A Publication of the American Avalanche Association

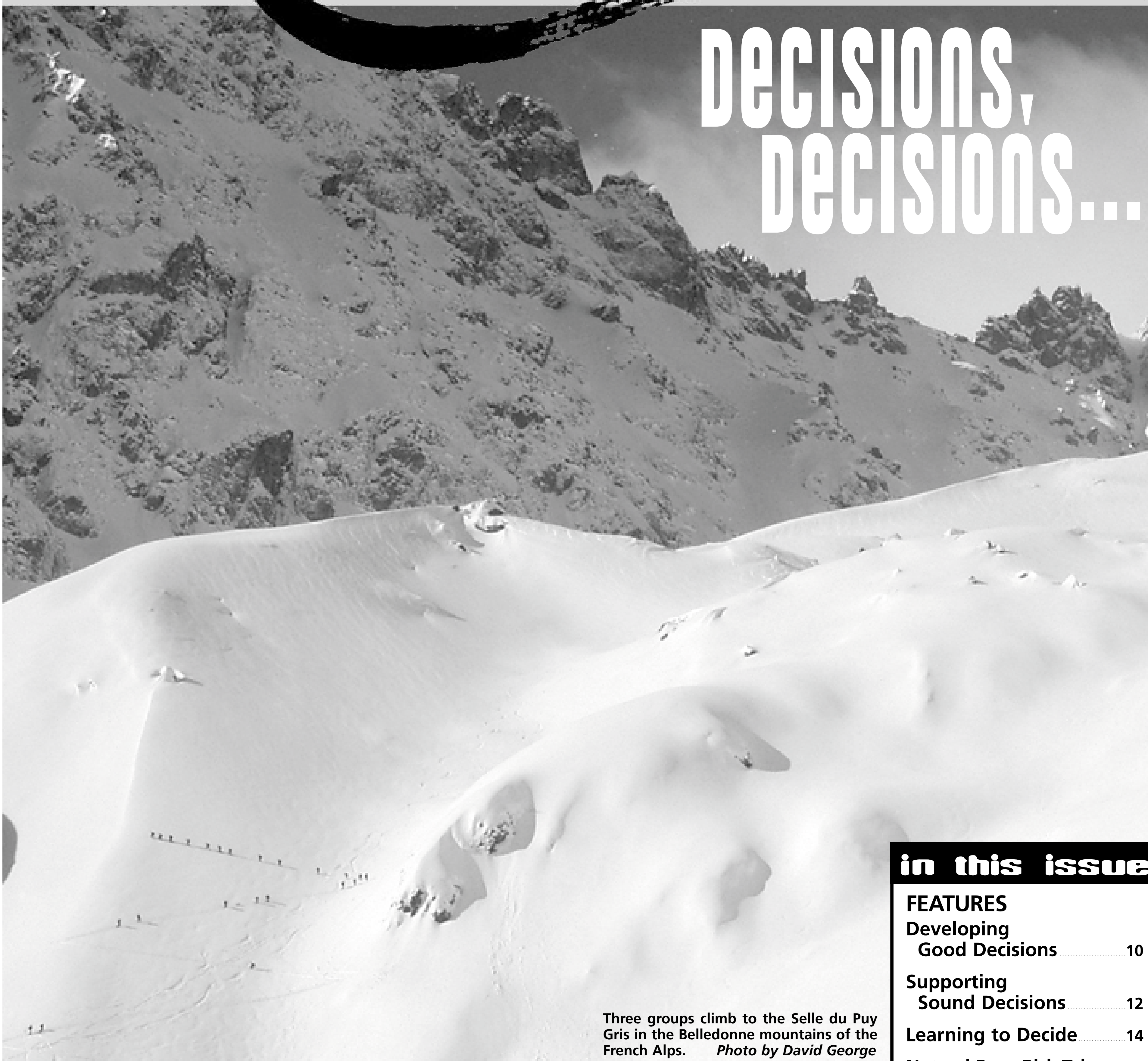
THE Avalanche REVIEW

US $4.95

VOLUME 23, NO.3 • FEBRUARY 2005

Web site: www.AmericanAvalancheAssociation.org

Decisions, Decisions...



Three groups climb to the Selle du Puy Gris in the Belledonne mountains of the French Alps. *Photo by David George*

January 9, 2005. 8 am.

Last week, I worked on this issue of *The Avalanche Review* non-stop. This week, as I begin a three-week Prescott College avalanche course and introduce the curriculum to 10 eager students, ideas and vocabulary from some of the articles I have edited pop into my head and blend into complete sentences. This course and this issue both revolve around decision-making. We have chosen and been offered a variety of tools and methods that work in different situations. Our goal is to make our decision-making process efficient, quick, and accurate. I borrow a phrase from Iain Stewart-Patterson's article, *Developing Good Decisions*: we are not content with adequate decisions; we are looking for the "elegant solution."

January 19, 2005. 5 pm.

Almost two weeks later, the "elegant solution" as goal seems to work for my students. They understand it intuitively; it means not being satisfied with short cuts. It means acknowledging their human factor filters and moving beyond them. We've been able to use Don Sharaf and Ian McCammon's work on strength, energy, and structure in the snowpack to streamline and complete our stability assessment picture. In planning tours, we use a "forecasters of the day" model with instructor guidance to help them move from novice toward expertise with a solid field base of experience, much as Steve Conger suggests in *On Becoming An Expert*—developing a repertoire of common patterns to recognize and rituals to perform.

From the editorial desks of *The Avalanche Review*, we hope you can use this issue as much as we already have. Perhaps the tools are immediately transferable or will sit and percolate for a while. Perhaps a story will provoke thought, debate, discussion. Perhaps these ideas will lead you and your students, fellow patrollers, or backcountry partners toward expertise and elegant decisions in the backcountry.

—Lynne Wolfe, TAR co-editor

in this issue

Human factors and decision-making processes are the main hazard, not the snow.

Supporting Sound Decisions pg 14

THE Avalanche REVIEW

FEBRUARY 2005 • VOL. 23 • NUMBER 3

The Avalanche Review is published each fall through spring by the American Avalanche Association, Inc., a non-profit corporation. The Avalanche Review welcomes the submission of articles, photographs and illustrations.

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american avalanche association

The mission of the AAA is:

A. To provide information about snow and avalanches;
B. To represent the professional interests of the United States avalanche community;
C. To contribute toward high standards of professional competence and ethics for persons engaged in avalanche activities;
D. To exchange technical information and maintain communications among persons engaged in avalanche activities;
E. To promote and act as a resource base for public awareness programs about avalanche hazards and safety measures;
F. To promote research and development in avalanche safety.

Subscription: $20 per year (4 issues). Subscription is included with membership dues to AAA. For subscription and membership information, see **www.AmericanAvalancheAssociation.org**.

Contributions: Please submit material eight weeks prior to publication date. Include address and telephone number. Please submit typed manuscripts by e-mail or disk (3.5", Zip or CD), using any popular word processing program. Submit any figures in B & W, or as a TIFF or JPG file (300 dpi resolution at 100%). We will return materials if you include a stamped, self-addressed envelope.

Articles, including editorials, appearing in ***The Avalanche Review*** reflect the individual views of the authors and not the official points of view adopted by AAA or the organizations with which the authors are affiliated unless otherwise stated.

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from the president

"at the end of the line"

Maybe somewhere down the road a ways
(at the end of the line)
You'll think of me, wonder where I am these days
(at the end of the line)
Maybe somewhere down the road when somebody plays
(at the end of the line)
Purple Haze

End of the Line: Traveling Wilburys

Although the mountains around here, the San Ysidros, the San Gorgornios and even Mt. Palomar are covered in snow today, I'm told it's only the second time in thirty years this has happened. Not that I think it has anything to do with me moving to the desert of southern California, but it does make me feel more at home. Of course, I'm still in touch with 760 – the patrol base at Squaw Valley – and we exchange notes usually around the time the Sierra is getting hammered. But it's not the same, and my interest, while still keen, is diluted by other pursuits.

I began my formal training for this era of my life with an avalanche class given by Norm Wilson at Rock Creek near Mammoth Mountain in 1984. That winter, with my friend and Alpine Meadows patroller Bernard Coudurier, I had been climbing and skiing on Shasta and in the southern Sierra. I decided that I needed to learn more about what we were doing instead of just relying on a steep-skiing-crazed Frenchman. When I was done with Norm's class, I didn't even want to go outside.

