A TOOL, NOT A TEST: USE OF EXPLOSIVES FOR AVALANCHE HAZARD ASSESSMENT

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ABSTRACT: By most widely accepted definitions a “test” is a procedure for critical evaluation; a measure to check the reliability of something, especially before putting it into widespread use. Tests are used—explicitly or implicitly—in conjunction with a hypothesis. That is, a predetermined belief about a specific phenomenon. In traditional practice the use of explosives has long been viewed as a test to validate the hypothesis of snowpack instability. However, when results are negative—i.e., the explosives fail to trigger avalanches—the actual stability of the snowpack remains undetermined. This situation may underlie a type I error, that is, the incorrect rejection of a true null hypothesis. The so-called “post control avalanche” phenomenon proves that the instability of the snowpack remains unknown when explosives fail to trigger avalanches. Therefore, explosives use in avalanche mitigation procedures does not satisfy a robust hypothesis test and may be considered only a “tool” to attempt to trigger avalanches. While positive results from the use of explosives may be effective at reducing the potential risk to life and property, we argue that when a significant avalanche hazard is forecast and the subsequent use of explosives yields negative results, this observation does not constitute a confirmation that the snowpack is stable and safe. Allowing public access to the avalanche terrain that is by definition “untested,” cannot be considered a valid forecasting or mitigation procedure. Given the known potential for significant residual risk to the public of “post control avalanches”, the use of explosives as a “snowpack stability test” is called into question.

KEY WORDS: Post control avalanche, stability, instability, null hypothesis, type I error, test, tool, cognitive dissonance.

1. INTRODUCTION

Throughout his classic book, “The Avalanche Hunters”, Monte Atwater (1968) proclaims explosives to be the recommended method for triggering avalanches. Explosives did indeed become the most widely accepted method for triggering avalanches throughout the world and remain so today. A one to two kilogram hand-charge of high explosives and similar payloads in the form of military artillery rounds or Avalauncher-type projectiles have long been the standard methods of triggering avalanches (Abrommeit, 2004). A variety of innovative delivery systems such as bomb trams and gas exploders have helped solve logistical problems of artillery availability and difficult access to terrain (Decker et al., 1982). Innovative targeting techniques such as suspending an explosive charge above the snow surface or firing rounds into a solid rock face adjacent to the starting zone have improved the effectiveness of the standard one to two kilogram blast. Over the years larger explosive charges also have come into vogue as avalanche technicians struggle with the problem of stubborn slopes that do not release as predicted. The fact is, however, that despite Atwater’s confidence in the use of explosives, they do not always yield the desired results.

An inherent conflict is created when a hazard forecast calls for significant avalanche potential, and then subsequent deployment of explosives fails to trigger the predicted release. In such instances the dilemma is that either the forecast was incorrect and over-estimated the avalanche potential, or the location, the timing, and/or possibly the size of the explosive charge was incorrect and the triggering opportunity was missed. Logic dictates that one and/or another of these factors must be true. This potential for residual instability is not resolved until additional data unequivocally confirms which one is true.

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The danger that is created in this scenario is the potential for so-called “post control avalanches” where skiers or snowboarders trigger the avalanche after explosives fail to do so (Ferrari, 2010). The occurrence of this well-documented phenomenon emphasizes the fact that the failure of explosives to trigger the expected avalanches is not sufficient data to resolve the dilemma. The instability of a slope cannot be determined with any certainty until additional conclusive data resolves the conflict between the forecast and the explosives results. The potential for “post control avalanches” in this scenario is a significant problem that to date has not been solved.

Occasional loss of life and property damage have occurred at mountain resorts in particular when explosives fail to trigger stubborn but still unstable slopes, and the terrain is then assumed to be safe and is opened to public access. We argue that the evidence associated with deaths from “post control avalanches” stands as categorical proof of the frailty of drawing conclusions about slope safety from negative explosives results (i.e., no avalanche triggered).

By re-examining the assumptions and procedures that precede the “post control avalanche”, this paper aims to shed light on the phenomenon that is perpetuating a suboptimal industry practice.

