The environment during the test
A site near the field laboratory of the Norwegian Geotechnical Institute in western Norway was chosen. A spring snowpack with high density and hardness proved to be a realistic simulation of dense avalanche debris. The “victims” were two bags normally used to carry firewood, sewn together and filled with straw. The texture of those bags closely resembled the stickiness of ski clothing to snow, therefore making it necessary for the rescuers to completely remove all snow before being able to transport the victims. In order to avoid a loosening of the debris around the victims, great care was taken to dig small shafts during burial. In addition, the snow around the victims has been left to re-freeze on the surface during one night. The next day the snow around the victims was stomped down layer by layer. The day after – therefore after three days – the victims were ready to be rescued.

Three different burial depths were used (1m, 2m and 3m) in 2 different slope angles (flat = 0-5 degrees, steep = 20-25 degrees).

Choice of rescuers
All “rescuers” were chosen carefully. With ages between 19 and 39, they represented the age group that statistically most often becomes avalanche victims. Men and women from three different countries were chosen; the ensuing language challenges simulated to a certain degree the communication problems that often occur between rescuers who speak the same language with each other. Between rescuers who speak the same language with each other in the V-shaped conveyor-belt approach to snow transport the answer is the same challenge.

How to work efficiently over a long period of time
One major requirement of an effective rescue is to maintain the efficiency of the rescuers at a constant level. So the question was: Why do rescuers get exhausted so quickly when they apply uncoordinated shoveling? We wanted to avoid having the rescuers fatigue easily when shoveling as this results in longer breaks and therefore an undesired slowdown of active resources. We noted that rescuers achieve rapid exhaustion due to holding an ergonomically challenging position when shoveling as this results in longer breaks and therefore an undesired slowdown of active resources. The idea of job rotation has been used in industrial production for a long time. An additional challenge to efficiency is the method of snow transport. Vertical lifting of snow constitutes one of the least efficient methods – despite maximum use of strength, snow still does not get transferred away from the victim. The bigger the lift with the shovel, the bigger the amount of snow that can fall off the shovel. A paddling motion, with which the rotation of the whole body can be utilized as opposed to just using the arms, is much more efficient and results in a bigger mass of snow to be transported (measured in liters/rescuers/minute). Methods that suggest steps be dug for snow transport or methods suggesting kneeling or sitting positions are just as inefficient.

Size of the V and required number of rescuers
The size of the “V” can be deduced from the burial depth known by probing. In a flat debris field (0-5 degrees), the required length of the V equals double the burial depth. On a steep slope (20-25 degrees), the length of the V equals the burial depth. Values in-between can be guessed. The width of the V at its open end always equals burial depth.

As a general rule, one rescuer can cover 80cm of the V’s height. If a victim is buried 2m on a flat area, 2x2m = 4m/80cm = 5 is the perfect number of rescuers. It’s up to the rescuers where to position themselves within their sector of V height.

Choice of shovel
Companion rescuers have shown difficultly shoveling with the same efficiency on both their right and the left sides. Therefore the working position may be individually adapted to the current working situation in the V and the best position to cut or transport snow, as well as the personal, body-specific preference of the rescuer.

Correct handling of the avalanche shovel
All rescuers were taught the correct way to use the shovel (i.e., cut blocks).

Observations considering uncoordinated shoveling
Statistics and video analysis clearly show how often rescuers stepped all over the top of the buried victim as well as in each other’s way, resulting in diminished efficiency for excavation. Onset of fatigue was rapid, and work was interrupted for everyone while exchanging a shoveler. With increasing burial depth, not all rescuers could be utilized.

Using the V-shaped conveyor belt approach to snow transport
Rescuers form a V whereupon the two front shovelers are a distance of one shovel length apart; the rest are distance two shovel lengths from each other. This positioning – which can be assumed quickly – enables everyone to work without disturbing each other while offering an optimal length of motion in the snow conveyor for each person. The primary job of each person is to move the snow from their segment onward to the next section behind them. Once there is no snow to transport, blocks should be cut to increase depth. The person closest to the probe only cuts blocks.

The digging experiment
In order to eliminate exhaustion as cause for potential mistakes, the digging experiments were spread over four days. After digging for a short while, the rescuers were assigned a less physically challenging learning module, after which another section of work with the shovel was completed.

Collection of data
The hole’s depth increase was measured every 30 seconds. After every excavation the hole and excavated volume were carefully measured. The time measurements included first visual contact with the victim, head (airway) access time, and positioning the victim outside the burial site. Documentation included high-definition pictures as well as real-time video. An instructional video is available.

Challenges for an efficient and careful excavation
During companion rescue a single probe is normally used to locate the victim; this can result in little knowledge about the positioning of the body. On one hand a quick approach to the airway is necessary; on the other hand a certain amount of snow needs to be transported to facilitate efficient removal of the mass of snow. Furthermore, rescuers should be positioned so that the buried subject and possible air pocket are not endangered. The V-shaped conveyor-belt approach to snow transport is the answer to this challenge.