The following winter I was hired on at Squaw Valley and the hands-on training began. There was an avalanche school with Ed LaChapelle and others at Alpine Meadows, the National Avalanche School with its host of reputable teachers, and more schools at Alpine. Among my many fuzzy memories, one is the transition I made between attending these schools as a student and as a teacher. In any case, sometime in the early '90s my passion for avalanche work combined with my California teacher-credential training, and I found myself teaching the outdoor sessions of the Northwest Avalanche Center School and the National Avalanche School at Alpine Meadows.

Yes, I was there on the deck at Squaw Valley in 1986 when a group of avalanche workers planted the seed for what became the American Association of Avalanche Professionals. But as a relative rookie I had no real idea of what was going on. I asked my patrol director if he was going to join, and he replied, "Only if they give away t-shirts." I guess at some point Mark Mueller changed his mind about that.

In late August I went over to 760 to clean out my locker. I had several errands that day and stopping by and cleaning out the locker was just one. I was genuinely surprised at the emotions which came over me as, alone, I turned in the gear which was not mine and made trips out to the car with my stuff. When I thought of all the stories, the people, and what had gone down in that humble room over the past 20 years, I was really moved. It was like ghosts were moving around in there. The people I had known so well who had moved on were reminding me of all the times we had. From the birthday and engagement parties to the famous chicken incident (Alpine Meadows payback) to the reversal of fortune for Jim Mott (formerly president of Squaw Valley) to a million small things, the room reverberated with life as I closed the door on my way out for the last time as a patroller. Now, I too am one of those ghosts.

—Russ Johnson, AAA President

The AAA thanks the following members for contributing an additional donation beyond their membership dues to further our efforts in 2005:

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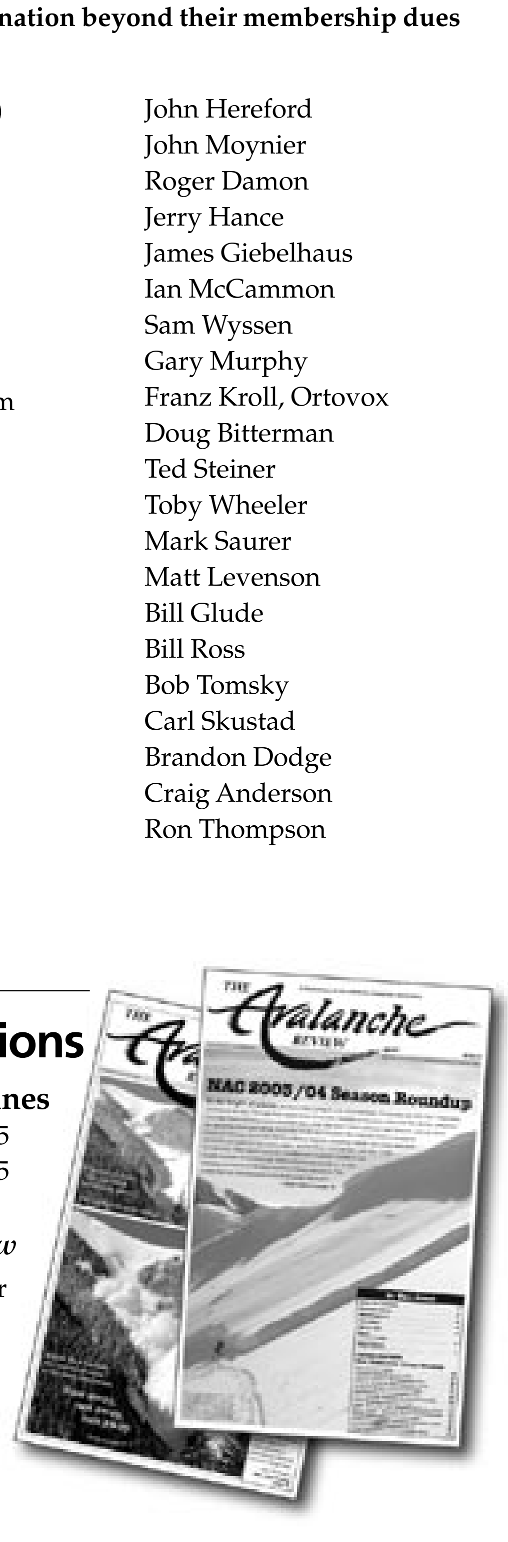
The Avalanche Review: A Call for Submissions



- Seen any good avalanches lately?
- Got some gossip for the other snow nerds?
- Developing new tools or ideas?
- Learn something from an accident investigation?
- Send photos of a crown, of avalanche workers plowing roads, throwing bombs, teaching classes, or digging holes in the snow.
- Pass on some industry news.
- Tell us about a particularly tricky spot of terrain.

Write it up; send it to us. *The Avalanche Review* is accepting articles, stories, queries, papers, photos.

Submission Deadlines
Vol. 23, Issue 4... 2/15/05
Vol. 24, Issue 1... 7/15/05

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metamorphism

Ethan Greene, research chair of A3 and a Ph.D. candidate at Colorado State University, was recently awarded a National Science Foundation (NSF) grant in support of his Ph.D. research, which is on *The effects of buried ice lenses on snow microstructure*. The $13,000 grant is from NSF's International Program, and it will enable Ethan to travel to Davos, Switzerland and work with Martin Schneebeli at the Swiss Federal Institute for Snow and Avalanche Research…**Peter Carvelli** has taken over the Snow Safety Director job at Aspen Highlands that was vacated when Kevin Heinecken moved on (see Metamorphism last issue)…In the Equal Opportunity Employer category, the Utah Avalanche Center (UAC) has hired snowboarder **Brett Kobernik** as a seasonal avalanche specialist. Brett designed the Voilé Split Board binding and has been touring on his snowboard since 1989.

what's new

Canadian Patnership Funds Avalanche Research Chair

On November 23, the Canadian government announced federal funding of CAN$673,700 over five years for the Science and Engineering Research Canada (NSERC) Research Chair in Snow Avalanche Risk Control at the University of Calgary. The funding is provided through an NSERC program that promotes research partnerships between the private sector and universities. The Canadian Avalanche Association, Mike Wiegele Helicopter Skiing, Canada West Ski Area Association and B.C. Helicopter and Snowcat Skiing Operators Association are contributing a total of CAN$592,100 in cash and CAN$200,000 in kind over five years. Parks Canada (Glacier National Park) also provides almost daily advice, data and in-kind support to the Chair's research program. Dr. Bruce Jamieson will hold the chair. He is currently an Associate Professor in the Department of Civil Engineering at the University of Calgary. He is well known for his research on properties of weak snowpacks, failure planes, snow-slab stability and avalanche forecasting. The Honorable Anne McLellan, Deputy Prime Minister and Minister of Public Safety and Emergency Preparedness, made the announcement on behalf of the Honorable David L. Emerson, Minister of Industry.

Avalanche Education Study

Christian March and Nancy Pfeiffer are requesting help from avalanche-safety instructors for a nationwide study. Their study examines the effectiveness of avalanche education; it investigates the question of how much students are remembering and actually using from their Level I avalanche class. The study consists of two questionnaires issued to students one week and one year after course completion.

Among the participants are the Alaska Avalanche School, Alaska Pacific University and Avalanche Level I educators and schools across the country. For more information contact: **avaledu@alaskapacific.edu**

European Geophysical Union General Assembly

The European Geosciences Union will hold its General Assembly in Vienna, Austria, April 24-29, 2005. The program will include oral and poster sessions, as well as various short courses, workshops, lectures, and meetings. Topics will be disciplinary and interdisciplinary and cover the full spectrum of the geosciences and space and planetary sciences. The deadline for pre-registration is April 8. The official language of the conference is English. **www.copernicus.org/EGU/ga/egu05/index.htm**

1st Alexander von Humboldt International Conference on El Niño

The European Geophysical Union (EGU) and the Centro International para la Investigación del Fenómeno de El Niño are hosting the 1st Alexander Humboldt International Conference on the El Niño Phenomenon and its Global Impacts in Guayaquil, Ecuador, May 16-20, 2005. The meeting is a forum for discussing the El Niño-Southern Oscillation in all aspects related to the Ocean, Atmosphere, Climate, Biology and Human Dimensions, its impact in South America and teleconnections worldwide. It is the first of a series of Alexander von Humboldt Conferences initiated by EGU; these conferences are international meetings related to geophysical topics of particular importance to South America, which are jointly organized by South American and EGU experts. Conference languages are English and Spanish. Registration fees are $120. **www.copernicus.org/EGU/topconf/avh1** or **www.ciifen-int.org**

11th International Conference on Landslides and Avalanches

Several Norwegian agencies are hosting the 11th International Conference on Landslides and Avalanches (ICFL) in Norway, September 1-10, 2005. The ICFL is divided into three parts, including a three-day cruise along the coast of Norway, several days around Trondheim, and a bus trip through alpine areas. Snow avalanche topics are scheduled for September 2-4.

