PROBING FOR AVALANCHE VICTIMS

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ABSTRACT: Experience from avalanche rescues and rescue drills reveals that often the buried victim is not found on the first or even second pass of an organized probe line. Traditional probe spacing used in North America is based on assumptions and practice done nearly 40 years ago (Schild, 1963 and 1973). More recent work by Jamieson and Auger (1997) challenged those assumptions and presented evidence that the original probabilities of detection (POD) were high, but still their probe targets were not human shaped, and thus did not offer a realistic search target. We developed a computer program PROBE that simulates a fully articulated human body, "buries" the body, and then implements the probing technique specified by various command line options. The derived "bodies" offer realistic targets, and the program can compare the PODs for different probe-pole grid patterns. 10,000 trials were run for a variety of probe-grid spacings, including the standard coarse probe, Canadian 3-holes-per-step, and European methods. Results suggest significantly lower PODs for the commonly used probe-grid patterns. Search and rescue leaders should reconsider their use of the traditional techniques. Some options are offered that may make searching more efficient, for the sake of the searchers and of the buried victim.

KEYWORDS: avalanche rescue, probing, POD, probelines, PROBE

1. INTRODUCTION

Probing is still necessary, even with other preferable methods – beacons, dogs, etc. – getting more attention all the time Not all victims have beacons, or even reflectors for the Recco, and a trained dog is not always immediately available. Rescuers will continue to need probes and to know how to use them to their best advantage.

2. HISTORY

From Fraser (1966), we learn that more than 2000 years ago, the Greek geographer, Strabo, wrote about shepherds in the Caucasus Mountains who carried staffs that could be used if they were caught in avalanches, thrusting the staff upwards so that their companions could locate them. Perhaps the other shepherds would use their staffs as probe poles. By the 1700s and 1800s rescuers in Europe and then later America were using organized probelines (Fraser, 1966; Martinelli and Leaf, 1999).

By the 1950s, the "state of the art" was typified by these instructions in Atwater-Koziol (1952), "Probers are spaced shoulder to shoulder and probe every square foot." In Daffern (1973), we find, "Probing is the oldest and least efficient method of searching for an avalanche victim."

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According to one source, Schild (1975), the 25 cm by 30 cm spacing was standard until about 1960. (All grids mentioned will have the lateral spacing first, and the step size second.) A 30 by 24 inch coarse probe was recommended in Perla (1968), with a claim of "a 76% chance of locating a victim on a given pass." LaChapelle (1978, 1985) also recommended 30 by 24 inches. Schild (1975) explains that a 75 by 70 cm grid results in one probe in 0.525 m^2, or 1.9 probes per m^2. Using an average body with an area of 0.4 square meters, multiply 0.4 by 1.9 to get 0.76, and expect to hit the body on the first pass 76% of the time. The difference between recommendations in metric and English units caused significant confusion. Citing probabilities of detection as in Table 1, Perla and Martinelli (1976) recommended the 75 by 70 cm coarse probe and the open order coarse probe, with each rescuer probing twice at each step in order to double the area probed in a single pass. Hotchkiss (1985), Fredston–Fesler (1994), and Hotchkiss, et al. (1996) give the grid as 30 by 28 inches, or have both metric and English units.

Person lying on his stomach or back	95%
Person on his side	75%
Person in vertical position	20%
Average position	70%

Table 1. Probability of detection for 75x70 cm grid, in Perla and Martinelli, (1976).

Auger–Jamieson (1996) proposed a three-hole-per-step (3HPS) technique in which rescuers spaced 175 cm apart probe 50 cm to each side, as well as in the center. The right and left probes could be angled out at the convenience of the prober. Jamieson–Auger (1997) used an elliptical body that is arguably closer to reality than the 0.4 square meter body used to calculate the 76%. The ellipses used had the same areas as the squares used earlier, but it was expected that the ellipses would fit between the grid holes more easily than the squares. Averaging their results over the five depths studied, 0.1m, 0.5m, 1.0m, 1.5m, and 2.0m, they found lower PODs for the traditional 75 by 70 cm grid (Table 2).

Orientation	Vertical 75 by 70 cm grid	J-A 3HPS, <10° angles 50-70 by 70 cm
Vertical	19%	26%
Prone/Supine	75%	84%
Side	63%	74%

Table 2. Percentage of Victims Found on First Pass (Jamieson–Auger, 1997)

In Atkins (2000) the 3 hole-per-step method is recognized for improving efficiency, but the insertion of probes at an angle is rejected. This paper claimed that uniform spacing and vertical probes would give better results, and proposed a 60 by 70 cm probe spacing.