2. TRADITIONAL AVALANCHE HAZARD FORECASTING AND MITIGATION PRACTICES

An essential element in any mitigation effort is the avalanche hazard forecast (McClung et al., 2006). Using timely information gathered from the snowpack layering, the known terrain, and weather trends, “avalanche forecasters” exercise their best judgment in interpreting this data. Often grappling with conflicting indicators from these three sources, forecasters try to accurately predict the potential for large, deadly avalanches. However, forecasts that predict the potential for significant avalanche activity are rarely issued with complete certainty.

It is commonly accepted in both the literature and field practice that a “forecast” is only an estimate of the probability that avalanches will occur. Subsequently it is most common to then deploy teams of trained and experienced field technicians to previously identified avalanche starting-zones. Their mission is first to try to verify the accuracy of the avalanche hazard forecast by using explosives to attempt to trigger avalanches (McClung et al., 2006).

If an avalanche is triggered on a particular path, the results are conclusive and the forecast of high avalanche hazard is confirmed for that slope. As a consequence, the emphasis of explosives use turns towards triggering as many avalanches as possible on slopes predicted to have similar avalanche potential. Once a path has produced an avalanche, it can be assumed with a high degree of certainty that the slope is safe. That is, of course, unless an additional threat comes from an adjoining slope. In contrast, drawing meaningful conclusions about slope stability from the failure of explosives to trigger avalanches can be extremely problematic. In theory, the explosives, themselves, may create isolated weak zones (McClung et al., 2006).

In the absence of conclusive data (i.e., an avalanche) the hypothesis of high snowpack instability remains unproven when explosives fail to yield expected avalanche activity. The institutional memory of the avalanche professional and his or her feelings about the situation based on experience are additional factors that often enter into estimating the extent of any residual instability in the snowpack. However, memory and feelings are inherently unreliable and clearly do not resolve this question with a high degree of certainty.

Snow pit observations in starting zones of stubborn avalanche paths may yield a more objective assessment of snowpack layering and weak shear planes. The risk and time factors often render this measure undesirable from an operational standpoint. Finding a representative spot in which to dig and the relative experience of the person making the observations also may be problematic.

Therefore, any conclusions about stability or instability drawn from negative explosives results or the other factors described above cannot be considered persuasive. As can be inferred from the following cases, such conclusions are frequently based on these unreliable factors, with the ensuing consequences.

3. FAILURE OF TRADITIONAL PRACTICES: THE “POST CONTROL AVALANCHE” PHENOMENON

The “post control avalanche” phenomenon refers to avalanches that are triggered by either natural or human activity soon after explosives have failed in the course of so-called “avalanche control” operations. In such cases, the subject slopes were declared stable and public access was granted after explosive failed to trigger expected avalanches. Arguably the most famous of these occurred in 1982 at the Alpine Meadows Ski Area in California where seven people were killed including the legendary mountain manager at the time, Bernie Kingery (Penniman, 1987). In that case the slopes of the resort remained closed, but human activity in the base area and parking lot that were no less threatened by avalanches continued after artillery fire yielded no significant, observable results. The following are three additional examples of which the first author has detailed knowledge obtained from personal experience, site investigations and/or litigation documents:

Alpine Meadows Ski Area

A prior event in 1976 occurred one morning after a large storm at Alpine Meadows (Williams et al., 1985?). A full compliment of one-kilogram hand-charges was deployed in Beaver Bowl by experienced patrollers in the course of avalanche control operations. No avalanches were released on the steep slopes of the Bowl despite the forecast for “high avalanche hazard”. The highly experienced route leader who had skied down through the Bowl after all of his hand charges were thrown expressed his extreme fear at having done so to the Patrol Director. He proclaimed that he had no idea why explosives had failed to trigger the expected avalanches, but that Beaver Bowl should remain closed to the public until the cause could be determined. Despite this wise advice and the concurrence of the Patrol Director, the slopes of Beaver Bowl were proclaimed “safe” and subsequently ordered opened to the public by the resort Manager. His justification was that explosives had been deployed at all the appropriate shot points, including a few extra, with no results. The slopes of Beaver Bowl, the Manager concluded, must be stable. The consequences of this decision were deadly. Soon after it was opened to the public it was reported that several skiers entered and exited Beaver Bowl with no apparent hint of what was to come. Several more skiers entered and triggered a very large “post control avalanche” with crown depths of nearly two meters that buried and killed three and partially buried others.

