FIVE PROBLEMS IN AVALANCHE RESEARCH[1]

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INTRODUCTION

Avalanche technology has come a long way since 1950, the beginning of the LaChapelle-Sandahl period. We can cite these examples of progress: the development of rescue transceivers, advanced meteorological and snow pack instrumentation, innovative methods of explosive delivery, improved mountain weather forecasts, introduction of the forecast centers, and the use of computers for data management. Progress was due to the collective efforts of many people working in many different locations.

Other research problems were studied during this period, some of these have not yielded the same degree of progress as the above mentioned topics. The five problems I would like to discuss with you today fall into this latter category. They are specialized problems in avalanche forecasting and control, and are drawn mostly from my experiences in Little Cottonwood Canyon, Utah.

1. THE BALDSIEFEN QUESTION

Winter, 1967, a three day storm dropped a meter of new snow in Little Cottonwood. It was a depth-hoar year. LaChapelle set aside his research and assumed the role of head avalanche forecaster. The Canyon was sealed tightly, with guards posted to block road and interlodge travel. Guests were moved to the safer areas. We shot, and brought down moderate to large avalanches on all exposures. The final target of the day was Mount Superior, where we surely expected results since we had released slides on the similar exposures of Flagstaff, Hellgate and Little Superior. We positioned our 75 mm Howitzer and fired on all targets. Nothing moved. It didn't seem right. We tried again. Nothing. Finally, four tired snow rangers and volunteer Warren Baldsiefen, who was always there to help during a major shoot, stood silently together next to our still warm howitzer. Baldsiefen turned to us one by one: " Lindquist, why didn't Superior slide? Why didn't it slide, Sandahl? Why didn't it slide, Bassett? Why didn't it slide, Perla?" I will always remember that moment, for none of us had an answer. We opened the road. Superior did *not* post-control, its stability held until the next storm cycle. But we know about unlucky examples, in fact, two major Alta avalanches (1963 and 1967) that I survived were indeed post-control.

Baldsiefen's question continues to haunt us today, not only on Superior, but on every slope where we believe it should slide, try hard to make it slide, but it refuses to slide. We may try especially hard on ski area slopes that should be opened as soon as possible to receive the benefit of compaction. Avalanche forecasters have

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good reasons for believing a slope should run. They have been observing and thinking about the slope from the beginning of the season. They recognize the basic ingredients of instability. They *see, feel* and *hear* weakness. They see activity on similar slopes. They make use of reports from observers who also see, feel and hear weakness. They have their tools and instruments which are improving every year. They have experience, including hard earned lessons. They are usually not far off in their judgment. A good dose of explosives should do it. So what is special about a slope that refuses to run on command, that may release when we don't want it to release? We are good at sensing general instability, but how do we know when a particular slab is unstable and ready to fail? To answer, I believe it is fair to say that we still lack a comprehensive model of slab failure. We need more inputs, predictive measurements and models of the slab failure process.

2. ENOUGH IS ENOUGH

One approach is to put aside what we don't know, and fall back on explosives and more explosives. Slab instability is clearly transient. We cannot always control at the optimum time. A popular solution: compensate for timing uncertainty with bigger and bigger explosives. For example, on the day of the Baldseifen question, Superior was the last target. Perhaps it had self-stabilized while waiting its turn. The 75 mm howitzer rounds with their 0.7 kg payloads were not enough. Superior would have run if we had used—what? Maybe 105 mm rounds with over 2 kg payloads? Or maybe 5 kg helibombs? 10 kg?

Despite the large amounts of explosives used in avalanche control, I don't believe anyone knows what is enough in a given situation. About one kg is the *de facto* standard. But this is often varied in either direction. Good results are obtained with the 75 mm howitzer and with 0.5 kg hand charges, while at the other extreme, the Sunshine road in Banff National Park, Alberta, is heli-bombed with charges ranging up to 40 kg.

You may say "the bigger the better" or "if in doubt, user a bigger one." In helibombing operations, on some missions using hand-thrown explosives, and where it is feasible to radio detonate pre-planted charges, indeed it may be practical to detonate charges much bigger than one kg. But we know about problems with the big bomb philosophy. First, on complex control routes or when it comes to artillery and related systems of delivery, practicality requires " the smaller the better." We are at the practical upper limit with 75 mm and 105 mm sized weaponry. It is difficult to imagine avalanche weaponry of the future throwing larger projectiles. On the contrary, reduce the shrapnel and it is then possible to launch one kg payloads to a maximum range of 4500 m with 57 mm weaponry (as proposed in preliminary design by the Honeywell Corporation.)

Second, although no one denies that bigger explosives will release more and bigger slabs, what are the quantitative guidelines? What is the expected gain for the added effort? If one doubles the explosive amount, how many more avalanches should we expect? Will a statistical study show avalanche activity doubles? Or increases proportional to the $\sqrt{2}$? $\sqrt[3]{2}$? I think we can do more in this area of research.

Last, and perhaps most important, post-control release seems to occur irrespective of explosive size. A bigger explosive may not be the cure. Sometimes, could it be the problem?

