

THE V-SHAPED SNOW CONVEYOR BELT

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ABSTRACT: The excavation of buried subjects takes by far the greatest amount of time during rescue. The V-shaped snow conveyor-belt has been developed and field tested to provide an efficient solution to the excavation of avalanche victims.

The method achieves an efficient snow transport conveyor leading to fast head access, but at the same time provides a work environment which is spacious enough for multiple rescuers to work simultaneously. The constellation of the rescuers and the starting point of the V lead to a significant reduction of the probability of causing further injury to the buried subject or destroying the respiratory cavity.

Work efficiency as an important contributing factor has been investigated by analyzing ergonomic and motivational aspects.

The comparison with uncoordinated shovelling shows that the importance (reduction of burial time) of a strategic approach to the excavation process increases with increasing burial depth.

The V-shaped snow conveyor-belt is a systematic and easy-to-teach approach to excavation of buried subjects. Novice rescuers apply the method strictly rule based, where as more professional rescuers can adapt the method to fit any rescue situation by applying micro management within the V.

KEYWORDS: Avalanche Rescue, Efficient Rescue, Companion Rescue, Excavation Strategy, Snow Conveyor

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1. INTRODUCTION

During a rescue, excavating an avalanche victim takes the largest amount of time, by far. When considering the task progression between the initial beacon search to the final transport of a victim, there exists a gap — in an otherwise tremendously well-structured knowledge on rescue — of recommended procedures for excavating a victim. This occurs specifically between locating the victim via a successful hit with the probe and establishing and maintaining an air channel, and constitutes a missing link in the chain of rescue knowledge. This paper suggests a strategy for shoveling called the V-Shape Conveyor Belt which addresses both the lack of information on the subject, and an effective reduction in rescue times.

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. For comparison the uncoordinated approach to shoveling was measured during this test as well.

2. THE ENVIRONMENT DURING THE TEST

A site near the field laboratory of the Norwegian Geotechnical Institute in western Norway was chosen. A spring snow pack 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. This made 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 had been left to re-freeze on the surface for 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).

2.1 Choice of rescuers

All “rescuers” were chosen carefully. With ages between 19 and 39, they represented the age

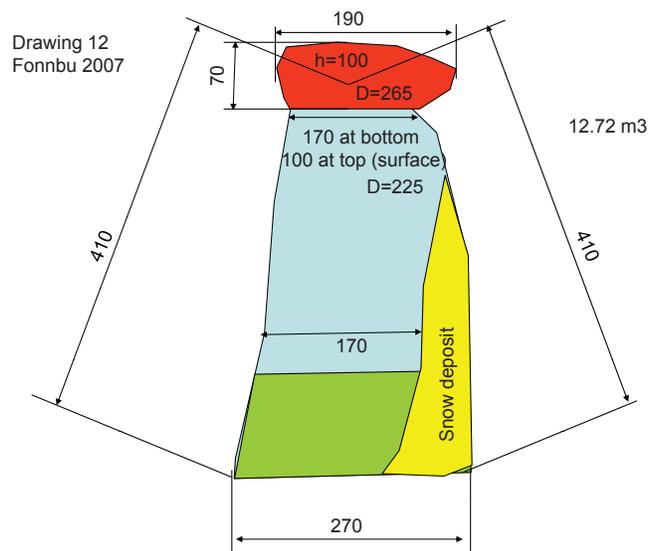
group that statistically become avalanche victims most often. Men and women from three different countries were chosen; the ensuing language challenges simulated to a certain degree the communication problems that often occur between rescuers who speak the same language with increased stress levels during a real incident. The call for volunteers read: “four-day avalanche course free of charge, including food, including active participation in a two-day field test on shoveling strategies.”

2.2 The field test

In order to eliminate exhaustion as a cause for potential mistakes, the excavation sessions were spread over four days. After shoveling 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.

3. COLLECTION OF DATA

The excavated depth was measured every 30 seconds to establish excavation rates. At the conclusion of each “rescue” the dimensions of every excavation site were carefully measured. The time measurements included first visual contact with the victim, head (airway) access time, first visible identification of the full body, lifting of the victim, and positioning the victim outside the burial site. Documentation included high-definition pictures as well as real-time video. An instructional video is available.



