the avalanche journal

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THE VOICE OF **CANADA'S** PROFESSIONAL AVALANCHE COMMUNITY

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Working **Together**

Karilyn Kempton
Managing Editor

THIS IS MY TENTH ISSUE at the helm of *The Avalanche Journal.* Thanks to all of our readers, contributors, photogaphers and my colleagues and peers. Every issue we're so impressed with the quality of articles and photos submitted, and all because you believe in sharing your experience or research. I look forward to spending time with many of you at ISSW in Banff, and meeting new folks. If you're picking up the magazine for the first time, welcome! I encourage you to learn more about the Canadian Avalanche Association by visiting avalnacheassociation.ca. Become a member, take an Industry Training Program course, or find out how InfoEx, our professional data exchange platform, will work for you.

Thanks again to Larry Stanier for putting together a super feature on cornice avalanches, including case studies from resorts, heli operations and private guides, as well as some excellent photos and an interesting research piece. Many of the cornice case studies touch on how you just can't trust them, reminding us to not get complacent. Life's full of surprises, but that encourages us to constantly evaluate and re-evaluate our decisions.

The theme of the winter issue is planning ahead. How do you plan for uncertainty? How do you manage risk to avoid unnecessary surprises? What sort of planning does your team, company or organization do? How far in advance do you plan? Who is responsible? Send your submissions to kkempton@avalancheassociation.ca.

Temperatures are dropping here in Revelstoke, and it's time to get our heads back in the game. I hope everyone had a wonderful summer and feel recharged for another winter. Let's cross our fingers for a deep and stable snowpack.

Karilyn Kempton

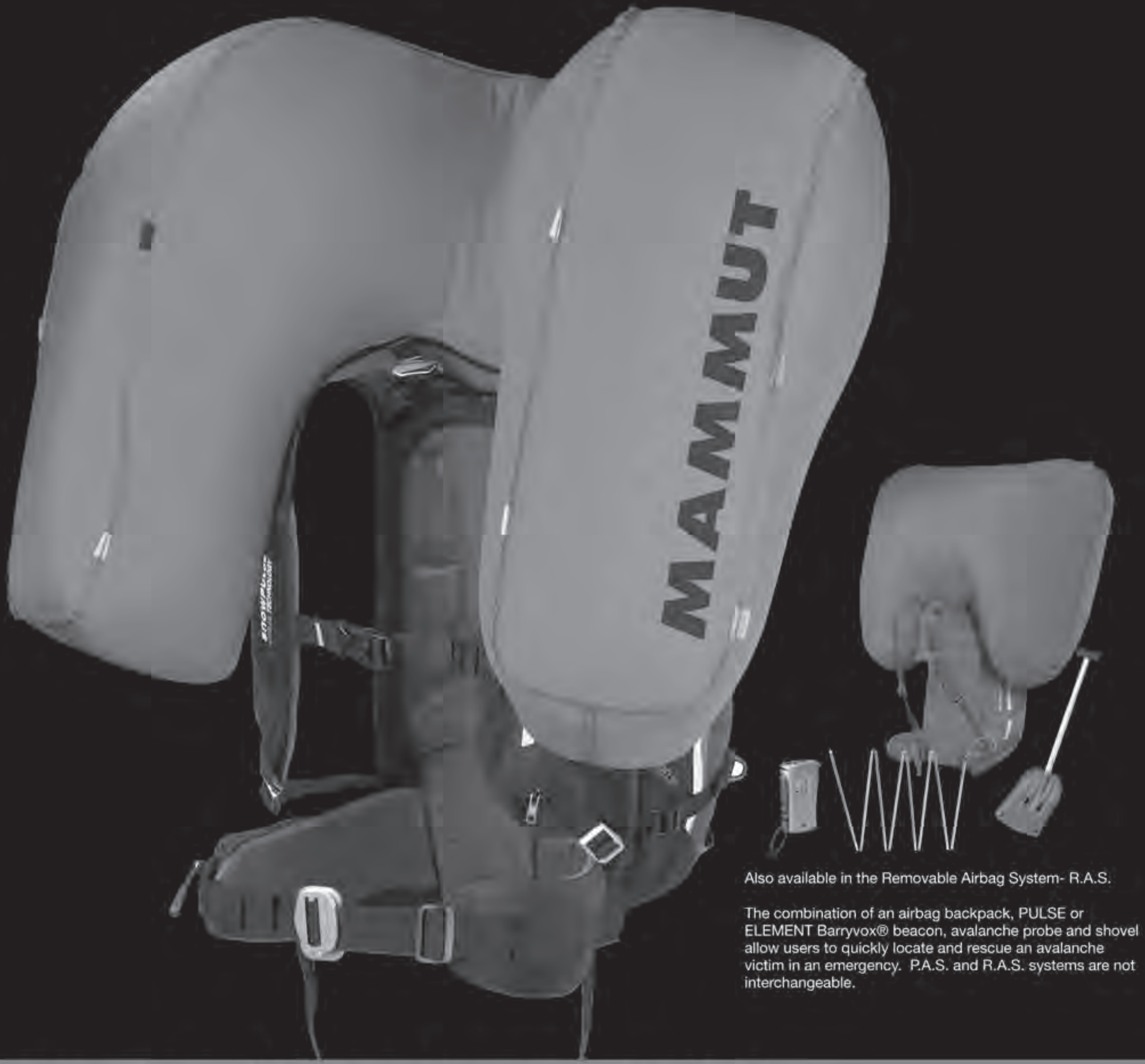
The **Avalanche Journal** wants you!

WE'RE ACCEPTING submissions for upcoming issues of *The Avalanche Journal*. We welcome articles relating to the professional avalanche industry or public avalanche safety, teaching tips, research papers, avalanche accounts, book reviews, historical avalanches, gear reviews, hot routes, global updates, event listings, interviews, letters to the editor, humorous stories, and anything else relevant to those involved with avalanches. We are also seeking winter mountain photography: avalanches, terrain, touring, skiing, snowboarding or sledding.

Please email Managing Editor Karilyn Kempton at kkempton@avalancheassociation.ca with your ideas and submissions.

The Avalanche Journal is published three times per year in April, September and December.

UPCOMING DEADLINES:
July 1 (fall issue)
October 15 (winter issue)
February 15 (spring issue)


MAMMUT

Contributors

GRANT HELGESON

Grant Helgeson is a Revelstoke-based avalanche professional who makes good decisions 99% of the time. If he's not at work or playing in the hills, he's probably lusting after carbon skis, bikes or fly rods.

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MARKUS ECKERSTORFER

Markus "Max" Eckerstorfer grew up skiing and mountaineering in Austria, and now lives in Tromsø, Norway with his girlfriend and baby-to-be. After a winter at the Tyrolean Avalanche Warning Service, he moved to Svalbard in the Norwegian High Arctic to take a Ph.D on the snow and avalanche climate of central Svalbard. He works on satellite borne radar remote sensing for avalanche detection in Tromsø.

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Robert Hemming has worked in avalanche risk management for the mining and ski industry and for highway operations in Canada since 1985. He is currently an Avalanche Operations Officer for the Avalanche Control Section in Mount Revelstoke and Glacier National Park.

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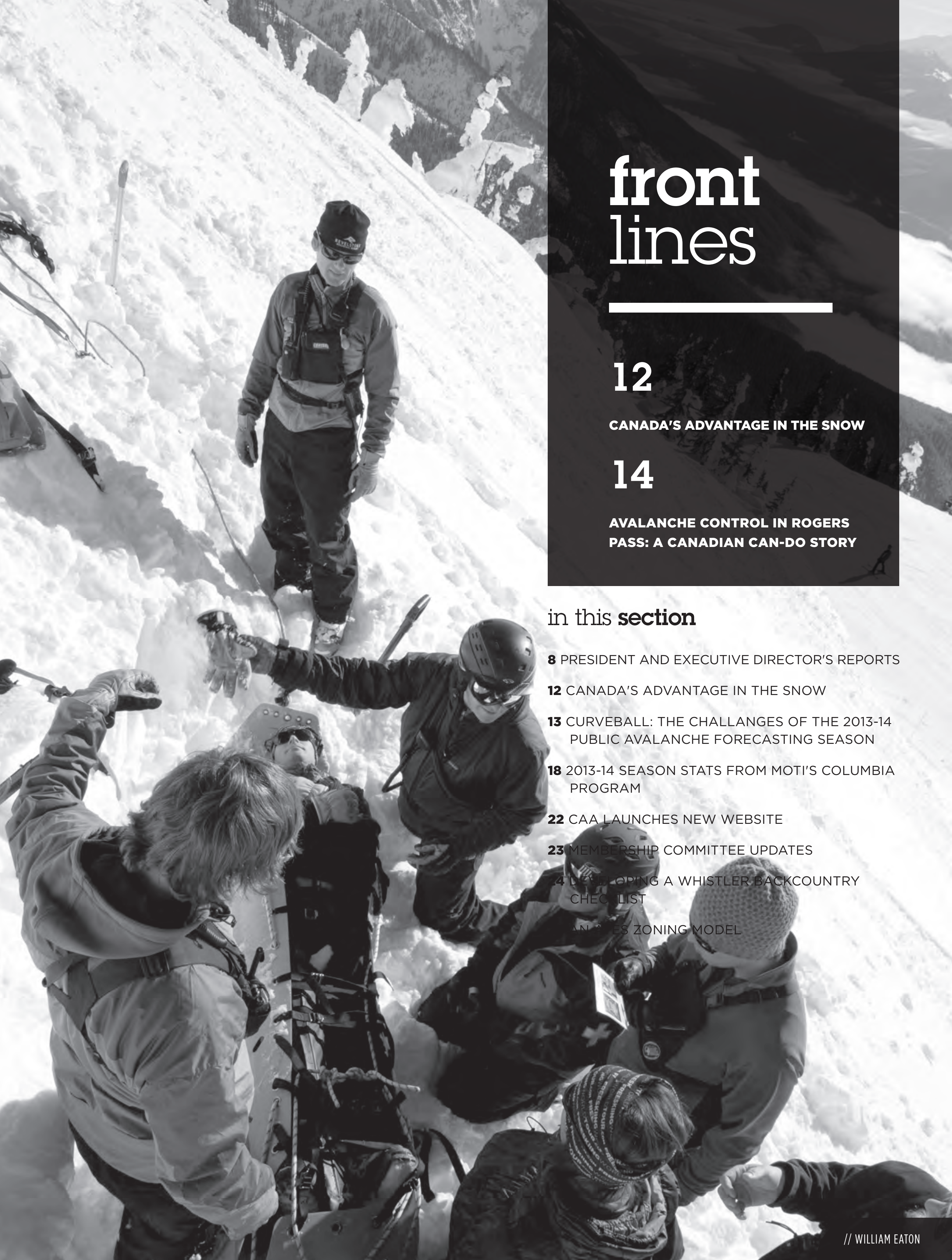

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in this **section**

// WILLIAM EATON

CAA President's Message

A REGULATORY FRAMEWORK FOR AVALANCHE PROFESSIONALS PART ONE: THE FOUNDATION COMPONENTS

This is the first in a three-part series. Watch for the next in Volume 108: Winter 2014-15.

Editor's Note: Aaron Beardmore is the CAA President, elected in May. As Co-Chair of the CAA's Ethics and Standards Committee (formerly the Professional Practices Committee), Aaron is using his President's Message section to update members on the regulatory framework for avalanche professionals.

Aaron Beardmore
CAA President

INTRODUCTION

At the 2014 AGM, the CAA took a major step towards our long-term objective of establishing ourselves as self-regulated professionals acting in the public interest. Self-regulation will enable our profession to enter into a social contract with the public that ensures our practice[1] is safe, effective and ethical. Together, we voted to adopt a code of ethics and supporting bylaws that underpin the values and professionalism of our association. Additionally, the new code and bylaws demonstrate that we are ready to enforce rules of behaviour within our professional community and advance towards self-regulation.

In this three-part article, I will summarize the critical steps to achieving professional self-regulation. During his keynote address at the 2013 AGM, the CAA's legal counsel George Bryce explained why completing these steps would result in a comprehensive framework for regulating our profession.

The CAA is developing a regulatory framework with nine components. This series of articles will help members understand how the different components are integrated, and diagrams will illustrate how the components relate to and support each other. These nine major regulatory components come together in the final diagram, showing how the framework evolves.

Understanding the regulatory framework starts with a discussion of the scope of practice, because this statement sets the foundation for what our profession does.

COMPONENT 1: SCOPE OF PRACTICE STATEMENT

A scope of practice statement is a concise statement that explains a profession's activities and areas of practice. A good scope statement should use broad, inclusive wording to describe in general terms what a profession does and how it does it. A scope statement should *not* try to be an exhaustive list of every service or function the profession provides or performs.

Recently, the Ethics and Standards Committee (formerly ProCom) produced the following scope statement, approved by the CAA Board of Directors:

> ***"Snow avalanche risk assessment and management"*** *means the profession in which a person (a) develops, directs and participates in the assessment of snow avalanche risk, (b) communicates information regarding avalanche risks, and (c) designs and operates programs for managing avalanche risk.*

A profession's scope of practice may overlap with the scopes of other professions; ours is no exception. For example, engineers, mountain guides or foresters may also provide some of the same services described in our scope of practice.

While two or more professions may have a number of common or overlapping aspects to their professional practice, only those aspects of practice that constitute a serious *risk of harm* to the public should be restricted (risks of harm are described next).

As the CAA works on the other components of the regulatory framework in the coming months, these developments may require revisions to the recently approved scope-of-practice statement. This is a normal part of the process, due to the dynamic nature of the framework itself. Indeed, a change to one component of the regulatory framework can have a ripple effect through the rest of the integrated framework.

COMPONENT 2: RISKS OF HARM

The primary reason to regulate a profession is to protect the public from the risks associated with a highly complex, specialized and expert practice. The higher the risk and more significant the harm, the more compelling the need is to regulate that profession. For some professions, like medical doctors, this leads to self-regulation. For others, like airline pilots, this is handled by government licensing.

Risks come in many forms or arise in different circumstances, but a risk-of-harm analysis focuses on identifying situations where, if a non-professional tried to perform

[1]Practice is what workers do in the workplace.

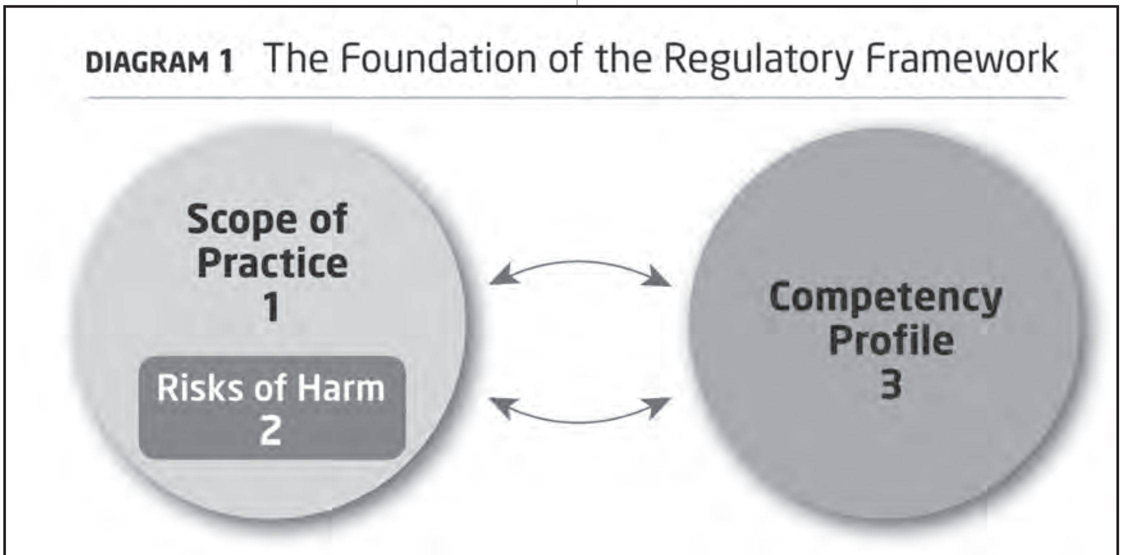


FIG.1

an activity or service, the outcome would likely result in harm to others. Risks of harm generally arise in four situations:

a) Due to incompetence, lack of training, or failure to meet a commonly accepted standard;
b) Due to poor business practices, such as poor record keeping;
c) Due to breaches of privacy, etc.;
d) Due to failure to follow ethical standards, such as conflicts of interest.

A risk analysis is necessary to make informed regulatory decisions. Analyzing the risks tied to performing professional activities identifies "restricted activities," as they are known in the health care sector."[2] Fig. 1 illustrates that risks of harm (component 2) fall within the scope of practice statement (component 1).

A risk-of-harm analysis identifies areas of practice that may need to be restricted, meaning that only members of the identified profession are allowed to perform them. It is also possible that members of other professions with the same competencies may be able to perform the same high-risk (restricted) activities. Thus, not only can the scope of practice of two or more professions overlap, but they may also share one or more restricted activities that fall within their respective scopes of practice.

Professions may have fairly broad scopes of practice—possibly even overlapping with other professions—while defining their restricted activities more narrowly, supporting inter-professional and multidisciplinary practice. It also increases consumer choice while maintaining public safety.

As part of the CAA's work on regulatory framework, our Ethics and Standards Committee is already considering how to undertake a risk-of-harm analysis for our profession. Details on this important initiative will be provided to the membership as work on this component continues.

COMPONENT 3: COMPETENCY PROFILE

Nearly all regulated professions develop a competency profile. Practice involves applying knowledge and skills in the workplace to perform *tasks*. Therefore, in order to regulate practice it is primarily necessary to identify the tasks that are to be performed and how well those tasks are to be carried out. You cannot regulate what people know, think or believe, only what they do and the tasks they perform. A competency profile will help us regulate these tasks.

These abilities are sometimes called "entry-to-practice competencies." A competency profile identifies the common ground of knowledge that exists within the profession. A competency profile can be made up of dozens, if not hundreds, of separate competency requirements, classified under topical headings.

As EdCom reported to the membership at the 2014 AGM, the CAA has started the process to develop the Avalanche Body of Knowledge (AvBoK): the core knowledge base of our profession. We plan to build on this work by creating a related competency profile.

A competency profile reflects the broad scope of practice (component 1) and, in particular, any aspects of practice where there are identified risks of harm (component 2). Thus, as shown in Fig. 1, there is a direct link between these components, and the link can be a two-way relationship.

[2]This is the term used within BC's regulated health professions to identify those aspects of health care practice that constitute a high risk to the public if they are not performed by persons with the appropriate competencies.

Often the development of one will influence the development of the other.

When completed, the competency profile will be the foundation from which entry-to-practice requirements can be developed (component 4). The competency profile can also be used to develop the standards of practice (component 5). Details on these components of the framework are discussed in the upcoming second part of this article.

In the months to come, the membership will be asked to participate in developing a comprehensive competency profile for our profession. Stay tuned for further notice.

SUMMARY

The development of any profession's regulatory framework is fluid. There is no mandatory program, and identifying how best to go about it is a dynamic process.

In the first piece of this three-part article, we described the foundation components of a comprehensive regulatory framework. The diagram illustrates the relationship between these three components, and, as this diagram evolves over the next two parts of the series, the relationship between these components and the remaining six will be more apparent.

Aaron Beardmore, CAA President

CAA Service Award

EACH YEAR, THE CAA IS PROUD TO AWARD the CAA Service Award to honour hard work and commitment to the professional avalanche industry. Please join us in congratulating 2014 winner Dominic Boucher.

Dominic was instrumental in the creation of the Centre d'avalanche de la Haute Gaspésie in Quebec, and has served as its general manager since 2001. Since 2007, he has been bringing CAA ITP courses to Quebec.

FROM LEFT: ZUZANA DRIEDIGER, ROBB ANDERSEN, ROCKET MILLER, DOMINIC BOUCHER, AARON BEARDMORE, DAVE DORNIAN, JOE OBAD AND JOHN MARTLAND

Joe Obad
CAA Executive Director

CAA Executive Director's Report

WELCOME TO CANADA!

THERE'S A GOOD CHANCE THAT if you're reading this you're one of the hundreds of delegates to the 2014 International Snow Science Workshop in Banff. The CAA thanks the organizers for their tireless efforts that started shortly after being awarded this ISSW a few years ago.

This issue of *The Avalanche Journal* was written with many of our international friends in mind. You might get as many answers about "the Canadian way" as practitioners you ask, but I think at its core the Canadian avalanche community adapts to the circumstances it faces without sitting on its laurels. We hope many of the case studies, as well as Chris Stethem's piece, explore Canada's adaptation to its challenges in ways as interesting to long-time members as visitors to Banff.

Whether in Norway or New Denver, the avalanche profession's summers are increasingly crowded with planning and raising the bar for the coming winter. It's not just ISSW organizers who have been busy. Staff, committees, the board and many other members of the CAA have been plugging away at challenges over the summer. This is a good problem to have!

At the spring meetings in Penticton, the board set the bar high for itself, and the membership endorsed its path towards further defining the professional self-regulation of the CAA. President Aaron Beardmore's piece on the previous pages articulates the proposed framework for self-regulation. We welcome questions and discussion from members and the international community in Banff.

The horsepower to support many of the changes President Beardmore outlined at the AGM are significant in both human and financial terms. Thankfully, on the human resource side CAA members have answered the call. Rupert Wedgwood and Rod Gee have stepped up to lead the revised Complaint Investigation and Discipline Committees, respectively, along with a host of new members. If you see these members at ISSW or elsewhere thank them for stepping up for your association. From attending training to rewriting terms of reference and procedures to ensuring they are aligning committee practice with CAA bylaws, they have taken on and achieved a lot in the last several months.

Of course, moving ahead also requires fiscal resources. A couple of years ago, the board and staff were challenged to balance the CAA books with a new full-time ED and costs related to separating the Canadian Avalanche Centre. During this period, the CAA was able to grow its reserves by carefully managing costs. Because of that prudence, we are now well positioned to make investments to achieve the regulatory framework laid out in this issue. For this I thank members for their patience, as much as the budget hawks on board and staff I am fortunate to work with.

We have also invested in ramping up the quality of our Industry Training Program. ITP manager Emily Grady and the Education Committee, led by Chair Steve Conger, worked diligently to vet and integrate advanced avalanche search and rescue curriculum developed by Manuel Genswein. Under Emily's leadership, we have not just adopted new teaching materials, but have structured a path for instructor proficiency to ensure the quality of instruction student receive for years to come. Industry and other stakeholder confidence in ITP graduates should increase, as they understand the clear advanced AvSAR training that course graduates will have.

We can't forget to mention InfoEx as well. The subscriber feedback on InfoEx and the CPD session this spring made it clear that we have more steps to take on our journey together as a community. The CAA needs to be responsive to the InfoEx community, and we are working on the application to meet subscriber needs. Likewise, subscribers learned from each other at the CPD session. The CAA is working on methods to allow subscribers to work on challenges shared together in a safe, confidential web-space. We also listened to industry about the non-exchange services it would like to see on the InfoEx platform. We look forward to sharing our work on both route control and run list extensions with subscribers soon.

ISSW 2014 in Banff offers the chance to look at some of these challenges in the globally diverse contexts of professionalism, research and practice. I hope CAA members and our international friends can put aside the cares of the quickly advancing winter season briefly to engage with ISSW's provocative mix of ideas and questions. Indeed let's make "theory and practice merge!"

Joe Obad, CAA Executive Director

Canada's Advantage in the Snow

Chris Stethem

THE QUESTION was recently asked of how the tight-knit Canadian avalanche community had evolved, as opposed to—given the medium—fractured. Several factors rooted in the early days of avalanche safety help explain this success: a large geographic area of big-mountain terrain dotted with a small community of avalanche professionals, the need for neighbourly support, and, more so, the work of a man named Peter Schaerer.

