other subsystems of each class compliment rescue by maximizing the potential to save a life.

Let's take a look at some of the individual technologies in more detail.

THE TECHNOLOGIES

Individual Rescue

The responsibilities of the individual is to use technologies that can protect the person, notify others for help, and be searchable, figure 3. (Of course their primary responsibility should be to not get caught!)

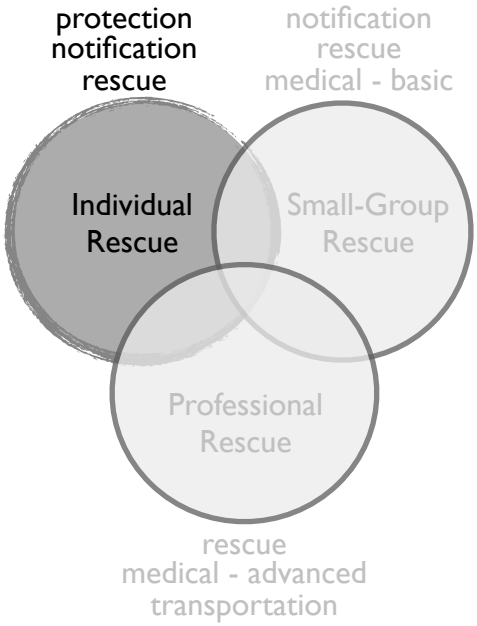


Figure 3. Individual Rescue and its subsystems.

Protection

These technologies should be thought of as PPE (personal protection equipment).

Helmet

A helmet may not necessarily help locate someone but helmets do offer some protection. Recent medical studies of avalanche victims in North America reveal that notable numbers of victims suffer head injuries; however, most injuries involve the chest and extremities. Wearing a helmet may reduce the severity of head injury—but not necessarily traumatic brain injury—if caught in an avalanche.

Body Armor

Protective tops for the spinal, back, chest and torso can lessen or even prevent serious injuries in case of collisions with rocks or trees. Such gear has been popular with free skiers/ snowboarders, racers, and snowmobilers for many years.

AvaLung™

Protects the airway and creates an artificial air pocket. Snow is mostly air and even the heaviest avalanche debris is still 40 percent air. But for the buried victim it is difficult to draw the air out of the snow. Even more troubling is that victim must re-breathe exhaled CO_2 causing asphyxia. In concentrations slightly higher than found in ambient air CO_2 can quickly become deadly. A membrane (AvaLung System) provides for inhalation of air from the surrounding snow on one side of the device and exhalation to the other side preventing the

build up of deadly levels of CO_2. The separation of inhaled from exhaled air presents an ingenious trick of avoiding asphyxia. Extensive testing has shown the AvaLung™ can prolong survival time of a totally buried person to at least 60 minutes. There have been well a couple of dozen reports of successful use, but little or no information captured about those events. In recent winters there have also been several cases where users could not or did not put the tube into their mouth. The reasons for the unsuccessful use include: tumbling and unable to reach the tube, didn't think about reaching for the tube, or the tube was stored away and not available. There have also been reported cases where the breathing tube was "ripped" from one's mouth. Additionally, there have been several deceased victims equipped with AvaLungs but the tubes were not in their mouths. It is unknown if they tried to use the tube, but in one case the tube was safely stowed away and not available.

Notification

When an individual or a companion needs help they must have a means to "call" for help to notify rescuers.

Smartphones and Apps

The cell phone, and specifically the smartphone has likely saved more lives than any other rescue device for land, water and city emergencies because rescuers can be notified immediately. These phones have also caused considerable consternation for rescuers as sometimes, though rarely, the capability is misused by people who are only inconvenienced and not in an emergency situation.

Smartphones are superior to old-style mobile or cellular phones because smartphones have global positioning system (GPS) location-services capabilities to capture, show, and transmit GPS coordinates. Also, phone service—when available—provides two-way communications with rescuers.