3. PROCEDURES

Rather than using the simple geometric forms used by our predecessors, we have tried to model an articulated human body. A computer program, PROBE, was written to generate a human body composed of overlapping spheres. The program permits totally random orientation of the body as well as natural bending of the major joints. (See website for more detail.) While it can also generate bodies with normally distributed heights and weights, for this paper, we are using a standard body, 175 cm tall, with average build. This size body took about 950 spheres to model. In order to run tests on the same bodies with different probing techniques, we created a file of bodies that could be reused for many tests.

3.1 First probe pass

The initial probing investigation was modeled by generating a buried body, then backing away, out of range, choosing a random starting point, and probing a grid starting from that point until a strike is made or until the probing has clearly missed the body. To test *each* probe spacing, we used 1000 bodies and 10 random starting points, giving 10,000 trials. These results (Table 3) may explain why, in field exercises, probelines seem to miss targets more frequently than the literature led us to expect. Except for vertical burials, we found that our model gives even lower PODs for the 75 by 70 cm grid.

We were not just interested in understanding past results and unexpected failures. We wanted to find a technique we can recommend

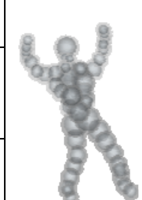
Orientation	Target area m^2	Schild (1963)/Perla (1976)	Schild/ Perla POD	J–A (1997)	J–A POD	PROBE (2004)	PROBE POD
Vertical	0.10		20%		19%		22%
Prone/ Supine	0.50		95%		75%		74%
Side	0.40		75%		63%		49%
Average	0.37	—	70%	n/a	n/a		59%

Table 3. Comparisons of targets (approximately to scale) and PODs for traditional 75 by 70 cm grids. (A typical body generated by PROBE will have a surface area in the prone/supine position of 0.4 to 0.5 m^2.)

and teach, so we started by collecting some more statistics (Table 4). These tests were run on bodies in random positions rather than the specific orientations used above, and using several different grid sizes.

We also compared 50 and 60 cm grids and the traditional 75 by 70 cm grid with the Jamieson–Auger angled probe 3HPS method, with both 60 and 70 cm steps. To do this fairly, we generated groups of bodies with similar burial depths, at 20 cm intervals (Table 5).

Table 5 shows slightly higher PODs for the shallowest burial (20 cm) and slightly lower PODs at the deepest depths. At shallow depths nearly all bodies are flat while at deeper depths more bodies can be buried in vertical positions. This happens because the program generating bodies discards any body that protrudes from the snow. The different PODs also indicate the PROBE bodies used at different depths are indeed different.

Probe grid (cm)	PROBE POD on first pass (percent)
30x30	99.9%
40x40	97%
50x50	88%
60x60	75%
70x70	63%
80x80	51%
75x70	59%

Table 4. POD for first pass of probe line calculated from PROBE.

When the probes are inserted vertically there is little dispersion about the mean POD values. However, when the probes are inserted at a slight angle (J-A grid, 10° angle) the POD decreases with depth. Probes 75 cm apart and inserted at 10° angles will cross at about 212 cm deep. This means that the grid is 87.5 cm between holes at this depth. Interestingly, the angled probes are nearest to an equal grid (about 58 cm apart) near the 60 cm depth, possibly accounting for the better results.

Averaging the results above may seem to be assuming that buried victims are uniformly distributed in the top 2 meters of the avalanche debris. If we had usable data about the distribution of victims at various depths, we could weight the averages accordingly.

3.2 Expected time to discovery

First pass probabilities are not the whole story. If they were, we would still be using a fine probe. We need to consider the need for speed. As Schild pointed out, it takes about 5 times as long to do a fine probe as a coarse probe. And there is an obvious advantage to probing more times per step. Other studies have looked at probing efficiency by calculating probes per area per second. We decided to take a different approach, finding the average time until a victim is found, by simulating an actual probeline.

To find the expected time to discovery (ETD), a new program was written that would simulate a probeline searching for a buried victim in a given area. We used 20 person probelines and 10,000 square meters (1 hectare). We also used 3.7 seconds per probe, 4.4 seconds per step, a descent speed of 1 meter per second, and

	square grid		J-A grid w/angled probes, 3HPS		Traditional
Depth (cm)	50 cm	60 cm	60 cm steps	70 cm steps	70x75 cm
20	90%	78%	79%	72%	63%
40	87%	75%	73%	67%	59%
60	88%	75%	73%	73%	60%
80	89%	76%	73%	67%	60%
100	89%	76%	73%	66%	60%
120	89%	77%	72%	66%	61%
140	88%	75%	69%	68%	59%
160	87%	74%	67%	61%	59%
180	88%	74%	66%	60%	58%
200	87%	75%	65%	58%	59%
mean	*88%*	*75%*	*71%*	*65%*	*60%*
SD	1.0	1.3	4.2	4.9	1.4

Table 5. PODs calculated by PROBE for bodies buried at different depths

a sixty second reorganization allowance. The probing and step times were taken from a Swedish study by Peter Mårgåd, (1998, personal communication). The other numbers are pretty arbitrary, but as long as they are reasonable and consistent across the various trials, it shouldn't make much difference.