Peter arrived in Canada from Switzerland in the 1950s to work as an engineer for the federal government in the Department of Public Works. His major project back then was the construction of structural avalanche defences for the Trans-Canada Highway in Rogers Pass. After a brief return to Switzerland, Peter returned to Canada in the 1960s to work for the National Research Council Canada (NRCC). With research projects in Rogers Pass and the building of avalanche defences for Canadian Pacific and Canadian National railways, BC Highways and BC Hydro, Peter's network grew. As the heli-ski and ski-area developments expanded in the late '60s and '70s, a greater number of people benefited from Peter's well-organized thinking, teaching and diplomatic approach.

At the same time, brothers Fred and Walter Schleiss employed and trained avalanche technicians at Rogers Pass. Fred and Walter's manual for observers formed the basis for the Guidelines for Weather, Snowpack and Avalanche Observations later published by the Avalanche Research Centre of the National Research Council, edited by Peter and with contributions from others in Canada and elsewhere.

By the early 1970s, avalanche schools expanded from occasional events in Rogers Pass to a joint venture between NRC and British Columbia Institute of Technology (BCIT). Peter remained at the helm, and others—including Willi Pfisterer (Parks Canada), Geoff Freer (BC Ministry of Transportation and Highways and former employee of Peter's), Norm Wilson (Alpine Meadows and Granduc), and Ron Perla (Environment Canada)—became involved in the first NRC/BCIT schools. The first and largest introductory course open to the public (about 60 students) was held at Whistler in December 1973. The unforgettable Garry Walton managed the programs for BCIT. Others, including Paul Anhorn (NRCC), Herb Bleuer (Granduc and Whistler Heli Ski), Clair Israelson, Darro Stinson and Tim Auger (all three from Parks Canada), Chris Sadleir (BC Parks), and Roger McCarthy and Chris Stethem (both from Whistler), rounded out the school teams in the 70s. Extended recognition to anybody whose name is mistakenly absent from this list.

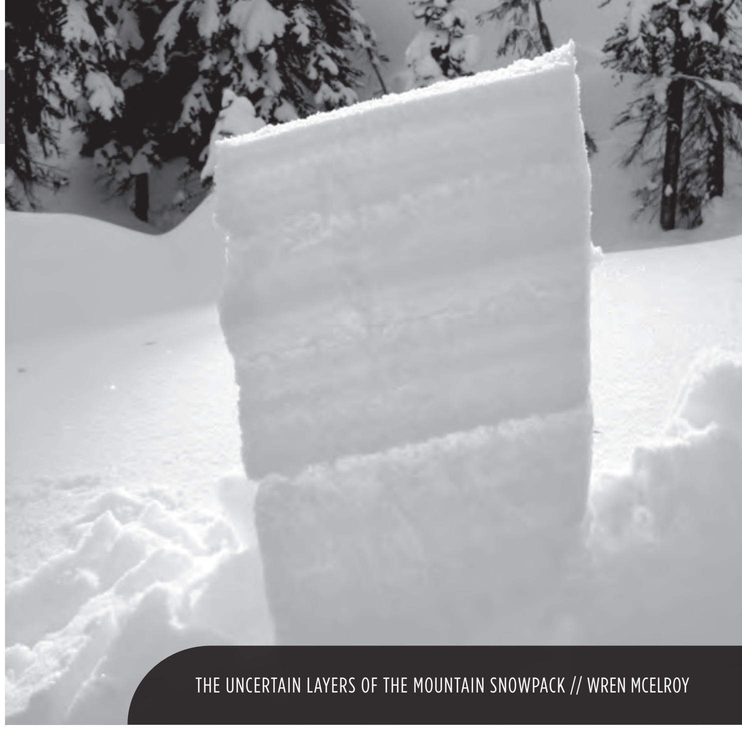
In the mid '70s, the Avalanche Committee was formed from a variety of government agencies, including Peter Schaerer, Geoff Freer (BC MoTH), Dave Pick (Parks Canada) and Ron Perla. One of the committee's goals was to create an avalanche centre, but a location could not be agreed upon given that its members and agencies were located in Vancouver, Victoria and Banff/Canmore.

Late in the '70s, Peter organized meetings for personnel from avalanche safety and control operators, with approximately 30-50 team leaders from Parks, BC Highways, heli-ski operations, ski areas, mines and researchers. These brought together people from all over Western Canada and from various public and private sector employers. Everyone shared stories, experiences and ideas, and became friends. At one of these meetings in Banff, Brian Weightman (Canadian Ski Patrol) suggested this group form an association. In 1981, the Articles of Incorporation for the Canadian Avalanche Association were filed. The rest, as they say, is history—extensive avalanche schools, the InfoEx, the Canadian Avalanche Centre, widespread co-operation with researchers, and a collegial group of avalanche professionals in Canada.

The future challenge for the CAA is to maintain its integrity in a world of increasing pressure for risk management from government, occupational health and safety regulators, employers and the public. This will be no easy task. However, with continuing professional development for CAA members and Peter Schaerer's steadfast example, the CAA will continue to be that forum for cooperation among a range of professionals engaged in and committed to avalanche safety work.

PETER SCHAERER, APRIL 1957 // REVELSTOKE MUSEUM & ARCHIVES PSA.58 GOVERNMENT OF CANADA

Curveball: The Challenges of the 2013-14 Public Avalanche Forecasting Season


THE UNCERTAIN LAYERS OF THE MOUNTAIN SNOWPACK // WREN MCELROY

Grant Helgeson

WHEN A PERSON CALLS SOMETHING an "X" year event, my ears perk up—especially when the intervals approach 50+ years. If something is a 50-year event, then in theory an avalanche professional could go his or her entire career without seeing it happen. I am not sure if last winter's complex snowpack was a 1:25 or a 1:100 year setup, but I know that it was humbling.

We all know the tale of the 2013-14 winter. A strong ridge of high pressure dominated the BC weather pattern for most of January, resulting in the formation of the drought layer. The drought layer consisted of crust, surface hoar and facets. The mix was aspect dependent, and it varied a bit from range to range, but overall was pretty consistent across the province.

As I basked in the "ride it if it's white" glory of peak bagging in January, a nagging thought lingered in the back of my mind—at some point, we were going to pay.

It was no surprise that when the snow returned in late January the drought layer produced an incredible rash of very large natural avalanches. At that point, my job as a Public Avalanche Forecaster with the Canadian Avalanche Centre (now Avalanche Canada) was pretty easy and the messaging was simple: stick to the most simple terrain you can find and don't trust anything.

By the time we got to late February it was different. The drought layer would occasionally rear its head in isolated large events, but these instances were the exception rather than the norm. The discussion on what would happen next was interesting. Some thought the layer had done its thing and would not be a player until the spring thaw. Others felt that the setup of both surface hoar and facets with a crust sprinkled in some locations was going to keep the layer relevant all season. My best guess was that it was largely done, and if it did wake up again, I expected the activity to be isolated.

It seems we all have our own availability biases. An availability bias refers to the collection of our personal experiences that we tend to weigh more heavily than those we have only heard or read about. I often like to think that a mid-season Persistent Weak Layer (PWL) typically has a lifetime of three to four weeks. It's convenient for me to compartmentalize things that way, and the majority of the time, that estimate is fairly accurate. I figured that this PWL would fit nicely into that box.

It turns out I was wrong.

In early March, the drought layer went through an entirely new wake up that resulted in another surprisingly widespread large natural avalanche cycle. This also happened a few more times during the remainder of the season. It was a good wake-up call that really drove home how persistent a compound layer of facets with surface hoar can be.

The only thing we were certain of was our own uncertainty, and that made even local forecasting very challenging. In the large-scale regional forecasts, it was difficult to convey just how unusual and volatile the mountain snowpack was without repeating the same thing each day. As a forecaster, I was cognizant of message fatigue, and I feel like my team did a great job of turning to alternative products like videos and blogs to express just how spooky the snowpack really was.

Our own availability biases steer us towards what we expect to happen with different types of PWLs, but this one was a curveball. It took my pre-conceived idea of a one-month PWL life cycle and blew it out of the water. I know I'm not the only one who was surprised by the tenacity of the late January PWL.

Going forward, I have a newfound respect for mid-season facet/surface hoar combos. I'm really hoping I don't deal with one again for a while. But the next time it comes around I know that I can be certain about only one thing: it is okay to be uncertain.

Avalanche Control in Rogers Pass: **A Canadian Can-Do Story**

Robert Hemming

THE HISTORY OF ONE OF THE MOST SUCCESSFUL AVALANCHE CONTROL OPERATIONS IN THE WORLD BEGAN IN ROGERS PASS, LOCATED WITHIN GLACIER NATIONAL PARK IN THE HEART OF BRITISH COLUMBIA'S SELKIRK MOUNTAINS. IT TOOK THE DETERMINATION, HARD WORK, COOPERATION AND INGENUITY OF GOVERNMENTS, NATIONAL ORGANISATIONS, PRIVATE CONTRACTORS AND INDIVIDUALS FROM DIVERSE NATIONALITIES AND WALKS OF LIFE TO MAKE IT HAPPEN.

CANADIAN PACIFIC

The story begins with the Canadian Pacific Railway (CP) in the 1880s. Nothing was going to stop the company from blazing a rail line across the country, not even the severe terrain and deep snow in Rogers Pass. The earliest snow and avalanche studies in Canada were conducted here when snow and avalanche observation camps were established during the winters of 1884-87. CP Engineer Granville C. Cunningham published a paper on snow slide observations relating to snowshed design and placement in a civil engineering journal in 1887.

Thirty-one snowsheds were constructed in the Rogers Pass between 1886 and 1888, covering over eight kilometers of rail bed. The sheds were costly but necessary; they were the only form of avalanche control in those days.

GOING UNDERGROUND

Although avalanches were only one of the many dangers that faced rail workers, trains and structures, they cost the company dearly. On March 4, 1910, 58 rail workers died in Rogers Pass; it stands as Canada's worst avalanche accident and contributed to the decision to go underground. In 1916, CP completed the Connaught tunnel under Mount Macdonald, thus by-passing the most severe section of avalanche terrain.

A NEW BREED

After the tunnel was built, CP continued avalanche observations along the exposed rail line on either end of the tunnel. Then, in the winter of 1948-49, Noel Gardener, a new breed of parks employee who patrolled the backcountry on skis during the winter, was stationed in Glacier National Park. Noel took note of the avalanche paths and avalanche activity during his travels.

FIRST SNOW PROFILE

In addition, in 1949 the first snowpack profile in the area was observed by Swiss avalanche expert Marcel de Quervain, who came at the invitation of the National Research Council of Canada (NRC). Quervain later became the Director of the Institute for Snow and Avalanche Research at Davos, Switzerland.

THE HIGHWAY

Snow research activity increased in 1952 when Rogers Pass was proposed as a possible route for the Trans-Canada Highway (TCH). Noel Gardner began working with James R. Webb, a civil engineer with the Engineering and Construction branch of Canadian Public Works Department, to determine the best placement for the highway. Meteorological weather stations were established on either side of the pass and regular avalanche study patrols began.

In 1956, the federal government chose Rogers Pass as the route for the TCH over the Selkirk Mountains. Snow and avalanche studies continued, with the addition of snow and weather observation stations established at upper elevations.

PETER SCHAERER

In 1957, the Canadian Public Works Department requested an engineer from the National Research Council to assist with avalanche risk reduction at Rogers Pass. Peter Schaerer was hired. He was responsible for snow avalanche observations and the design and location of avalanche defence structures. He brought with him a skill-set particularly well suited for the job. Schaerer obtained a diploma in civil engineering at the Federal Institute of Technology in Zurich, Switzerland, that included courses in snow mechanics and avalanche control taught by leading international snow scientists. After graduating in 1950, he acquired a deeper

TRACK REPAIR ON THE EAST SIDE OF SHED 11 IN THE ROGERS PASS CIRCA 1886 // CANADIAN PACIFIC ARCHIVES

knowledge of snow physics while employed as a research assistant at Switzerland's Institute for Snow and Avalanche Research. He was also an accomplished backcountry skier, making him a good fit for working with Noel Gardner and his team.

THE CANADIAN MILITARY

With the decision to build the TCH through some of the most dangerous avalanche terrain in the country, a method of active avalanche control was necessary to supplement the static defence structures (e.g., snowsheds, dykes, mounds, trigger-zone fences). The Department of National Defence (DND)—now the Canadian Armed Forces—came to Rogers Pass to test the effectiveness of artillery for controlling avalanches. Trials began March 6, 1958; however, deep snow interfered with moving the guns into position, so further testing was postponed until a plowed road grade was established.

THE FIRST TEAM

In 1959, Noel Gardner became head of Parks Canada's newly established Snow Research and Avalanche Warning Section (SRAWS). He was joined by brothers V.G. (Fred) and Walter Schleiss: Austrian mountaineers, avalanche forecasters and expert skiers. Also part of the team was mountain guide/photographer Bruno Engler, who documented avalanches and the highway construction using still photography and film. That winter, limited artillery trials continued with mortars and the 75mm Howitzer.

THE GUNS

A rough-plowed road grade was finally available in the winter of 1960-61, and DND resumed artillery trials for the highway that concluded the 105mm Howitzer was the most effective gun for avalanche control in Rogers Pass. Local observers were very impressed with these gunners, whose experience in Korea enabled them to hit precise targets high above the roadway without the benefit of target data and aiming stakes. Under Parks Canada, Glacier National Park now had an operational mobile avalanche control programme.

THE HIGHWAY OPENS

The highway was officially open for the winter of 1962-63. The new winter route provided an economic boost for western Canada and was a source of national pride. The highway was protected from avalanches by the mobile avalanche control programme along with snowsheds and other forms of static defences. The combined efforts of Parks Canada's SRAWS team and DND's artillery operation called AVCON (now Operation Palaci) formed an avalanche hazard risk reduction programme that set national standards and easily exceeded the expectations of its designers.

THE COST

The avalanche control programme, while effective, was not without risk. A great price was paid January 8, 1966 when two Parks Canada heavy equipment operators were killed by a natural release avalanche while clearing snow off a closed highway. Since then, constant improvement and innovation in highway infrastructure and operational procedures have resulted in an enviable safety record with no additional fatalities.

Research and Training
With the new highway providing easy access, Rogers Pass became a hot spot for avalanche research and training. SRAWS hosted avalanche safety courses and deep-snow ski schools for park wardens. The first course for avalanche industry professionals was held at the pass in 1969, presented by Fred Schleiss and Peter Schaerer. Avalanche courses for industry and recreationalists continue to this day in the park.

NRC scientists conducted snow research from 1966 until 1991 under the direction of Peter Schaerer. Since then, scientists from western Canadian universities and other researchers from around the world continue to conduct snow and avalanche research in the park.

THE FORECASTERS

In 1965, Fred Schleiss took charge of SRAWS. His brother Walter became second-in-command and co-forecaster. They led the SRAWS team responsible for the avalanche safety of the highway through Rogers Pass until their retirement in 1991. They were followed by Dave Skjonsberg (until 2004) and Bruce McMahon (until 2012) and finally, Jeff Goodrich (2012 to present). The avalanche safety programme is now called the Avalanche Control Section of Glacier National Park, Highways Service Centre.

Many leaders in the Canadian avalanche industry (avalanche risk consultants, mountaineers, mountain guides) have worked for the avalanche control programme at Rogers Pass at some point in their careers.

CONCLUSION

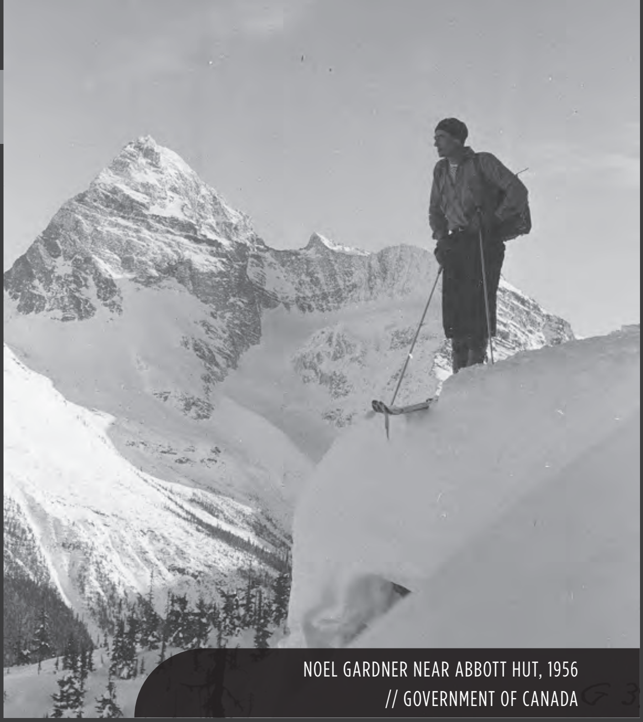
The history of avalanche control at Rogers Pass is not over. The legacy of the programme founders continues to guide those still involved, while the new generation brings fresh skills, knowledge and new techniques to meet today's and future challenges.

THE LOCATION

Rogers Pass is approximately 643km by road from Vancouver, BC, and 342km from Calgary, AB, in Glacier National Park.

THE AVALANCHE PROGRAMME

Parks Canada avalanche forecasters and technicians continuously monitor snow, weather and avalanche activity in the pass in order to determine when and where avalanche control measures are needed. When static defences such as snowsheds, mounds and dikes are insufficient measures against



NOEL GARDNER NEAR ABBOTT HUT, 1956 // GOVERNMENT OF CANADA

the avalanche threat, Parks Canada closes and secures the highway and blocks of the CP line as required, and with the support of the Canadian Armed Forces, conducts avalanche control.

ACKNOWLEDGEMENTS:

Dr. John Woods for sharing his research with Parks Canada on the early history of the avalanche control programme and for reviewing this article. The Revelstoke Museum and Archives' project "The Land of Thundering Snow" for sharing preliminary information. And finally, Parks Canada's Jacolyn Daniluck for editing.

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NATURAL RELEASE AVALANCHE DEPOSIT ON THE RAIL LINE AT THE WEST END OF GLACIER NATIONAL PARK IN THE 1930S // REVELSTOKE MUSEUM & ARCHIVES # 1242

FRED SCHLEISS AT ABBOTT HUT, 1978 // PARKS CANADA, JOHN G. WOODS

105MM HOWITZER 2013 // PARKS CANADA, ROB BUCHANAN

MOTI STAFF CHECKING CONDITIONS // CHRIS HRABB

2013-14 Season Stats from MOTI's Columbia Program

Mark Karlstrom

THE WINTER OF 2013-14 was my first working with the Ministry of Transportation and Infrastructure in a snow avalanche program. With two decades of experience, I am not new to the avalanche profession. I started my career as a professional ski patroller for four years, then made ski films in the backcountry for two years, and then worked for 14 years as a mechanized ski guide. With my previous experience, I thought I had a pretty good idea of what to expect.

I had heard about the late nights and constant monitoring of remote weather stations during storms, the huge forecast area and the reliance on remote weather stations. All respective disciplines in the avalanche industry have their challenges. We can all relate to thinking we know what something will be like, and then seeing the difference between reality and expectation upon reflection.

In the mechanized ski industry, I had worked with vast operational areas. However, I had never worked in one that spanned an area that included three mountain ranges containing everything from near coastal-like conditions in the Monashees to the facet factory of the Kicking Horse Canyon in the Rocky Mountains. We deal with every avalanche problem from storm snow instabilities to solar loading, and depth hoar to glide cracks. Another unanticipated aspect was the sheer volume of occurrences and the workload to control an area our size.

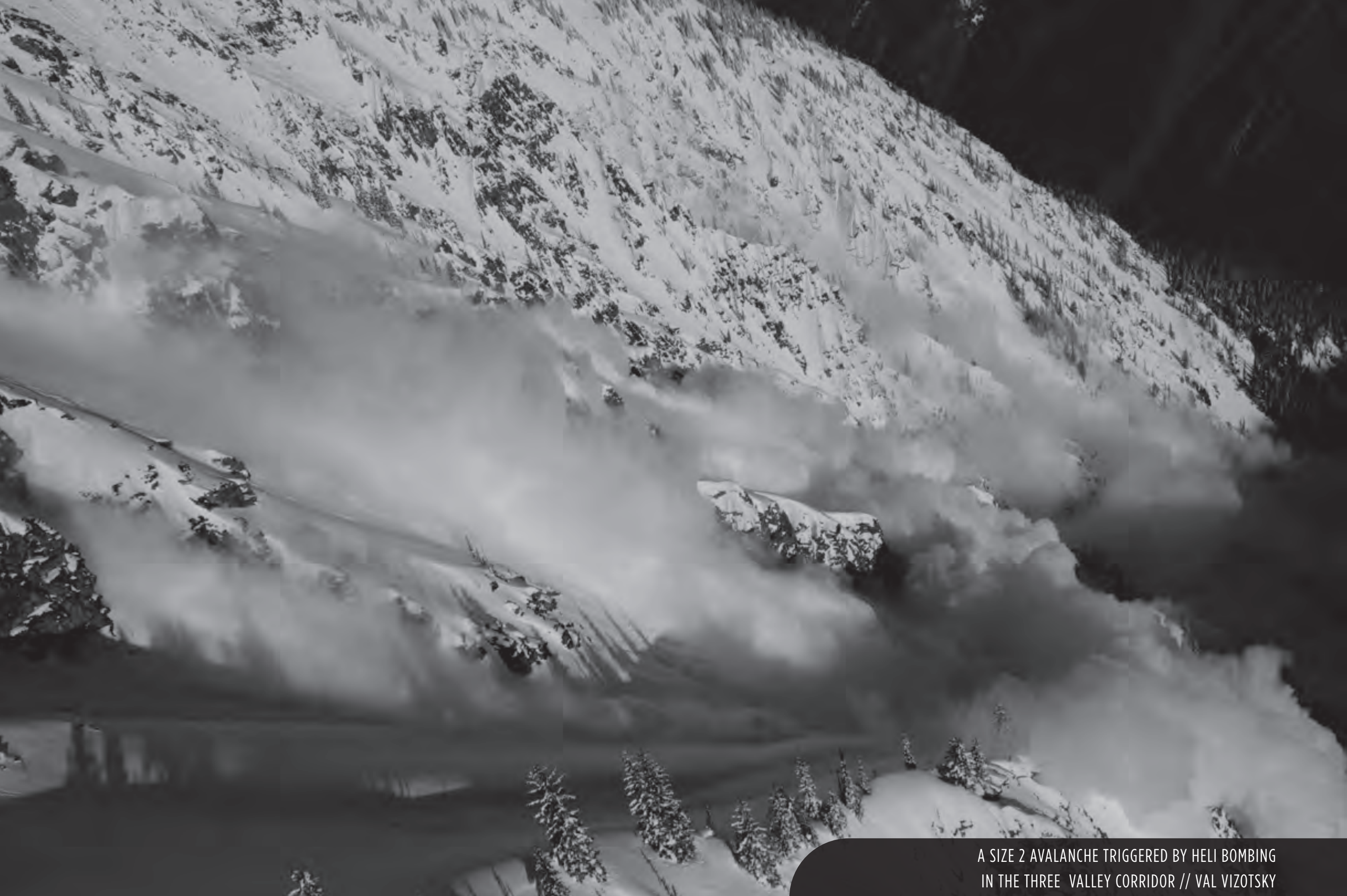
The following is some background on the Columbia Program. The program encompasses approximately 450km of highway, with 200 avalanche paths. It contains three mountain ranges: the Monashees, Selkirks and Rocky Mountains. The Columbia Program includes six different areas: the Trans-Canada Highway west of Revelstoke, the Trans-Canada Highway east of Revelstoke, Highway 23N to north of Revelstoke to Mica Creek, Highway 31 Galena Pass, the Greenslide area south of Revelstoke and the Trans-Canada Highway east of Golden.

There are three snow sheds east of Revelstoke on the Trans-Canada Highway, and three Avalanche Guard towers. We have one Daisy Bell. Forecasters typically monitor 12 remote weather stations. The longest path that affects a BC highway is Greenslide #1, with a vertical fall of 2,135m. In the winter, traffic volumes on the Trans-Canada Highway are approximately 5,000 vehicles per day.