With smartphones are a variety of search and rescue Apps for both Android and iOS platforms that capture your GPS coordinates and can send those coordinates and an emergency message via SMS/text message or email to a rescue call center. Interestingly, however, the US along with Australia and the Netherlands are the only developed countries that do not consider email or SMS as an appropriate form of notification. While the US 911 system lags behind the rest of the world, these Apps have value as they show one's location (usually on Google Maps) along with GPS coordinates. A screen shot can be captured and relayed to rescue authorities. Perhaps the best App available is the Swiss iRega app (iOS and Android), but it is not so handy in the US.

While phones can save lives, travelers into mountainous areas should not expect to always have cellular service. In these situations travelers should consider satellite phone or SEND products.

Satellite Emergency Notification Devices (SEND)

Where cell phones service is unavailable and satellite service too expensive, mountain travelers may want to carry a SEND device. Most common are Personal Locator Beacons (PLB) or a satellite messengers (SPOT or Delorme now Garmin inReach) to notify rescuers in the event of an emergency. Both technologies rely on sending a distress signal through satellites. PLBs use an international array of search and rescue satellites. When a PLB is activated the signal is detected by the US Air Force, which notifies state search and rescue officials. In 2016 NOAA data showed that PLBs were used to rescue 307 lives. Of those saved, 205 were waterborne rescues, 23 from aviation incidents, and 79 were land-based rescues. PLB users are required to register their units with NOAA. SPOT is a subscription service that uses a commercial satellite array operated by Globalstar Inc. DeLorme/Garmin use the Iridium satellite network. When a distress signal is sent monitoring programs notifylocal law enforcement of an emergency. A PLB will work virtually anywhere in the world, while a SPOT's signal can be blocked by dense forest canopies or narrow canyons. PLBs, SPOTs, and similar products have been activated each winter in a few but growing number of avalanche rescues.

Considerable information on SEND products (SPOT, inReach and PLBs) can be found on the Internet. The SPOT and PLB are one-way communicators—can notify rescuers but cannot respond to rescuers. The inReach allows for SMS/text messaging giving vital two-way communications with rescuers. Also, if carrying a PLB, please register it with authorities (as required by law but most are not registered). Unregistered PLBs may result in delays.

Radios

For ski patrollers radios are their go-to communication tool. While patrollers use their radios every day, few patrollers have experience calling in a colleague's accident. Consideration and practice should be given to dealing with communicating an "in-house" accident and the general radio chaos—despite best intentions—that will likely and suddenly develop.

Rescue

The rescue tools are those devices that make one searchable and easier to be found by others. For the individual they are devices that make the individual easier to find, these include transceivers, RECCO reflectors, and avalanche airbags. In *Small-Group Rescue* companions or others use their rescue tools—transceivers, probes and shovels—to find a buried person. In *Professional Rescuer* rescuers also carry these devices and more. These additional devices will be addressed separately.

Avalanche Rescue Transceivers (aka beacons)

A transceiver makes one searchable to their companions. The term *transceiver* is preferred over the use of *beacon* to avoid confusion with personal locator beacons (PLB) and emergency position indicating radio beacons (EPIRB) in the eyes of the general public and media. Details about transceivers can be found under the Small-Group Rescue section.

Avalanche Airbags

An avalanche airbag can help protect someone from burial, and for companions, avalanche airbags are also excellent visual markers that allow for quick localization of the victim. Avalanche airbags make the user a very large particle in the granular flow of an avalanche where particle segregation will force the large particles—the person—to the surface, The first, best known, and most rigorously tested airbag system is the German Avalanche Airbag System (ABS). A German forester conceived the product first in the 1970s when he noticed larger trees stayed on the surface of avalanches while smaller trees were buried. (Experience also shows snowmobiles tend to stay on the surface, but their riders are buried.) His idea was to use a balloon to make a person the largest object in the avalanche, so the flowing snow would force the person to the top. The same principle can be applied to a bowl of mixed nuts. Shake the bowl and the larger nuts rise to the top. This principle of inverse segregation is sound and well known from particle-flow dynamics, and it is also at work with avalanches.

Nearly all brands use compressed gas to inflate or help inflate the airbags. However, in recent years Black Diamond Equipment and Arc'Teryx have introduced devices that use a small electric fan or blower. These devices while very expensive work very well and provide the opportunity for multiple deployments.