In order to continue probing until the body is found, we have had to define exactly what to do after the first pass (Figure 1). To maximize the probability of finding the body, the second pass is offset from the first by half the grid dimensions. Thus, when doing the standard 70 cm by 75 cm grid, the second pass would be offset by 35 cm up the hill and 37.5 cm laterally. The probes of the second pass are exactly in the middle of the holes left by the first pass. In a square grid, the result of two passes is a regular grid that has dimension 0.707 times the original dimension, at 45° to the original grid.

1		3		**1**		3		**1**		3		**1**		3	
	6		8		6		8		6		8		6		8
4		2		4		2		4		2		4		2	
	5		7		5		7		5		7		5		7
1		3		**1**		3		**1**		3		**1**		3	
	6		8		6		8		6		8		6		8
4		2		4		2		4		2		4		2	
	5		7		5		7		5		7		5		7
1		3		**1**		3		**1**		3		**1**		3	

Figure 1. Possible probe positions for 8 probeline passes.

Every time one doubles the number of passes, the grid is improved by 0.707 (the reciprocal of the square root of 2). Thus, after four passes, the grid is half the size of the original, and in eight passes, it is about 0.36 times the original grid size.

The important results in Figure 2 are that three holes per step is more efficient than two and that the time cost of a tighter grid gets increasingly large below 50 cm.

In order to compare the Jamieson–Auger proposal, we average the expected times until discovery for the sets of bodies at different depths. While the Jamieson–Auger proposal is actually better than the traditional 75 by 70 cm grid at shallow depths (Figure 3) where the resulting grid is effectively tighter; below a meter, the angled probes result in less efficiency. The square grids, 50 or 60 cm, have fewer problems with missing bodies, so they come out ahead. The differences are not huge – less than 17 minutes out of more than 90.

Figure 3 compares probe grids that seemed viable, historically or in recent proposals, with some square grids added for reference. We found that the traditional open order coarse probe, 50 and 60 cm square grids, and the Jamieson–Auger proposals are pretty comparable. All other things being equal, the 60 cm square grid seems to be the optimal grid spacing.

3.3 *Multiple probeline passes*

But other things are not equal. The computer can simulate multiple passes with precise offsets. Rescuers have problems just trying to do the first grid accurately. The standard way to ensure an accurate probeline is to use a guidon cord marked at the desired intervals. If the area probed is well marked, then the cord handlers could offset sub-sequent passes relative to the first pass. If the area is not marked, or if a guidon cord is not used, subsequent passes will not be optimal, and may even tend to be useless as experience has demonstrated probers sometimes gravitate to the same footprints they used on the earlier passes. Without a guidon cord to accurately place probes, there is little or no accumulation of PODs. Even with the best probing technique, field conditions will make the computer's results impossible to reproduce, especially for multiple passes.

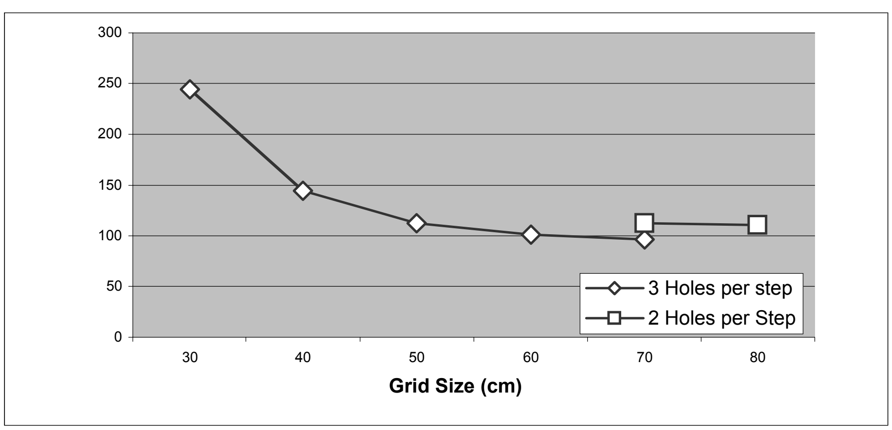


Figure 2. Shows that 3HPS is more efficient than 2HPS, and that the time cost of a tighter grid gets increasingly large below 50 cm.