Here are some statistics from 2013-14 that I found interesting being new to a highways program:

- The weather station with the most precipitation from November to March was Caribou Ridge, Selkirk Mountains, with 968mm (average is 811mm).
- The weather station with the least precipitation from November to March was Kicking Horse, Rocky Mountains, with 228mm (average is 245mm).
- All weather stations were cooler than average for all months from November to March, with the exception of January.
- There were 1,400 avalanche occurrences recorded.
- Of these 1,400 occurrences, 500 affected the highway. This is well above the average, which is 800 occurrences with 275 affecting the highway.
- Of these 500 occurrences, 70 were size 3 avalanches or larger.
- The Columbia avalanche team controlled 825 avalanches.
- To control these avalanches, the team helicopter deployed 668 charges for a total weight of 8,220kg of explosives, launched 34 rounds out of the Avalanche Guard system, and flew three Daisy Bell missions.
- The largest single avalanche of the season was Greenslide #1, which was a size 4.5 that ran its full 2,135m vertical fall, depositing 9m of debris on the road.

Granted, the season's higher-than-average precipitation levels combined with cooler temperatures significantly increased our workload. Knowing the program, even in an average year it is still impressive. I have to give credit to my supervisor Val Visotzky and my coworkers Greg Paltinger, Ross Campbell and Neville Bugden for the tremendous effort they put forth. I feel fortunate to have had the opportunity to work with them in such a diverse, challenging program.



A SIZE 2 AVALANCHE TRIGGERED BY HELI BOMBING
IN THE THREE VALLEY CORRIDOR // VAL VIZOTSKY

DEBRIS FROM A SIZE 4 AVALANCHE OFF MOUNT CARTIER ON THE
GREENSLIDE PATH // ROSS CAMPBELL

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THE AVALANCHE JOURNAL is the voice of Canada's professional avalanche community. Read about the issues and events affecting the professional avalanche industry in Canada. Regular features include research, industry news, avalanche team profiles, photo spreads, case studies, training tips, product and publication reviews, and updates from around the world.

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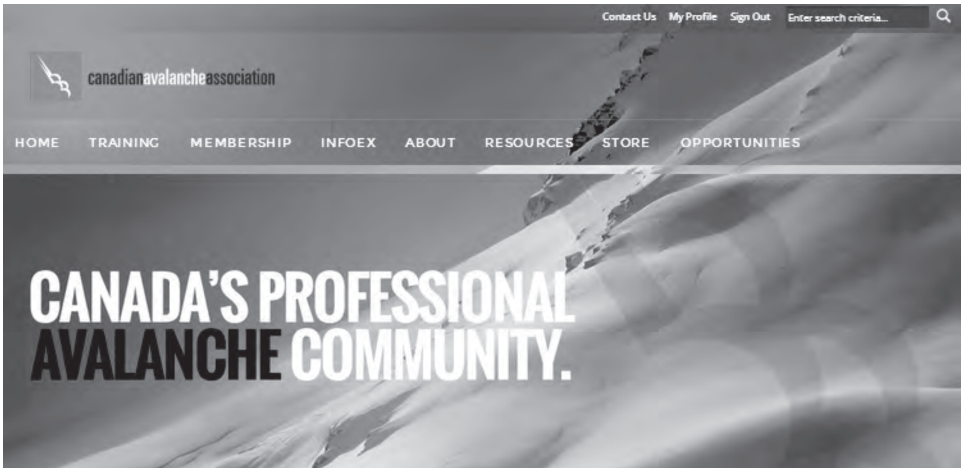
// K. HJERTAAS

CAA Launches **New Website**

Stuart Smith



IN JUNE, THE CAA LAUNCHED a new website on our new domain: avalancheassociation.ca. As well as moving on from the old seriously creaking website infrastructure, the new site helps define the CAA as a separate entity from the CAC (now Avalanche Canada) and the Canadian Avalanche Foundation (now Avalanche Canada Foundation).

Implementing the new website was a year-long project. Consideration was given to in-house development versus commercially-available software. With a wide choice of package software now available at different price levels to support the operations of membership associations, the decision was made not to "reinvent the wheel" by building our own site, with the benefit of freeing up IT resources for InfoEx work. By choosing commercially-available software, the lead time to launch could be measured in weeks rather than years, once the decision on which software to use had been made.

We had a variety of choices. As many as 100 companies offer software solutions for associations, and narrowing the field was time-consuming. I demo'ed approximately 15 systems, and after identifying a preferred supplier most of the CAA staff were involved as we evaluated in detail whether the system was a good match for our requirements. After considering many factors (functionality and cost being two main drivers), we went with the market leader for mid-sized associations: yourmembership.com.

As well as providing the tools to design your website, this cloud software offers many other features, including:

- a membership database with consolidated information (which can be accessed and easily updated by the member);
- online dues processing, including an automatic credit card payment option;
- the option for members to make their contact information publicly available and promote their businesses;
- course and event registrations;
- communication options between members, directors, committees and staff (messages, forums, blogs, latest news);
- certification and Continuing Professional Development tracking;
- an online store;
- a career centre;
- group (i.e., committees) collaboration tools;
- surveys; and
- the option to bulk email the membership or specific segments.

These features will be implemented (and website page content added) in stages as we move towards the winter season. We hope members will find many benefits with the new website, such as streamlined dues processing and access to invoices/proof of payments, online communication methods making it easier to share information and get involved with issues concerning you and the association, and improved opportunities for online networking and career development.

If you have not done so already, please visit the website, log in to access the members' only features, and get involved. We welcome all feedback as we move forward with implementing new features we believe the membership will value. Please email me at ssmith@avalancheassociation.ca or call 250-837-2435 ext. 257 with your feedback, or for any support with using the website.

Membership Committee **Updates**

Rocket Miller, Membership Committee Chair

AT THE TIME OF WRITING, the CAA's Membership Committee is presently working on our annual Continuing Professional Development (CPD) audits. CPD audits are completed each year as a way of checking in with membership to see how we are doing with our obligations of maintaining—or, even better yet—enhancing our competencies.

We ask ten professional and five active members to submit their activity report forms from the past three seasons. The forms provide a means of demonstrating continuing professional development or competency management. The forms are available on the CAA's website when members log in. Check out the new, refreshed website. As I trust you are maintaining your CPD activity report forms, seeing the new site and links to the forms will get you familiar with it.

The new website offers new opportunities for committees as well. MemCom is now using the site for communicating and operating, receiving membership applications and references, and then discussing the merits of these applications for potential approvals and denials. There is never a dull moment and we would not have it any other way. Please continue to encourage your colleagues to apply for CAA membership; we will continue to review and hopefully accept these potential new members.

The CAA's Board of Directors recently presented a new 2014-16 Strategic Plan with six main main goals. The third goal relates to membership and has four objectives. The objectives are sequential to the board and MemCom—by pursuing and successfully executing the first objective, we can then move onto the second, and then the third and eventually the fourth. It is important to us that we build a platform with each objective to ensure a solid foundation for the next.

CAA STRATEGIC PLAN 2014-16
GOAL 3: MEMBERSHIP

The CAA membership is highly regarded by members, industry, regulators and the public.

STRATEGIC OBJECTIVES:

3.1 Members in all categories understand and value membership obligations and benefits.

3.2 Industry, regulators and the public understand and value the competencies and professionalism of CAA members.

3.3 The CAA maintains and expands the CAA's membership to provide a strong credible voice for members to other professions, industry, regulators and the general public.

3.4 CAA membership categories are appropriate to CAA goals and scope of practice.

First, we would like to ask you about 3.1. We brainstormed four or five directed questions that resulted in a survey for your completion on the new website. Our best chance of success with this goal and the entire new strategic plan is reliant on our members' collective participation in this and other surveys—your voiced thoughts are necessary.

Yes, winter memories fade over the summer, but I implore that you set yourself up with laptop, some shade, colleagues and cold beer(s). Get the creative juices flowing and respond to the membership survey. It works for me and I know it will work for you.

Developing a Whistler **Backcountry Checklist**

Ryan Bougie

A LONGTIME WHISTLER BLACKCOMB SKI PATROLLER and backcountry skier/snowmobiler, last winter I was part of Wayne Flann's interesting project to develop rules for the Whistler backcountry. My anti-authority tendencies had me initially cringing at the idea of a backcountry code—I only saw it as clamping down on the freedoms and fun that the backcountry offers.

When Wayne gets excited he tends to obsess, and it was obvious that the idea had been brewing in his head all summer. As a 30+-year ski patroller and guide, Wayne has watched backcountry use grow. With the boom of backcountry equipment sales and technology, it is obvious how many people are getting into the backcountry. From avalanche skills training course attendees to renegade heli-drop clubs, snowmobilers to snowshoers, the backcountry has something for just about everyone and we wanted the backcountry checklist to serve them all. Wayne noticed many people venturing into the Whistler Blackcomb backcountry without necessary preparation and knowledge. He felt compelled to do something about it—and I'm not talking about rescues after they needed help, as he is also a longtime search and rescue volunteer.

Wayne's first step was to assemble an "expert" panel to oversee a public forum. This panel was to represent a diverse group of winter backcountry professionals. Mitch Sulkers, Keith Reid, Dave Sarkany, Dave Treadway and I agreed to participate, and the Whistler Museum (Jeff Slack) provided the venue and advertising for the event. On our panel we had an avalanche educator, guide, SAR member, pro snowmobiler/skier, and a ski patroller. The crowd that attended to give input was heavily stacked, from experienced policy makers to psychologists, to mention a few. We invited several of them to sit in on further meetings. They included Staff Sergeant Steve LeClair from the Whistler RCMP, communications consultant Randi Kruse who has worked with the Canadian Avalanche Centre, and Katy Chambers, BC Parks Area Supervisor, Squamish/Sea to Sky.

We wanted to model our backcountry checklist after the skier's responsibility code, but quickly realized that it spoke more to lawyers than the end user. We had strong references to draw from, like existing winter backcountry checklists from Parks Canada and the CAC, so we were not re-inventing the wheel. None of this information was new or groundbreaking, but we did have strong public engagement. If people are going to follow rules, it helps if they have a say in making them.

The point of the project was to gain acceptance in the mainstream, and not be just another sign cluttering our mountains. With busy winter schedules, it took a huge effort from Wayne to keep consultations, group emails and meetings happening. I was very impressed with how well our group worked together through all our challenges. Everyone brought forward valid points and creative solutions to get the language just right, so that it conveyed the messages as intended. What we had in the end amounted to a very carefully worded, itemized list of essentials.

Accompanying our list were drawings that may as well have been scribbled on napkins. We had established the importance of a rich visual component to the sign, but no one possessed the artistic aptitude to incorporate it so we enlisted help from Whistler Blackcomb's Jill Grotto. She ingeniously brought together the ideas in one simple-to-understand format that could cross the language barrier.

The final step was mounting the signs up in the alpine, which reinforced our sense of hope for the work. The sign has been posted on both Whistler and Blackcomb mountains, in high-traffic alpine areas and at exit points where Whistler Blackcomb has transceiver checkers into Garibaldi Provincial Park. This is not just for the beginners entering the backcountry, it is a reminder for everyone to be prepared and play safe out there.

We want to offer this product to anyone who thinks it would be good to use in his or her area. Contact Wayne Flann at wwflann@me.com if you have any further inquiries.


THE 10 ESSENTIALS
for backcountry exploration
Have you read the current local avalanche bulletin?
Assist others in need!
Do you know where you are and where you are going?
Does someone know where you are going?
Do you have your shovel, probe, and transceiver?
911
Can you call out in an emergency? (911, spot, etc.)
Be aware of people above and below you!
Get trained. Practice often. Have a mentor.
Be prepared to spend the night!
The conservative choice is never the wrong choice!
IF YOU DON'T KNOW, DON'T GO.
Whistler Blackcomb Backcountry Avalanche Advisory
Whistler Search and Rescue
Wayne Flann Avalanche Blog
Canadian Avalanche Center Avalanche Forecast Sea-to-Sky
CACAF Avalanche Observations

An ATES Zoning Model

Cam Campell and Brian Gould

INTRODUCTION

The Avalanche Terrain Exposure Scale (ATES) was first introduced in 2004 to classify backcountry recreational trips in terms of overall exposure to avalanche terrain (Statham et al., 2006), and was immediately embraced by backcountry recreationists as a valuable avalanche safety tool. It was initially intended to serve as a text rating for an individual route or drainage; however, as stated in a concluding remark: "ultimately the visualization of ATES ratings on terrain maps is the next logical step" (Statham et al., 2006).

In 2009, the ATES started to emerge as a classification system for zoning backcountry recreation areas (Campbell and Marshall, 2010). The success of ATES mapping as a public safety tool was immediately realized from the enthusiastic uptake by self-directed backcountry recreationists, recreation map and guidebook authors, and public land managers alike. Since then, over 5,000km^2 have been zoned for recreational safety purposes in western Canada alone. Mapping projects have twice been nominated for BC Premier's Awards, and have been credited with a noticeable reduction specifically in snowmobile-related avalanche fatalities, a previously difficult user group in terms of public safety communication. Canadian ATES zoning methodology has also caught the attention of alpine nations around the world, and has been used for public safety projects in Norway, Sweden, Spain, Switzerland and Andorra. In addition, it was the subject of a designated day-long workshop held at the 2013 IKAR Conference in Croatia.

More recently, ATES zoning has started to show its utility in worker safety programs (Fig. 1). Although traditional avalanche mapping, such as locator and atlas mapping, is useful for project sites and access roads, its application for providing guidance to roving backcountry field workers is limited unless detailed field checking is completed (at potentially significant time and effort). ATES zone mapping is a simple and cost-effective way of indicating the seriousness of avalanche terrain for roving field workers who are generally not limited to a fixed location or particular access route for their work, such as wildlife biologists, timber cruisers, and surveyors (Gould and Campbell, 2014). In addition, the ATES system is an easily understood terrain scale that can be incorporated into a rule-based operational safety system.

Until recently, ATES zoning has been based on the ATES Technical Model v.1/04 (Statham et al., 2006) using methods described by Campbell et al. (2012). With frequent use of terms like *mostly, generally, large percentage, primarily, minimal* and *limited*, this model has a high degree of subjectivity. There is also a certain amount of redundancy within and between the eleven parameters (e.g., forest density, start zone density, interaction with avalanche paths, and exposure time). For its purpose of guiding expert judgment in classifying a pre-determined route into three different exposure categories, this subjectivity and redundancy works well. However, it poses challenges for the purpose of Geographical Information System (GIS) assisted ATES zoning.

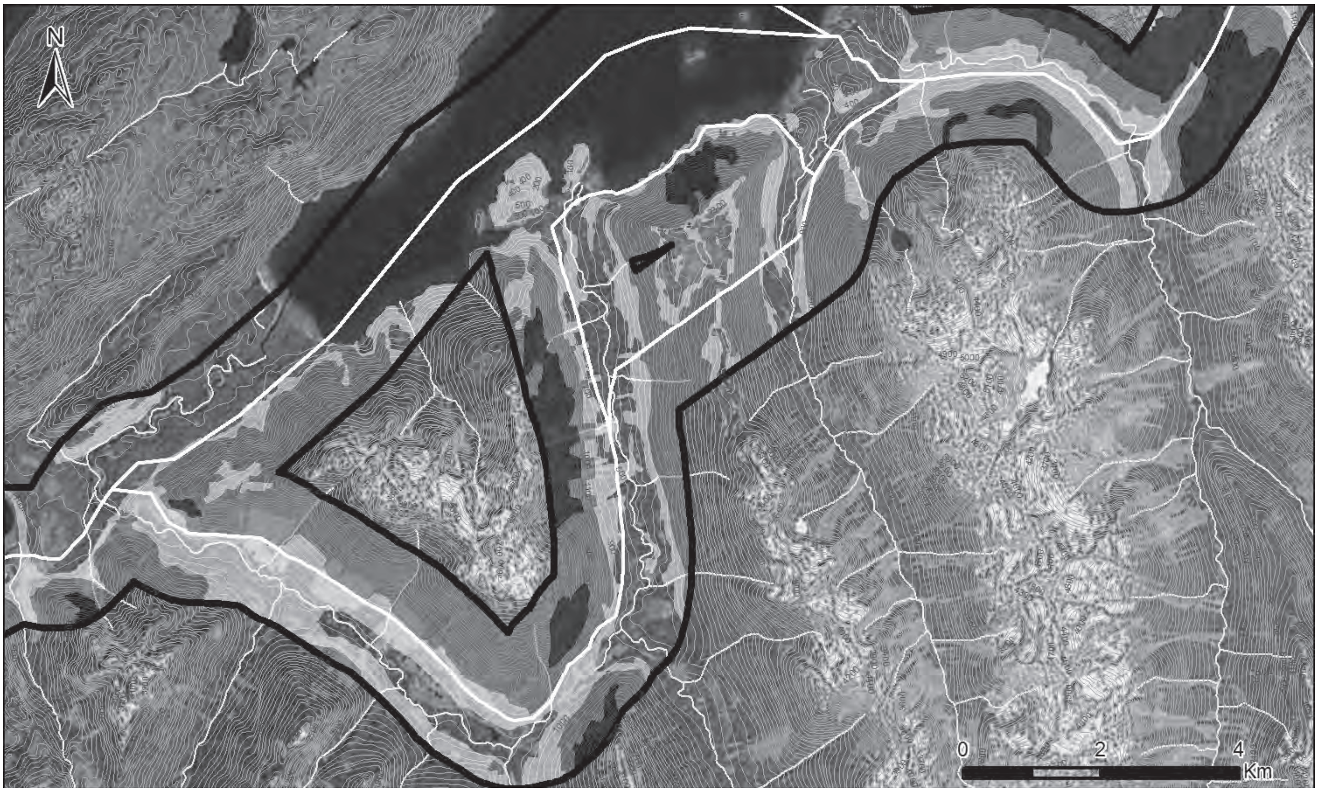
Despite widespread use, technical specifications for a practical ATES zoning model have only recently been proposed (Campbell and Gould, 2013). These specifications propose a model that aims to be:

- accessible (e.g., does not require specialized computer applications);
- comprehensive but not overcomplicated;
- compatible with the ATES Technical Model v.1/04 (Statham et al., 2006), while reducing the subjectivity of the parameters as much as possible;
- applicable at an appropriate scale for trip planning purposes; and
- based on the analysis of previously zoned terrain for the two primary avalanche terrain parameters: slope incline and forest density (Delparte, 2008).

ANALYSIS

Approximately 2,150km^2 of zoned avalanche terrain spanning the four major mountain ranges in British Columbia (Coast, Cascade, Columbia and Rocky Mountains) was used in the analysis. All terrain was zoned according to the methods described by Campbell et al. (2012) at a scale of 100-1,000m. Several ATES parameters can be digitally modelled and analysed with GIS (e.g., slope incline, forest density, start zone density, avalanche runout, slope shape). However, this initial study focuses on two parameters that have the most influence on ATES classification: slope incline and forest density (Delparte, 2008). Fig. 2 shows histograms of slope incline by forest density for each ATES class. The average slope incline increases with forest density and ATES class for Class 1 and 2 terrain. For Class 3 terrain, the average slope incline remains relatively constant despite forest density, due primarily to the lack of maximum slope incline threshold for Class 3 and the limited amount of Class 3 zones in forested terrain. These results are incorporated into the slope incline

FIG 1: EXAMPLE OF ATES ZONE MAPPING FOR AN ENERGY CORRIDOR (WHITE LINE). ATES CLASSES ARE INDICATED BY SHADING WITH LIGHT GREY AS CLASS 1, DARKER GREY AS CLASS 2, DARKEST GREY AS CLASS 3, AND NO SHADING WITHIN THE STUDY AREA (BLACK OUTLINE) AS CLASS 0. *PLEASE NOTE: GREEN-BLUE-RED COLOURED ATES ZONES WERE CONVERTED TO GREYSCALE FOR THIS PUBLICATION.*



and forest density thresholds used in the ATES zoning model outlined in the next section.

ATES ZONING MODEL

The resulting model for delineating ATES zones is outlined in Table 1. The parameters are listed in the table generally in order of importance, with the intent of placing more emphasis on the top two or three parameters. The parameter thresholds intended to be used as general guidelines to inform expert judgement in zoning avalanche exposure to people. There may be exceptions where zones do not explicitly meet all parameter thresholds for the class at which they are zoned.

Zoning with this model usually begins with GIS analysis followed by detailed field surveys. However, terrain can often be reliably zoned using a combination of these and other resources, such as topographic maps, air photos, and intimate knowledge of the terrain. Zones should be delineated in such a way that uses the lowest class possible (except Class 0, which is optional) at a scale of 100 – 1000 m. Detailed methods for preliminary zoning and field surveys are described in Campbell et al. (2012).

Since ATES zone mapping uses an exposure scale developed for travelling in avalanche terrain, it is not intended to provide an accurate extent of avalanche hazard. There are areas (islands of safety) in all four classes that are not exposed to avalanches, and are 100% safe. However, these islands of safety are smaller and more isolated in Class 3 than in Class 1 terrain. Class 0 is considered to be essentially 100% free of avalanche exposure.

The level of accuracy required for ATES zones often depends on the intended application. For recreational trip planning purposes, a high level of accuracy is often not needed because trip planning exercises usually involve only general overviews of the nature of the avalanche terrain. However, for operational decision support, a high level of accuracy may be required to maximize efficiency. Depending on the scale at which the zoning is presented, it is common to overlap zones to indicate that zone boundaries are not precise.

The highest accuracy can be achieved through GIS analysis and detailed field surveys. However, for straightforward terrain, high accuracy can often be achieved without field surveys, assuming high quality imagery and digital terrain models are available. For highly variable terrain, more detailed field surveys may be necessary to achieve reasonable accuracy.

DISCUSSION AND CONCLUSIONS

The ATES zoning model represents an evolution of a time-tested public communication tool. This is the first attempt at developing parameters and thresholds specifically for zoning with the ATES. This is also the first attempt at specifying thresholds for a non-avalanche terrain class.

This model represents results from analysis of a large and representative sample of avalanche terrain in British Columbia zoned with methods described by Campbell et al. (2012). It also represents ideas developed during years of experience zoning with these methods.

One of the main considerations in developing this model was accessibility. This means that if necessary, the model can be applied without the use of specialized computer application, or even computers, and helps to ensure that the model will become widely accepted and utilized.

Another consideration for increased utility of the model was agreement with the ATES Technical Model v.1/04 (Statham et al., 2006) so that it would honour previously rated terrain. The scale also needs to be compatible with widely used decision support systems based on the ATES (e.g., Haegeli et al., 2006). Finally, widespread acceptance and utility requires that this model be applicable across all snow climates, and as such it needs to be almost entirely terrain-based.

TABLE 1: PROPOSED MODEL FOR ZONING WITH THE AVALANCHE TERRAIN EXPOSURE SCALE.