4. CHALLENGES FOR AN EFFICIENT AND CAREFUL EXCAVATION

During companion rescue a single probe is normally used to locate the victim. This results in only very limited information about the positioning of the buried subject in the snow (*). Furthermore it is unknown where the buried subject has been hit by the probe. On one hand the volume of snow which needs to be removed should be kept as small as possible to speed up physical access to the buried subject and its airways in particular, on the other hand a certain amount of space is required to facilitate efficient snow removal. Furthermore, rescuers should be positioned so that the buried subject and possible air pocket are not further endangered. As the exact position of the buried subject is unknown, this can only be done by reducing the access angle. The V-shaped conveyor-belt approach to snow transport is the answer to these various challenges: The tip of the V is narrow-angled which lowers the chance of mechanical impact to the buried subject and allows a fast gain of burial depth due to the relatively small volume which need to be excavated whereas the bottom of the V is wider and allows effective removal of the snow.

(*)If multiple probes are available, they may be used to get more information about the position of the buried subject.

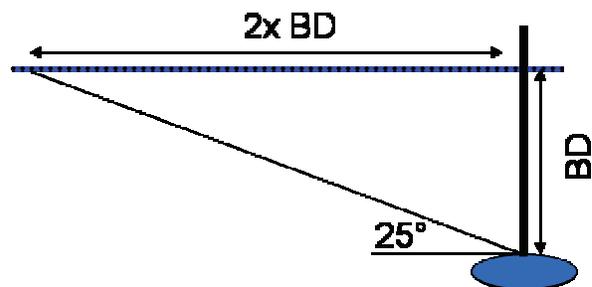
5. MAINTAINING EFFICIENCY OVERTIME

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 found that rescuers become exhausted quickly because they hold an ergonomically challenging position over a long period of time. In response, we found that clockwise rotation of rescuers every four minutes in the V-shaped conveyor belt method avoided this premature exhaustion. 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 higher the lift with the shovel, the larger the amount of snow that can fall off the shovel. A paddling motion, which utilizes the rotation of the whole body, as opposed to just using the arms, is much more efficient and results in a larger mass of snow being transported (measured in liters/rescuers/minute). Methods that suggest steps be dug for snow transport or shoveling in kneeling or sitting positions are inefficient for the reasons mentioned above.

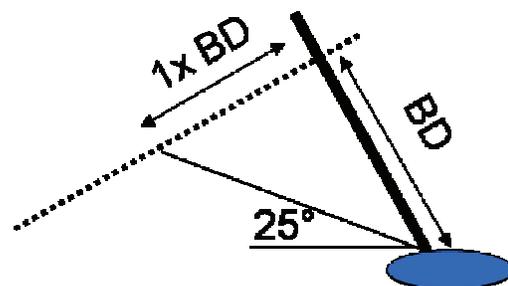
6. SIZE OF THE V AND NUMBER OF RESCUERS

Length of the V: The optimal length of the V has been evaluated based on the following considerations: 1. A steep ramp angle reduces the excavation volume and therefore speeds up the rescue process 2. A limitation in steepness of the ramp angle is given by the problem that loose snow blocks start to fall back on their own, which defeats the purpose of the conveyor belt approach. This “critical” ramp angle has been evaluated by practical experiments during the field tests and has been identified to be more than 26 degrees.



Length of the V in flat terrain (0-5 degrees)

BD = Burial depth



Length of the V in inclined terrain (20-25 degrees)

Therefore the optimal ramp angle has been defined as 25 degrees. As trigonometric calculations might be seen as impractical “on site,” a fast, easy to remember rule of thumb has been defined which leads to feasible results:

The size of the “V” can be deduced from the burial depth as determined by probing. In a flat debris field (0-5 degrees), the required length of the V is 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 interpolated. 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 length. If a victim is buried 2m deep in a flat area, $2 \times 2\text{m} = 4\text{m} / 80\text{cm} = 5$ is the perfect number of rescuers. It’s up to the rescuers where to position themselves within their sector of the V. Companion rescuers have shown difficulty 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.

7. CORRECT HANDLING OF THE AVALANCHE SHOVEL

All rescuers were taught the correct way to use the

shovel (i.e., cut blocks).