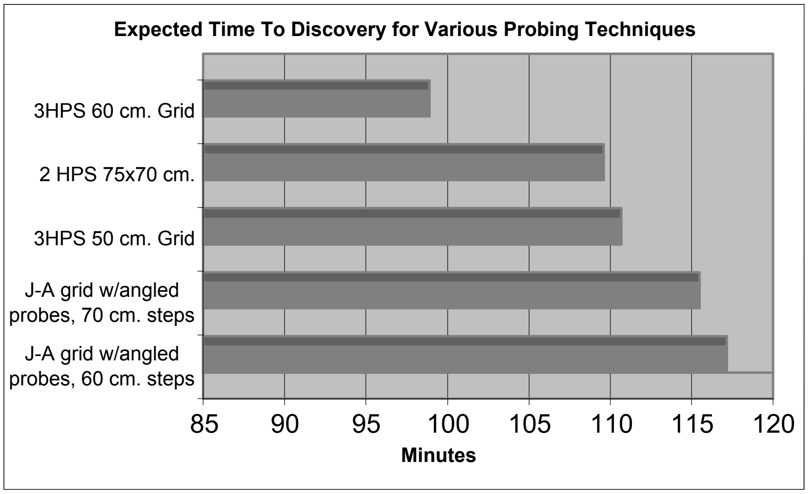


Figure 3. Expected time to discovery for various probing techniques.

Considering the significant need for multiple passes when the grid spacing is relatively wide, we would like to take into consideration the difficulties of trying to offset subsequent passes for optimal effectiveness, the strain on rescuers when they have to reprobe an area, and the strain on the leader who has to decide whether to reprobe the area or to shift the probeline to a different part of the avalanche debris. Since these difficulties are all related to the number of passes required, we can look at the average passes.

In Table 6, we see a big jump in the dependence on 3 or more passes between the 50 cm square grid and the 60 cm square grid. A similar jump is seen in the dependence on the second pass both in going from 30 cm to 40 cm and in going from 40 cm to 50 cm. But the times for 30 and 40 cm grids were so large that they are not practical. If we can just do a good job on the second pass, with proper guidon cords and flagging, then the 50 cm square grid keeps the stress factor low, the ETD reasonable, and finds over 99% of the victims in 2 passes. Some older rescue plans recommend a fine probe after two coarse probes, but after two passes of the 50 cm square grid, a fine probe is practically redundant. Another reason not to try to do the 60 by 60 cm grid is that for the smaller rescuer, this can be quite a stretch.

4. CONCLUSIONS

The numbers do not lie but many interpretations are possible. One can always choose which ones to weigh more heavily.

- Probing really does take a long time.
- Three holes per step are better than two.
- Vertical probing gives better PODs than angled probing.
- The articulated body model gives lower PODs for the 75 by 70 cm grid than earlier models.
- The expected time until discovery may be lessened with the right choice of grid size, a guidon cord, and a well-marked search area.

5. RECOMMENDATIONS

We feel it is important to remember what part probing should play in avalanche rescue as well as to use efficient and effective probing technique.

- ❖ Use a 50 cm square grid, with three holes per step.
- ❖ Use a guidon cord to facilitate precise probe placement and offsetting in sub-sequent passes.
- ❖ Mark the area probed with wands or flags so that a second pass can be offset consistently from the first.
- ❖ Whenever a probeline is to be used, try to limit the area to be probed based on all available evidence.
- ❖ Organized probelines are tremendously resource consuming. The rescuers should not start using probelines

	% Found on Various Passes					
Technique	1st	2nd	3 or more	Time per Pass	Average Passes	ETD (min.)
30 cm sq.	99.9%	0.1%	0%	487 min.	0.50	244
40 cm sq.	97%	2.8%	0.04%	274 min.	0.53	144
50 cm sq.	88%	12.1%	0.8%	175 min.	0.64	112
60 cm sq.	74%	20.8%	4.4%	122 min.	0.83	100
Trad. 70x75	60%	26.5%	13.6%	111 min.	1.15	111

Table 6. Comparison of several statistics for several grids (ETDs are the same as in Figure 2, but slightly different from Figure 3 because different bodies were used for the comparisons with J-A techniques.)

until the Immediate Search has been adequately completed.