		Class 0 (optional)	Class 1	Class 2	Class 3
Slope Incline[1] and Forest Density[2]	**Open**	99% ≤ 20°	90% ≤ 20° 99% ≤ 25°	90% ≤ 30° 99% ≤ 40°	< 20% ≤ 25° 45% > 35°
	Mixed	99% ≤ 25°	90% ≤ 25° 99% ≤ 35°	90% ≤ 35° 99% ≤ 45°	
	Forest	99% ≤ 30°	99% ≤ 35°	99% ≤ 45°	
Start Zone Density		No start zones.	No start zones with ≥ Size 2 potential. Isolated start zones with < Size 2 potential.	No start zones with > Size 3 potential. Isolated start zones with ≤ Size 3 potential, or several start zones with ≤ Size 2 potential.	Numerous start zones of any size, containing several potential release zones.
Interaction with Avalanche Paths[3]		No exposure to avalanche paths.	Beyond 10-year runout extent for paths with ≥ Size 2 potential.	Single path or paths with separation. Beyond annual runout extent for paths with > Size 3 potential.	Numerous and overlapping paths of any size. Any position within path.
Terrain Traps[4]		No potential for partial burial or any injury.	No potential for complete burial or fatal injury.	Potential for complete burial but not fatal injury.	Potential for complete burial and fatal injury.
Slope Shape		Uniform or concave	Uniform	Convex	Convoluted

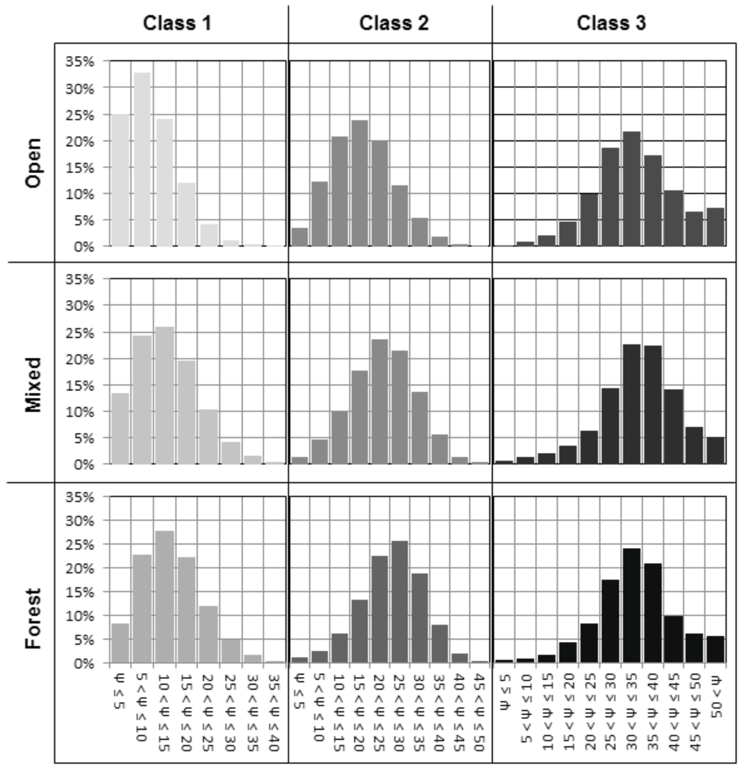
[1] Slope inclines are averaged over a fall-line distance of 20-30m.
[2] Open: < 100 stems/ha or > 10m tree spacing on average. Mixed: 100-1,000 stems/ha or 3.2-10m tree spacing on average. Forest: > 1,000 stems/ha or < 3.2m tree spacing on average.
[3] Position within paths based on the runout extent for avalanches with a specified return period.
[4] Terrain traps are features in tracks or runouts that increase the consequences of being caught in an avalanche. Thresholds are based on the potential increased consequences they would add to an otherwise harmless avalanche. For this purpose, terrain traps can be thought of as either trauma-type (e.g., cliffs, trees, boulders) or burial-type (e.g., depressions, abrupt transitions, open water, gullies, ravines). Degrees of burial used in this model are based on Canadian standard avalanche involvement definitions (Canadian Avalanche Association, 2009).

In order for this model to be compatible with GIS applications, an attempt was made to use parameters that could be digitally modelled and thresholds that were deterministic as possible. However, in order to be comprehensive and include all the important characteristics of avalanche terrain, assumptions must still be made for fully automated modelling. Furthermore, like other forms of avalanche risk zoning, ATES zoning is based largely in expert judgement. Because of this, ATES zoning is not always exact; one person's zone may look slightly different than another's depending primarily on the resolution at which they were drawn, but also on the evaluation and weight given to each parameter.

We do not propose that this model replace the ATES Technical Model v.1/04, as that model works well for its intended purpose of guiding expert judgment in classifying a pre-determined route. But as ATES zoning becomes more commonly utilized, a designated model and standards are necessary to establish common practice, consistent methodology and uniform criteria.

Ideas for future research include GIS analysis of other parameters that have the potential to be digitally modelled, including slope shape, avalanche runout, start zone density and terrain traps. Further model development could include GIS algorithms for automating the preliminary zoning phase.

FIG. 2: HISTOGRAMS OF SLOPE INCLINE (Ψ) IN DEGREES FOR OPEN (<100 STEMS/HA), MIXED (100 – 1,000 STEMS/HA), AND FOREST (>1,000 STEMS/HA) TERRAIN IN CLASS 1, 2 AND 3 ATES ZONES.



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Schedule of Upcoming **Events**

INTERNATIONAL SNOW SCIENCE WORKSHOP 2014
September 29-October 3
Banff Centre, Banff, AB

The ISSW promotes exchanges between practitioners, mountain professionals and researchers in the field of snow and avalanches.
For more information: issw2014.com

CANADA WEST SKI AREAS ASSOCIATION ZONE MEETINGS
October 1-2, 2014: AB, SK & MB Zone
Where: Mt. Norquay Ski Resort, Banff, AB
October 7-8, 2014: BC & YT Zone
Where: Sun Peaks Grand Hotel & Conference Centre, Sun Peaks, BC

For more information: cwsaa.org

WILDERNESS RISK MANAGEMENT CONFERENCE
October 1-3, 2014
Atlanta, GA

An outstanding educational experience to help you mitigate the risks inherent in exploring, working, teaching, and recreating in wild places.
For more information: nols.edu/wrmc

ICAR CONFERENCE 2014
October 5-10, 2014
Where: Lake Tahoe, NV

The 2014 ICAR-CISA Congress is hosted by the US Mountain Rescue Association.
For more information: ikar-cisa.org/2014

BANFF MOUNTAIN FILM AND BOOK FESTIVAL
November 1-9, 2014
Where: Banff Centre, Banff, AB

The Banff Mountain Festival brings you the world's best mountain films, books and speakers.
For more information: banffcentre.ca/mountainfestival/

WORLD EXTREME MEDICINE CONFERENCE AND EXPO
November 8-11, 2014
Where: Royal Society of Medicine, London, UK

Four days of knowledge, insight and innovation in the field of remote medicine.
For more information: extrememedicineexpo.com/

AVALANCHE AWARENESS DAYS
January 17-18, 2015
Where: across Canada

AAD is a national celebration of Canada's avalanche safety expertise and an invitation to enjoy the winter backcountry with education and training. Mark your calendars and get involved.
For more information: avalanche.ca/cac/events/avalanche-awareness-days

avalanche community

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BRINGING IT TO BANFF: ORGANIZING ISSW 2014

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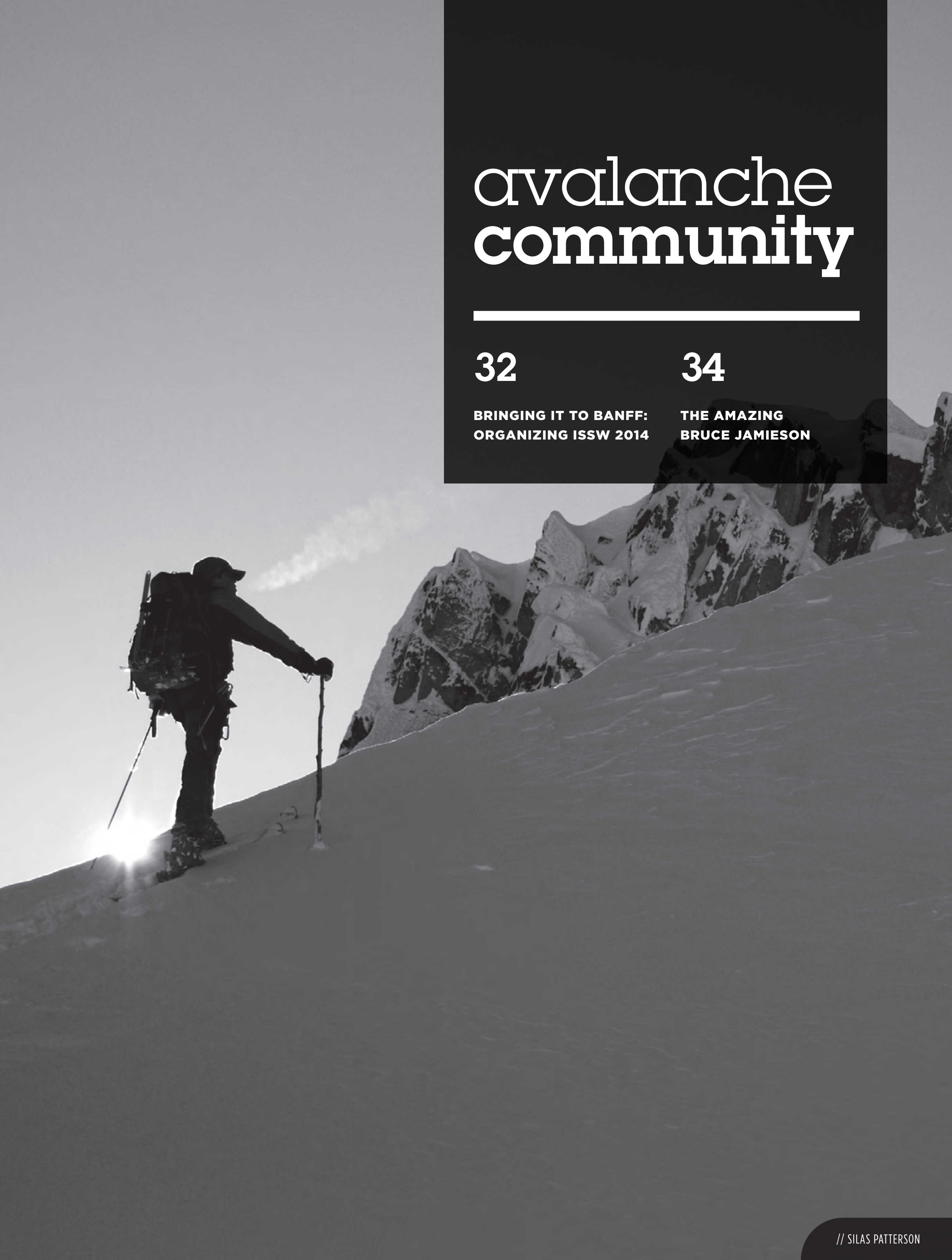
THE AMAZING BRUCE JAMIESON



// SILAS PATTERSON

Bringing It to Banff: Organizing ISSW 2014

Grant Statham

THE FIRST ISSW WAS HELD IN BANFF IN 1980. IN 1996, THE ISSW RETURNED TO BANFF FOR THE SECOND TIME. THIS IS THE STORY OF HOW IT CAME TO BE FOR THE THIRD TIME.

IT WAS IN SEPTEMBER 2010 when Rowan Harper and I first went up to the Banff Centre to see what would be involved with hosting the 2014 International Snow Science Workshop. Ninety minutes later we walked back down the hill, after being told we'd better book the space within weeks as 2014 was selling out quickly. What? Our dates were still four years away, they had to be kidding!

But no, they were not kidding, and thanks to a generous loan from the Canadian Avalanche Foundation we paid the $10,000 deposit and immersed ourselves in the gritty details of contract negotiations. The ISSW is no small conference, making this an intimidating contract to commit to—particularly since neither of us had organized a conference before. These days, the ISSW is a $600,000 undertaking. We called the Whistler 2008 guys for advice, and they sold us their company for a buck: *International Snow Science Workshop Canada Inc*. We opened a bank account and John Gillette said he'd keep the books. Susan Hairsine said she'd organize things. Rocket Miller said he was in. We were set.

Without a doubt, the best part of planning this conference has been working with everyone on the planning committee. The national and provincial parks crews, the Lake Louise and Sunshine ski patrols; the local mountain guides, Pascal in Vancouver, Ian, James and Mary in Revelstoke, John in Canmore—we have a great talent pool to draw from around here, and there is nothing like hosting the world in your home valley to bring everyone together. So we vowed to make it fun, to drink a few beers and to laugh our way through this whole journey.

I figured the most important thing I could do as the conference chair was to structure a good set of committees and fill them with motivated people. I wanted to brainstorm the ideas with each committee, then step away and let them concentrate on the details. My job would be to watch the big picture to provide ideas, support and oversight. But if I was going to steer the good ship ISSW, I needed some help, and fortunately Susan Hairsine stepped up and joined me at the helm.

Next we had to convince Parks Canada's executive that half a dozen of their staff would work on this in their spare time for a few years. We sent briefing material to Ottawa, and were relieved to get the big thumbs up right from the top. Parks Canada has always provided significant support to their avalanche programs, and hosting an international conference in Banff National Park would be an excellent way to highlight their contributions in this area.

After the 2012 ISSW in Alaska, we did an exit survey, hoping to learn a few things. We were surprised to get close to 500 responses, making it a really worthwhile exercise. While there was lots of valuable information in there, the topic that stood out above all else was the desire for more presentations that the everyday avalanche worker could relate to. This made sense to us; the ISSW has grown over the years, and has become the place to publish and present avalanche-related research. Combined with a growing international attendance, and a marked increase in MA and PhD students, the science portion of the program has been dominating. Ski patrollers, avalanche forecasters and mountain guides are not known for their propensity to collect data, run statistics, and publish papers—but their experiences are at the very core of professional avalanche work, and they comprise about 70% of the conference delegates. We needed to rebalance the conference program.

We turned to the Association of Canadian Mountain Guides, asking Marc Piché, Larry Stanier and Peter Tucker to organize a series of panel discussions on issues that matter to avalanche practitioners. Over the course of the week, 28 experts will participate in four different moderated debates in panels of seven. These will be must-see events, and we hope for strong audience participation.

One of the biggest jobs of the conference is the Papers Chair. Pascal Haegeli organized a large international panel to review the 275 abstracts we received, which they turned into 60 oral presentations and 200 posters. Ultimately, it is these guys who will create the balance of theory and practice, and this theme has been a central focus of their work. As I write this, the papers deadline is tomorrow and Pascal tells me his inbox is overflowing with requests for extensions. Everyone is jamming to the deadline right now!

Sponsorship is another key element of the conference, and really helps to keep the registration fees down. While a $525 price tag might seem high, consider that most other conferences of the same duration at the Banff Centre are at least twice that price. In 2013 we shook hands with both Arc'teryx and TAS who committed to become our Title Sponsors, Wyssen and Black Diamond/Pieps who committed to Supporting Sponsorship roles; and TECTERRA, Osprey, CIL Explosives, Mammut, Backcountry Access and AvaTech who joined as Contributing Sponsors. Together these companies have invested over $100,000 into ISSW 2014, and we are very grateful for their support.

Down the final stretch, this is what it looks like: Ian Tomm keeps everyone informed with daily website and Facebook updates, the Lake Louise guys are down to the wire with the social events, the girls are finalizing Diva Night, Brendan Martland and Ian Jackson are sorting out the logistics of 600 people for field trips, Donna White is preparing the best retail offering ever, Brad White is curating our art auction, Mike Koppang is coordinating the volunteers, Mischi Boenesh is organizing the banquet, Chris Stethem is building his keynote address, Todd Guyn is getting the simulcast ready, Mary Clayton is taking media requests and Dave Stark is mapping out trade show booth locations.

We're fine tuning now; our four year window is evaporating, and by the time you read this it will be long gone.

See you in Banff.

BRUCE TAKING A TELECONFERENCE CALL IN THE EARLY DAYS OF CELL PHONES // THOMAS EXNER

The Amazing **Bruce Jamieson**

FEW INSPIRE SUCH UNEQUIVOCALLY POSITIVE PRAISE AS DR. BRUCE JAMIESON. BRUCE HAS MADE A REAL IMPACT ON MANY FOLKS, ENCOURAGING AND INSPIRING STUDENTS, COLLEAGUES, PEERS AND FRIENDS.
WE THANK HIM FOR HIS DEDICATION AND PASSION FOR AVALANCHE RESEARCH AND SAFETY AS HE MOVES ON FROM THE UNIVERSITY OF CALGARY'S APPLIED SNOW AND AVALANCHE RESEARCH PROGRAM.

Dave Gauthier

THOMAS EXNER'S PHOTO was taken in 2007, near the top of the Fidelity slide path at Rogers Pass. Bruce spent the first part of the day working with Thomas, James Floyer and me to get to this site and dig a huge pit for a field experiment. Then he stepped aside to join a teleconference on his cell phone (cell service was brand new then). Hence the jacket over the head—possibly to cut the wind noise? Who knows what he was talking about on the phone; it could have been anything to do with research or practice, or recreational avalanche safety. Whatever it was, I guarantee it was important. I think this photo sums up, in a way, what Bruce does for so many folks in the avalanche community: he skis with us, works with us, and then works for us, often in the same day. It's pretty amazing when you think about it.

I feel extremely lucky to have had Bruce as a teacher and mentor, and I am certain that many other folks feel the same way.

I've also attached another photo (oppsite page); in it, I am leaning on my shovel taking a break while Bruce keeps digging a huge, half-day pit. It's amazing to think about where we were, how we got there, what we were doing, and the amount of effort it took for Bruce to make it all happen (both the big pit we dug that day, and ASARC in general!). I can assure you that there is no other field research program like this anywhere in the world. I think that we (the avalanche community) have all been very fortunate beneficiaries of the hard work Bruce put in to ASARC, and I really hope that we made the most of it while we had it. I think its legacy will continue for a long time, in any case, as the state of practice catches up with the state of the art that Bruce developed with ASARC. I wish Bruce my most sincere thanks for having made ASARC the great success that it was, and all the best wishes for whatever challenge he takes on next.

Cam Campbell

BRUCE FIRST GOT EVERYONE THINKING about the role of the slab in slab avalanche release. He introduced Canadian avalanche practitioners to the rutschblock test and pioneered methodology for cutting the sides instead of shovelling, greatly reducing the time required to perform the test. He then used the rutschblock test in the first slope-scale stability test arrays to study spatial variability. He coined the term *persistent weak layer*, refined methodology for compression tests to include observations of fracture character, etc., etc.

Of course I could go on about Bruce's numerous contributions to snow and avalanche research and merging theory with practice, but I think some of his most important contributions (to date) have been on his role as a mentor. During his time at the University of Calgary, Bruce has supervised dozens of successful graduate students who are now working around the globe in the avalanche industry. It's hard to find an avalanche forecasting and control program in western Canada where one of Bruce's former students doesn't work or hasn't worked. His program at the University of Calgary (affectionately known as Bruce Jamieson's School of Avalanche Forecasting) is arguably the most successful program of its kind in terms of job placement after graduation.

Bruce's graduate students are sought after in the avalanche industry, largely due to his reputation as a great mentor. He is supportive to the point where he is your best advocate. He is open and approachable and sees the merit in all ideas. His passion and enthusiasm for snow and avalanche research encourages everyone around him to ask important questions and think outside the box. But perhaps most importantly, he has the unique ability to present complex scientific concepts in a simple accessible manner, like my favorite, the "Oreo Cookie Model."

I wish Bruce all the best on his future endeavors and I look forward to hearing about his next practical solution to the avalanche problem.

ANOTHER HARD DAY AT THE OFFICE // BRUCE JAMIESON COLLECTION

BRUCE SHOWING THE YOUNG LAD HOW IT IS DONE // THOMAS EXNER

James Floyer

AS I THINK OF HOW TO SUM UP my personal experience studying and working with Bruce Jamieson, three words spring mind: ideas, action and leadership. While I've met a number of people with seemingly good ideas, Bruce's special skill is to tease out those ideas that combine novelty, applicability and attainability. Researching hard problems is one of the *raison d'êtres* of the university system; however, it still pays to pick your battles. Bruce has an uncanny knack for bringing well-intentioned but completely unrealistic ideas back into the realm of plausibility, a knack that is reflected in his prolificacy as well as his reach to practitioners and researchers alike.

Action implies immediacy, and I am always amazed by Bruce's immediate attention to everything, from major grant applications right down to seemingly trivial details. With Bruce, you always feel as though he is fully engaged, and will offer advice or assistance to the best of his ability. His energy for helping people, especially students, but also practitioners, associates, and members of the general public, is second to none.

Bruce's low-key but highly effective approach to leadership proves you don't need to be a blustery A-type to inspire people and garner a loyal following. Bruce's leadership style softly and seamlessly marries respect, trust, belief, stories, guidance and humility. It is an unusually rewarding feeling to be mentored by someone who can make it seem as though you have been a crucial part of every idea and concept, and a key member of a team striving towards a common goal.

Thanks, Bruce, for the inspiration, the mentorship, the wisdom and the turns!

Colin Johnston, CAA Affiliate Member and U of C Professor Emeritus

WHEN BRUCE JAMIESON FIRST SHOWED UP at my University of Calgary office in 1986 to inquire about graduate studies leading to a master's degree in civil engineering, I soon learned that this was no ordinary graduate student applicant. With the unusual combination of an undergraduate degree in mathematics and snow-related field work experience on the Fernie ski patrol and at Nakiska, Bruce wanted to investigate how snowpack structure and properties influence avalanche phenomena, a topic far removed from my research activity in concrete technology for the previous 20 years. Thus commenced an unusual and, for me, exciting partnership.

Needing as first prerequisite a bachelor's degree in engineering, Bruce tackled with determination the challenging menu of undergraduate engineering courses prescribed to augment his mathematics degree to the requirements for a B.Sc. in civil engineering, no easy task for one who had left university some years previously with a non-engineering background.

Since both concrete and snow slabs are brittle in tension and I had some relevant research experience with concrete, we set about developing a technique for measuring the tensile strength of snowpack layers in the field, aiming to relate the results to microstructure, density and hopefully avalanche frequency in the vicinity. For the project to be viable, naturally we needed a field station for tests adjacent to avalanche slopes, and a source of avalanche occurrence reports for this project. Enter Clair Israelson and his coworkers at Parks Canada in Lake Louise, who provided avalanche occurrence data and mentored us for two winters of testing in Wolverine Valley, where I found myself plucked from the warmth and safety of an indoor concrete testing laboratory to working snowpit days in the vagaries of a Rockies winter. This was to be the first of many collaborations with snow practitioners throughout Bruce's career, and culminated with the completion of his M.Sc. degree in December 1988.

Some of Bruce's presentations on this work came to the attention of Mike Wiegele, who expressed an interest in financially supporting further research relevant to the heli skiing industry. We agreed on a plan that would involve primarily shear frame and rutschblock testing in relation to slope stability evaluation. Thus began in November 1989 the first three-year phase of a university-industry collaboration funded by Mike Wiegele Helicopter Skiing and the Natural Sciences and Engineering Research Council. As Bruce continued to raise the profile of his work in publications and presentations to industry, Mark Kingsbury at Canadian Mountain Holidays became a strong supporter during the second three-year phase from 1992-95. Mark then brought on board support from members of what is now Helicat Canada for the third three-year phase of 1995-98. During this period, Bruce not only managed to complete the requirements for his Ph.D., submitting a thesis which his external examiner stated was the best he had ever seen, but also found time to serve on the Board of Directors and as President of the Canadian Avalanche Association. His capacity to juggle all these diverse involvements, including managing and staffing field stations in winter at Blue River, Bobby Burns and Rogers Pass, was amazing. It made my role as principal investigator responsible for project administration not only exciting but rewarding, because of opportunities to meet many interesting avalanche practitioners, spend snowpit days in beautiful places far from my office, and further my knowledge of backcountry skiing.

> So many of us have learned through his books, papers, presentations and individual communications. Just like good wine, he can only get better with age.

Following my retirement in 1998, Bruce was appointed Adjunct Professor, becoming eligible to be principal investigator in his own right. As his research reputation grew internationally, he attracted new graduate students from many countries to participate in two further three-year university-industry collaborations, 1998-2004. With ever-widening recognition of his work, he was successful in applying for a five-year Industry Research Chair awarded in 2004, and subsequently renewed for a further five years to 2014. As principal for the ASARC continuing program at the University of Calgary, he has mentored numerous students to M.Sc. or Ph.D. degrees, many of whom have followed careers as avalanche professionals. He has also become an accomplished author of practical handbooks on avalanche awareness and safety for backcountry recreationists, a major contribution to the promotion of public safety.