3. THE SLAB BUG

One widely held view is that, even if the explosive fails to produce an avalanche, it at least stabilizes the slope. I am not sure if anyone really knows how an explosive stabilizes an avalanche slope. Perhaps the slab moves slightly to a more stable position. Perhaps tiny fractures propagate and relieve tension. Perhaps the slab is broken into individual blocks that cannot begin to slide, unsynchronized with neighboring blocks. Should one conclude, in the absence of slab release, that the bigger the explosive, the greater the stabilizing effect? Well, that conclusion is not intuitively obvious. Explosives destabilize most structures. Hence, it would be rather remarkable if proved true.

Is it possible to measure how an explosive blast changed the stability of a specific slope? I think it is time to unveil the *slab bug.* This technological masterpiece is a small, spiked sphere, about the size of a tennis ball, which houses several sensors. Further details about these sensors are classified (they are believed to be state-of-the-art microseismic detectors.) A spool of signal cable joins the bug to a digital meter. The bug can be thrown out on a slope and fished back after a reading. Bug and meter are carried on a control route to a ridge above the problem slab. The control team throws the bug onto the slab. A digital readout indicates the index of stability, and a suggested amount of explosive. The slab is controlled. If there is no avalanche, another reading is taken to confirm that the slab was stabilized by the control. Control teams practice with the device at the National Avalanche Clinic, where the question is often asked: " How was it possible to forecast and control in the old days before the slab bug?"

4. NAAZHOOSH

Avalanche forecasters don't have a slab bug. They may never have one. They don't have a forecast equation. They have few if any critical numbers. Many of their inputs are strictly qualitative. They would have some difficulty, I believe, to set down a list of numerical forecast rules. They may even find it difficult to verbalize qualitative rules in the formal sense *if..., then....* What do they have? Dear audience, we can make a long list! They have: Sensitivity to Nature's signals. Judgment. Experience. Communication abilities. Ski and mountaineering skills. Physical and mental toughness. Oh! I almost forgot. An incredible capacity to keep irregular work hours. They really know their area, which among other things includes terrain, the snow pack, weather, people and facilities. In their minds, they can create a model of the mountain, the snow and the weather. They move the wind around. They carry snow into the starting zones.

And they really understand avalanches. Their minds can soar into the starting zone. The image is readily created because they have been there either physically or mentally enough times in the past. They see the slab load and fail. They can see the avalanche move down the mountain. They follow it into the runout zone, not far from the people and facilities that depend upon them for protection. The models they form in their minds of this total system are superb.

Having said all this, I nevertheless feel that our words fall far short of describing the thought process for modeling the phenomenon. The alpine nations of Europe call it *Lawine* or *avalanche* or *valanga*. The committee which developed the international language, *Esperanto*, mixed these words together and came up with a new word *Lavango*, a word which sounds like a tropical fruit, and moves us further from the phenomenon. If we have to replace the word *avalanche*, I vote for the Navajo expression *naazhoosh*. If it could be translated into English, it may mean "to be an avalanche." It recaptures the spirit of the phenomenon.

5. REPLACING LACHAPELLE AND SANDAHL WITH A COMPUTER

There was once a well-meaning computer engineer who was intent on developing an expert system for avalanche forecasting. The more she heard about the spirituality of the process, the keener became her interest. Here was a research project without a well-marked road to solution, precisely the sort of research that she found exciting. One day, she interviewed Sandahl in order to obtain a set of *if...,then...*rules. At first, Sandahl was mildly dubious: " What? Replaced by a computer program?" But eventually he cooperated fully, especially when told that the program would be for eternal inspiration. After all, for the sake of eternity, it would be far more practical to distribute software containing his ideas then to place an urn of his ashes on every forecast desk. Kind, patient Sandahl helped the engineer to verbalize nearly 1000 rules. For relaxation, he also taught the engineer how to soar up to the starting zones.

Sandahl suggested that the engineer also interview LaChapelle. The engineer found an open-minded scientist who had thought about similar projects for many years. LaChapelle helped the engineer construct an additional set of rules that would make the expert system more universal, beyond the boundaries of Little Cottonwood. On the side, he taught the engineer how to soar to starting zones in a variety of mountains and climate zones.

Finally, LaChapelle returned the engineer to Sandahl to learn advanced soaring techniques, such as how to soar to several places simultaneously, the starting zones, the runout zones, the test areas, and even the bosses' office in Salt Lake City. The engineer was grateful. In return, she made certain the program was designed to allow the forecaster to sleep-in an extra hour or two.

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Little Cottonwood Canyon, the realm of LaChapelle and Sandahl, is one of the few places where almost everyone on the streets is willing to discuss avalanche problems, winter and summer. It is filled with people who have thought about the problems, have contributed solutions, and will continue to contribute—people who are anxious to test solutions developed in other areas. If one happens to spend a winter in Little Cottonwood, that person will become very interested in avalanches. It is a pleasure for me to return today to this fascinating canyon to honor two people who have contributed enormously.