- ❖ Check out our website on probing. There will be a link on the CAIC web site, http://geosurvey.state.co.us/avalanche/papers/

6. REFERENCES

Atkins, D. (2000). The probe efficiency index and better ways to do the coarse probe. *The Avalanche Review*, Vol. 18, No. 3, p 10–12.

Atwater, M., Koziol, F., 1952. *Avalanche Handbook*, U. S. Department of Agriculture Forest Service, 146 pp.

Auger, T. and B. Jamieson (1996). Avalanche probing revisited. *Proc. of the Int'l Snow Science Workshop,* Banff, Oct. 6-11, 1996, 295-298. Canadian Avalanche Association, Revelstoke, BC, Canada. May 1996. Also reprinted in *Avalanche News* 49, 16–19.

Daffern, T., 1983. *Avalanche Safety for Skiers and Climbers*, Rocky Mountain Books, Calgary, 172 pp.

Fraser, C., 1966. *The Avalanche Enigma*. Rand McNally & Co., 301 pp.

Fredston, J A., and Fesler, D., 1994. *Snow Sense: A Guide to Evaluating Avalanche Hazard* Alaska Mountain Safety Center, Inc., 116 pp.

Hotchkiss, W. R., 1982, 1985, 1989, 1996, *Avalanche Rescue Quick-Guide*, National Ski Patrol, 22 pp.

Hotchkiss, W., D. Atkins, and L. Ballard, 1996. *Avalanche Rescue Fundamentals*. National Ski Patrol, 51 pp.

Jamieson. B., and T. Auger, 1997. Improved probing for avalanche victims. www.eng.ucalgery.ca/Civil/Avalanche/papers.htm, Jan. 23, 2004.

Martinelli, M., Jr., and Leaf, C., 1999, Historic Avalanches in Northern Front Range and the Central and Northern Mountains of Colorado, *General Technical Report RMRS-GTR-38*, USDA Forest Service, Rocky Mountain Station, p 43.

McClung, D.M. and P.A. Schaerer, 1993. *The Avalanche Handbook.* The Mountaineers, Seattle, 271 pp.

Perla, R.I. 1987. Optimal probing for avalanche victims, USDA Forest Service Miscellaneous Report 13.

Perla, R.I., 1968. Snow Safety Guide No. 1, Modern Avalanche Rescue, U.S. Dept. of Agriculture, 91 pp.

Perla, R.I. and M. Martinelli, Jr., 1976. *Avalanche Handbook*, U.S. Dept. of Agriculture, Agriculture Handbook 489, 238 pp.

Schild, M. 1963. Absuchen und Sondieren. Symposium über Dringliche Massnahmen zur Rettung von Lawinenverschütteten, *Vanni Eigenmann Foundation*, 30–32.

Schild, M. 1975. Previous experience in the practice of avalanche rescue. *Avalanche Protection, Location and Rescue.* Vanni Eigenmann Foundation, 51–75.

USDA-FS, 1961. *Snow Avalanches: A Handbook of Forecasting and Control Measures*, Agriculture Handbook No. 194. 84 pp.

Why is the avalanche probe an indispensable item of avalanche safety equipment? The probe is an important component of avalanche safety equipment. Only with a probe can the exact location and the burial depth of the victim be determined, allowing quick action to be taken. Because in an avalanche accident itâ€™s all about working at speed to save lives. Investigations have shown that without an avalanche probe for locating and pinpointing, it takes twice as long to dig out the victim: approx. 25 minutes. With a probe the average rescue time is eleven minutes. Without a probe, therefore, it is unl Avalanche victims are often risk takers that set aside safety concerns in the pursuit of their goals, and 89% of them are men. While the majority of avalanches happen naturally, 90% of avalanche fatalities occur in avalanches triggered by the victim himself, or by someone in the victimâ€™s party. So avalanches arenâ€™t exactly freak accidents, and there is a lot you can do to avoid getting swept up in one and to increase your chances of survival if you do.Â Avalanche probes. Using a transceiver will get you close to the victim, but a probe will allow you to pinpoint him in the snow. The best kind to get are collapsible probes that you put in your pack and assemble like a tent pole. Ski poles that can be screwed together to form a probe are also available. Avalanche probes help you pinpoint the exact location of an avalanche victim and measure the burial depth. Use of a probe in a burial situation has been show to cut up to fifteen minutes off rescue times, making it an essential part of a successful recovery. All three pieces of avalanche safety gear are mandatory: transciever, shovel, and probe, so making sure you get the right avalanche probe to suit your needs and learning how to use it is key to becoming a competent backcountry traveller. Probe Length. Materials and Construction.