The best way to survive an avalanche is not to get buried, and airbags are the only tool that may prevent burial. This makes airbags a potentially attractive device for those who work and play in avalanche terrain. While airbags have been demonstrated to reduce mortality rates, if the user continues to use their airbag in hazardous situations or to take greater risks they may be reminded painfully that airbags—like all other avalanche rescue devices—are not a shield.

RECCO Reflector

The reflector makes one searchable to professional rescuers. It is a small transponder about the size of a band-aid that reflects back a directional signal to professional rescuers at the avalanche. The reflector contains a diode and a foil aerial that receives the Detector's (carried by ski patrols and mountain rescuers). More than 200 brands incorporate reflectors into outer garments, boots, and helmets. Reflectors are the most commonly carried avalanche rescue technology millions and millions are worn by skiers both in area and in the backcountry.

Small-Group Rescue

The responsibilities of companions or a small group is to use technologies that can notify others for help, find the avalanche victim (transceiver, probe and shovel), and provide basic medical care (figure 4).

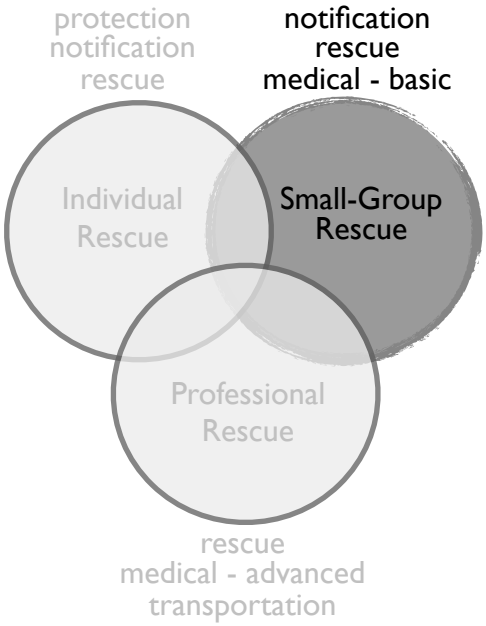


Figure 4. Small-Group Rescue and its subsystems.

Notification

The capability to call out for help is critical when a burial or injuries are suspected. Details about specific technologies was presented earlier in the Individual Rescue section.

Rescue

Avalanche Rescue Transceiver

The avalanche rescue transceiver was developed in the late 1960s by John Lawton of the United States. Lawton's unit called the "Skadi" generated an audio frequency induction field—basically a audio signal from an electromagnetic field—that could be followed and located by changes in volume. Other brands and models followed, and while the frequencies changed over the years, the devices and their use changed little. Even today all transceivers transmit a signal generated in the same analog fashion as Lawton's Skadi. Today all transceivers work on the general proximity principle that the closer the sending and receiving units, the stronger the signal. In 1986 a single international frequency—457 kHz—was adopted by the manufacturers.

In the late 1990s dual-antenna units were introduced. These devices provide approximate distance and direction (along the magnetic field) to the sending unit. These units use a digital signal processor—hence the "digital" name applied to many brands—to provide the user more information about the location of the sending unit by providing distance readings, directionality, and changes in cadence and/or pitch of the audible tone. These transceivers have been found generally easier (thus faster) to use then analog transceivers. All modern transceivers use three antennas. It is this author's opinion that single- and dual-antenna units not be used.

When two or more victims are buried multiple signals can pose special problems for both the searcher and for the receiving device as signals begin to overlap. Generally the further apart the sending units, the easier the searching task for both the searcher and their receiving unit. When sending units are within 5 meters of one another the more complicated the task for both the transceiver and the operator. Obviously, as the number of victims increases, so too does the complication of overlapping signals.

Modern transceivers use signal strength or signal timing to differentiate the signals and then use marking, flagging, or suppression functions to hide or identify the separate signals. The

better devices use these tactics. However, once there are more than three or four sending units it may become impossible for the the receiving device to separate the signals. To be able to handle these situations successfully it is imperative that you become proficient at generic multiple victim search strategies—*Three Circle* or *Micro Search Strips*—regardless of the device you own. Please consult your device's users manual or check the Internet for descriptions of these techniques. Most modern transceivers have signal separation features to better search for multiple sending units. Most of the time these features work well, but these features cannot be expected to work all the time. Therefore, users should practice multiple burial (signal) searches and know basic backup multi-signal search techniques for when their unit is confounded by multiple signals.