8. OBSERVATIONS ON UNCOORDINATED SHOVELING

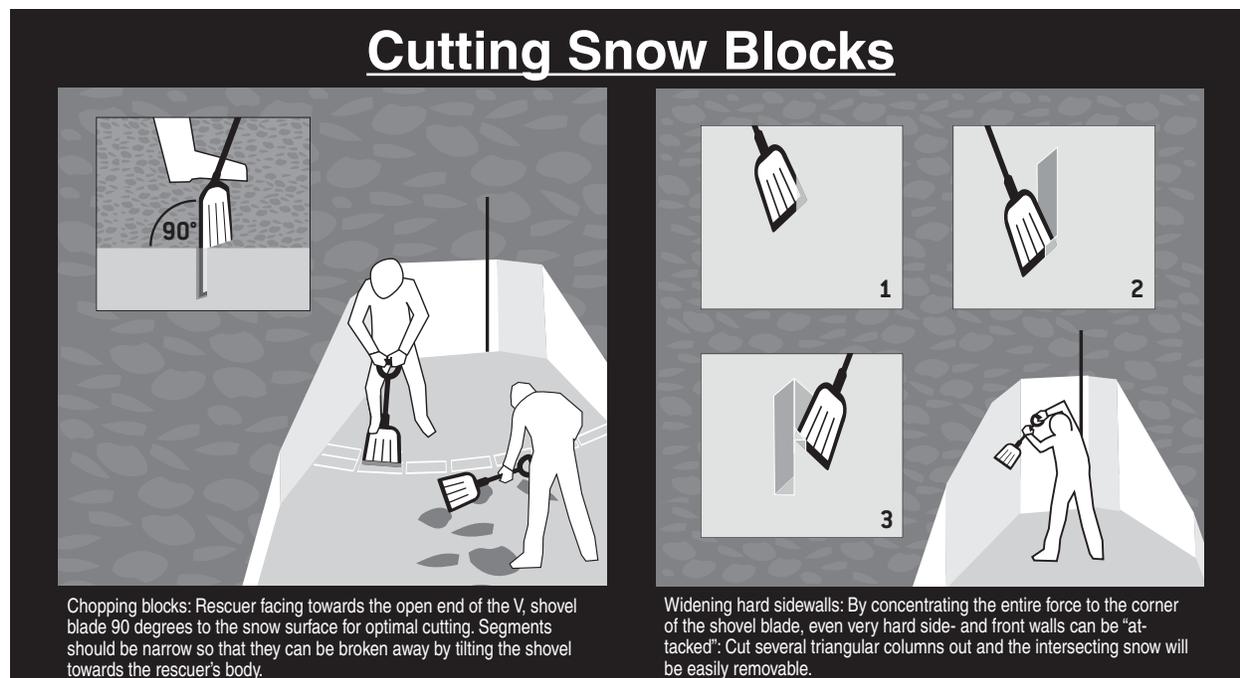
Statistics and video analysis clearly show how often rescuers stepped all over the top of the buried victim as well as got in each other’s way, resulting in diminished efficiency for excavation.

Onset of fatigue was rapid, and work was interrupted for everyone while exchanging a rescuer. With increasing burial depth, not all rescuers could be utilized.

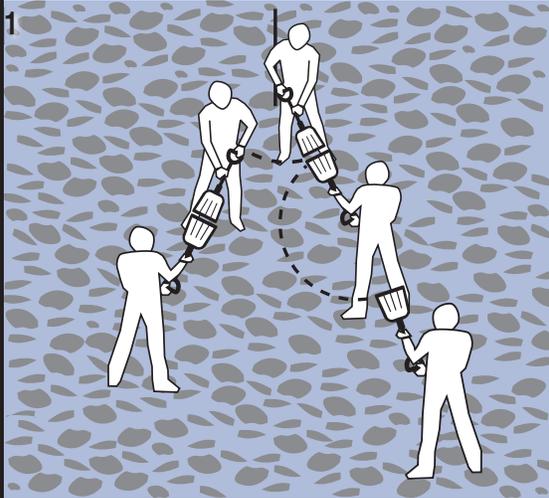
9. TRANSPORTING SNOW WITH V-SHAPED CONVEYOR

Rescuers form a V whereupon the two persons in front are a distance of one shovel length apart; the rest are distanced 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.