In April 2014, Mike Wiegele arranged a celebration of 25 years of association with Bruce's research, at which I was delighted to be presented. His success was also celebrated at the May 2014 CAA meeting with the presentation of the Peter Schaerer Award on behalf of the many CAA members with whom he has collaborated over the years. He hastens to assure all of us who know him that he has no intention of retiring yet, so we may look forward to a continuation of the knowledge transfer on avalanches from which so many of us have learned through his books, papers, presentations and individual communications. Just like a good wine, he can only get better with age.

Peter Schaerer

BRUCE JAMIESON HAS MADE AN AMAZINGLY large number of contributions to the knowledge on avalanche formation and awareness. In summary, he carried out research on the stability of snow packs, published research results in a user-friendly form, authored and co-authored books on avalanche awareness, and served the Canadian Avalanche Association.

Bruce balanced his work between scientific research and applications for the professional avalanche technician and the general traveller in snow. His principal research concerned the stability of snow packs that may or may not lead to the start of avalanches. He engaged himself in difficult and often frustrating work, because the study data had to be collected in the field on snow that varies strongly with the weather. Some winters offered perfect conditions for observations of weak snow packs, but in other years the snow was disappointingly stable. Therefore, useful results had to be collected over several years, and this obstacle generally is a concern for funding agencies who want to see results for the money in a short time. Bruce, with the support of his supervisor Colin Johnston and graduate students of the University of Calgary, were able to conquer the difficulties of the variation of snow packs through dedicated, extended work that has produced excellent results. They carried out observations tirelessly when the conditions were right. I became aware of the dedication and long hours put into work when I assisted by cutting numerous Rutschblocks during a full day, and on another occasion when I prepared numerous rows of columns for pressure tests.

Bruce's research work was significant not only with respect to science, but because it was user-oriented. The results were published in scientific journals and proceedings of snow science conferences, and the techniques and recommended validities that Bruce developed for the rutschblock and compression test are contained in the observation guidelines and recording standards of the Canadian Avalanche Association. Avalanche technicians now apply them in their work. But the stability of snow packs was not Bruce's only interest. For example, he also investigated and made recommendations of the technique of probing for victims buried in avalanches.

In addition to writing research papers, Bruce has authored publications on backcountry avalanche awareness for skiers, sledders and snowboarders, Volumes 4 and 5 of *Avalanche Accidents in Canada,* and the *Land Managers Guide for Snow Avalanche Hazards in Canada*, among others.

The research and publications on snow pack properties and avalanche formation are not Bruce's only contributions to avalanche safety workers. He has instructed ITP courses, formed and chaired a nomination committee for the election of directors of the CAA in 1990, and in 1992-94 served as president of the CAA. His tenure as president was in the first years, after the CAA had established a permanent office with hired staff and needed leadership for strengthening and its reputation. Bruce has also been a member of the CAA's Technical Committee since its inception.

Of course, applied research and producing guidelines for avalanche awareness cannot be achieved without practice in the snow. Bruce is a keen backcountry skier and impresses on his snowboard when he joins groups of helicopter skiers.

We are honouring a man who truly combines scientific investigations with practice-oriented information and we are looking forward to more studies and publications of Bruce Jamieson.

// BRUCE JAMIESON COLLECTION

research

in this **section**

// M. ECKERSTORFER

Hypothermia: Current Concepts and Field Treatment

Mike Inniss
MD, DiMM ICAR

ALL OF US WHO WORK and recreate in cool or cold environments should know the importance of preventing hypothermia and recognizing its presence. Timely application of interventions to treat and stabilize those exhibiting the clinical signs of hypothermia are critical. This article updates current concepts of hypothermia by reviewing a practical field staging and triage system, patient packaging and field rewarming options.

It is a reasonable assumption to consider all exposed or injured subjects in a cool or cold environment to be suffering some degree of hypothermia that will undoubtedly worsen if no action is taken. Consider subjects to be "hemorrhaging heat," a colleague teaches. If a patient is hemorrhaging blood, something must be done immediately to attempt to stop it. Like blood, it is wise to consider heat loss on a mountainside as heat lost. In my field practice, interventions to prevent further heat loss are undertaken right after the ABCs of the primary patient survey. The first thing to do for a skier with a broken femur is to put a down jacket on them. It is that critical, and one of the few ways we can make a difference while far from more advanced medical care.

FIELD STAGING AND TRIAGE

The Swiss Field Staging is a practical method of triaging hypothermic subjects. It does not require taking the subject's temperature (since it is difficult to take a core body temperature in the field), as it is based on simple physical signs. Interventions are dictated by the stage determined.

PATIENT PACKAGING

The main packaging concept is to insulate from the environment (e.g., ground, snow, wind, precipitation, cold air). Minimize patient movements if possible and handle gently, as a cold heart is a jittery heart and rough movement can trigger life-threatening cardiac arrythmias. Remove

Swiss Field Stage	Signs	Intervention
I	Conscious; Shivering	Warm enviroment; dry warm clothing; active movement; food; warm sugar drinks; rewarm in the field
II	Impaired level of consciousness; Not shivering	Minimal careful movement; microclimate (tent/tarp rescuers inside); horizontal immobilization; active external rewarming (e.g.chemical heat pac vests/blankets, Norwegian army charcoal heater, warmed water bottles to armpits/groin); cardiac monitoring (if available); transport to nearest hospital
III	Unconscious; Not shivering; Vital signs/any sign of life present	As in HT II, plus: airway management; transport to nearest hospital
IV	Vital signs absent (prolonged [>2min] vital sign check); Limbs can seem stiff and pupils fixed and dilated in profound hypothermia; No obvious lethal trauma; Chest wall not frozen.	As in HT II, plus: airway management/ventilations; begin CPR/AED and follow commands. If no return to vital signs after two shocks, consider stopping shocks. Continue CPR if practical; package and transport to hospital with external blood rewarming (heart lung bypass or ECMO).

FOUR RESCUERS INSIDE A MICROCLIMATE TARP // MIKE INNISS

wet clothing if practical without increasing exposure. If wet clothing has to stay on, wrap subject with a non-breathable wrap like a space blanket or heavier nylon against the wet clothing. This will act like a wetsuit and the thin water layer may warm up with the subject. Don't forget to loosen tight clothing and ski boot buckles (if left on). Ski helmets are good insulators and may be protective during patient transport. Use the burrito concept: wrap the subject with insulating layers (down, blankets, etc.), followed by a tarp/bivy sac on the outside. Covering the subject and rescuers/medical attendants within a microclimate (e.g., tent, guide's tarp, rescue tarp) completes the packaging during initial management and at all times while not in transport. The benefit of treating the subject within a microclimate cannot be overemphasized. It can get downright warm and cozy inside a microclimate, even in very cold, nasty weather. The edges of the tarp need to be well sealed from the weather, and the more people inside the warmer it gets.

FIELD REWARMING OPTIONS

It is difficult, if not impossible, to actively rewarm a seriously hypothermic (HT II-IV) patient in the field back to normal. More realistically, we can probably only slow the rate or stop further heat loss while we get them to hospital.

Shivering (mild hypothermia) is the most efficient way a body can rewarm, and is a reassuring sign that as long as you are preventing further heat loss your patient will rewarm. Providing warm sugary drinks and food to an alert and mildly hypothermic subject who is shivering (HT-I) will help that recovery along. Subjects that have stopped shivering (HT II-IV) require evacuation. Commercially available chemical heat pack panel blankets/vests that activate upon exposure to air are valuable tools to include in advanced first aid kits and incorporate into your patient packaging system. Warmed water bottles to trunk, armpits and groin can be helpful if you have camp stoves to warm the water (heat water to hot tub temperature). The Norwegian army developed a commercially-available charcoal-burning device that some organized rescue agencies employ. Studies have shown it to be effective as a field rewarming device, but the device has limitations due to venting issues and the inability to be used in enclosed spaces and helicopters. Direct body-to-body heat usually ties up a valuable resource (a rescuer) and is mostly ineffective and impractical.

The medical and rescue literature reports numerous cases of profound hypothermia victims recovering with normal neurologic function after prolonged rescue. A Norwegian woman with a core body temperature of 13.7°C (37°C is normal) and no vital signs survived prolonged extrication and resuscitation, and a recent case in Squamish hit the national news when a severely hypothermic young woman survived many hours of CPR to walk out of hospital two weeks later. These patients (HT IV) survived because of knowledgeable rescuers who followed up-to-date field treatment algorithms for hypothermia, and transported them directly to advanced medical care facilities with advanced blood rewarming capabilities. It's important to be able to identify and differentiate subjects who are suffering life-threatening hypothermia (HT II-III) who need to be evacuated to the nearest hospital, from those subjects who are suffering profound hypothermia (HT IV) who deserve prolonged attempts at resuscitation and the effort to transport them to advanced medical centres with external blood rewarming machines (coronary bypass or ECMO). In British Columbia and Alberta, those are Kelowna General Hospital, St. Paul's Hospital and Vancouver General Hospital in Vancouver, Royal Jubilee Hospital in Victoria, Calgary Foothills Hospital and University Hospital in Edmonton. It is hoped that the BC provincial emergency services system will soon have a protocol in place for transporting critical hypothermia patients directly to these centres.

IN SUMMARY

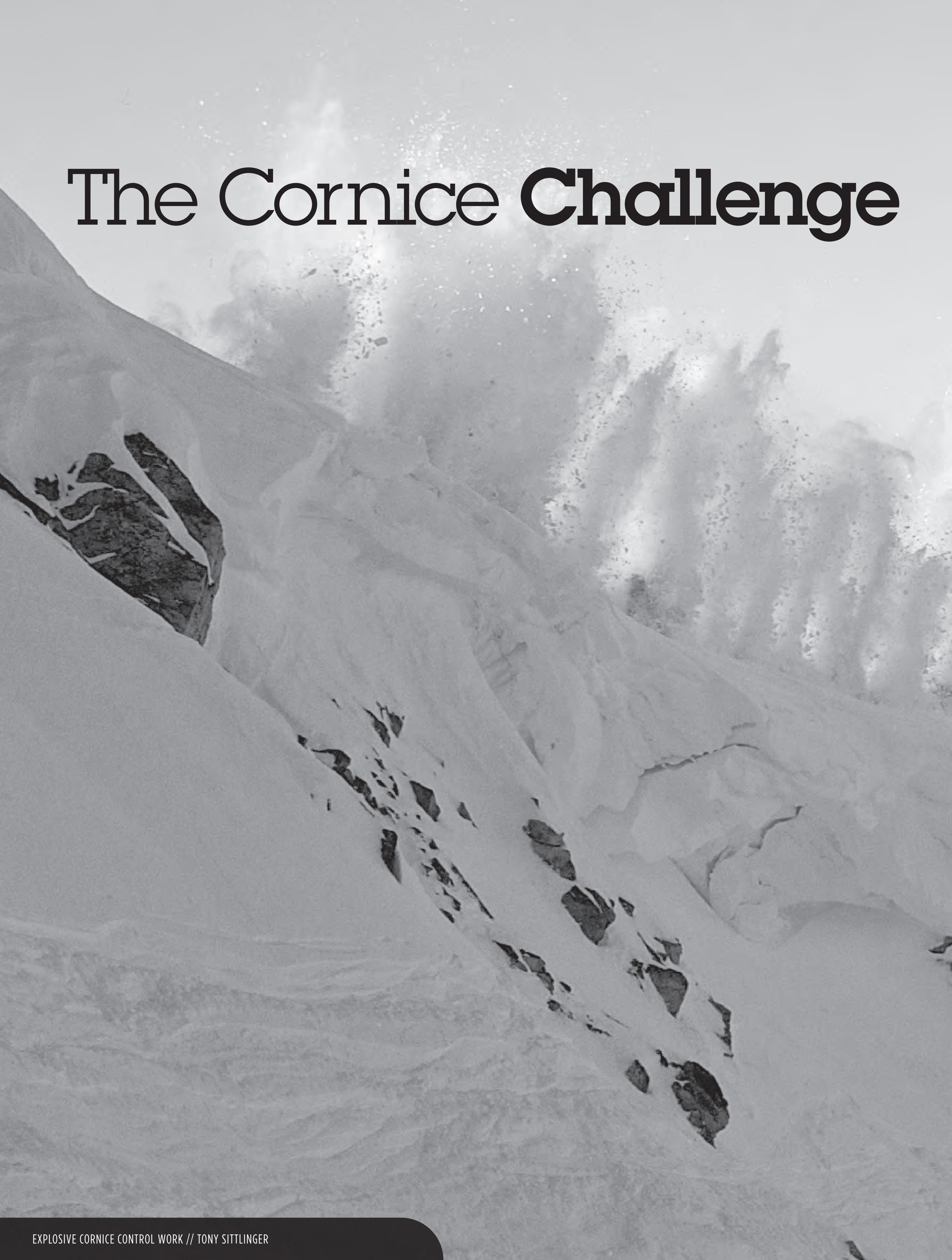
The most important concept as a rescuer is to never underestimate the role hypothermia is playing or may potentially play in a poor outcome for the exposed subject in a cool or cold environment. Immediate decisive action is required as subjects hemorrhage heat that is not recoverable in the field. A simple staging and triage system helps identify and guide treatment principles that include a layered packaging system, incorporating available field rewarming options, all accomplished within a microclimate. Emergent evacuation to advanced medical care for all but mildly hypothermic patients who can be rewarmed in the field by simple measures is of utmost importance. Knowing the closest medical centre with rapid external blood rewarming capabilities is an important part of any rescue organization's emergency preplan. The decision to attempt prolonged resuscitation and directly transport to that facility if possible is warranted in cases of profound hypothermia if the subject is to have a chance for a successful outcome.

ACKNOWLEDGEMENTS

Thank you to my colleague Dr. Doug Brown for his peer review of this article and his pioneering work on hypothermia protocols for the province of BC.

HOW NOT TO DO IT: THE PATIENT IS NOT INSULATED FROM SNOW, THEIR CHEST IS EXPOSED, AND THEY ARE NOT PROTECTED FROM THE ENVIRONMENT WITHIN A MICROCLIMATE // MIKE INNISS

The Cornice **Challenge**



EXPLOSIVE CORNICE CONTROL WORK // TONY SITTLINGER

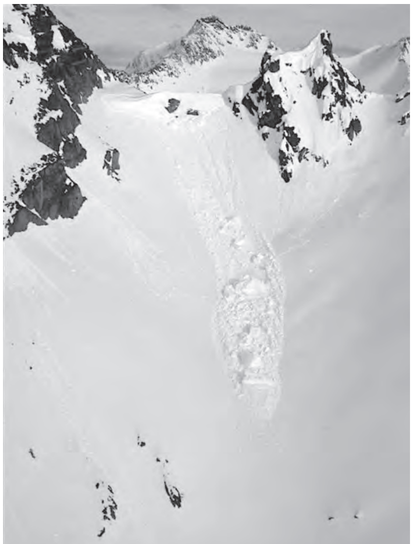
Larry Stanier

CORNICES ARE A SIMPLE FACT OF LIFE in snowy mountains. As I write this in early August, I will still be dealing with them this coming week in the mountains. Talk to veteran big mountain ski patrollers and they will all have cornice control horror stories. Way too many professional and recreational skiers and climbers have fallen through cornices. Yet, since cameras first came into the mountains, we have seen photos of people standing cavalierly on cornices, skiing off them and climbing through them. How do people get away with such behaviour when others die or come damn close every year?

Though you won't find the answers in these coming pages, we sure hope to stimulate some deep thought and careful consideration on the topic. Larger margins, better route finding, more probing, more belaying, bigger bombs and snow fencing would all help, but as usual our minds are probably the best tools if we know how to use them. I would sure like it if no one else I knew was injured or killed by a cornice fall.

Now You See Me, Now You Don't

Story and photos by Bob Sawyer



IN MID-APRIL 2009, the snow stability and the character of the Cariboo mountains were at a season's best, with a bluebird day to match. I took the reins of lead guide at CMH Cariboo Lodge that week—I was busy determining what to do and where to go, finally deciding to ski the north part of the tenure, which would result in north-facing glaciated terrain.

After four or five runs, we looked at a run called The Chute. We slowly did a dry run pass to check on landing and run features, as we only ski this line late in the season. Everything looked good. Once landed, I asked the pilot to move forward two meters or so and hold power while we exited the aircraft. I got out of the co-pilot seat and opened the sliding door, telling the door man to inform guests to move forward to the snow dirt line.

I moved around the front of the 212 towards the basket. As I grabbed the lower bar of the basket with both hands to open it, I heard a thunderbolt sound and found myself airborn. Stunned and holding on, I was flying and realized I had to make a decision quickly. Glancing downwards, it looked bad—as the milliseconds passed, I decided to cut loose, pushing back if possible. Upon landing (after a six to eight-metre fall), I was barely able to get my radio out to call for help.

Once help had been established I tried to figure out my next move, as I could only see one other person. Running over to the broken edge, I saw three people—two standing and one on his back, non-responsive, three to four meters below. Running over to a safe entry to assist the three, I noticed a waving hand 40-50m below me in the lower cornice debris. After establishing an airway on the non-responsive guest, I moved down to the lower arm waver with transceiver on search.

Meanwhile, help started to arrive and I slowly accounted for all of my guests—not an easy task. All guests were taken to the local hospital and cleared of any trauma. After a late lunch back at the lodge, we resumed skiing and had a couple more runs. One could only imagine the outcome had luck not been with us. My thanks go out to super pilot Chris Norman and my very supportive guide group.

Mt. Collier Cornice Case Study

Larry Stanier

CLIMBING CONDITIONS WERE GOOD in the Rockies alpine in mid July 2010. Lots of summer snow was around, so rockfall and wet slides were probably the biggest hazards and were easily managed with a good freeze and fast, well-timed travel. Cornices were still a factor and avoidance was my main strategy.

The "Millar boys" from Lake O'Hara lodge are fit and good on their feet. I usually go as fast as I can with them, and they patiently try not to blow by me. We had been waiting for a fine day to climb the North Glacier on Mt. Collier from the O'Hara road, and now we had it. None of us had climbed it before.

Early morning had us up the glacier and onto the NE ridge, which was a little more complex and corniced than I had hoped. We passed the first few cornices easily, as we could scope them well in advance.

Then, we came to a bit of a mystery. It was obviously a huge cornice, with no simple way to scope it in advance. It was steep on the windward side (about 40 degrees), and there was a long, steep, rocky couloir below the lee side, but it looked like there should be a good anchor in solid rock on the far side. I left the boys and went for a look. I really wanted to stay high, keep the flow going and avoid having the three of them do a steep descending traverse. But I was spooked and uncertain, so I went way down to where I felt I was just below the lowest possible fracture line, kicked in big steps, and was grateful to find an easy, solid anchor on the far side.

We were on to the summit from there and back to the mystery spot in about an hour. There were still no good views of the beast, so I rebuilt the anchor and belayed them down and across the steps. Ka-whoosh! The big mofo broke right along the steps, slammed into the couloir, and, along with a big, wet, greasy avalanche, roars down onto the upper Victoria Glacier. The boys and I were impressed! The rope and anchor would have held the fall, but it would have been a fart knocker of a tumble before the rope stopped them.

THE FOOTPRINTS ARE STILL VISIBLE IN PLACES ALONG THE FRACTURE. THE SLOPE ABOVE THE PRINTS WAS EASILY 40 DEGREES AND RAN UPHILL FOR 5-10M WHILE IT SLOWLY FLATTENED OUT. AS A WILD GUESS, IT WAS MAYBE 20 TIMES THE SIZE OF THE CORNICE IN THE PHOTO // LARRY STANIER

Despite going much farther downhill than I would have liked, I still cut it too close. My imagination failed me, as I didn't realize that the gap between the rocks was that deep and that the cornice was that big and poorly supported.

Lesson learned (again): time and flow is important but wide margins are more important. It would have added maybe one minute to the day to go even a bit further downhill. That would have increased the risk and consequence of a fall while the boys were moving, but in hindsight I was sure I could get a good anchor, I had lots of faith in their movement skills, and little faith in my cornice size estimate. Probing may have helped but my 240cm summer probe may not have been long enough.

How do I apply those lessons? There are certainly no rules that should come out of an event like this, but my take home is realizing when I have a high degree of uncertainty around cornices I must leave an even bigger margin to account for that uncertainty. And the main thing is bringing everything (and everyone) home.

TRAVERSING CORNICE BUILD UP AREA IN DELIRIUM DIVE // BRENDAN MARTLAND

Cornice Theory at Sunshine Village

Brendan Martland

CHAOS THEORY: "a field of study in mathematics, with applications in several disciplines including meteorology and physics. Chaos theory studies the behavior of dynamical systems that are highly sensitive to initial conditions—an effect which is popularly referred to as the butterfly effect. Small differences in initial conditions yield widely diverging outcomes for such dynamical systems, rendering long-term prediction impossible in general" (Wikipedia). Cornice Theory: see above, and add increased uncertainty and a false sense of security due to the existence of a non-event feedback loop (B. Martland). Cornices are among the most challenging and unpredictable elements at play in avalanche forecasting. My experience with them, from both near and far, has been what might be described as an "unhealthy relationship." Poor feedback, lots of mistrust, little understanding and the occasional spanking.

Basic cornice dynamics are well described and documented, but their failure is not extensively researched or well grasped by avalanche professionals. Several key heuristics (helpful decision-making "mental shortcuts") have become commonly accepted within the industry. Some of these are very helpful: "Be cautious of any temperature spike, be it rapid warming or rapid cooling." "Sudden or intense solar input is a common cornice trigger." "Rapid windloading often causes a cornice release." "Cornices can pull back all the way onto flat terrain well off a ridgeline." We can and do use these heuristics to help forecast and manage cornice failures, but what about all those times when nothing happens, or when you thought it would fail but did not? These often become a non-event feedback loop, where there is an ongoing lack of events (failures) that may lead to a false sense of confidence or security. A cornice will often survive numerous dramatic sunrises, several cold spells after warm days, wind events of varying intensity and direction, even a cornice-cutting mission or a bomb sitting on top of it, and still hang in there somehow at the end of the day. In our world of confidence and uncertainty, cornices may well reign supreme.

My own perspective on cornices is mainly that of a ski resort avalanche technician and forecaster. As such, I have access to an arsenal of explosives, closure systems and human labour hours dedicated to decreasing or eliminating this particular hazard. My

PEYTO'S CORNICE BEFORE AND AFTER
// BRENDAN MARTLAND

approach to the problem comes from a combination of all the hand-me-down heuristics that were mentored into me, and a key heuristic I developed on my own. It is not a new or original concept, but one that so many of us had to learn the hard way before we really believed in it or followed it in practice.

Sunshine Village Ski and Snowboard Resort has a profound history of cornice-related near-misses, accidents and even a fatality. I will touch on a select few of these events in the interest of preventing similar accidents or close calls. I will then offer you my own solution and heuristic for cornice assessment and mitigation.

FATALITY, BEYOND THE SOUTH SIDE CHUTES OF GOAT'S EYE MOUNTAIN

A 19-year-old male snowboarder left the ski area boundary for some fresh turns in the adjacent backcountry. At the top of the run, he stopped to take photos and have a look around. He decided to look at the view from the edge, with an acquaintance only a few feet away. As he took a step onto a cornice, he suddenly fell into space as it broke away from the ridgeline. The ensuing 445-metre fall proved to be unsurvivable.

In hindsight, this appears to be an obvious and avoidable accident. Unfortunately, cornices are not well understood or appreciated by the general public, and accidents like this continue to occur. As professionals, we have to try our best to educate the users we come into contact with of the dangers of cornices. We also have to set the example of complete avoidance whenever possible—there are times when one may be tempted to venture out onto a well-supported, mature cornice, but keep in mind that they have and will continue to fail with just a small amount of added stress or load. The weight of a person is sometimes all it takes to tip the scales, even with a dense, seemingly well-supported specimen.