The Japanese Landslide Society and the International Landslide research group founded the ICFL; previous meetings have been held in Japan, USA, Australia/New Zealand, Switzerland, Austria, Italy, Czechoslovakia, Spain, England and Poland. The ICFL's goal is to provide a favorable environment for scientists, engineers and planners concerned with landslides to meet to discuss and exchange ideas about landslide processes, investigations and monitoring.

This ICFL concentrates on the aspects of landslides and avalanches that affect human life in Norway. The field trips cover a broad range of the types of landslides found in the country. Themes include landslides in quick clay and other soil types, rock slides, submarine slides, landslide-generated flood waves, snow and slush avalanches, and the impact of climate change. **www.ivt.ntnu.no/ICFL05/**

correction

The photo of Knox Williams (left) on page 15 of issue 23-2 of TAR (December, 2004) was miscredited. The photo was taken by Nick Logan, not Rich Marriott.

Custom avalanche shovel courtesy of Backcountry Access.....$50

Libations from New Belgium Brewery.....free

Tropical shirt.....priceless

aaa news

Bruce Tremper Receives the AAA Bernie Kingery Award

Bruce Tremper (left) receives the Kingery award from John Montagne at the 2004 ISSW in Jackson, Wyoming. *Photo by Doug Richmond*

Several years ago, the AAA realized that among its membership were many who stood alone for excellence and long service in the cause of snow avalanches. A highly respected award was thus created in honor of Bernie Kingery who embodied those traits and who died in the Alpine Meadows avalanche of the 1980s.

The organization chose Bruce Tremper to receive the award, and it was my great honor and pleasure to convey this citation.

Bruce, a native Montanan, learned to love the Rocky Mountains as a very young man and followed his father's advice to pursue an educational degree in the theory and practice of the then early program in the snow and avalanche science at Montana State University. His ultimate award of a master's degree was preceded and followed by many competitive ski accomplishments with the US Junior National Ski Team and the NCAA, as well as ski patrol assignments at Bridger Bowl and as Director of Avalanche Control at Big Sky ski area.

In 1984 he was employed by the Alaska Avalanche Center as forecaster, and in 1986 he began and continues to serve as director of the USFS Utah Avalanche Center in Salt Lake City. Coincidentally, Bruce has published several outstanding papers on a variety of avalanche topics. He was editor of *The Avalanche Review* for six years and has been an invited speaker and consultant in Japan, Norway, and Canada. In 2002 he coordinated backcountry avalanche safety for the Olympic Winter Games in Salt Lake City and continued providing outstanding service as a lead forecaster in the avalanche center. Bruce more recently produced the avalanche education video, *Winning The Avalanche Game* and published the book *Staying Alive In Avalanche Terrain*. He has been featured on a dozen programs produced by *National Geographic*, PBS, Discovery Channel and many national network news programs.

The consistency and quality of the above work qualifies Bruce Tremper to receive the Bernie Kingery Award for Sustained Career Excellence in the avalanche field.

—*John Montagne,*
American Avalanche Association

Bruce Tremper in the field (right) and in the office (below). *Photos by Matt Turley*

Citation for Paul Föhn

Paul Föhn (right) receives the Honorary Fellowship award from Jürg Schweizer. *Photo by Doug Richmond*

Paul M.B. Föhn was born on December 16, 1940, and raised in a small mountain village in the Swiss Alps. A geophysicist by training, he earned a Ph.D. degree from ETH Zurich, Switzerland in 1969 on the mass balance in the accumulation area of the Aletsch glacier. After a subsequent post-doctoral fellowship with the National Research Council of Canada in Ottawa, he joined the Swiss Federal Institute for Snow and Avalanche Research (SLF) on the Weissfluhjoch in 1972. When he retired in July of 2004, he was the deputy director of SLF.

His very first avalanche-related work dealt with testing a statistical avalanche forecasting model and with measuring snow loading by wind. The poor performance of the forecasting model caused him to abandon the subject soon, but later in his career he continued this work with much dedication and developed an expert system, including snowpack information as an additional input in the model. The studies on snow transport at the Gaudergrat site near Weissfluhjoch concluded with a simple relation to calculate the additional amount of snow deposited on lee slopes, which is still used today.

Paul Föhn measures the Swiss snowpack *Photo by Jürg Schweizer*

This result is exemplary of his research, which always aimed to be useful for the people who have to make decisions on avalanche safety. Paul is among the very few who succeed to merge theory and practice in the very best sense of the International Snow Science Workshop, which he attended frequently in the last 20 years. Based on shear-frame measurements, he introduced the Rutschblock test as a semi-quantitative snowpack-stability test, which is still the only one which involves the true trigger: the skier. Paul also improved snowpack stability evaluation by considering the skier as the principal triggering factor. Two outstanding contributions resulted – definite classics in avalanche research: the Rutschblock as a practical tool for slope stability evaluation, and the stability index and various triggering mechanisms, both presented in 1986 at the anniversary symposium to celebrate 50 years of snow and avalanche research at the Weissfluhjoch.

At that time, Paul was in charge of the Swiss avalanche forecasting service (1982-1993) and best known on radio and TV as "Mr. Avalanche Bulletin." He strongly influenced avalanche forecasting in Europe, in particular, by introducing a well-defined danger scale for Switzerland in 1985. From this, the five-degree danger scale now used all over Europe and with variations in North America was developed in 1993 by the working group of the European avalanche warning services – a working group Paul had initiated 10 years earlier. For six years he was also head of the Swiss Army avalanche warning service and used the troops for research purposes on the spatial variability of snowpack stability (a 1988 ISSW contribution).

In addition to his consulting work that led him around the world, he has been a dedicated teacher who easily communicates his enthusiasm on snow and avalanches to his students and audiences. He is at his very best when chasing weak layers in the field – surface hoar is his favourite. The above summary clearly shows that his work covered all the aspects of snowpack stability evaluation and avalanche forecasting which are considered to be most important today. Over the past 30 years, Paul Föhn has made eminent contributions toward the improvement of snow avalanche safety.

—*Jürg Schweizer*

media

Avalanche Bulletin Writers Workshop

Story by Greg Johnson

The Forest Service National Avalanche Center and the Canadian Avalanche Foundation hosted the second International Avalanche Bulletin Writers Workshop and Information Exchange at the 2004 ISSW. The goal of the workshop was to bring a group of public avalanche forecasters together from around the globe and discuss how we communicate avalanche risk.

This year the workshop drew 35 forecasters from the US, Canada, Switzerland, and Austria. Eight forecasters gave short presentations and lead great discussions on a number of interesting topics. Alan Jones, coordinator of the Canadian Avalanche Centre Public Avalanche Warning System, and Grant Statham, avalanche risk specialist for Parks Canada, discussed innovations in the way avalanche risk will be communicated to the public in Canada. Canada has significantly stepped up funding for their avalanche programs following the two large accidents during January and February of 2003 and is pursuing new philosophical approaches. For this winter, Parks Canada developed a three-level terrain-classification system with which to rate their popular ski-touring terrain. This classification system is intended to help people choose an appropriate level of risk. In addition to the regular public avalanche forecasts, a new three-level picture-based avalanche advisory will be issued for all Canadian forecast regions. The media was involved in its development, and they will disseminate it in a similar manner as weather maps. These advisories are intended to provide basic information for people who have very little or no avalanche awareness.

Patrick Nairz, forecaster with the Avalanche Warning Center Tirol in Austria, discussed different decision making tools from across Europe. His presentation clued us in to why these tools were developed and how backcountry skiers use them. This was particularly interesting for Canadian forecasters, where a comprehensive research project is underway to develop a similar tool.