Today's transceivers are literally small computers and offer huge improvements over models from even a few years ago. Because of the significant improvements included into today's new devices with components and firmware, units older than say 10 years should be retired, even if in excellent working condition. Also as manufactures improve their devices' firmware, a unit from even three years ago will not be as good as today's unit. New units are simply superior and easier to use. Speaking of firmware (basically the internal software that operates the device), it is important that users update their device's firmware when updates become available. As with all transceivers make sure to read and follow the unit's user's manual and practice regularly so its use becomes automatic.

When digital transceivers were introduced in the mid and late 1990s the avalanche mortality rate of people equipped with transceivers went down. This was attributed to the units' ease of use. However, this trend only lasted for a short time. The trend in the last 10 years or so has reversed, and now many more people die with transceivers than survive. This is a function of numbers—more people then ever use transceivers—and attitudes. The old attitude of using knowledge to avoid avalanche terrain and to carry rescue gear as a backup has shifted. Today people actively seek out avalanche terrain, even during periods of significant instability, and carry transceivers as if they are a ticket to the steep and deep.

Smartphone Apps

The smartphone has brought a computer and the ability for wireless networking to our hands. In about 2012 several Apps for both the iOS and Android platforms came to market with the goal of replacing the traditional 457kHz avalanche rescue transceiver. The Apps do work but they do not work well enough to find someone reliably in all situations and under all conditions. It is my opinion that they do not and <u>should not</u> be used as a 457 transceiver replacement. However, these Apps signify the future of things to come, and these "things" are happening right now.

Here's a short list of some of these Apps:

- SnoWhere – www.freshapps.com/snowhere/
- Snøg Avalanche Buddy – www.facebook.com/pages/Snøg-Avalanche-Buddy/359262604157294
- iSis – once promising seems to have disappeared.

While these Apps should not be used to replace a 457 transceiver, some of these apps could augment or enhance a transceiver search by quickly guiding the searcher to the immediate burial area, say within 5-10 meters, where the 457 unit would be used to complete the fine search, and the probe to pinpoint the victim.

Probe

While many may not consider a probe to be a piece of technology, the probe is the oldest technology used in avalanche rescue. Described to find avalanches victims more than 2000 years ago the probe's function remains unchanged: to pinpoint the buried person. Initially a wooden staff, then a steel rod, then simple aluminum tubing (conduit) in recent years collapsible probes have morphed from heavy tank antennas to feather weight aluminum alloys or carbon fiber. The lightweight collapsible probes are adequate for occasional/infrequent backcountry use. However, ski patrollers, guides and mountain rescuers will do better with heavier weight, more robust collapsible probes.

Shovel

A transceiver is of little help without a shovel, and accidents still happen to people equipped with transceivers but whose companions do not have a shovel. Many avalanche workers have a very strong preference for metal (aluminum, steel, or titanium) bladed shovels; however, polycarbonate bladed shovels are just as durable and are even more durable than many aluminum blades. Polycarbonate shovels are fine for companion/small-group rescue. Lexan is the most recognized brand name of polycarbonate plastics and besides being used in avalanche shovels it is also used in the aerospace industry for aircraft canopies. A polycarbonate-bladed shovel—from a respected avalanche company—can be trusted to withstand the rigorous action of companion rescue. In professional rescue where digging takes place hours or even days after the avalanche a metal bladed shovel is easier to use to chop out blocks of the hard snow.

Having a strategic plan to remove snow will save minutes. In companion rescue, minutes may mean the difference between life and death. A simple and effective strategy starts down-slope 1.5 times the victim's burial depth and digging down and towards the victim. The goals of operating a shovel should be to never shovel the same snow twice, never lift the snow above the waist, and to quickly create a sizable workspace to treat and care for the victim.

Rescuers should remember that any shovel—metal or polycarbonate—can be broken if misused.