Canyons Mountain Resort

In December of 2007 at the Canyons Mountain Resort in Utah, an avalanche hazard forecast of “high” was issued because continuing heavy snowfall overlying a persistent weak layer buried deep in the snowpack. Near the end of the storm a deep-slab avalanche was triggered with explosives on a familiar avalanche path high on the mountain. It was observed to release down onto the known weak layer. As a result of this large avalanche, an adjacent avalanche path with similar terrain characteristics that had not yet released was blasted with explosives at normal shot points along with some additional ones using some creative placement techniques. The results were negative, and a patroller skied the slope immediately after with the confidence that the snowpack was stable. The next morning that slope was opened to the public. Several customers triggered and were caught in a deep slab “post control avalanche” that completely buried one child who survived. Another skier- a patroller from a neighboring resort- was swept into a tree and died of severe trauma.

Jackson Hole Mountain Resort

More recently, late in December of 2008 at the Jackson Hole Mountain Resort a high avalanche hazard forecast had been issued for several days in a row for the popular Toilet Bowl area because of heavy snowfall and wind and a deeply buried weak layer that persisted from earlier in the season. Avalanche mitigation activities with hand charges that included most of the standard explosives shot points for the Toilet Bowl avalanche slopes were conducted with negative results. The area remained closed during the storm. As the storm subsided, once again hand charges were deployed but again yielded minimal avalanche activity. The area was subsequently declared open to the public. According to a statement later given by the person who authorized the opening, he had opened the Toilet Bowl area having felt significant pressure from the resort Manager to do so; similar to the Alpine Meadows scenario in 1976. Subsequently, a young man attempting to retrieve his ski after he fell in deep powder triggered a large avalanche below a cliff band in the Toilet Bowl. He was buried in nearly three meters of debris as a patroller standing nearby watched. Rescue attempts were immediate but unsuccessful.

4. THE NULL HYPOTHESIS AND THE TYPE I ERROR

The null hypothesis represents a theory that has been put forward, either because it is believed to be true or because it is to be used as a basis for argument, but has not been proven (Easton et al., 1997). In the case of expected avalanche activity, the common null hypothesis is that the snowpack must be unstable. Because the snowpack did not fail with explosives, the typical conclusion drawn from that observation is that there is sufficient evidence to reject the null hypothesis, and hence the assumption that the snowpack is unstable must be false. The danger of such an approach in this case is the so-called “type I error”. That is, a situation in which the null hypothesis is rejected when in fact it is true (Easton et al., 1997).

When dominant indicators support an avalanche hazard forecast of “high” and explosives yield negative results, a type I error occurs when it is concluded that the slope is stable when in reality it is not. The existence of “post control avalanche” phenomenon proves conclusively that this error is made in such cases. We submit that part of the root cause for this error may be found in the very terminology used in common communications among avalanche professionals and misinterpretations of and possible misnomers within popular avalanche literature.

5. COGNITIVE DISSONANCE, PUBLIC SAFETY DECISIONS AND THE IMPORTANCE OF COMMUNICATION

The best interests of public safety depend on accurate communication to the appropriate decision-makers of the inherent uncertainty of the snowpack in light of negative explosives results. At mountain resorts after large storms, decisions must be made to open or leave closed to the public popular skiing and snowboarding terrain threatened by avalanches. When ticket sales are perceived to be at risk and customers are clamoring for access to their favorite powder slopes, cognitive dissonance creeps into the decision-making process.

Cognitive dissonance is the mental stress experienced by an individual who is confronted by new information that conflicts with existing ideas (Festinger, 1957). With institutional and commercial avalanche forecasting and mitigation decisions it is reflected in the tendency to believe the seemingly convenient, but false notion that negative explosive results are a valid indicator of slope stability despite a high hazard forecast (the type I error). This is what happened at Alpine Meadows in 1976, at Jackson Hole Resort in 2012, and elsewhere when communication with the ultimate decision-makers did not convincingly convey the uncertainty inherent in the failure of explosives to trigger expected avalanches. Avalanche terrain was opened to the public prematurely with tragic results. The importance to life and property of understanding the uncertainty of negative explosives results when high avalanche potential is forecast, and then communicating precise information to decision-makers in such circumstances is vital.