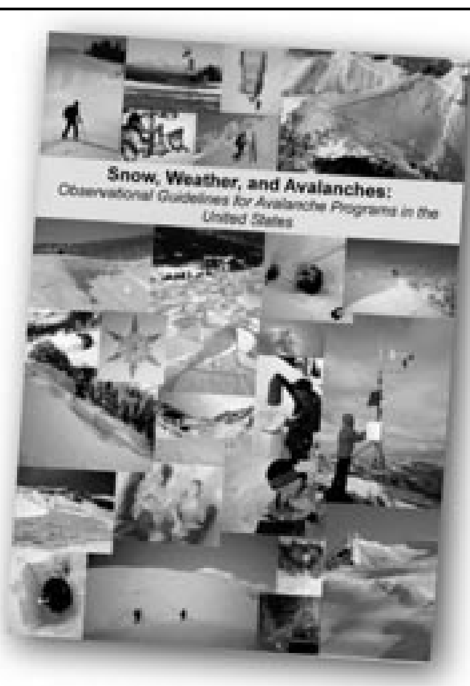
In North America, many of us consider the Swiss Federal Institute to be the world leader with public forecasting, and we always look forward to hearing about their practices and ideas. Avalanche forecasters Andreas Stoffel, Hans-Juerg Etter, Thomas Stucki, and Christine Pielmeier gave short talks on *10 Years of Experience With the 5 Level Danger Scale*, *One Level Rule: the Experiences and Consequences*, *Tools in Danger Communication: Bulletin Interpretation Guide, Multilingual Glossary of Avalanche Terms, Snow and Avalanche Summary of the Current Week*, and *Warning Products and Their Distribution Channels*. Their talks planted many seeds on how we can effectively build our avalanche programs.

> ***Our biggest challenge isn't forecasting, but rather the way we communicate risk***

Doug Abromeit, director of the US Forest Service National Avalanche Center, gave the final presentation. He discussed the importance of workshops and forecaster exchanges. Last winter the SLF and USFS had a formal exchange, and both groups felt that they had benefited. In the coming years, exchanges between the Swiss, Americans, and Canadians will likely happen on an annual basis.

Throughout the ISSW week, I received positive feedback from forecasters that attended. Many have expressed that they feel that our biggest challenge isn't the actual forecasting, but rather the way we communicate avalanche risk. After organizing a few of these events, it is amazing to see so many passionate people from different countries basically up against the same issues of risk communication. We hope that these workshops provide a venue to help tackle them. Look for another workshop on registration day of the ISSW 2006 in Telluride.

Greg Johnson completed his master's degree in civil engineering at the University of Calgary under Bruce Jamieson. Since then he has worked in Logan, Utah, and Ketchum, Idaho, as an avalanche specialist with the US Forest Service and as a climbing ranger at Mt. Rainier National Park. This winter he is working as an avalanche forecaster with the Canadian Avalanche Centre in Revelstoke, British Columbia.



High Resolution Weather Products for Avalanche Programs in the western United States

by John Snook, Ethan Greene, Ned Nikolov, Michael Fajardo and Karl Zeller

Have you ever spent an early morning looking at a host of weather forecasts and wished for more detail in your local area? Or maybe you have spent an hour reading meteorological charts and found that you still don't know how to translate the current weather pattern into a local forecast? Well, the Rocky Mountain Center for Mesoscale Weather Intelligence can't solve all of your weather-forecasting woes, but they can provide you with detailed weather model runs and point forecasts for any location within the western United States!

The Rocky Mountain Center (RMC) is part of the USDA Forest Service's Rocky Mountain Research Station (RMRS) and was formed as part of an effort to provide detailed weather information to the fire-management community. Since its inception, the RMC has created useful products for fire weather applications as well as conduits to deliver them. Along the way, the RMC staff realized that many user groups need detailed weather information. Last winter, the RMC and the Forest Service National Avalanche Center (NAC) created products to help some of the Forest Service regional avalanche centers with winter weather forecasting. The results of this collaboration and other weather products developed by the RMC are now available to any avalanche program via the Internet. This article presents some background on how we use computers to create weather forecasts and highlights the unique nature of some of the RMC products.

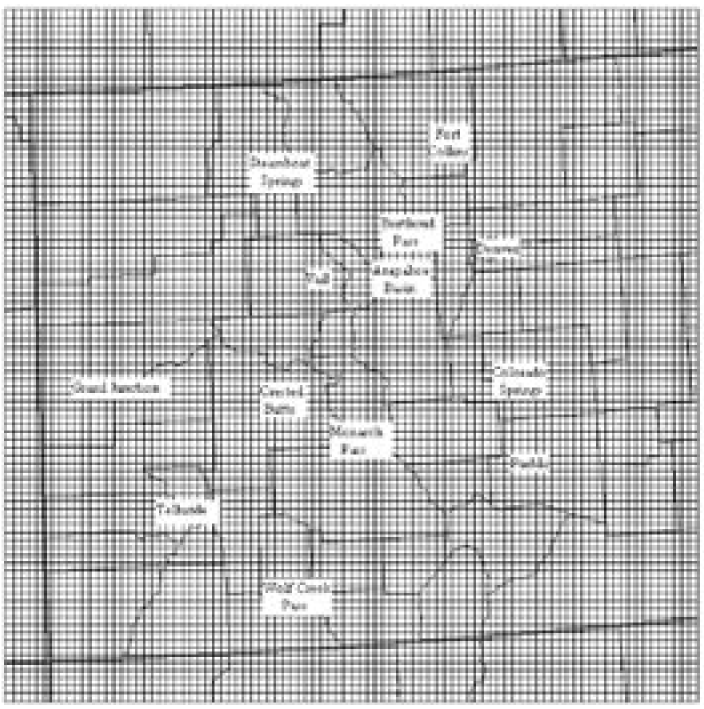


Figure 1. A two-dimensional representation of the 6-km (3.6-mi) model grid mesh over Colorado, a subset of the entire RMC western US NWP model domain. A model grid point is located at every position where horizontal and vertical lines cross. The image shows the increased model resolution with much smaller grid cells than those available from National Weather Service models.

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12/09/2004 20:00 12 12 100 310/35 53 0.1 SNOW   0.01 0.2 101571 2448 310/48 ** **  4
12/09/2004 21:00 13 13 100 300/35 53 0.1 SNOW   0.02 0.3 102430 2520 310/47 ** **  4
12/09/2004 22:00 13 13 100 300/34 46 0.1 SNOW   0.03 0.3 98620 2497 300/46 ** **  4
12/09/2004 23:00 14 14 100 300/33 46 0.1 SNOW   0.03 0.4 89710 2362 300/44 ** **  4