Medical – Basic

CPR and Wilderness First Aid

For recreationalists one of the best technologies to take advantage of is the knowledge learned from taking both a first aid and a CPR class. Nearly every winter an avalanche victim somewhere in the US likely died because their companions did not know how to open or manage an airway, do rescue breathing, or perform CPR. Less often are tragic reports of

friends who could not manage serious bleeding. A wilderness first aid course along with CPR could be the difference between life and death.

Professional Rescue

Rescue

Ski patrols and other rescue organizations can provide more resources to find a buried person or to care for and injured person than in Small-Group Rescue. The responsibilities of rescue organizations is to use technologies that can rescue (locate), care for and transport avalanche victims (figure 5).

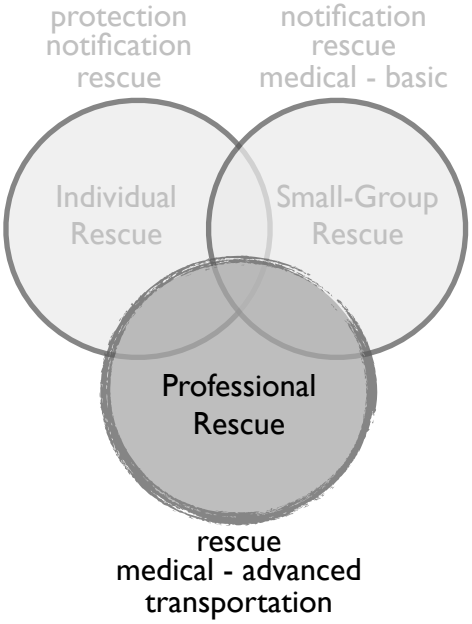


Figure 5. Professional Rescue and its subsystems.

RECCO Detector

In addition to the RECCO Reflector worn by skiers and other outdoor enthusiasts, and the Reflector worn in pairs by the subject. About the size of a textbook and weighing slightly less than 1 kilogram the detector is an electronic transmitter/receiver with a directionally sensitive antenna; this Detector also includes an avalanche beacon receiver (457 kHz) so one rescuer can perform both the RECCO search and a beacon search at the same time. Searching can be done from the ground or the air. A helicopter fixed system has been introduced successfully in Europe for both winter and summer searching of lost and overdue people. Because millions of reflectors are in use, ski patrollers and mountain rescuers need to be proficient in using the RECCO detector, the detector will covered under rescue tools for professional rescue. The concept for how to search with the detector is easy; however, actually searching takes significant practice, like with a transceiver.

Dogs

A form of natural technology, the trained avalanche dog is a capable alternative to probing—when a victim is not equipped with a transceiver or RECCO reflector. The first "rescue" dogs were the St. Bernard dogs raised and kept at the St. Bernard Hospice in Switzerland. In the late 1600s the monks started traveling with the dogs because of the dogs ability to cut a track in deep snow. The dogs where originally thought of as a travel companion, however, in time the dogs learned to detect the scent of a person and could then lead their master to the missing traveler. During the winter the dogs saved several lives by scratching at the snow and alerting their master to a buried avalanche victim. In Europe by the late 1800s dogs were used occasionally to search for buried avalanche victims. While a few trained avalanche dogs have been utilized in the United States, it was not until the 1990s when a greater emphasis has been but on their use.

Trained avalanche dogs can search areas in the fraction of the time required by probers, but even a dog's success is not guaranteed. According to Swiss statistics trained dogs on rescues find about 8 in 10 victims; however, in the US the success rate is much lower at about 60%. When trained dogs failed to find a buried victim the blame can frequently be placed on their handlers.

Helicopter External Transceiver Antennas

One of the most time consuming portions of an avalanche transceiver search is simply traveling on foot across the debris. When the transceiver search can be performed from the air via helicopter the search can be done faster. For more than 20 years helicopter transceiver searches have been done in Europe and New Zealand with good success. Very large areas can be searched quickly. The system is very effective, IF the buried person is equipped with a transmitting avalanche beacon.

The signal search pattern from the air is the same as a surface—on foot—pattern. When a signal is detected the pilot uses the bracket method for the coarse search to get close to the buried victim. A marker is dropped to the snow, and a rescuer is dropped off to complete the fine and pinpoint searches to exactly locate the victim.