NEAR MISS, GALAXY RIDGE IN DELERIUM DIVE

At the far end of the ridge that defines the Delirium basin, there is a complicated ridgewalk that has occasionally been used to access the top of an outlying run named Milky Way, or more commonly to access the backcountry to the southeast. The leasehold is defined by the ridge itself, so technically speaking this feature is (just) outside of the ski hill boundary. There is an area on the ridge where a short, deep incut exists. By mid-winter, the feature is filled in and looks to be a part of the ongoing ridge, but, in fact, it is a short cornice bridge over a significant drop to a large, uncontrolled avalanche path.

In the last decade or so, there have been several separate parties with near-miss events on this same feature. There are likely more that the author is unaware of—the following all occurred to either avalanche professionals or professionals in training. In each instance, there was a group travelling across the terrain with someone out in the lead. All had close calls where a member of the party fell through the cornice and was then hanging by their arms, feet kicking in space. Fortunately these events did not end in injury or worse.

The solution we came up with is simple. Because the relatively small

EXPLOSIVES CONTROL ON FOOL'S GOLD // B. THUMLERT

piece of cornice is difficult to access and quick to form, we now maintain a much lower traverse that avoids all exposure to the ridge. It may be a chore to take the more windward snow/scree option to make it to the col, but the extra effort is surely worth it. The hazard remains, but we do our best to alleviate any potential exposure. We also caution anyone who plans to travel on or near the ridge that the feature exists and has a history of surprising people.

As a take-away note for professionals, this should act as a reminder of the nuances of the mountain landscape. If you are not familiar with the terrain, stay well off the ridge whenever possible, even for micro-features that appear benign.

NEAR MISS, MEMBER OF THE PUBLIC, GOAT'S EYE MOUNTAIN

This event occurred on a late winter's day in one of the southwest-facing chutes accessed from the Goat's Eye chair. There were a number of fairly large chunks of cornice lingering along the cross-loaded ridges in this area, but efforts had been made to get rid of as many as possible. Early in the afternoon, the ski patrol received a call that there was a fresh pile of debris in one of the paths. They raced out to investigate and learned that a roughly 120-pound male had been standing on the very beginning of an overhanging portion of cornice in an easily accessed area when it failed in one go, with a 10m propagation. No slab was pulled on the slope below but the debris pile qualified as a size 2, piled up in a terrain trap gully feature to boot. Fortunately this was another near-miss event: no injuries, no lost gear. In the following days, we put a concerted effort into removing all the remaining pieces, with very mixed results: some failed quite easily, others were nearly impossible to dislodge.

The stable weather and non-event feedback leading up to this close call gave the staff no reason to suspect any of the cornices lingering in the area were touchy enough to be human-triggered. Evidently some were, while others were not. More information gathering combined with a more diligent approach to cornice control were seen as being the solution.

NEAR FATALITY, STAFF MEMBER, LOOKOUT MOUNTAIN

On this day, a team of patrollers were conducting avalanche and cornice control in a steep piece of north-facing terrain. There was a large, mature cornice above much of the slope, which was being tested by throwing a series of hand-charges tied to ropes in order to get airblasts just below the cornice and above the start zones below. Fresh cornice growth was breaking off with the charges and mostly small, loose avalanches were failing on the slopes. After control was complete, a patroller entered the run by skiing off a section of cornice at a point where a ridge comes up from the run to split the feature somewhat. Two more people then approached the edge, when much of the entire 80m cornice-line failed catastrophically. This massive load then triggered a dormant deep persistent weak layer near the base of the snowpack, resulting in a size 3 avalanche.

Incredibly, only one person was carried right down to the runout zone several hundred metres below. There was a full burial and an extremely heroic, efficient rescue performed by another patroller who had chosen to spot the crew from the bottom. The injured patroller was flown away with life-threatening injuries. The two others that fell with the cornice managed to dig in and stay high in the start zone.

This event changed many people's lives. A patroller nearly died, but thankfully a near-full recovery occurred after years of healing, both physically and mentally. Post-traumatic stress disorder was widespread among the staff, even among those who were absent on the day in question. Strategies and protocols were questioned, as well as revisiting the risk tolerance the program had been maintaining, and what it should strive to maintain. Was this a "low probability, high consequence" event that avalanche professionals literally lose sleep over? Perhaps it was closer to a "high probability, high consequence" event that was not recognized as such until after the fact.

Several key factors contributed to this accident: insufficient communication and a non-event feedback loop. The communication was not thorough enough for the team to opt to avoid this piece of terrain, which was the original plan. Assumptions were made and a hierarchy followed, and there may well have been too much weight placed on the stability of the slope itself and not enough on that of the cornice. The non-event feedback was the clincher: only small surface results, both on the slopes and the large cornice, led everyone involved

GALAXY RIDGE // R. CAMPBELL

to a false assumption. Had more shots been thrown, or the size of the charges increased, who knows what would have happened—possibly the same result, possibly not. Obviously, if the team had revisited the plan to travel through the terrain (which was still going to stay closed), then this accident could have been avoided. One of the most important aspects of the event's aftermath is that it has and will continue to inform and remind others—professionals or not—about the danger and unpredictability of cornices.

Fortunately, we continue to evolve and work together as an industry to prevent such tragedies from occurring again. Listing cornices as an avalanche problem in the InfoEx or on a public avalanche bulletin helps to spur operational discussions on likelihood and sensitivity to triggers, as well as to track the problem closely and be mindful of trends and outliers. One thing is for certain: there will always be outliers, and there will always be non-event feedback loops.

DEALING WITH CORNICES

Control work on cornices is something of a black art. I have spent hours digging in trunk-lines with sizeable charges only to crack the entire feature, making it even more suspect. On other occasions, trunk-lines have been dramatic and utterly productive, although I have personally never been a fan of all the exposure involved in setting up such a blast, and the time commitment associated with belaying, digging and stringing the shots in sequence. I have tried using shaped charges such as two-pound Rock Crushers sitting on top of the cornice—they do well on small pieces that are easy to place, but generally do not seem to be worth the extra expense. We have gotten only mediocre results after dropping bags of ANFO into large cracks or calving sections and then tamping them into place. Det cord can be piled methodically into these as well—this strategy seems to be more effective on smaller, less mature pieces. I have cut all sorts of cornices off with knotted rope, which again has had very mixed results: sometimes the first attempt is successful, but often the rope gets stuck, the cornice is too dense to cut through, or sometimes—in fact, far too frequently for my fancy—the whole overhanging piece gets cut right through and somehow stays put. In more accessible terrain, a concerted effort to shave and shovel cornices as they form is perhaps the optimal mitigation technique; however, this is often not a feasible solution due to access issues and time constraints. Wind fences can certainly help reduce the speed of cornice growth, but they do not prevent their formation outright.

So what is the final answer? For us, it's using everything in the arsenal. Our approach is to employ various techniques depending on the cornice in question: picking away as much as we can with shoveling and shaving new growth, building and maintaining wind fences on key ridgeline features, cutting small, touchy pieces with ropes, and hanging big charges off the lips of mature cornices seem to be the most effective in our terrain. We sometimes place a number of bags of ANFO with longer five-minute fuses on plastic saucer-style toboggans to deliver them off low-angled ridgelines—the toboggan can usually be brought back after the shot falls over the lip. This has produced the most consistent results for large mature cornices. If all of these approaches fail, then we are forced to play the final card for our operation: avoidance. Close the terrain, keep staff away and try another day.

As for the promised heuristic, I fear this one will be a tad on the disappointing side. I'm sure many readers have a similar one they bring out while teaching courses, training staff, guiding clients or just ski touring with friends. Mine is short and to the point: "Cornices are always trying to fool you. Be afraid."

Cornice Tales: Cornice Incidents at Revelstoke Mountain Resort

Chad Hemphill, Assistant Avalanche Forecaster

SINCE THE OPENING OF Revelstoke Mountain Resort in 2007, ski lifts and terrain openings have given both public and employees access to alpine and treeline ridgelines prone to cornice formation. The northwest ridge of Mt. Mackenzie divides the front side from the back side of the mountain. The predominant southwest flow of the wind, combined with large annual snowfall, results in large cornices forming over the north and northeast aspects. The following are accounts of operational and public incidents related to cornice collapses.

FEBRUARY 1, 2013: While conducting patrol sweep, a ski patroller was scouting an entrance on top of a cliff band feature above the run Sweet Spot. The cornice collapsed; he fell 30m with skis on and landed on the compacted run below. He sustained only minor injuries, was able to self-extricate and no first aid was rendered.

DECEMBER 23, 2012: Ski patrol received a report of an avalanche involvement outside of the ski area boundary in an alpine chute named Door#1. The victim fell through the cornice, triggered a size 2 avalanche, was carried 200 vertical metres and was partially buried. The ski patrol responded with a first party task force and avalanche dog strike team. The patient was equipped with a transceiver but was located visually with a clear airway and was evacuated by toboggan with only minor injuries. A secondary hasty search, transceiver search and dog search was conducted to ensure no further involvement.

MARCH 16, 2012: A near-miss incident involved a member of the professional ski patrol engaged in an avalanche control route with the use of explosives. The incident occurred on the alpine ridge of Powder Assault near the sub peak of Mt. Mackenzie.

The sub peak had been closed on March 15 due to extreme winds gusting to 80km/h, which forced a lift closure at 13:00. That morning, a 13.5kg explosive had been detonated on the aerial tramway to mitigate an overhead avalanche risk so the lower elevation terrain could open. Explosives were also deployed on the northwest ridge above Upper North Bowl; however, no explosives had been deployed along the ridge of Powder Assault.

The operational plan on March 16 was to reopen the sub peak to the public. Wind values had diminished and temperatures had cooled. I directed three control routes using a moderate amount of explosives to cover the northwest ridge and Powder Assault. Another ANFO charge was detonated on the tram and four two-kilogram charges were allotted for the Powder Assault ridge. A fourth-year team member with an extensive avalanche control background prepared his first shot of the route by tying it to a rope. He ignited the fuse and threw the shot over a large cornice overhanging a 15m cliff. As the rope became taut, the cornice failed and pulled back right to where he was standing. He managed to jump back and not fall with the 25m section of cornice and the lit explosive. He was uninjured and only lost his ski pole.

A number of errors occurred during the hazard forecast that morning. I used an availability bias while looking at the wind values over the previous 24 hours. I concentrated on the maximum wind gust and assumed that there would be more sublimation than cornice development, when in fact the average wind speed was between 28-36km/hr. I was anchored to my assumption and didn't build enough explosives for the route, and inadequately adjusted my direction when observing deep snow on the ridgeline.

Steel and bamboo ridge markers had been placed in the summer at the edge of the rock. At this point in the season, these markers were buried and the rope line delineating the edge of the ridge had been misplaced, making it too close to the edge. The patroller's rope was also too short to allow the shot to clear the edge, which prompted him to step on the other side of the fence line.

Permanent longer edge definition has been identified as a risk treatment slated to be placed on all exposed ridgelines. It has also been communicated that fence lines will act as the safe line if the edge definition is buried, and each member is required to have a length of rope that enables them to stand on the safe side of the fence while deploying explosive charges.

JANUARLY 23, 2012: During the annual Avalanche Awareness Days event, the ski patrol received a report of an avalanche outside the ski area boundary in an alpine chute above Greely Bowl named Door #4.

A party of four had looked at the line from below and made a plan to access the route from the ridge. The first member of the party approached the "get-in" without his snowboard, fell through the cornice and triggered a deep slab avalanche that released to a basal crust layer. He was carried 500 vertical metres and was completely buried.

An avalanche rescue response was initiated prior to the confirmation of an involvement. As the first party task force was en route, two off-duty patrollers were teaching an AST course in Greely Bowl. They witnessed the powder cloud but were unable to determine an involvement. An audible call for help could be heard throughout the bowl that was so loud it was difficult to discern where the voice was coming from. By the time we received confirmation of the involvement, the first party task force was conducting a transceiver search with an avalanche rescue dog team close behind. The victim was located by transceiver (which he had borrowed from his roommate that day) and was recovered conscious and breathing after being buried for 25 minutes. The voice was that of the victim yelling from underneath the snow. He was evacuated by toboggan and helicopter to the local hospital where he was released a few hours later with minor injuries.

JANUARY 13, 2012: A ski guide touring with a group of guests approached a ridge feature in the col between Mt. Mackenzie and Montana peak to the south of the ski area boundary. We had hosted the Freeride World Tour ski and snowboard competition on the east face of Mt. Mackenzie the previous day, and over 200 people crowded the ridge to watch the event. The intention of the guide was to show his group the venue. The cornice collapsed beneath him and triggered a size 2 avalanche, which released to ground over a rock slab. He was able to self extricate after being carried 400m and partially buried. He was evacuated by helicopter with minor injuries.

JANUARY 19, 2010: Ski patrol received a report that someone had fallen through a cornice 50m from the ski area boundary on the alpine ridgeline of Powder Assault, above Door#1. We deployed two response teams, one to the top of the ridge and one to the runout of the size 2.5 avalanche triggered by the cornice collapse. The scene at the top revealed footprints leading to a broken cornice edge with one ski pole in the snow beside the fracture. The avalanche ran 300m down two sides of a large rock buttress and the subject managed to remain on top of the buttress. He was extricated by helicopter long-line with no injury.

FEBRUARY 2009: Two professional ski patrollers were conducting avalanche control along the alpine ridgeline of Powder Assault. I asked for an explosive to be placed in an out-of-bounds northeast-facing feature overhead of Greely Bowl. The patroller had tied a one-kilogram charge to a rope and as he stepped off his skis he punched into the snow near a rock. The cornice failed and propagated 100m, triggering a size 2 avalanche with an average depth of 60cm. The patroller was left hanging from the crown and managed to climb back to safety without injury.

LESSONS LEARNED

Throughout these events, the staff and public involved have been fortunate to sustain only minor injuries. Cornices often overlie terrain with serious consequences where a fall could result in injury or death, and often trigger an avalanche increasing the mass of snow moving down the mountain and escalating the possibility of a burial.

Cornices build quickly during storms and periods of moderate winds (26-40km/h) and the fastest development seems to be between 35 and 40 km/h. Soft cornice development can lead to long propagations resulting in a large trigger on the slope below. When cornices are fresh, there is most likely a slab on the leeward slope that could also be triggered. Mature cornices that consist of hard, high-density snow have the ability to fail and pull back into the snow that is usually on the safe side of the ridge.

As part of avalanche operations at Revelstoke Mountain Resort, cornices are assessed daily under the avalanche hazard and risk forecast. We control cornices to keep them small, vertical and not overhanging. Rope lines are conservatively placed away from the line where the rock ends and the snow begins. During periods of low avalanche risk, regular maintenance consists of kicking small cornices with skis above slopes with low exposure. In areas of higher risk, explosives are used to trigger the cornice. One- or two-kilogram charges tied to a cord and hung over the cornice offer an effective shot placement to impact the cornice. This often results in a load applied to test the slope below. As cornices grow bigger, trunk lines linking a series of explosive charges with detonating cord are placed by a worker on belay. However, cornices beyond the ski area boundary should be considered "uncontrolled."

When approaching a cornice, I always ask myself these questions: How big is it? Where is the edge of the rock? Where is it going to break? What will happen if it does break? The only consistent answer to these questions is "Never trust a cornice!"

Managing Unpredictability at Whistler Blackcomb

Tony Sittlinger

IN THE ARCHITECTURAL world, cornices are horizontal decorative moldings that crown structures like walls or columns. In the mountains, they are overhanging masses of snow and ice that form mostly along ridgelines or along sharp or marked transitions in wind-exposed terrain. From the correct vantage point, snow cornices can be aesthetically pleasing, but from the wrong location can pose a significant hazard.

The very same cornices that present an unpredictable hazard can be a useful tool when managed correctly. Cornices can be used to test slope stability in the backcountry as well as in industrial settings. In the ski area, cornices can be used as triggers that are exponentially larger than the explosives used to remove them.

Cornices grow differently every season. In recent years, changing weather patterns have resulted in a wide range of prevailing wind directions. This has led to annual variations in cornice size and distribution. Some cornices fail to form where we would expect them, while others appear where we've never seen them before. One constant is the fantastic rate of cornice growth that can happen when temperatures near zero. Occasionally, cornices will grow with nothing more than a strong warm wind and some redistributed snow stripped from windward slopes.

Given their potential for rapid growth and the questionable decisions made by some of our guests while travelling near them, at Whistler Blackcomb we have had to learn how to effectively trim cornices on the ski hill. As ski patrollers we use a variety of methods to deal with small cornices. These methods include kicking off small noses, sawing small chunks off with rope, or even throwing rocks at thin "diving boards." More typical of our avalanche control operation is the testing of new snow instabilities with one-kilogram explosive charges. As mentioned earlier, a cornice release is often a more significant test to the slope below than the explosive detonation itself.

We noticed several years ago that hanging a one-kilo charge over a curling cornice nose would provide a good air-blast to the slope below, but it did not remove much of the cornice nose. This led to some experimentation with shot placement. These experiments resulted in changes to how we deploy charges along corniced ridge lines. We now train patrollers to place their roped charge on the top surface of the cornice where the charge is just out of sight. This technique has proven to be very effective at removing a much larger volume of the cornice nose because they shear farther back, leaving behind vertical faces.

As cornices get larger they become more resistant to explosives testing. Cornices can quickly exceed a size where one-kilogram charges will produce acceptable results. The obvious adjustment is to simply use bigger charges, but there is a downside to this approach. Bigger charges may effectively trim the cornice, but their results can also present some long term problems.

Large charges tend to take "bites" out of cornices. This seems to be true of every charge size from 4-26kg. The size of the bite varies, but rarely do we see a result with a nice vertical wall. These bites can result in very rapid rebuilding of the cornice. The holes in the edge of the cornice line can quickly bridge over resulting in even bigger cornices that are now attached to the ice-hard root created by the heat from the detonation.

We found a way to take care of cornices without these side effects. When larger cornices are hanging out over our terrain and regular hand charging will not clean up the hazard, we get out the detonator cord and link pairs of charges together. We refer to these linked charges on the surface as "Y" shots.

Y shots have proven so effective that they have almost eliminated my favourite kind of avalanche blasting from our operation: long-linked detonator cord missions. Y shots are typically two doubles or triples linked by detonator cord and placed about 10m apart on the roof of a relatively mature cornice. The effect is amazing for such a simple, fast technique. We can remove relatively large cornices quickly, with little or no residual over-hang in about the same time it takes to deploy a few hand charges.

Y shots are both a safe and effective means of addressing cornice hazard. With Y shots there is no need to approach the cornice edge, as the charges can be delivered from a safe distance and the pig tail tied to the trunk line in the safe zone.

Despite the success of the Y technique, some monster cornices still form. As mentioned earlier, cornices can grow quickly during periods of mild and windy weather, and we operate until the end of May. Even a big Y shot will not bother a 10m high cornice wall. This is when we dig out the "kerplunza" and go old school.

Kerplunza missions are just that: missions. Two teams are required to stage these projects. A rope team is responsible for anchors, ropes and belaying the blasting crew. The blast crew is responsible for establishing the "safe line," assembling the charges with pig tails and a trunk line, ensuring the danger zone remains clear, and sharing the kerplunza duties. The safe line is set behind the cornice roof and no one is allowed to venture past it. While it is very important that everyone be focused and attentive to detail, these projects can be fairly social affairs.

In case you haven't had the pleasure, a kerplunza is made of tapered steel pipe with a t-handle on one end, about 1.5m long and weighing about 25kg. This delicate bit of technology is driven into the snow until the handle is at the surface, creating 1.5m-deep hole for each charge used in the blast. A big cornice can require 15 to 25 holes. We've talked about using an auger, but that seems too refined.

In the past we spaced the holes at about 2-2.5m and used 2kg charges in each hole. This worked reasonably well, but we occasionally ran into the "bite" problem. We now make more holes, approximately 1.5m apart and we only place a 1kg charge in each hole. This requires that more time and effort be expended working the kerplunza, but the result is usually a beautiful plumb wall of completely smooth, hard snow with minimal "bite marks" along the ridge line.

In my opinion, if you are going to blow stuff up you may as well go big, and the results should look good too.

KERPLUNZA // TONY SITTLINGER

Snow Cornices and Cornice Fall Avalanches: **A Short Review of Current and Past Research**

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INTRODUCTION

Snow cornices are a natural hazard causing fatalities worldwide. Cornice hazard has two distinct components, with people either being killed by stepping onto a cornice, which then collapses, or by being buried by a cornice-induced avalanche (cornice fall avalanche). In 2013, there were two notable accidents reported involving the first component: one in Haines, Alaska, and the other in Tromsø, Norway, where backcountry users stepped onto a cornice which consequently collapsed underneath them. This also happened in a number of fatal accidents involving famous alpinists such as Hermann Buhl, Alfred Pallavicini and Fritz Kasparek.

It is therefore surprising that only limited research has been conducted on cornice accretion (formation), deformation and collapse, and the trigger of cornice fall avalanches.

RESEARCH HISTORY

Cornices are wedge-like snowdrifts that form on lee sides of ridges and slope inflections (Montagne et al., 1968). Fundamental work on cornices was carried out in the European Alps, due to their particular shape, hazardous nature, and their ability to trigger avalanches when collapsing (Paulcke and Welzenbach, 1928; Seligman, 1936; Welzenbach, 1930). These German and Austrian geographers thought about snow as sediment, accumulating in layers. They conducted field studies and small-scale experiments on cornice accretion and its controls, internal stratification and mechanical behavior. They further distinguished between different cornice types, based on their formation (suction vs. pressure cornices), their duration (permanent vs. temporary), and their topographical location (ridge vs. plateau).

Seligman (1936) translated the newly-invented terminology into English, so this early work became accessible to the international research community. However, only in the late 1960s did cornice research gain momentum again, mainly due to the efforts of John Montagne, working on the Bridger Range in Montana, USA. Montagne et al. (1968) were interested in the internal deformation mechanics of a cornice. They attributed snow creep and glide to the opening of tension fractures between the cornice mass and the ridgeline bedrock. Montagne was also concerned about the mechanics of cornice accretion. Together with his British colleague John Latham, he hypothesized that besides the initial mechanical binding of snow crystals, the refreezing of a liquid water layer due to frictional contact and pressure melting at temperatures close to 0°C, and electrical forces in the adhesion process were of importance (Latham and Montagne, 1970).

In the next decades, only limited cornice research was conducted. One case study looked into the distribution of snow grain sizes in the cornice surface layer and found decreasing grain sizes from the cornice root to the leading edge (Naruse et al., 1985). McCarty et al. (1986) monitored one particular cornice and reported its quick mechanical response to meteorological change. Kobayashi et al. (1988) dug a trench on a ridgeline and calculated a collection coefficient of windblown snow particles in the range of 2-50% at a newly-forming cornice. Only the more recent work by Burrows and McClung (2006) worked on identifying key meteorological triggering factors for cornice fall avalanches in western Canada (Kootenay Pass, BC) They determined that loading the cornice with additional snow through precipitation and wind, distinctive air temperature changes, rain-on-snow events and direct insolation were the key meteorological factors. Recent work by the team of Prof. Lehning from SLF in Davos rather works with cornices as wind-induced snow distribution features in complex terrain (Mott et al., 2010).

SVALBARD, NORWAY CASE STUDY

Svalbard is a Norwegian archipelago, located between 76 and 79 °N in the High Arctic. Glaciers

CORNICE FALL AVALANCHES IN LONGYEARBYEN, NORWAY, MARCH 2009. THE LEFT NATURALLY RELEASED WHILE THE RIGHT WAS ARTIFICIALLY TRIGGERED // M. ECKERSTORFER

cover about 60% of Svalbard; the remaining 40% is underlain by permafrost. Snow cover persists for eight to nine months at lower grounds, and year-round at higher grounds. In central Svalbard, where the main settlement Longyearbyen is located, the geological setting determines extensive plateau mountain topography and deep valleys (where the town is located). Steep, concave slopes rise up to 500m a.s.l., sharply transitioning into flat plateaus. These plateaus act as snow source areas for extensive cornice accretion on the leeward plateau edges. Annual precipitation rates are only in the order of 200mm w.e. at sea level, however due to the lack of any high vegetation and orographic enhancement, snow is freely redistributed in the landscape.