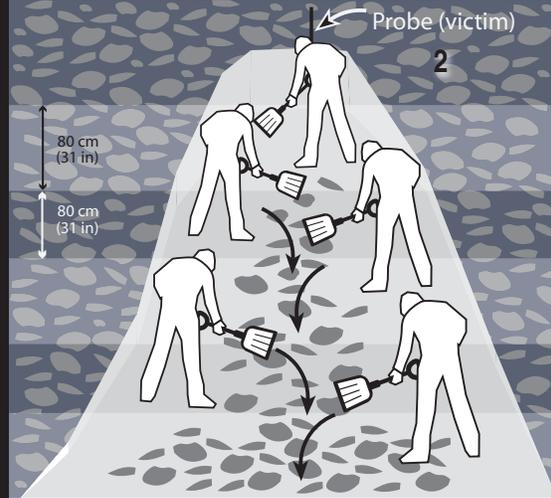
Once there is no snow to transport, blocks should be cut to increase depth. The person closest to the probe cuts blocks only. The second person starts



V-Shaped Conveyor Belt Method



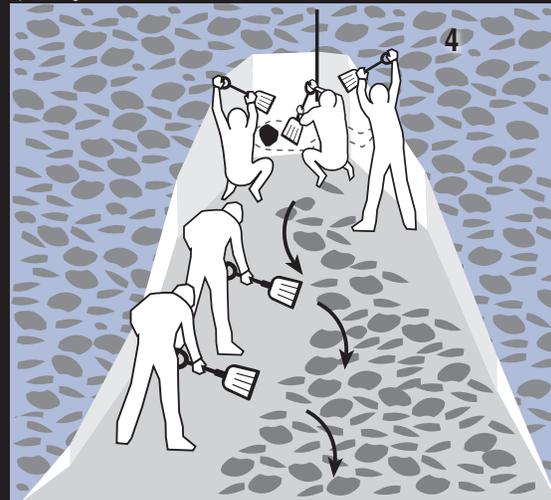
1 Positioning of rescuers: quick measurement of distance between shovelers



2 Working in sectors on the 'snow conveyor belt': Snow is transported with paddling motions



3 Clock wise 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, the snow conveyor belt only need to be partly kept running.



5 Careful work near the buried victim while some shovelers 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 is shoveled only after medical treatment of victim has started

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the transport of the blocks; but will still have capacity to cut blocks. The further back in the V, the more work is used to transport the snow and less is used to gain depth. This results in a sloping plane, gaining more depth towards the buried victim. Due to the right length of the V, it is ensured that the critical angle of 25-26 degrees is not surpassed, therefore avoiding snow falling back into the pit.

Rotation of rescuers 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.

Excavation continues in this way until the buried victim is first seen. At this point the last rotation is made. Two rescuers should be on top of the V. Those two will work directly and carefully near the victim. As a result the amount of snow feeding the human snow conveyor will decrease. To compensate for this decline, 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.

10. INTERFACE TO ORGANIZED RESCUE

Once organized rescuers appear on the scene, they often require additional space for first aid and

transportation 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 rescuers 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.

11. SPECIAL APPLICATION CASES

11.1 Application of the V-shaped snow conveyor as a single rescuer

When there is only one rescuer available, the starting position is some distance to the probe so that the V still has a certain ramp angle. The V-shaped access to the buried subject makes sense independent of the number of rescuers available.

11.2 Application if burial depth is very shallow

If the burial depth is very shallow, the rescuer at the tip of the V-formation should leave some additional distance to the probe pole as this will prevent unnecessary mechanical impact to the buried subject and its potential respiratory cavity.