Ground Penetrating Radar

The best technology would be one that does not require the subject to carry or wear anything special or extra. Since the early 1960s attention has always turned to the application of radar technology to detect buried or hidden objects. Since then ground penetrating radar (GPR) has been used by law enforcement agencies to buried bodies in the ground. GPR is more widely used to measure the thickness of ice and snow, to survey archaeological sites, and to look for buried weapons. Only in recent years has GPR become a viable tool for avalanche search.

GPR works by pulsing a signal down through the snow (ice, rock, soil, etc.). When the signal hits a boundary of another material some reflection occurs because of a change in the materials' dielectric properties. The greater the difference between dielectric constants of the materials, the greater the amount of signal reflection. Ice has a dielectric constant of 4 and bone has a dielectric constant of 13. The dielectric constant of soils is even greater.

Though GPR may sound easy to use in principle, but it requires a trained and experienced operator. Successful testing of GPR on snow since the late 1960s has demonstrated its viability; however, it has only been since the mid to late 1990s that units have become sufficiently small and lightweight to be practical. GPR has been used successfully in a couple of avalanche rescues in Scotland, Norway, France, and Alaska. GPR can find clues such as shovels, backpacks, vehicles, and almost any object not composed of snow that will help steer rescuers toward the buried victim. For deep burials beyond the length of normal probe poles GPR maybe the most useful technology. In general, to search with a GPR is a very slow process.

Metal Detector

Buried clues will always help steer rescuers toward the buried person and probably the oldest technology available to searchers of buried objects is the metal detector. The first reference of a metal detector was nearly 200 years BC. A Chinese Emperor had a doorway metal detector constructed to prevent would be assassins from carrying in weapons. When carried over the threshold any iron weapons were drawn against the doorway and held fast. Today we experience metal detectors whenever we pull up to a stop-lighted intersection. The grooves cut into the pavement contain metal detector search coils that detect the presence of cars and trucks.

The modern metal detector is simply an electromagnetic device that will detect the presence of conductive metals (and certain minerals). The metal object must be within the detector's detection area, and for most units that means the metal must be pretty close. The detection area of a detector is ice-cream-cone shaped—it shrinks the further away from the unit. In experienced hands the larger coil-shaped antennas (12-16 inches in diameter and much larger then those owned by treasure hunters and most survey companies) will only have a detection depth of up to about 4 feet whether the object is a ski, snowmobile or dump truck. The search width is also very narrow, only about one-half of the coil diameter. There must be a very tight overlap to ensure a high probability of detection.

To get extra depth penetration requires a two-box Depth Multiplier that can extend the depth to 10 to even 20 feet. Generally, the larger the object, the greater the depth that can be searched. The Depth Multiplier also has a much wider detection area, so the search width maybe 5 to 6 feet wide rather than 6 inches.

Metal detectors have been used with success in very few avalanches, but most often their use is a failure. The most common reasons for this are two fold: one, the detector is too small for the job, and two, the user is inexperienced.

Magnetometers

Unlike metal detectors that detect conductive metals, magnetometers or magnetic detectors measure magnetic field intensity. Ferrous (iron) objects change the surrounding magnetic field. A magnetometer was first successfully used to find Vanni Eigenmann when he was buried in 1961. The unit was able to detect the steel in his ski boots. Since then magnetometers have been used to find buried vehicles, including snowmobiles. In today's snowmobiles aluminum or composite materials are replacing much of the steel providing a smaller target, which makes the search more difficult.

Magnetometers are very expensive and relatively scarce, but fortunately they are relatively easy to use. Power companies, ore mines, and large construction companies are probably the best place to find a magnetometer. Whenever a magnetometer or metal detector is utilized in avalanche rescue the operator must test the unit by looking for similar objects in a controlled setting. This test will allow the operator to develop search patterns that will save hours or perhaps even days.

Gradiometers
Even more sensitive are gradiometers that are essentially two magnetometers connected together. Gradiometers are not affected by diurnal or local variations, but these devices are more sensitive to movements, so rugged and irregular surface of avalanche debris can be challenging. Gradiometers and magnetometers are effective but required skilled experts that may be found with at geophysical departments at universities or mining operations.