SUMMARY INFORMATION FOR PERIOD
-------------------------------------------------
HIGH TEMPERATURE:  26.1 AT 12/11/2004 12:00
LOW TEMPERATURE:   9.5 AT 12/09/2004 11:00
AVG TEMPERATURE:  17.7
AVG DEWPOINT:   16.5
TOTAL PRECIP:   0.60
TOTAL SNOW:    8.90
```

Figure 2. An abbreviated forecast (24-hour instead of 72-hour) for the Arapahoe Basin ski area. The header information indicates the location of the station and the NWP model elevation (the elevation might be a little different than the actual station elevation especially in mountainous regions). The DATE and TIME columns show the time for which the forecast is valid. Columns of forecasted temperature (TMP), dew point temperature (DPT), relative humidity (RH) and wind direction/speed follow. Wind direction indicates the direction that the predicted wind comes from (0 degrees is a wind from the north, 90 degrees is a wind from the east, etc.). Predicted cloud ceiling (CEI in hundreds of feet), visibility (VIS), and weather are next. One-hour amounts of melted precipitation and snow follow in the next two columns. The remaining columns are fire weather parameters (including ventilation index, mixing height, boundary layer wind, Haines indexes – medium and high, and Fosberg index) that may not be of interest for avalanche applications. A summary for the forecast period is provided at the end of the table. Note that the forecast indicates sustained wind speeds up to 74 mph. This particular storm did indeed create wind gusts to nearly 100 mph at Arapahoe Basin. This is an example of how the high model resolution can better predict local weather phenomena.

What is Numerical Weather Prediction (NWP)?

The idea of trying to predict the weather using mathematical physics equations was conceptualized about a century ago. V. Bjerknes recognized that the atmosphere is a fluid and that forecasting is fundamentally an initial-value problem. Furthermore, he realized that the system of equations to be solved was already known (Haltiner and Williams, 1980). During World War I, several attempts were made to solve the equations using desk calculators. These predictions took several months to generate and the results were unrealistic. Theoretical research continued, but positive results were not achieved until computers became a viable tool in the late 1940s. Thus dawned the age of Numerical Weather Prediction (NWP), in which computers generate forecasts using numerical methods. By the mid 1950s, computer-generated forecasts were already more accurate than subjective predictions from the most skilled human forecasters.

We still joke about the accuracy of modern-age weather forecasts. Statistical evaluation, however, shows that today's three-day forecast is now as accurate as the one-day forecast from 20 years ago. The reasons for this improvement are two-fold. First, our ability to observe the current state of the atmosphere has improved as ground-based, satellite and weather radar observation techniques developed and networks expanded. Second, the computer revolution provided inexpensive yet fast computational platforms to perform the complex calculations required by NWP. Sophisticated NWP computer models were developed and used in the research community for many years. These models were typically run on large mainframe computers and often took weeks to generate a two-day forecast – certainly not of any use to the operational community. Today, using clusters of inexpensive personal computers, the same forecasts can be generated in hours or even minutes.

Rocky Mountain Center NWP System

The RMC provides technology transfer services for Forest Service applications. The primary goal of this effort is to develop state-of-the-art support for the fire-management community. RMC has acquired and clustered together 65 dual-processor personal computers for the specific purpose of implementing a sophisticated meteorological NWP system. These computers are used to create 72-hour forecasts twice per day. The NWP model that is implemented (MM5, http://box.mmm.ucar.edu/mm5/) uses sophisticated, research-level techniques to generate wind, temperature, moisture, and precipitation predictions. The modeling system used at the RMC also includes a cloud microphysics scheme that predicts precipitation in the form of rain, pristine ice, snow, and hail/graupel. While the primary motivation of the RMC is to provide fire weather support, the forecast applications are of use to many others, including the avalanche community.

NWP Model Resolution

All NWP models use a three-dimensional grid system (Figure 1). The spacing between model grid points is very important. An analogy can be made with a fish net. If the fish net has large holes, then the net can only catch large fish. As the mesh of the fish net gets closer together, then smaller fish can be captured. Similarly, if the space between each grid point in an NWP model is large, then the model can only resolve large weather systems. As the spacing between model grid points gets smaller, then the model can capture smaller weather systems. This is especially important in the mountains, where the terrain can create local, small-scale weather features. The highest model resolution used by the National Weather Service (NWS) is currently 12 km (about 7.2 miles), and most NWP model data available on the Internet uses a grid spacing between 20 and 80 km. Information provided by the RMC uses a NWP model with a grid spacing of 6 km (about 3.6 miles). Since the grid spacing is half in both the north-south and east-west directions, the RMC model resolution is 75% finer than the best NWS model; hence, much smaller weather features can be resolved.

Forecast Products

Generating sophisticated meteorological forecasts is of no use if the end-user cannot understand them. The RMC system post-processes the NWP model data into a variety of products that are designed specifically for users in the field. As the products become available, they are immediately displayed to a Web site at http://fireweather.info. Observed and forecast images are grouped into a number of domains ranging in size from the western US down to the Colorado Front Range. Observed images illustrate current weather conditions while forecast images are derived from NWP model forecasts that are started at 11am and 11pm every day. Forecast images are available every hour out to 72 hours of forecast and can be viewed individually or in animation. Unique to the RMC, forecast verifications are available for assessment in real time. Analyses maps of most observed weather parameters can be compared with forecasts on an hourly basis two hours following measured observations. In addition, verification plots of forecasts versus observations are updated hourly and available for regions and individual observation stations.

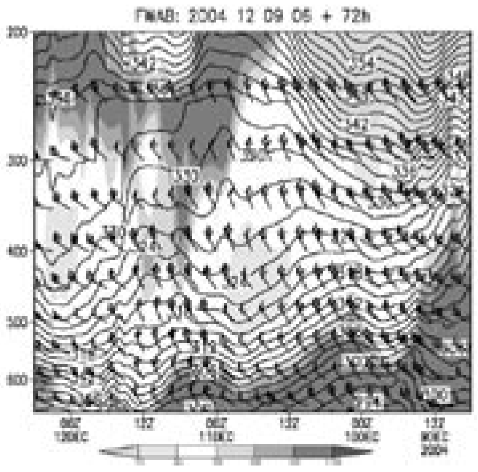

Figure 3. A black and white (actual images are in color) time-height cross-section of forecast potential temperature (contours), relative humidity (shaded image), and wind. Forecast time increases from right to left so that the right side of the plot is the 0-hour forecast and the left side is the 72-hour forecast. The vertical scale of the plot is in pressure (mb) so that the bottom is at ground level and the top is at 200 mb (about 38,500').

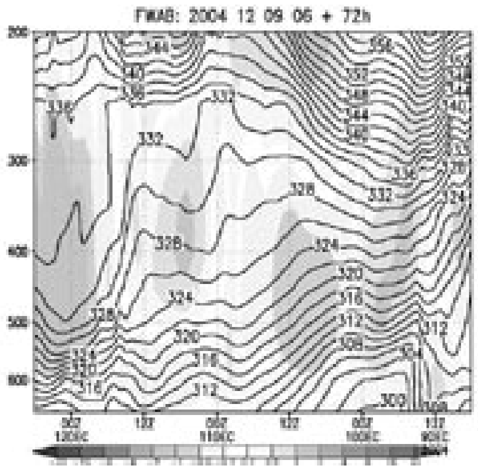

Figure 4. A time-height cross-section of forecast equivalent potential temperature (contours) and vertical motion (shaded image). Positive vertical motion indicates rising air that is typically associated with moist conditions while negative vertical motion suggests sinking air that is typically associated with dry conditions. For more details on how to interpret these cross-section forecasts, see Steenburgh and Greene (2004).

Another set of specialized products are the point forecasts. These are predictions for a specific location and are displayed in text format (Figure 2). Forecasts for the first 48 hours are typically available at 7:00 (morning and evening). These forecasts are continually updated and extend to 72 hours by about 10:00. Users can add locations (by latitude and longitude) to the list of point forecasts generated. Each time a forecast point is added, a forecast is generated during the next model cycle.

Two types of time-height cross sections are also generated at each point-forecast location. These images depict the vertical structure of the atmosphere through time (Figures 3 & 4). Time-height analysis can be used to determine the depth of moisture in the atmosphere as well as vertical wind and stability profiles (see Steenburgh and Greene, 2004).

Summary