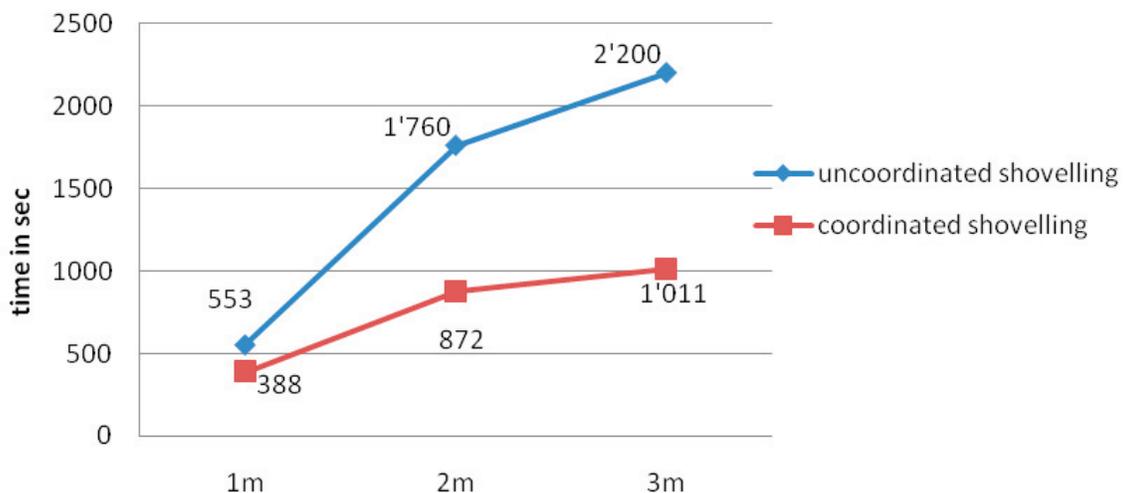
12. EQUIPMENT: THE AVALANCHE SHOVEL

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 reinforcement of

13. RESULTS

Excavation times to free the entire body



Excavation times until the entire body is free:

The higher the burial depth, the more important uncoordinated shoveling is suffering from its inefficiency.

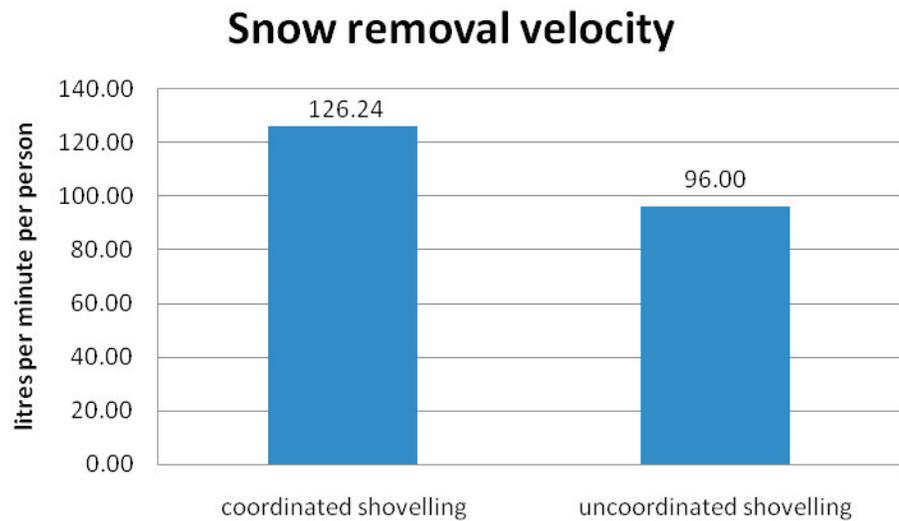
At 2m burial depth, times for uncoordinated shoveling are 102% longer (more than twice as long!), at 3m burial depth, the difference is +117%.

The increase of excavation time at 1m burial depth is 42% based on the data set of the field test, however, it needs to be considered that the uncoordi-

nated shoveling exercises were always done with the full group size whereas the coordinated shoveling exercises only were using the amount of rescuers as recommended by the V-shaped conveyor approach, which mean only 2-3 rescuers.

If the uncoordinated 1m excavation would have been carried out with the same amount of rescuers as the coordinated ones, the time advantage would certainly be greater.

Due to the higher efficiency of the V-shaped snow conveyor, 31.5% more snow gets removed from each rescuer per minute compared to an uncoordinated excavation procedure.



14. DISCUSSION AND CONCLUSIONS

An intelligent excavation strategy such as the V-shaped snow conveyor leads to a very important reduction of the necessary excavation times and therefore strongly influences the survival chances of the buried subjects. Excavation strategies need to be implemented in every companion and organized rescue training.

After some success stories with the new system in real avalanche cases in the season 2007 / 2008, the authors hope that the V-shaped snow conveyor continues to contribute to save lives of people caught in avalanches in the future.

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