Historically, during coal mining operations on the slopes underneath the plateau edges, cornices were controlled using explosives. This safety measure not only mitigated the destruction of the mining facilities, but also of the barracks on the slope foot. The Norwegian Geotechnical Institute (NGI) later suggested installing snow fences on the plateau as a permanent measure, however, such fences were never constructed (Hestnes, 1996).

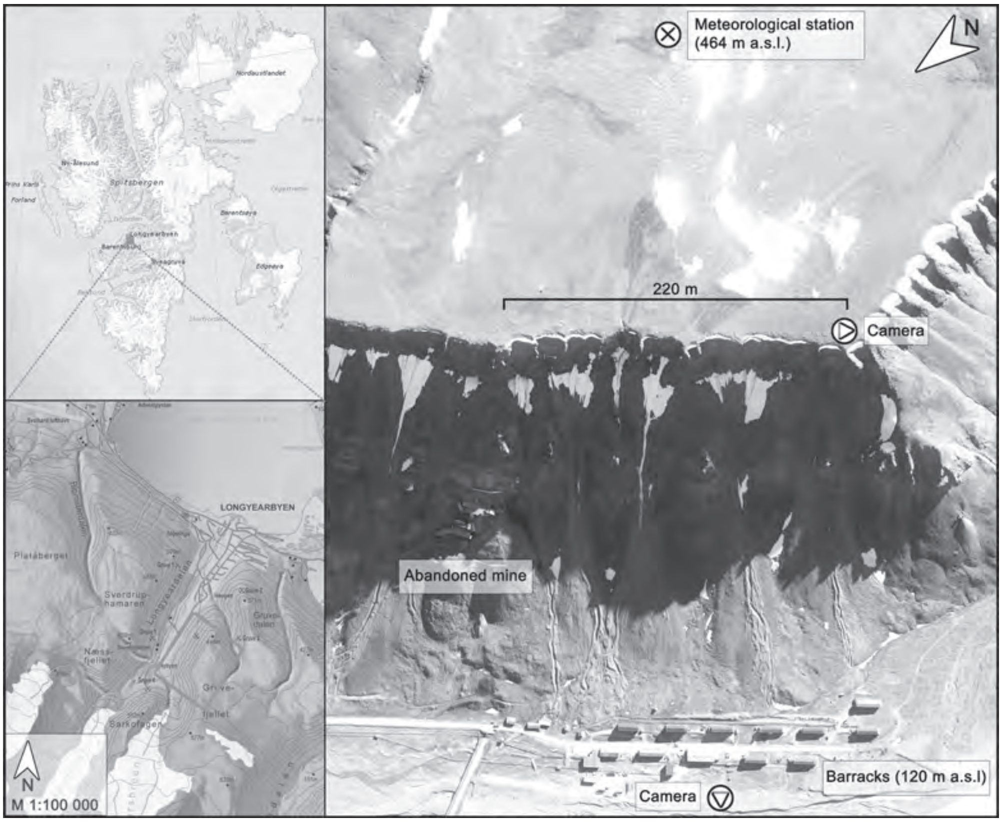
Presently, the mine is abandoned; however, the barracks are used as student and tourist quarters. In spring 2008, snow mounds were piled up in front of the barracks after a tension fracture in one of the cornices was observed. At the end of March 2009, a cornice triggered a slab avalanche that destroyed the historical mining infrastructure. As a mitigation measure, the local government controlled the remaining cornice with explosives. The falling cornice triggered another slab avalanche that ran across the main road to the student housing, and a student had a narrow escape.

These events lead to increased research efforts on cornices and cornice fall avalanches at the University Centre in Svalbard (UNIS), located in Longyearbyen. Prof. Hanne H. Christiansen initiated a research project in 2006, with the aim to systematically monitor all avalanche activity in the most used area around Longyearbyen. In a three-year period, over 800 avalanches were observed in a 17km^2 area and stored in a database along with their topographical parameters and associated snow and meteorological conditions (Eckerstorfer and Christiansen, 2011). This first systematic effort to describe the avalanche climate of central Svalbard had a surprising result. The most dominant avalanche type were cornice fall avalanches, with 45% of the total (Fig. 2). The simple reasons are the above-mentioned plateau mountain topography and a prevailing winter wind direction, forming cornices on leeward edges and slope inflections (Eckerstorfer and Christiansen, 2011). The vast majority of avalanches were observed from April onward, which the researchers initially attributed to the time a cornice needs to accrete, deform to the point of natural collapse, and then trigger an avalanche upon impact. However, little was known about these processes, thus the focus of the still infant avalanche research in Svalbard shifted towards cornices.

METHODS

The field-based approaches were inspired by the early work of Seligman in Europe and Montagne in the USA, and focused on a particular set of cornices above the student and tourist barracks of Longyearbyen. Methodologies included daily time-lapse camera monitoring from different angles, along with snow stakes placed on the edge to accurately read off cornice dimensions, as well as frequent field work to the cornice site. Temperature loggers were installed on the ground surface near the edge of the plateau and on the snow stakes to monitor differential response of snow layers within the cornice due to meteorological conditions. On the main plateau, approximately 100m away, a meteorological station recorded

FIG. 1: MODIFIED FROM VOGEL ET AL. (2012). LOCATION OF THE STUDY SITE ON A PLATEAU MOUNTAIN ABOVE THE BARRACKS OF THE SETTLEMENT LONGYEARBYEN. THE CORNICE STUDY SITE ALONG THE EDGE OF THE PLATEAU MOUNTAIN IS 220 M LONG. THE LOCATION OF THE TWO AUTOMATIC TIME-LAPSE CAMERAS IS INDICATED, AS WELL AS THE LOCATION OF THE METEOROLOGICAL STATION.



basic weather data including air temperature and wind speed. All data were collected during two snow seasons (October 1-July 31).

CORNICE ACCRETION AND MELTING

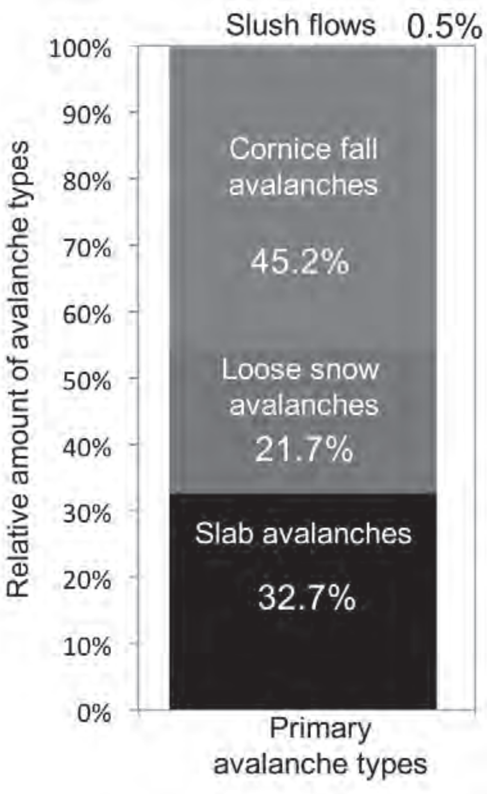
Initial cornice accretion started during the season's first snowfall in October, with maximum wind speeds of 11m/s. After the first two snowstorms, the cornice was in place, with already 90% of its maximum vertical height (Eckerstorfer et al., 2013). During such accretion events, the wind direction was perpendicular to the edge for the majority of time, ± 5°. Average wind speeds were 12m/s, with maximums of up to 30m/s (Vogel et al., 2012). These characteristic meteorological thresholds were significantly different to those from no accretion days (Fig. 3). Only air temperature did not vary between accretion and no accretion days (Fig. 3). Each consequent accretion event then added one or multiple snow layers to the cornice mass, accounting for its stratigraphy, similar to the seasonal snowpack. These layers were initially bedded horizontally, gradually folding downward due to snow creep, giving the cornice its typical roll face and roll cavity. Both the roll cavity and newly accreted snow layers were weak spots where many partial cornice failures were observed (Fig. 4).

These failures reduced the cornice volume, along with scouring events, when maximum wind speeds of over 30m/s blow straight towards the cornice's leading edge (Vogel et al., 2012). Maximum vertical and horizontal extent was reached in April (Fig. 4), when the observed cornice was about 6m in height and 12-14m in length. As air temperatures rose above 0°C in May, the cornice melted away within a two-week period, making it a seasonal cornice.

CORNICE TENSION CRACKING AND TILTING

While the snow temperature in the lower 50cm of the cornice remained constant below freezing, the upper parts were subject to large, air temperature-induced fluctuations. Temperature gradients within the cornice mass were at times large enough to create weak, faceted layers, as well as differential creep rates between snow layers (Eckerstorfer et al., 2013). This differential movement inside the cornice mass would have induced high shear stresses and strain rates, which we did not directly measure. However, we hypothesize that these stresses and strains were responsible for the opening of cornice tension cracks. Such cracks look like crevasses and effectively detached the entire cornice mass from the snowpack on the plateau. We did not monitor

FIG. 2: MODIFIED FROM ECKERSTORFER AND CHRISTIANSEN (2011). RELATIVE AMOUNT OF AVALANCHE TYPES, OBSERVED IN A 17-KM² LARGE STUDY AREA IN CENTRAL SVALBARD. THE OBSERVATION PERIOD WAS BETWEEN 2006-2009 (N=800).



enough tension cracks to pinpoint triggering meteorological conditions; however, two observations support the idea that similar mechanisms responsible for fracture initiation in slab avalanche release were responsible. One tension crack was observed after a heavy snowstorm, suggesting slow and gradual stress increase by snow loading, while another tension crack catastrophically opened after one researcher accidently stepped onto the cornice.

We monitored the opening rates of one tension crack over an almost two-month period and found a linear development, suggesting creep and glide processes within the cornice mass being the driving mechanisms (Vogel et al., 2012). As the cornice mainly rotated along its pivot point, deeply buried close to the ground surface, the linear opening of the tension crack was not influenced by meteorological fluctuations (Eckerstorfer et al., 2013).

CORNICE COLLAPSE AND CORNICE FALL AVALANCHES

Over the period of two seasons, along the 220m-long edge of our study site, a total of 180 cornice collapses were observed (Fig. 5) (Vogel et al., 2012). The majority of releases took place between May and the end of June each season, both small failures as well as entire collapses. By this time in the season, full-developed cornices were able to crack, tilt and fail. However, large cornice fall avalanches were also observed as early as December. Entire cornice collapses always developed a tension crack before failure, with a lag time between tension crack opening and failure of one week to two months (Vogel et al., 2012). Thirty-two percent of all cornice fall avalanches were size 2 avalanches and 22% size 3, directly correlating to the size of the collapsed cornice. The entrainment of snow in the avalanche path was of minor importance for the actual avalanche size.

Vogel et al. (2012) analyzed meteorological conditions during cornice fall avalanche and non-avalanche days but found no difference in maximum wind speed and amount of precipitation for the 24 hours preceding the event. Only air

FIG. 3: MODIFIED FROM VOGEL ET AL. (2012). DAILY METEOROLOGICAL VALUES FOR OBSERVED CORNICE ACCRETION DAYS AND NON-ACCRETION DAYS FOR TWO SNOW SEASONS.

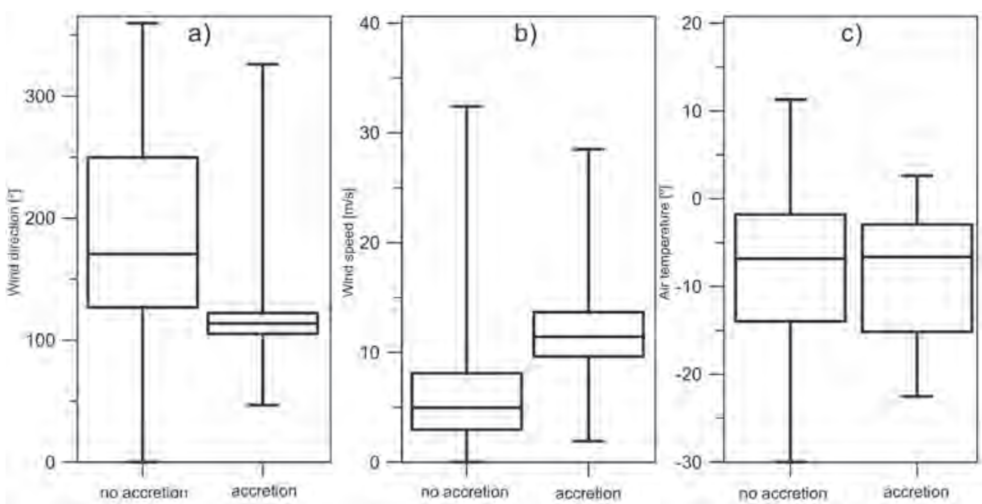


FIG. 4: MODIFIED FROM VOGEL ET AL. (2012). MODEL OF THE SEASONAL CORNICE DEFORMATION DYNAMICS FROM INITIAL CRACK DEVELOPMENT (B, C), CRACK OPENING (D), AND EVENTUAL COLLAPSE (E) OR MELTDOWN (F). THE CORNICE TERMINOLOGY IS EXPLAINED IN (A).

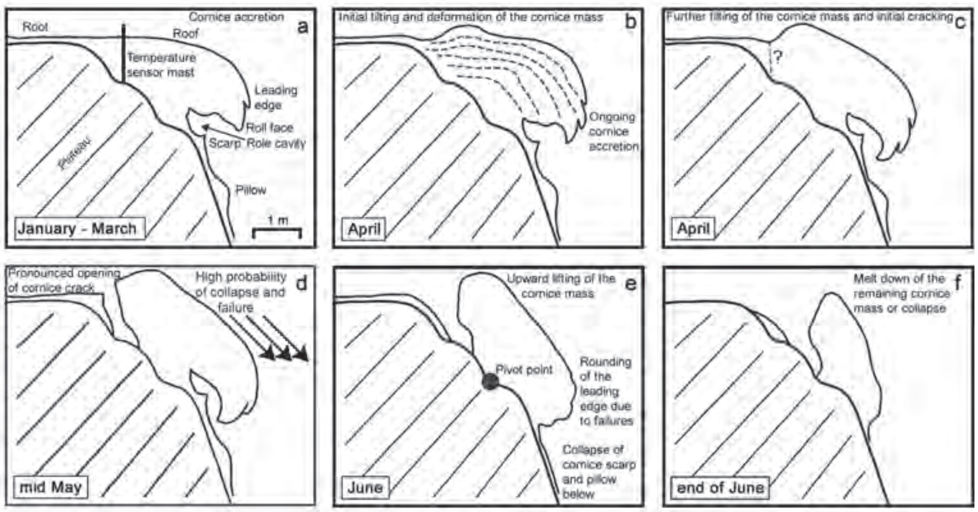
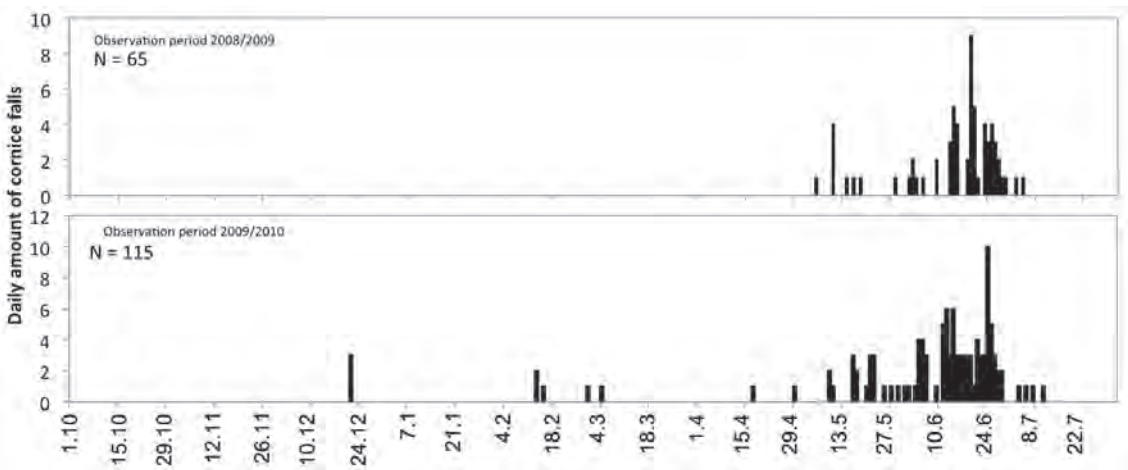


FIG. 5: MODIFIED FROM VOGEL ET AL. (2012). DAILY TIMING OF CORNICE FALL AVALANCHES DURING TWO SNOW SEASONS.



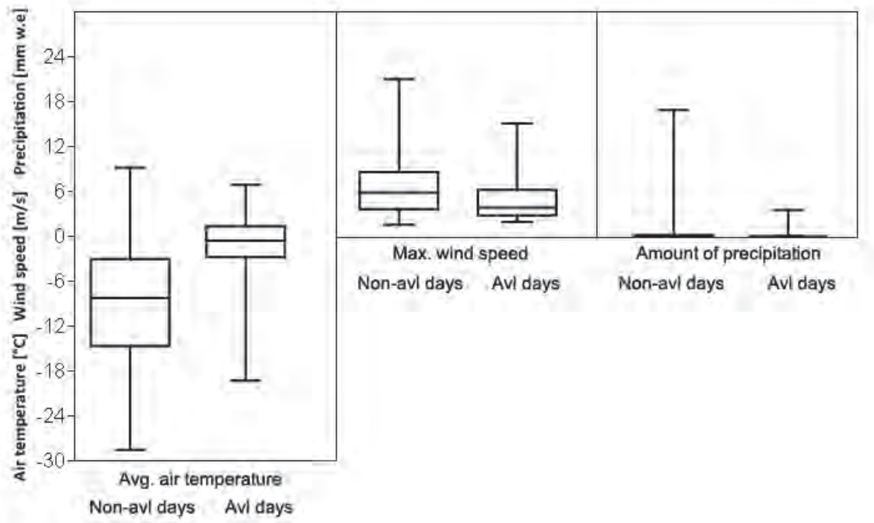
temperature during avalanche days was on average higher, probably as a function of maximum activity at the end of the snow season, and therefore probably also a function of direct insolation (Fig. 6).

CONCLUDING REMARKS

The detailed field studies from a particular set of cornices in central Svalbard was inspired by previous work from the European Alps and Montana's Bridger Range. Limited research has been conducted on cornice formation and deformation, leading to cornice collapse and cornice fall avalanches. However, this hazard-related research is important, as it provides improved process understanding, which will ultimately reduce the number of accidents and fatalities.

The recent work from Svalbard underlines the complex nature of cornice dynamics, reinforces the somewhat predictable initial opening of tension fractures, and the seemingly random entire cornice collapse. Detailed meteorological and field monitoring over a longer time period to establish a robust dataset would assist in the development of significant threshold values to distinguish cornice fall avalanche from non-avalanche days. However, the difficult accessibility of cornices makes such work challenging and dangerous. We therefore propose the use of ground-based remote sensing technology such as LIDAR to repeatedly scan cornices following their evolution. We also think that central Svalbard, with its existing cornice research efforts, natural setting, natural hazard application, and relatively easy field accessibility is an ideal cornice study site.

FIG. 6: MODIFIED FROM VOGEL ET AL. (2012). DAILY METEOROLOGICAL VALUES DURING AVALANCHE (AVL DAYS) AND NON-AVALANCHE DAYS (NON-AVL) FROM TWO SNOW SEASONS.



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An Up-to-Date Perspective on the **Effectiveness of Avalanche Airbags**

Pascal Haegeli, Markus Falk, Emily Procter, Benjamin Zweifel, Frédéric Jarry, Spencer Logan, Kalle Kronholm, Marek Biskupič, Hermann Brugger

OVER THE LAST FIVE YEARS, the use of avalanche airbags has increased dramatically, both among professional guides and amateur recreationists. While there were only a couple of different airbag types on the market ten years ago, backcountry enthusiasts can now choose from a wide range of models produced by at least four different manufacturers. In additional, a few new manufacturers are pushing into the growing market with their own innovative designs.

Avalanche airbags have a tremendous potential to save lives, since they are the only avalanche safety device that can directly prevent or reduce the severity of avalanche burial—the root cause of the majority of avalanche deaths. As a consequence, some avalanche warning centres now recommend airbags as a useful complement to the traditional avalanche safety tool kit of transceiver, probe and shovel. Whereas the underlying mechanism for the effect of avalanche airbags[1] has been validated conclusively using mathematical models and field tests, the precise effect of airbags on avalanche mortality is still being debated. While manufactures like to present airbags as the ultimate avalanche safety device (e.g., "97% survival", "8x safer!"[2]), prominent avalanche educators try to warn against this "silver bullet" marketing by highlighting that the number of lives saved per 100 fatalities might only be in the single digits.[3] Since both sides claim their analyses are based on solid data and rigorous statistics, it is difficult for the layperson to determine what's right and what's wrong. However, an accurate and easily understandable presentation of the true effect of airbags on avalanche mortality is important. According to a study by Christie (2012) from Backcountry Access, survival statistics are the most important reason for airbag purchases among their customers.

A number of independent statistical evaluations have assessed the effectiveness of airbags, the most prominent of them is the analysis by Brugger et al. (2007). However, due to the small number of incident records involving airbags available at the time, the analysis has limitations and the results should be interpreted cautiously. More recently, Shefftz (2012) compared the available ABS airbag involvement data to various avalanche accident datasets to estimate the range of impact airbags might have on avalanche survival. However, this type of comparison also has challenges that limit the resulting conclusions. The goal of this article is to provide an up-to-date perspective on the effectiveness of airbags based on a detailed study we recently published in the journal *Resuscitation* (Haegeli et al., 2014). In addition to simply presenting the results of the study, we also want to take this opportunity to describe the challenges that evaluations of avalanche safety equipment face in detail. We hope that this information will help backcountry recreationists to assess marketing claims more critically and make better informed choices when deciding whether to add an airbag to their avalanche safety kit or not.

MORTALITY, MORTALITY DIFFERENCE AND MORTALITY RATIO

Whenever you read statistics—airbags or otherwise—you should immediately ask yourself the following questions:

- What is the question they are trying to answer?
- Where is the dataset coming from?
- What kind of assumptions were made during the analysis?

Without a clear understanding of this context, the presentation of statistical figures is meaningless, even if the number might actually be technically correct.

The first step of examining the effectiveness of any safety device is therefore to specify the question you want to answer. We think that the most interesting questions for the evaluation of avalanche airbags are:

1) How does the use of an avalanche airbag affect my chance of getting killed in a serious avalanche involvement?
2) How many avalanche fatalities could be prevented with the widespread use of avalanche airbags?

The statistical measures used to answer the two questions are the *mortality difference* for the first

TABLE 1: DATASET OF BRUGGER ET AL. (2007).

	Survived		Killed		Total
Without an airbag (control)	1191	(81%)	278	(19%)	1469
With an airbag (treatment)	34	(97%)	1	(3%)	35
Total	1225		279		1504

question and the *mortality ratio* for the second question. These two measures are closely related, but they offer different perspectives on the effectiveness of airbags and it is important to clearly understand their differences.

We are using the results of the study by Brugger et al. (2007) to explain the meaning of these two statistical measures in detail. The dataset used by Brugger and colleagues consisted of 1,504 avalanche involvements occurring in open terrain in Switzerland and Austria between 1990 and 2005. Thirty-five of the avalanche victims included in this dataset were equipped with airbags during their involvement. Out of 100 victims involved in avalanches without airbags (control group), 81 survived because they did not sustain any fatal injuries and did not get buried or were found and extricated in time (Table 1). This is equivalent to a mortality rate of 19%. Out of 100 avalanche victims equipped with airbags (treatment group) 97 survived, which corresponds to a mortality of 3%.