Using the V-shaped conveyor-belt approach to snow transport
Rescuers adopt shoveling technique to suit individual strengths, such as coordinated sideways snow transport (center). After first visual contact with a buried victim (above), the front team continues to work together.

V-shaped conveyor-belt approach to snow transport
Story by Manuel Genswein and Ragnhild Eide • Photos courtesy Manuel Genswein

To excavate an avalanche victim takes by far the greatest amount of time during a rescue. When considering the flow between beacon search and transport of victim, the gap between a successful hit with the probe and care for the air pocket constitutes a missing link in the otherwise tremendously well-structured knowledge on rescue. Development of the “V-shaped conveyor-belt approach to snow transport” started in 2004 and was tested quantitatively in the spring of 2007 during a large field test. During this test the uncoordinated approach to shoveling was measured as well.

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By contrast, uncoordinated shoveling results in rescuers working centrally around the probe, repeatedly stepping on the victim in the process (above). Lack of a coordinated approach leads to inefficient use of rescuers (center), and once a victim is found, the steps out of the hole are too high, there is no exit ramp, and gentle transport of the patient is almost impossible (right).

is initiated by the front person. A four-minute cycle has been found to be the optimal balance between getting used to the new position and onset of fatigue. A greater gain in depth was measured during the first two minutes of the rotation, as opposed to the last two minutes. The psychological effect, resulting in increased motivation when expecting the rotation, was rated as very important. Of course, those four minutes don’t have to be measured exactly. At the latest, the rotation should be made upon the first sign of fatigue by any of the rescuers.

Digging continues in this way until the buried victim is first seen. That’s when the last rotation is made. Two rescuers should be on top of the V. Those two will work directly and carefully near the victim, therefore decreasing the amount of snow available to feed the capacity of the snow conveyor. To compensate for this decrease, the person behind the first two rescuers should aggressively cut out the sidewalls in order to make more space for the two front rescuers and to adapt the tip of the V to the real orientation of the buried subject. During this phase the first sign of a cave can be observed, as it does not make sense to take out the entire height of the front and sidewalls. The reason for stopping further rotation after first visual contact with the victim is the challenge of passing on the positioning of the victim in a timely manner from the front person to the next. Furthermore it would be psychologically challenging for a conscious victim to have to adapt to a different rescuer every few minutes.

During this phase, more rescuers are used at the tip of the V. The V does not need to be fully maintained anymore. Often it is sufficient to keep only one side of the V open and to use the free space as an additional depository for snow.

Interface to organized rescue
Once organized rescuers appear on the scene, they often require additional space for first aid and transport of victim. While this request is well founded, it should not, however, result in wasting time to gain access to the victim’s airway. Therefore the V-shaped conveyor belt approach to snow transport should be used for all user groups until commencement of first aid. At that time the diggers can step back a couple of meters, and while keeping the V formation they can start transporting the snow further away to create more space – unless they are needed for more pressing tasks.

Basic method: additional optimization through micro-management within the V
The V-shaped conveyor belt approach to snow transport constitutes a fast, efficient, and careful excavation method of avalanche victims. Experienced rescuers may adapt the base method to suit each individual rescue situation by micro-management.

The avalanche shovel
This test was not conducted to systematically test avalanche shovels. However, valuable observations were made regarding different models of shovels. All rescuers received detailed instructions in the correct use of each shovel. Not one single shovel failed due to incorrect use. Plastic shovels serve the purpose of merely “having a shovel” but usually fail before reaching the first meter of depth. Light metal-alloy shovels need to be hardened by a metallurgical or temperature process, as the majority of those metal-alloy shovels from prominent manufacturers were seriously bent after little use. The front edge cannot end in a triangle with one exposed tip, since that will bend and deform the entire blade after continued stress. Collapsible handles have a clear advantage because of the increased length of the shaft, but the two parts must sufficiently overlap in the extended state. By creating a second hole this doubling can be increased. A D-shaped (curved) grip proved to be superior to a T-shaped grip. The Voile Extreme proved to be a very sturdy and ergonomic working tool.

THANKS—We would like to thank our participants for their extraordinary efforts. A further thanks goes to Kristian Kristensen of NGI for providing us with a very affordable work environment at the modern field station. The results of the study will be presented in Whistler, Canada, during ISAV 2008, www.isav2008.com.

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Ragnhild Eide has been working as a NF mountain guide in Norway since 1997. Since 2005 she has, together with Manuel Genswein, been part of the development of the V-shaped snow-conveyor technique for excavating avalanche victims.

V-SHAPED CONVEYOR-BELT APPROACH—1) Positioning of rescuers quick measurement of distance between shoveler. 2) Working in sectors on the snow conveyor belt, snow is transported with paddling motions. 3) Clockwise rotation is initiated by the front person. job rotation maintains a high level of motivation and minimizes early fatigue. 4) Buried victim is first seen, more rescuers are needed at the front, and the snow conveyor belt only needs to be kept partially running. 5) Careful work near the buried victim while some shoveler aggressively cut the side walls to adapt the tip of the V to the real position of the victim. 6) Interface to organized rescue. more space shoveled only after medical treatment of victim has started. All graphics ©Genswein /Eide