Magnetic Locators
Formally known as flux-gate magnetometers these are simple and relatively inexpensive cane-like devices that can locate ferrous objects. The devices can easily be found from surveyors utility companies. These devices are easy to learn to use.

Infra-Red Imaging (IR)
An often-considered technology because of its success in land search is IR imaging. Since a recently buried victim's body is of a higher temperature than the surrounding snow it would seem that a thermal imaging unit could easily detect the buried person. But it's not. Unfortunately, snow is a very efficient absorber of infrared energy, and a buried body is not detectable beyond a few centimeters of snow.

Probes
As mentioned earlier, probes are the oldest rescue technology, and they are still often used today. In professional rescue when prolonged probe searching is needed, fixed length aluminum tubing (conduit typically in 12-foot lengths) is most effective. Probe lines are effective at finding nearly all buried victims (about 5% off all avalanche victims are buried too deep), but are very inefficient because they are very labor intensive. The next section gives search rates for various technologies.

Shovel
In professional rescue, large shovels will make for faster moving of snow. Because professional rescue sometimes is delayed for days, a few steel-bladed shovels in rescue caches can be helpful.

Chainsaw
Yes, you read right. A chainsaw can be a valuable tool in avalanche rescue, especially in urban avalanche rescue and even in the backcountry when dealing with very hard, compacted snow. Chainsaws are very dangerous and using a chain saw in an avalanche rescue or recovery is against all factory recommended "safety" actions—do not use in windy, wet, or slippery conditions, cut only wood, etc. However, using a chainsaw to cut very hard snow or snow containing building or timber debris into manageable blocks may be the only practical way to quickly remove large amounts of snow.

Snow Blowers and Heavy Equipment

Sometimes when considerable amounts of snow and/or building materials must be moved, snowblowers and heavy equipment may be required. This equipment is typically bulldozers, backhoes, and snowcats. For deep and small debris areas not accessible to heavy equipment, push snow blower or two can be used. This equipment may be necessary to quickly move snow and rubble, but it is important to always use two spotters when using heavy equipment, one at each side of the blade or bucket. In the urban setting steel-cutting saws can be very useful. This equipment is in the realm of heavy-duty extrication and should be used by specially trained operators. When searching in and around damaged buildings rescuers may face special structure dangers unknown to wilderness rescuers; downed power lines, broken gas and water pipes can seriously injure or kill a searcher. When avalanche hazards could affect structures and vehicles, it is important that different rescue teams (mountain rescue, ski patrol, fire departments, etc.) work together to develop and rehearse a rescue plan before disaster strikes.

Gravity Socks

Used to provide pressurized water to fight wildland fires and to mine for gold, these gravity bags of water can turn water into an effective cutting agent. Obviously, a plentiful source of water must be available and this water must be located uphill of the digging area. Gravity socks have been used to pressure water to cut through more than 20 feet of snow.

Audio Amplifier

Over the years numerous—conscious—avalanche victims have been found alive when rescuers heard their yells from under the snow. When searching a damaged or destroyed structure, audio amplifiers can aid searchers seeking a conscious victim. Even if amplifiers are unavailable searchers should periodically stop and call out to the victim and listen carefully.

Medicine - Advanced

Professional rescuers can often provide a higher level of care for avalanche victims, and sometimes that can be the difference in living or dying. Entire books are written and courses taught on the emergency care and transport of injured persons in the wilderness. Unfortunately, little of this information has been applied directly to avalanche accidents and victims. In general, traditional emergency medicine programs (from OEC, First Responder, Woofer, W-EMT, EMT-P to MD) do not adequately address the unique circumstances of avalanche medicine. The Medical Commission of the International Commission for Alpine Rescue has prepared guidelines that should be considered by any rescue team that may be involved in avalanche rescue. Here are the two recent technical papers that should be reviewed with your physician advisors.

> Resuscitation of avalanche victims: Evidence-based guidelines of the international commission for mountain emergency medicine (ICAR MEDCOM): intended for physicians and other advanced life support personnel. *Resuscitation*. 2015; 95:148–201.