In recent years the use of vague and inaccurate terminology has become prevalent. McClung and Schaerer (2006) in the Avalanche Handbook, clearly explain that explosives can only be used to determine “instability” in the snowpack. They also emphasize that only the results from explosives that trigger avalanches can be considered conclusive. Stated another way, results from explosives that do *not* trigger avalanches *cannot* be considered conclusive. Despite this clear instruction, the term, “stability test”, is commonly used by many avalanche professionals when referring to the use of explosives when, in fact, they are using them primarily when trying to confirm the hypothesis that the snowpack is “unstable”. The difference in the pronunciation of the words, “stable” and “unstable” is subtle, but they have exactly opposite meanings and represent entirely opposite concepts.

The term “stability” implicitly leads to the construction of the null hypothesis to be tested: that the snowpack is stable, and will remain that way until proven otherwise. In contrast, the term “instability” leads to the construction of a different null hypothesis: that the snowpack is unstable, and will remain that way until proven otherwise. Starting with an instability null hypothesis as opposed to a stability null hypothesis leads to a very different approach to the phenomenon. In using the incorrect term, “stability test”, a potential layer of additional miscommunication is promoted among those who do not understand that the explosives are being used to try to confirm “instability.

We argue that it is not acceptable to use explosives to determine “stability”. The message this term conveys is erroneous and misleading.

Furthermore, the use of the word “test” in the literature and common parlance may be misinterpreted. According to Webster’ New World Dictionary College Edition (1966), the definition of a “test” is “an examination or trial, as to prove the value or ascertain the nature of something.” Dictionary.com defines a test as “the means by which the presence, quality, or genuineness of anything is determined.”

McClung and Schaerer (2006) and others describe various “stability tests” that can be performed in snow pits. However, by definition none of these procedures can be considered either a “test” or an objective measure of snow “stability” in the pit or of the overall snowpack. At best these procedures reveal only subjective suggestions of shear strength and/or quality at the location of the snow pit. Arguably the reliability of the observations varies with the skill and experience of the observer as well. Use of the questionable label, “stability test”, has migrated into common avalanche forecasting and mitigation parlance, and it gives an erroneous connotation to these procedures as a result.

With a hazard forecast of “high”, “post control avalanches” prove that explosives only reveal the “nature” of the snowpack to the observer when avalanches are triggered. A negative result in this case does not reveal the true “nature” of the snowpack nor the “genuineness” of the negative result. As proven by the existence of “post control avalanches”, when explosives fail to trigger predicted avalanches no conclusions can be drawn as to the “stability” or “instability” of the snowpack. The same is also true of snow pit “stability test” results. The use of the explosives or snow pit procedures, therefore, cannot be considered “tests” by definition. It is misleading and inaccurate to use either “stability test” or “instability test” to refer to any use of explosives or snow pit procedures when--in the best case--such instability is indicated only if an avalanche is triggered.

6. THE CASE FOR EXPLOSIVES AS A TOOL

One might well ask, “As professional avalanche forecasters and field technicians, what difference does it make what words we use? We know what we’re talking about amongst ourselves, so who cares? Why change words that are working for us?” The fact is avalanche professionals must communicate not only with each other, but also with fellow workers and managers who may know little or nothing about snow and avalanches.

Using precise terminology to convey facts and concepts that appear obvious to the trained eye may seem superfluous to the expert. But the message conveyed to a resort manager whose primary concern may be the business bottom line must be carefully considered. When he or she is told incorrectly that “stability tests” using explosives were completed and that no avalanche activity was observed, the as yet unproven concept that is conveyed despite the facts and what may be intended is that “the slopes are safe”. Likewise when training inexperienced people to understand the complex nature of snow and to undertake safe and effective avalanche hazard mitigation missions with explosives, the words they hear and use must also convey an accurate message. Effective avalanche hazard mitigation efforts and the safety of the field technicians and the public depend on clear and accurate communication. The validity of this concept is self-evident. The use of the word, “stability” in this context is clearly misleading.