Although some of the RMC products available at http://fireweather.info are created for fire weather applications, most of them are useful to any group that is interested in forecasting the weather. In addition to providing weather support to avalanche programs, the RMC is also interested in improving the accuracy of their forecasts. This high-resolution weather information is provided with the hope that observers will compare the point-forecast products to the daily observations they record. With your help, we can build a mutually beneficial relationship and maybe improve weather forecasts in mountainous regions.

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John Snook has spent over 20 years working with atmospheric models for the National Oceanic and Atmospheric Administration, the Forest Service and private consulting firms. He has a Ph.D. in Atmospheric Science from Colorado State University. John has also spent many years as a member of the volunteer ski patrol at Arapahoe Basin in Colorado and spends nearly every weekend working in the snow.

Ethan Greene is a Ph.D. candidate in Geosciences at Colorado State University. He has worked as a meteorologist, ski patroller, regional avalanche forecaster and avalanche educator. When Ethan is not digging long troughs in the snow on Rabbit Ears Pass or standing in a walk-in freezer, he likes to ride in the Never Summer range of northern Colorado.

Ned Nikolov has spent most of the past 14 years modeling the exchange of water vapor, energy, and trace gases between terrestrial ecosystems and the atmosphere. He has also done some original work in vegetation remote-sensing developing and implementing physics-based algorithms for retrieval of canopy leaf area index from multispectral satellite images. In 1997, he received a Ph.D. in ecological modeling from Colorado State University. As a member of the RMC team, he has recently specialized in Web design and Web application development. Ned enjoys switching between various research topics and work areas that stimulate different parts of his holographic brain.

Michael Fajardo has spent much of the past six years modeling systems on a molecular scale. In 2004 he received an M.S. in Biochemistry/Biophyics from Washington State University. His thesis centered on evolutionary studies of reduction potentials in iron-sulfur proteins. After joining the RMC, Michael shifted his research focus from molecular-level protein systems to more macroscopic atmospheric science systems. Additionally, Michael has extensive knowledge of web & graphic design and serves as the primary system administrator for the RMC team.

Karl Zeller is the Rocky Mountain Center's Chief Wizard and has spent about 40 years working in the field of meteorology for the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, The Bureau of Land Management, the Forest Service and for private consulting fir ms. He was a part-time Air Force Reservist Weather Forecaster for 26 years. He has a Ph.D. in Boundary Layer Fluid Mechanics from Colorado State University. Karl is also an American Meteorological Society Certified Consulting Meteorologist. His hobby is undisciplined meteorology. ❄

Manuel (center) passes out the briefcase-sized radio-controlled targets.

An Avalanche Rescue Seminar with Manuel Genswein

Story & photos by John Brennan

Easy Searcher 3 control unit

A stint in the military is mandatory in Switzerland. When his time came, Manuel Genswein enlisted in the mountain division. Part of his training involved beacon searches. After completing the primary and secondary search, if his first probe attempt wasn't a direct hit, then he was cordially invited to conduct another search. This experience got Manuel thinking about search strategies and associated instructing methods. Manuel has training in electrical engineering and extensive ski mountaineering experience in the Swiss Alps, a background which makes him well suited to understanding beacon technology and beacon use in avalanche rescue. He also has a gift for passing along this information in an easy-to-understand format. Snowmass and Aspen Highlands recently had the opportunity to host an avalanche rescue seminar taught by Manuel. Since he was traveling to the States for several other engagements, it was possible for us to share his travel expenses among the different organizations. Although Manuel was teaching a bargain-priced two-day seminar for the Summit County Rescue Group several hours from our resort, we felt that a separate course for a smaller group of like-minded professionals would best serve our needs.

The course was broken down into three days, the first being a set-up day for the field session as well as an opportunity to "train the trainers" who would be assisting. The second day was in the classroom, and the final day was held in the field. The field day consisted of four unique scenarios, and by having four assistant trainers, Manuel could spend his time where he was most needed.

One of the focuses of the field day was the multiple-beacon training site. Manuel has developed the "Easy Searcher 3" for this purpose. Up to 16 of these radio-controlled units, each the size of a small briefcase, can be run by a control unit. Beacon signals from each buried target can be toggled on either manually or automatically, depending on the search scenarios you want. The targets alert the control unit when they have been struck by a probe. Additionally, a target's transmit signal can be turned off while the strike indicator feature continues to operate—useful for probe-line exercises. The "Easy Searcher" can be permanently installed and toggled for automatic use by rescue groups or the public.

Multiple burial exercises can be difficult at best. Manuel has taught his search strategies for these events in over 14 countries as well as presenting them at the International Snow Science Workshop in 2000 and 2002 and in *The Avalanche Review* (See *Pinpointing in a Circle*, Vol. 19, No. 3, pp. 8-9, and *Statistical Analyses on Multiple Burial Situations and Search Strategies for Multiple Burials*, Vol. 21, No. 3, pp. 9-11 – ED.). While some of our patrollers were scratching their heads a bit over Manuel's strategies during the classroom session, in the field it became crystal clear that these systematic systems were the best way to find an unknown number of buried beacons. The field day also provided a chance to learn Manuel's strategy for pinpointing deeply buried victims—another potential exercise in futility given the number of false maximum readings that can be produced in these events. Once again, when theory and practice united, it became clear that we were learning and honing life-saving skills. His Web site www.genswein.com contains specific information on rescue courses as well as downloadable copies of all his papers.

*John Brennan has recently taken on the responsibilities of Rocky Mountain Section Representative for the AAA. In the rest of his life, he is an avalanche and explosives specialist who works at Snowmass, Colorado, and Las Leñas, Argentina. He has published several previous articles in **The Avalanche Review**. He can be reached at jbrennan@aspensnowmass.com* ❄

Manuel (in sweater) describes the control unit to Snowmass and Highland patrollers.

snow science

Compatibility of Avalanche Transceivers

Story by Felix Meier

AUTHOR'S NOTE: In their recent story published in *The Avalanche Review,* Edgerly and Hereford propose some actions to be taken to improve on the compatibility among avalanche transceivers. Most of their general conclusions are appropriate, but this author believes that some important details require a clarification. In particular, new standard requirements should not lead to inferior performance.

Introduction

The issue of transmitter frequency tolerance and receiver bandwidth has been around for quite some time, at least since the publication of the ANENA report on transceiver tests [2]. It is generally agreed that the current standard EN 300 718 should be improved by specifying a receiver filter bandwidth, and this will definitely be an issue in the next overhaul of the standard.

Transmit Frequency

The requirement for transmit frequency tolerance has been set to ± 100 Hz since the appearance of the first standards on avalanche beacons (ÖNORM S 4120, 1984 and DIN 32944, 1986). This requirement cannot be met by using ceramic resonators, but with X cut crystals it is possible. So any beacon using such resonators would not conform to the standard. Almost all older beacons with poor quality resonators should be phased out by now.

Excessive frequency offset or drift for transmit oscillators are due to:

- poor crystal quality
- improper crystal type selection (cut type)
- inadequate quality control (incoming parts inspection)
- improper design (circuits around crystal, minimizing mechanical shock to crystal)

All these effects can be controlled through careful design and production. Crystal aging is almost negligible, and the sensitivity to shock can be reduced by proper mechanical design. Those criteria apply to both analog and digital beacons. Good designs result in a frequency deviation of less than ± 50 Hz from the nominal 457.000 kHz over the entire temperature range.

AT cut crystals exhibit a better performance against temperature changes than X cut crystals, but the AT cut is not available for frequencies as low as 457 kHz. If an AT cut crystal is used, it will resonate at a higher frequency, which must then be divided to yield a frequency of 457 kHz. However, frequency divider circuits can produce strong interference at frequencies which are used by portable radios. If a ski patroller is using a transceiver with such a frequency divider together with a portable radio, you will get complaints about some nasty noise on the radio.

Being aware of the compatibility issue as stated in [1] and of the limits imposed by technology, some participants in the creation of the current EN 300 718 voted for an even more stringent frequency tolerance requirement of ± 50 Hz, but the committee finally compromised on ± 80 Hz in 2001.

Beacons not conforming to the ± 100 Hz requirement should therefore be replaced, and newer beacons (later than 2001) should not be put on the market unless they meet the ± 80 Hz requirement.

Receiver Bandwidth

As stated by [1], narrow bandwidth helps to increase receive range. The detection capability of a receiver is limited by the ratio of the signal power received to the noise power received, shortly the signal to noise ratio. Noise is always around; it is a feature of Mother Nature.

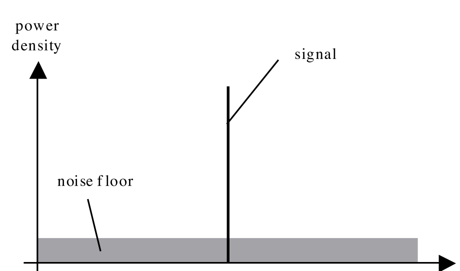

Figure 1

The signal to noise ratio as seen by the receiver is equal to the ratio of the signal surface to the noise floor surface in figure 1. The purpose of a receiver filter is to minimize the noise floor surface by limiting the frequency range where it is significant to the receiver:

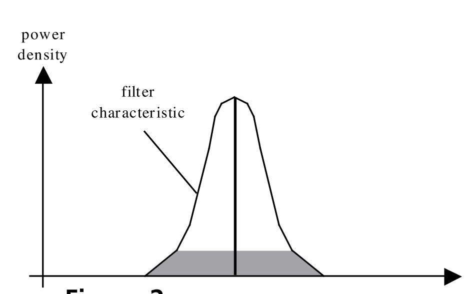

Figure 2

As can easily be seen from figure 2, using a narrow band filter is a good means for reducing the noise power seen by the receiver, thus increasing the signal to noise ratio. This is why crystal filters have been in use for more than 30 years in some receivers, which is a long time before the appearance of digital beacons.

The bell shape is typical for all kinds of crystal filters.

The more a transmitter frequency is offset from the center frequency, the more its signal is attenuated when it enters the receiver:

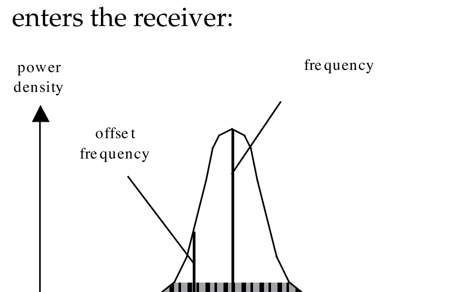

Figure 3

If the width of the bell shape is extended in order to produce less attenuation on the offset transmitter's signal, this also widens the noise floor area, thus reducing receiver performance or, in other words, receiver range:

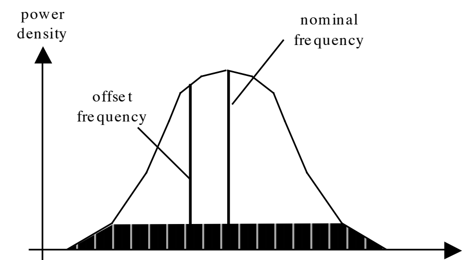

Figure 4

Standardizing on such a wider filter would force manufacturers to build beacons with inferior performance. This does not serve the user community well.

An obvious question would be why manufacturers do not use a filter with a rectangular characteristic to minimize the noise power as seen by the receiver and still provide no attenuation to offset transmitters:

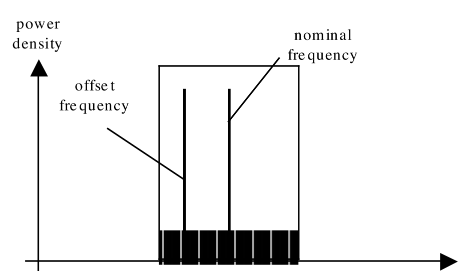

Figure 5

Unfortunately, the laws of nature prohibit the implementation of such an ideal filter, so we must live with a compromise such as the bell shaped filter curve shown in figures 2, 3 and 4.

A closer approximation to the ideal filter shape than provided by a single crystal filter can be obtained by means of a combination of a crystal filter and a Digital Signal Processor (DSP). The tradeoff between bandwidth and receiver range still exists with this approach. The drawbacks of this approach are an increase in the bill of materials as well as an increase in power consumption. Also, the performance is disastrous with transmitters that are outside the filter pass band. The bell shaped filter has the advantage of graceful performance degradation when used against offset transmitters. One manufacturer has selected the DSP approach. This is the reason why the sample D5 in figure 3 of [1] achieves zero range.

Receiver sensitivity is specified in terms of the maximum magnetic field strength required to produce a noticeable signal to the user. The unit of measurement is Nanoampères per Meter, or nA/m for short. This signal may be either a distinct audible tone or a change in some visual indication. The current requirement is a sensitivity of 80 nA/m at 457.000 kHz ± 0 Hz. A higher numeric value for the maximum field strength thus implies a lower sensitivity:

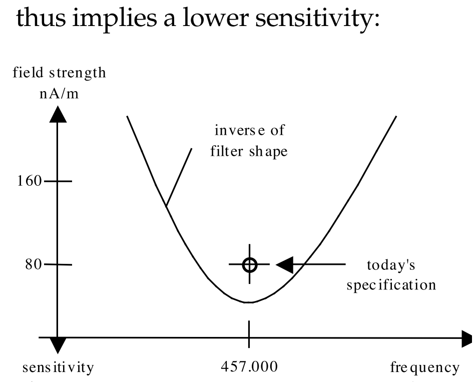

Figure 6

Upon the next revision of the EN 300 718 standard, a specification for receiver bandwidth should be introduced. A reasonable specification would be that the sensitivity of the receiver at 457 kHz ± 100 Hz be no more than + 6 dB relative to the sensitivity required at 457.000 kHz (dB is a logarithmic unit of measure for the ratio between two signals, 6 dB are equivalent to a ratio of 2 for field strength):

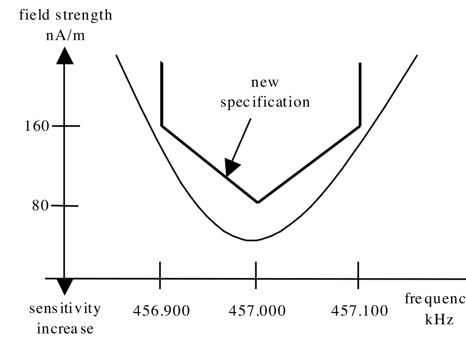

Figure 7

At the edges of the pass band, the sensitivity would thus have to be 160 nA/m at most. This requirement enforces a minimum receiver bandwidth and thus a minimum of compatibility among transceivers.

Electromagnetic field theory says that range is proportional to the inverse of the 3rd root of a change in field strength for this kind of application (operating in the near field). Doubling the maximum field strength is thus equivalent to a -2 dB or about 20% reduction in range. At the edges of the band, i.e. at 457.000 kHz ± 100 Hz, the range thus still is about 80% of the range against a transmitter operating at 457.000 kHz. Most transmitters operate within ± 30 Hz of the nominal carrier frequency. In that band, the reduction in range would be even smaller (about 7%).

Conclusions

Transmitter frequency tolerance requirements can easily be met by proper design and manufacturing. Rather than standardizing on inferior receiver performance, we should try to eliminate the beacons that are not conforming to the standard.

- Receiver bandwidth should be specified in a modified version of EN 300 718. We propose to settle on a specification of + 6 dB at 457 kHz ± 100 Hz for the maximum field strength to produce a noticeable signal.
- The receiver bandwidth should not be extended from the values currently in use, because this would mean standardizing on inferior performance.
- The issue of transmitter frequency offset is not limited to analog transceivers; it covers digital transceivers as well.
- Users should be encouraged to have their beacons checked and replaced if necessary.

Felix Meier is a consultant in electronics and software engineering. He has participated in all avalanche beacon standard groups since 1982. He was involved in the development of the Mammut Barryvox beacon. You can reach him at felix.meier@smile.ch

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High Frequency Radar: A Tool for Measuring Snow Statigraphy

Story and photo by H.P. Marshall

During my second year as a graduate student at the Institute of Arctic and Alpine Research, University of Colorado at Boulder, I received an American Avalanche Association (AAA) Graduate Research Grant. At the time, I was interested in adapting the Snow Slope Stability Model (SNOSS) (Conway and Wilbour, 1999) to a continental snowpack. Red Mountain Pass was an ideal location, as many direct-action avalanches occur each winter, and weather and avalanche observations are made daily. Hourly precipitation measurements, which were not measured, are required to run SNOSS. Using part of this AAA grant and some borrowed equipment, I got a precipitation gauge installed with the help of Andy Gleason, Jerry Roberts, and Maria McAlpin. During the first winter, this gauge did not collect data during enough avalanche events to evaluate SNOSS. However, Chris Landry (Center for Snow and Avalanche Studies) is currently maintaining a precip gauge at Red Mountain Pass. During the next year we plan to work together to test and adapt the stability model.

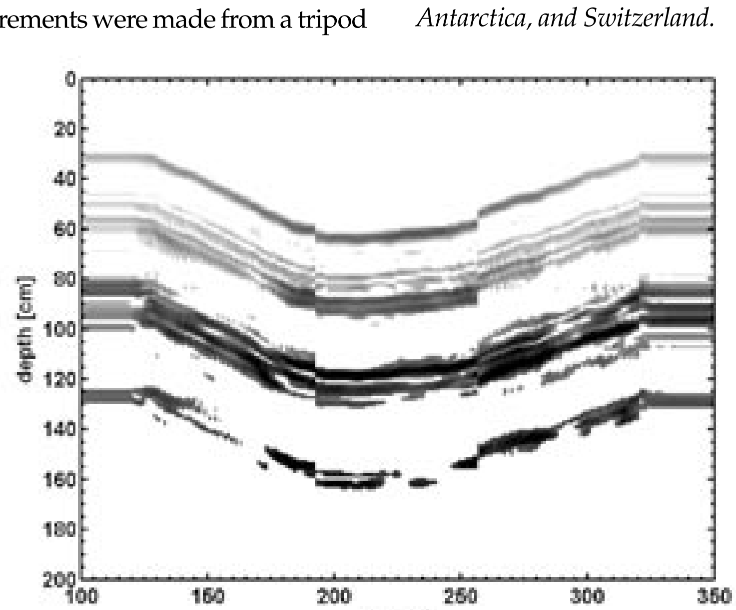