Wilderness medical society practice guidelines for prevention and management of avalanche and nonavalanche snow burial accidents. *Wilderness & Environmental Medicine*. 2017; 28(1):23–42.

HOW FAST AND HOW MANY SEARCHERS

Table 3 compares the average search rates and manpower needs to search a 100 x 100 meter (10,000m^2) debris zone. To make the comparisons more fair the techniques are normalized so they conform to a probability of detection of about 98 percent.

number of searchers	technique	search rate (m^2/hr)	search time (hrs)
1	fine probe (20x30 cm, 3hps) - 1 pass	25	400
1	course probe (70x75 cm, 1hps) - 3 passes	28	360
1	course probe (50x50 cm, 3hps) - 2 passes	87	115
1	dog (fine)	10,000	1
1	transceiver	60,000	0.17
1	RECCO	60,000	0.17

Table 3. Search rates and manpower needs to search a one-hectare area with a 98% probability of detection.

For decades an often cited and accepted rule of thumb has been about 20 searchers probing for about 16 to 20 hours to search a one-hectare area with a high probability of detection. A modified probe-line technique (3 holes per step) has been shown to slash search time to about 6 hours for 20 searchers. A well trained avalanche rescue dog can replace between 100 to 400 probe searchers. However, experience shows that dogs in the US fall far short of a 98% probability of detection. Electronic devices are the most effective requiring only about 10 minutes to search the area. To achieve this same efficiency requires six trained dogs or almost 700 to 2400 searchers to search 10,000m^2 in 10 minutes.

The probe pole has been around for over 2000 years, but with today's technology there is no reason the probe pole and probe lines should continue to be the dominate search technique. When transceivers are not used a rescuers' best tools are trained dogs and the RECCO System. Ideally, the probe pole should be used only as a tool to pinpoint buried victims.

While on paper it might seem that electronic devices dominate all others methods by huge margins, this does not imply that electronic devices are the best technologies for all searches. If a buried person is not equipped with a transceiver or RECCO reflector (or possibly some other detectable electronic device) then the best technology is the dog. If the dog is not successful, then probe poles becomes best technology. The most effective search efforts apply the primary search technologies—transceivers, RECCO, dogs and probe poles—simultaneously.

RESCUE OTHERS IN URBAN SETTINGS — PROFESSIONAL RESCUE

The person buried in a structure has a much higher chance of survival compared to the backcountry traveler. People trapped in buildings have survived for days and even weeks. The longest survival involved three women trapped for 37 days in Beremoletto, Italy in 1765. Closer to home and much more recent was that of a woman employee who survived a 5-day burial in a destroyed building at Alpine Meadows in 1982. Certainly luck is important for the survival of all avalanche victims, but the search for buried victims of an urban avalanche requires more than just avalanche rescue skills.

Also needed is expertise in dealing with damaged structures and extraction. The traditional search method of probing is foiled from all of the rubble of buildings and furnishings. Trained avalanche dogs have proven time after time to be the best resource to find victims in these situations. However, without careful planning a dog will quickly become injured and unavailable. The most common injury is cuts caused by broken glass hidden in the snow.

CONCLUSION

There is no doubt new or improved technologies will be applied to avalanche rescue. New ideas should be welcomed but carefully tested. Unfortunately, the setting of the typical avalanche accident and the needs of the rescue team tend to defeat or limit most technologies. From the manufacturer's perspective there is relatively little demand for a device that will work well in adverse weather conditions, that is easy to transport, offers fast search speed, and with a high probability of detection. In addition the unit must be simple to operate and offer a long working cycle. But such a device must also require minimal maintenance and be relatively low cost so money-starved search and rescue teams can purchase it.

While much of the technologies tried in avalanche rescue are decades old, it has only been in the last decade that the technologies have become practical. Advances in electronics and miniaturization of components caused by increasing market demands have driven the development of new and better products. These developments have resulted in better tools that can be applied to the search of buried avalanche victims, and the search for better tools will continue. In 1968 Ron Perla wrote, "Modern technology is being explored for newer and better means of locating avalanche victims." The quest continues.