Furthermore, we submit that an appropriate term to use in place of the word, “test”, is the word, “tool”. Merriam-Webster defines a “tool” as simply a “device that aids in accomplishing a task”. To illustrate the concept of using the word “tool” instead of “test” when describing avalanche hazard mitigation using explosives, consider a familiar tool; the common wood saw.

A saw that is designed to cut wood succeeds perfectly at accomplishing that task. If the same saw were used on a piece of steel, however, the attempt would fail. In other words the results of attempts to cut the steel with a wood saw would be negative. The fact that the wood saw did not cut the steel does not mean that the steel could not be cut with a different tool, or that the wood saw would not be effective if the steel were heated to a different consistency. It simply means that the wood saw is not an effective tool for cutting the steel in its present state.

Likewise, when explosives are used to attempt to trigger predicted avalanches, the failure of the explosives to trigger the snowpack does not lead logically to the conclusion that the snowpack cannot be triggered with something else; a skier for example. Failure simply means that the explosives used were not the correct tool to trigger that snowpack in that location, at that time, and/or with the amount of explosives used; just as the wood saw was not the correct tool to cut the steel.

7. DISCUSSION

Responsibility for the safety of people and property threatened by snow avalanches in an institutional or commercial setting falls onto the shoulders of professional avalanche forecasters and mitigation technicians. It is clear that a dependable "test" to determine snow instability when avalanches are forecast does not exist. When explosives fall short of producing a definitive conclusion (i.e., an avalanche), even institutional knowledge and experience do not yield data dependable enough to support a conclusion that the slope is safe.

With the current state of technology the snowpack remains an enigma. Recognizing this fact and communicating it accurately to decision-makers is arguably the most important and difficult task of the avalanche forecaster and mitigation technician.

A well-known and consistently taught precept in backcountry education holds that in making sound route selection decisions one must accurately differentiate between facts and assumptions; between wants and needs (Fredson et al., 2006). As it is for the backcountry decision-maker, so it is for the avalanche forecaster and mitigation technician in making sound decisions in institutional or commercial settings. It is not enough to want to open avalanche terrain to the public. When the hazard forecast is "high", the "post control avalanche" phenomenon proves that it is folly to assume the slope is safe because explosives did not release an avalanche. Forecasters and technicians must consider the fact that negative explosives results are inconclusive in these cases. They must ultimately resign themselves to the fact that sometimes when considering snowpack instability, available tools and indicators may not provide a high degree of certainty. This must be effectively and clearly communicated to those who need to understand the inherent uncertainty of the mountain snowpack and the limits of current technology.

Communicating accurately and completely with institutional or commercial decisions-makers who are unfamiliar with the nature of the mountain snowpack can be intimidating to say the least. They often want a "yes" or "no" answer to seemingly simple but clearly complex questions such as, "Is the snow stable?" and "Can we open the slopes to the public?" Of course, the ideal answer to both questions would be "yes". However, ego and/or the fear of losing the confidence of one's superior can cause anxiety and disquiet when giving an inconclusive, but technically accurate answer. Giving answers such as "I just don't know" and "I recommend the slope remain closed" can be very uncomfortable for obvious reasons. Using accurate terminology to convey what is and is not known, however, provides an objective assessment and a clear accounting of the nature of the snowpack--and reality. This practice can relieve the forecaster or technician of feeling the need to take personal responsibility for what is, in fact, beyond anyone's knowledge. Having no data to disprove the null hypothesis that the snowpack is unstable, the only safe decision is to isolate the questionable area from public access.

8. CONCLUSION

When considering proper decisions with respect to snowpack instability and avalanche potential, we submit that basing decisions on "facts" and "needs" rather than "assumptions" or "desires", considering residual "instability" rather than "stability" when interpreting negative explosives results, and referring to the use of explosives as a "tool" rather than a "test" can make great strides in lending clarity and accuracy when communicating with institutional and commercial decision-makers. We believe that in so doing, the credibility of vital decisions resulting from avalanche forecasting and mitigation procedures can be vastly improved. Using accurate terminology to communicate the uncertainty associated with interpreting negative results from explosives used to attempt to trigger avalanches when a high hazard is forecast is vital to an effective and robust decision-making process that considers the safety of all concerned.

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