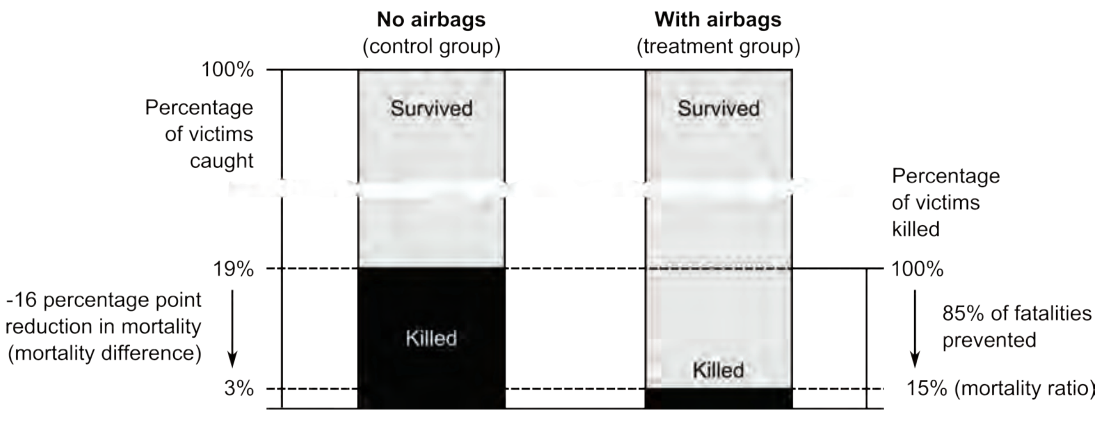
Based on the data presented in Table 1, Brugger et al. (2007) showed that that the use of avalanche airbags results in a significant reduction of the mortality by 16 percentage points from 19% to 3% (Fig. 1, left axis). This is the so-called *mortality difference*. The *mortality ratio* scales or normalizes the mortality of victims with airbags with the original mortality of victims without airbags (mortality of the treatment group divided by the mortality of the control group; Fig. 1, right axis). In the study of Brugger et al. (2007), the mortality ratio is 15%, which means that out of 100 avalanche victims killed without airbags, 15 would still die even if all were equipped with avalanche airbags. In other words, 85 of 100 fatalities could have been prevented with the use of airbags.

ONLY RELEVANT CASES

To date, the vast majority of analyses on the effectiveness of airbags were based on an airbag involvement dataset that was collected collaboratively by the ABS airbag manufacturer and the WSL Institute for Snow and Avalanche Research SLF. This dataset is almost entirely European and includes a wide spectrum of incidents ranging from large avalanches with multiple burials to small avalanches where single victims managed to avoid being buried. While all of these cases provide valuable information on airbag performance, not all of them are suited for a statistical analysis of the effect of airbags on mortality. A detailed description of the criteria used to put together the analysis dataset (were all known airbag incidents included in the analysis or did it only focus on a specific subset?) is of utmost importance when interpreting statistical results.

One of the goals of our study was to collect a larger and geographically more comprehensive dataset that is well suited for truthfully estimating the effectiveness of airbags. Existing records of well-documented avalanche accidents involving at least one airbag user were collected from data sources in Canada (Canadian Avalanche Association), France (National Association for Snow and Avalanche Studies), Slovakia (Avalanche Prevention Center), Norway (Norwegian Geotechnical Institute, Norwegian Red Cross), Switzerland (WSL

FIG. 1: MORTALITY DIFFERENCE AND MORTALITY RATIO ILLUSTRATED WITH THE RESULTS OF BRUGGER ET AL. (2007)



Institute for Snow and Avalanche Research SLF) and the United States (Colorado Avalanche Information Center).

Since airbags are designed to prevent or reduce the severity of avalanche burial, we focused on avalanche involvements with the potential for full burial. This was accomplished by including only incidents with avalanches of a destructive size 2 or larger according the Canadian or American avalanche size classification and including only victims who were seriously involved in the avalanche. This means that they were either seriously involved in the flow of the avalanche or hit by the avalanche from above then partially or completely buried. Victims who were only slightly moved at the edge of the avalanche, managed to remain standing during entire involvement or even ride out of the avalanche were excluded from the dataset, as airbags are unable to affect the outcomes of these types of involvements. The resulting dataset consists of 245 incidents with a total of 424 seriously involved individuals. Two hundred and forty-six (58%) of the included victims had an inflated airbag, 61 (14%) had an airbag that was not inflated during the involvement, and 117 (28%) were not equipped with airbags.

UNBIASED CONTROL GROUP

The accurate assessment of airbag effectiveness requires a reliable control group of victims without airbags. The challenge is that many avalanche incidents with good outcomes (i.e., no fatalities or major injuries) simply never get reported. This prevents us from calculating a reliable base mortality for avalanche involvements. Since both airbag manufacturers and avalanche safety researchers are actively hunting for the information on avalanche accidents involving airbags, it is likely that the reporting rate of non-fatal avalanche accidents with airbags is considerably higher. This difference in reporting rates can unintentionally skew the results of statistical analyses on the effectiveness of airbags.

To obtain a control group that is as comparable as possible to our airbag cases, we limited our analysis to only include accidents that involved both users and non-users of avalanche airbags. This allowed us to extract both the treatment group and the control group from the same accidents, therefore avoiding any reporting biases. However, the price for this unbiased control group is a considerably smaller dataset that only includes 35% (106 of 207) of the available records on seriously involved individuals with airbags and is skewed towards larger avalanches with multiple involvements. Remember this when interpreting the final results.

CONTROLLING FOR OTHER FACTORS AFFECTING MORTALITY: ADJUSTED MORTALITY RATES

Airbags are clearly not the only factor affecting your chance of surviving an avalanche involvement. The size of the avalanche, your location when the avalanche releases, the character of the runout zone, whether you get injured and whether you wear an avalanche transceiver all have the potential to affect the outcome of your involvement. Because all of these factors work together, a simple cross table like the one shown in Table 1 is unable to correctly separate the effect of airbags from the other contributing factors.

To account for the other contributing factors in our analysis, we collected information on a large number of parameters describing the characteristics of the incident, the avalanche and the victims. We then examined the influence of all these factors on mortality simultaneously using a statistical technique called binomial logistic regression analysis. This method allows us to properly identify and separate effects of the individual contributing factors. The results of this analysis were then converted into *adjusted mortality rates*, which are interpreted in the same manner as mortality rates calculated from cross tables. The interested reader is referred to our paper in *Resuscitation* to get the full list of parameters included in the analysis and read the full details on the logistic regression analysis.

WHAT DID WE DISCOVER?

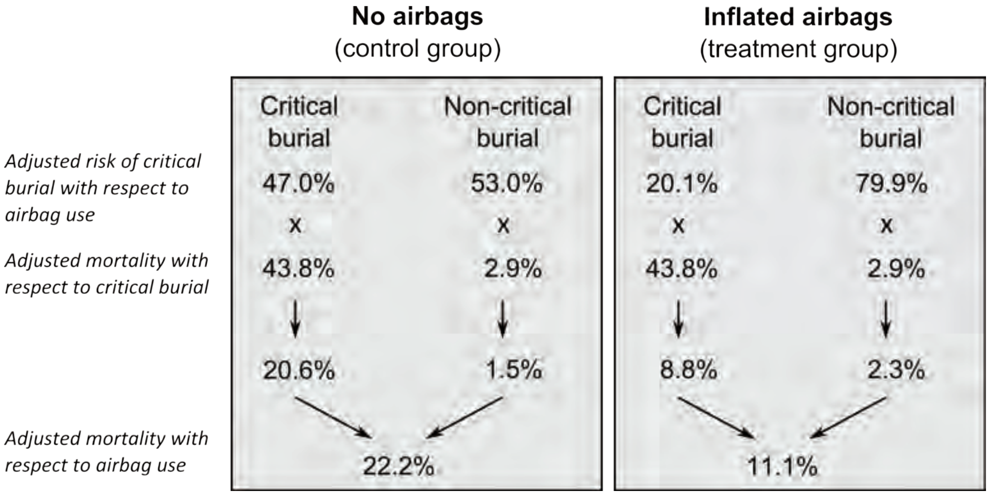
The results of our analysis support the finding that airbags significantly reduce the mortality in serious avalanche involvements, but the effect is lower than previously reported. The analysis revealed that airbags affect mortality only indirectly through their influence on victims' grade of burial.[4] Other factors affecting grade of burial are avalanche size (the larger the avalanche the higher the likelihood of a critical burial) and whether the victims sustained a major traumatic injury during the involvement (higher likelihood of critical burial with major injury).[5] The adjusted risk of critical burial is 47.0% for victims without airbags or with non-inflated airbags, and 20.1% for users with inflated airbags.

Mortality is subsequently determined by grade of burial, avalanche size and major traumatic injuries. The adjusted mortality is 43.8% for critically buried victims and 2.9% for non-critically buried victims. The adjusted mortality with and without an inflated airbag can now be calculated by multiplying the adjusted risk of critical burial with respect to airbag use and the adjusted mortality with respect to critical burial as illustrated in Fig. 2.

While the mortality without inflated airbags is 22.2%, the mortality with inflated airbags is 11.1%. This results in an *adjusted mortality difference* of 11 percentage points (95% confidence interval is -4 to -18 percentage points) and an *adjusted mortality ratio* is 0.5 (95% confidence interval is 0.3 to 0.7).

This means that out of 100 victims without airbags seriously involved in avalanches similar to the ones included in the analysis dataset, 22 are killed and 78 survive because they did not sustain any lethal injuries, did not get buried during their

FIG. 2: CALCULATION OF ADJUSTED MORTALITY WITH RESPECT TO THE USE OF INFLATED AIRBAGS.



involvement, or were found and extricated in time. Out of 100 victims equipped with inflated airbags, only 11 would have been killed. In other words, an additional 11 victims would have survived due to the airbags, which means that half of all fatalities could have been prevented. These effects are significant, but they are not as good as previously reported (-11 percentage points versus -16 percentage points in Brugger et al., 2007).

Furthermore, the mortality of airbag users is significantly higher than previously reported (11% versus 3% in Brugger et al., 2007). While this difference is partially due to the fact that our analysis focused on larger avalanche accidents with multiple involvements, it clearly highlights that airbags do not guarantee survival under all circumstances. Even if all victims in the present dataset were equipped with inflated airbags, one of every nine victims would have died.

WHAT ABOUT NON-INFLATIONS?

So far we have examined only the benefit of inflated airbags. In other words, the 11 percentage point decrease in mortality represents the best-case scenario when airbags are properly deployed and inflate as designed. However, past studies have repeatedly highlighted non-inflations as a serious problem for the performance of airbags. To examine non-inflations, we used all available records of airbag users including ones from accidents that only involved single users. The resulting dataset consisted of 307 records from 245 accidents. The overall non-inflation rate within this sample was 20% (61 of 307), which is very close to the rate reported by Brugger et al. (2007). This non-inflation rate reduces the 11 percentage point decrease in mortality from inflated airbags to roughly 9 percentage points (i.e., 80% of 11 percentage points). This clearly highlights that non-inflations still pose a considerable threat to the airbag performance.

What are the causes for these non-inflations? Information on suspected causes was available for 52 cases:

- 60% deployment failures by users
- 12% maintenance errors (e.g., canister not attached properly)
- 17% device failures (i.e., performance issues that resulted in design and/or production revisions)
- 12% destruction of airbag during involvements

Relative to the total number of users, the rate of airbags destroyed in involvements was 2% (6 of 307) and the rate of device failures was 3% (9 of 307).

To better understand the reasons causing users not to deploy their airbags, we examined the dataset for relationships between non-deployment and any relevant victim or involvement characteristics. Since we did not detect a significant relationship between deployment rates and avalanche size, non-deployments do not seem to be the result of more violent involvements. However, we found that the non-deployment rate is significantly lower among avalanche professionals (e.g., guides, ski patrollers, avalanche technicians) than recreationists (5% versus 14% respectively). This suggests that familiarity with airbags and their deployment procedures may considerably improve the effectiveness of these devices.

HOW ABOUT RISK COMPENSATION?

Risk compensation is a common concern when weighing the pros and cons of avalanche airbags. Are users going to feel less vulnerable when wearing an airbag and therefore expose themselves to a higher level of avalanche hazard? While there is no empirical evidence to date on risk compensation behaviour with respect to airbag use, it is a well-studied phenomenon in other areas. Hedlund (2000) offers a summary of existing evidence on risk compensation with respect to road safety initiatives. He states that while risk compensation does occur—even though not consistently—it generally does not eliminate the safety gains from the programs, but only reduces the size of the expected effect. It would be extremely difficult to collect the necessary data to properly quantify the effect of risk compensation on the effectiveness of airbags. However, Hedlund (2000) provides an interesting personal list of four characteristics of safety equipment or initiatives that make risk compensation more likely:

1) Is the piece of safety equipment obvious? Do I even know it is there?
2) Does the piece of safety equipment affect me negatively, physically and/or mentally?
3) Does the effect of the piece of safety equipment directly relate to the motivation and objective of my activity?
4) How much control do I have over my actions? Can I even change my actions if I want to?

Airbags seems to generally score highly on all of these characteristics:

1) It is difficult to forget the fact that you are carrying an airbag as they require frequent attention.
2) Airbags are expensive and heavy, and handling them during a trip can have its challenges.
3) If your primary reason for going into the backcountry is to ski challenging terrain, the benefits of airbags are perfectly aligned with your objective; if you are simply going into the backcountry to enjoy nature and calm, the effect of airbags is much less connected to your goals.
4) While amateur recreationists have complete freedom and control over their actions, avalanche professionals are likely more restricted due to company procedures and policies or professional best practices.

Based on this list of characteristics, it can be assumed that that risk compensation behaviour is likely among airbag users, particularly among recreationists who are interested in pushing their physical and athletic limits.

While our study does not provide any information regarding the presence of risk compensation behaviour with airbags, the results of our analysis offer some insight about the possible consequences of risk compensation behaviour. The parameter estimates from the binomial logistic regression analysis on critical burial indicate that the risk reduction gained from the use of an airbag is roughly equivalent to the risk increase from being involved in an avalanche of one size class larger. This means that personal safety benefits from airbags are quickly nullified if individuals use them to justify increased exposure to terrain where larger avalanches are likely.

LIMITATIONS

Clearly stating the limitations of an analysis is important when presenting statistical results. In our analysis of the effectiveness of this tool, the sample of airbag user records was substantially smaller than the complete dataset (201 records were excluded out of 307 total) to ensure an unbiased control group. The resulting dataset was therefore skewed towards large avalanches with multiple involvements. Furthermore, the dataset had a lower percentage of avalanche professionals and a higher percentage of victims located in the track or runout when the avalanche was triggered. Remember these limitations when interpreting the mortality statistics presented in this article. While the mortality among airbag users in the excluded records (i.e., smaller avalanches, single involvements) is smaller than in the analysis dataset, it is unclear how the effect of airbags shown in the present analysis transfers and contributes in relation to the reduced mortality from smaller avalanche and other differences.

TAKE HOME MESSAGES

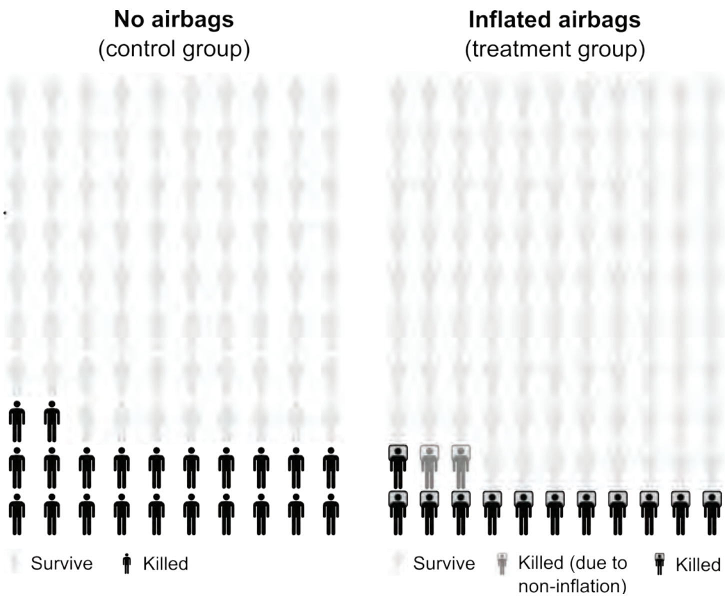
What are the most important take home messages from our study?

- Airbags are a valuable safety device, but their impact on mortality is lower than previously reported and survival is not guaranteed.
- For individuals seriously involved in avalanches of size 2 or larger, the use of an inflated airbag reduces the risk of dying from 22% to 11% (Fig. 3). This means that inflated airbags will save about half of the victims who would have otherwise died.
- Non-inflations remain the most considerable limitation to the effectiveness of airbags. The observed overall non-inflation rate from all causes is 20%.
- If non-inflations are taken into account, airbags reduce the risk of dying from 22% to 13% (Fig. 3) and the proportion of saved victims is only 41%.
- Sixty percent of all non-inflations are due to deployment failures by the user. Familiarity with deployment procedures and proper maintenance are paramount for ensuring that airbags work properly.
- Personal safety benefits from airbags are quickly nullified if users use them to justify increased exposure to terrain where larger avalanches are possible.

WHERE TO GO NEXT?

While our results show that airbags can reduce mortality in serious involvements in general, the analysis does not provide any insight about the benefit of airbags under different circumstances. For example, it would be useful to estimate and compare the effectiveness of airbags in avalanches with smooth runout zones versus avalanches with terrain traps. Another interesting question would be to examine the effectiveness of airbags as a function of the location of the victim when the avalanche was triggered (start zone, track, runout). However, collecting reliable avalanche accident data is challenging and

FIG. 3: EFFECT OF AIRBAGS ON THE MORTALITY OF VICTIMS SERIOUSLY INVOLVED IN AVALANCHES.



records are often incomplete. We would like to encourage national avalanche safety agencies, international search and rescue associations, airbag manufacturers and researchers to work together to develop standardized data collection protocols to facilitate future studies. In addition, we would like to encourage recreationists to diligently report all types of avalanche involvements to the local avalanche warning services. The resulting richer datasets will facilitate more detailed studies that will further improve our understanding of the benefits and limitations of airbags and other avalanche safety devices, avoid misleading statements on the impact of these devices, and help users to make better informed choices.

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[1]Inverse segregation, also known as the "Brazil nut effect," naturally sorts particles within an avalanche according to size with larger particles being moved towards the surface of the avalanche. Inflated avalanche airbags make avalanche victims, already large particles, even larger particles within the avalanche, which increases their chances to end up on top of the debris before the avalanche comes to a stop. Buoyancy effects, which are used by floatation devices, do not play a role in avalanche airbags.
[2]https://www.abs-airbag.com/us/abs-survival-principles.html.
[3]Dale Atkins in the 2011 November issue of *Powder* (http://www.powder.com/stories/know-boundaries-5/).
[4]Grade of burial was defined as either *critically buried* (i.e., head of the victim under the snow and breathing impaired) or *non-critically buried* (i.e., unobstructed airways).
[5]Traumatic injuries are considered major if the injured requires hospitalization.

Q & A
With AvaTech's Co-Founder and CEO Brint Markle

Q. Who is AvaTech?

A. We started AvaTech because we've had our own close calls and even lost friends in avalanches. We believe saving lives in our mountain community starts with understanding the snow under our feet and avoiding avalanches before they happen.

AvaTech builds proactive systems that instantly analyze the snowpack and facilitate the sharing of this information in real-time in order for individuals and groups to make better decisions. Our first products include the SP1, a high precision, portable, lightweight, and web-connected penetrometer that measures snow structure and other critical snowpack information; AvaNet, a global snowpack data platform that crowdsources information from the SP1; and a new easy to use drag and drop manual snow profile tool that we hope will become a new industry standard. We started AvaTech in 2012 out of MIT and are now headquartered in Park City, Utah. We'll be debuting our new technologies at the International Snow Science Workshop 2014 in Banff.

Q. What does the device measure exactly?

A. The SP1 leverages a variety of sensing technologies to help users gather and share rapid, objective information about the snowpack. The SP1 provides a high resolution readout of snow structure which can easily be linked with slope angle, aspect, and GPS location. The device helps professionals monitor and track specific weak layers in the snowpack, rapidly accelerate the data collection process, share information more easily among the community, and potentially improve the accuracy and objectivity of snowpack evaluation.

Q. How have you tested the device and technology so far?

A. Working with the guidance and feedback of some of the top industry practitioners and scientists who joined our advisory board such as Brian Lazar, Karl Birkeland, Dale Atkins and Ethan Greene, we conducted a rigorous winter testing program soliciting the feedback from this professional network.

From January to May 2014, AvaTech and a team of more than 50 partners rigorously tested 25 prototype SP1 units, as well as version 1.0 of our web platform. The testing program included both lab and field-testing, with snow professionals across six different countries around the world. We selected testing partners with a wide variety of avalanche experience and geographic diversity to ensure testing in every type of snowpack possible.

Our testing program included 20 ski resorts, seven avalanche education providers, nine avalanche forecast centres, eight guiding companies, five heli or cat skiing operations, three universities, military special forces, departments of transportation, professional athletes and others. Feedback from this broad set of professional users helped us focus on the solutions that the professional community valued most.

Over all, the opportunity to engage in rapid dialogue and feedback with experts in the field and our technical advisors was successful. We were able to gather feedback from a significant cross section of users and geographically unique snowpacks. This design feedback loop has been invaluable to the final development of the SP1, which launches this winter. Results clearly demonstrated the SP1's ability to gather rapid information about the snowpack in a reliable, repeatable manner. Quantitative results demonstrated a strong correlation to professional snowpit assessments and potential for the SP1 to even pick up layers that might be easily missed in manual assessments. Qualitative feedback supported the theory and practice of this new technology and that real solutions were being addressed.

Q. What are the limitations of the technology?

A. The SP1 supports more informed decision-making but is no replacement for sound judgment and experience. The avalanche problem is incredibly complex and we are not building a magic wand to solve it. There are other factors our technology cannot measure such as wind, temperature, and on-the-ground conditions. We present objective snowpack information and it's ultimately up to the user to decide how to integrate that information with other critical observations they are making in avalanche terrain.

The SP1 also does not replace digging a snowpit in any way. There is information you can gather from a snowpit, such as shear strength, which we are not currently measuring. We encourage users of the SP1 to continue to dig, but remember snowpits only give information about a very specific location. The device can help determine if a layer of concern discovered in a snowpit continues to be prevalent on other aspects and elevations, or it may find layers you do not even realize are there.

Q. How do the SP1 and AvaNet work together?

A. The AvaTech SP1 is a portable device that helps users gather and share rapid, objective information about the snowpack. SP1 measurement data is automatically synched via bluetooth to a smartphone application and the cloud, creating a unique crowd-sourced database of snow conditions from avalanche-prone areas. You get immediate translation from observation to documentation. Sharing this data across a broad network has the potential to create one of the largest sets of snowpack information in the world. The database will enable unprecedented day-to-day reporting, historical analysis, and event diagnostics which, when available online and in mobile apps, will provide for the first time a comprehensive, technology-based platform for proactive avalanche safety. The information and analytics we collect can improve decision making of individual backcountry adventurers as well as forecasting methods of ski resorts, mines, highways, railroads, military, avalanche forecast centers, guides, and other snow professionals.

THE SP1

Q. How is AvaTech supporting avalanche education?

A. We view the work we are doing at AvaTech as continued education. Avalanche education doesn't stop in the classroom—that's only the beginning. We want our new technologies and data platform to help encourage more and more people to want to learn more about the snowpack and provide some tools that they need to do so.

Flakes

ROB BUCHANAN

REACH THOUSANDS
OF PEOPLE IN
THE AVALANCHE
COMMUNITY