SNOSS is only a one-dimensional model, and with the large degree of spatial variability that exists, I quickly became interested in developing a method to efficiently quantify snowpack variations. An obvious candidate is ground-penetrating radar, as it is non-destructive, and measurements can be made very quickly allowing large spatial coverage. While radar measurements are known to be sensitive to changes in density and grain size, signal interpretation remains difficult. I began experimenting with a pulsed radar, which was the most sensitive of its kind and had the highest resolution commercially available. These radars have been developed mostly for applications in rock and ice, and therefore they are not ideal for snow. I found that although they can be used for snow depth monitoring, this type of radar did not have a high enough resolution (~15 cm) to monitor snow stratigraphy.

A different type of radar (FMCW), which still remains a research tool and is not yet commercially available, has been used for measuring snow stratigraphy in the past (e.g. Ellerbruch and Boyne, 1980; Gubler and Hiller, 1984; Koh et al, 1996). In collaboration with Gary Koh (U.S. Army Cold Regions Research and Engineering Lab), I made measurements in many different snowpacks with a large FMCW radar (Marshall et al, 2004a). This system weighed approximately 350 lbs; therefore measurements were made from a tripod over an arc of only 3 meters. During the last two years, we have built a small, lightweight version of this FMCW radar, which can be easily suspended between two skiers (see photo) and has a vertical resolution of ~1 cm. The remaining funds from my AAA grant helped to offset the costs of supplies for an early prototype (since grad students don't make the big bucks), which was used with success, in collaboration with Martin Schneebeli, while I was a visiting Ph.D. student at the Swiss Federal Institute of Snow and Avalanche Research last winter (Marshall et al, 2004b). The figure shows a typical signal from the portable radar, showing the snow surface, the ground, and more than 5 internal layers within the 85 cm snowpack. The depths of these layers agreed well with layers identified with the SnowMicroPenetrometer (SMP).

This winter I will be making extensive measurements with this portable system. Several AAA and AIARE instructors have generously offered to let me run the radar alongside snowpit measurements made during Level II and III avalanche courses in Colorado. Radar measurements will be compared with snowpit measurements, and the major radar reflections, corresponding to the important layer boundaries identified in the snowpits, will be followed along transects, resulting in a detailed description of variations in layer thicknesses. I will also take the radar to Montana this winter, to make side-by-side measurements with the radar and the SMP, with Kalle Kronholm (MSU) and Karl Birkeland (USFS). Although the cost of this radar is currently prohibitively expensive for most avalanche practitioners, this tool has great promise for improving our understanding of spatial variability and the 3-D geometry of snowpacks, as measurements can be made 50 times/second, suspended either between two skiers or off the side of a snowmobile.

Many thanks to the AAA – the Graduate Research Grant had a huge effect on my graduate studies!

As an undergraduate at the University of Washington, H. P. Marshall did research at Snoqualmie Pass, WA on rain-on-snow avalanches and wet snow densification, as well as glaciology-related work in the Olympic Mountains and in East Antarctica. As a graduate student at CU, his research has been focused on snow slope stability modeling, development of high frequency radar for snow stratigraphy measurements, snow hydrology, and landmine detection applications, and glaciology projects in Colorado, Alaska, West Antarctica, and Switzerland.



FMCW radar measurements made in Davos, Switzerland.

High school students Paul Kirschner and Austin Williamson make measurements with the new light-weight portable radar. The small battery and laptop used to acquire data are not shown.

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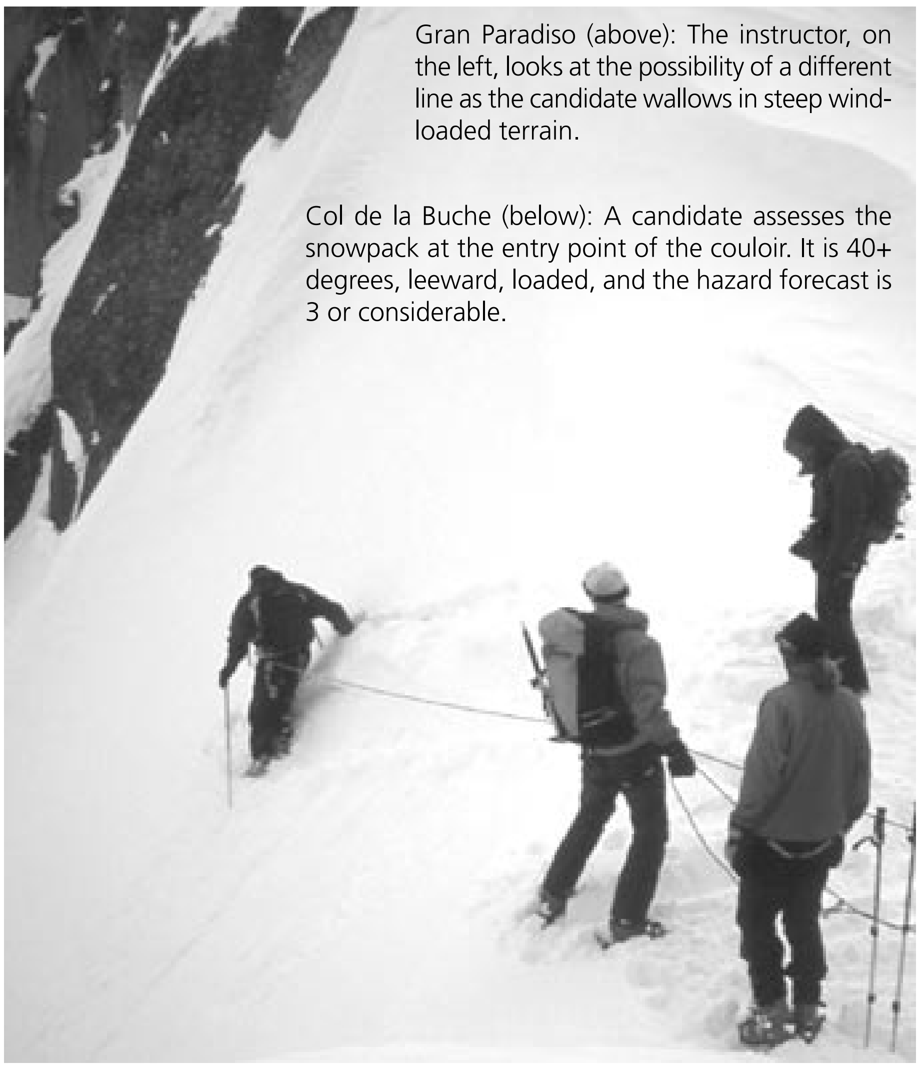
Developing Good Decisions

Story and photos by Iain Stewart-Patterson



Gran Paradiso (above): The instructor, on the left, looks at the possibility of a different line as the candidate wallows in steep wind-loaded terrain.

Col de la Buche (below): A candidate assesses the snowpack at the entry point of the couloir. It is 40+ degrees, leeward, loaded, and the hazard forecast is 3 or considerable.

Decision-making in avalanche terrain is challenging because it involves conditions of uncertainty. Often there may be a sense of doubt that blocks or delays our actions. We may not adequately understand what is going on since we have a diminished level of situational awareness. We may suffer from having incomplete, ambiguous, or unreliable information. All of this may lead us to generate options or solutions that conflict or are insufficiently differentiated. Nobody said decision-making would be easy.

A study of how decision-making is trained and assessed was conducted during the winter of 2003. It spanned mountain-guide and mountain-leader training programs in France, Britain, Canada, and the United States. The intent of the study was to gain insight into the best practices that are currently in use in these countries' mountain-training programs. Observations came from two ski-based programs: the Aspirant Winter Guide Exam conducted at the Ecole Nationale de Ski et Alpinisme in Chamonix, France; and the Association of Canadian Mountain Guides – Guide Training Ski Touring course conducted in Roger's Pass, BC, and the Assistant Ski Guide Exam conducted in Naden Pass, BC. Observation also came from two summer courses: the American Mountain Guide Association – Alpine Guide Course conducted in Lander and Jackson Hole, Wyoming; and the Scottish Mountain Leader Assessment conducted at Glenmore Lodge, Scotland.

The Challenge

There are a number of factors that we commonly consider within a decision-making matrix. They can be condensed into three major categories: internal or human factors, external or environmental factors, and luck. The external factors, also called objective hazards, tend to get the most attention. The avalanche community has been very diligent in finding technical solutions to these environmental hazards. An example of this would be the work done at the University of Calgary on Fracture Plane Characteristics. Armed with this increased knowledge base, both professionals and recreationists now head to the backcountry with the potential to ski, board, or ride more safely. Or do they? There is ample evidence that safety is based in attitude rather than knowledge and experience. The human factors side of the equation has received some attention, but needs further investigation.

Two of the questions that we face are "What is a good decision?" and "How do we recognize when we are making one?"

The CAA Level 2 course now includes a module on decision-making and describes a good decision as including the following components:

- It is based in situational awareness.
- More than one option is developed and assessed.
- Adequate margins are incorporated into each solution.
- The proposed solutions can be efficiently implemented with respect to resources and time.
- A good decision will contribute to the overall success of the endeavour.
- A quality decision-making process includes an element of reflection.

In many ways, situational awareness is the key to the interpretation of the human-factors dynamic. If we can maintain an accurate perception of what is happening to us and around us, we are capable of quickly identifying a situation that requires action. In essence, this boils down to:

> Where am I, How am I, and What is happening around me that may affect me? When people have well-developed situational awareness, they can make the continuous adjustments that prevent errors from accumulating and enlarging. Anomalies are noticed while they are still tractable and can still be isolated. (Weick, 2001 p.13)

The Current Research

The human factors that are commonly considered to contribute to decision-making include: physical, perception, confidence, hazardous attitudes, personal awareness of risk, situational awareness, and intuition. These factors become more complicated when including group dynamics such as: poor communication, operational pressures, competitiveness, and client expectations. The physical components alone are cause for consideration. Sleep, caloric intake, drug or alcohol consumption, stress, injury, illness, and lack of rest days have a huge impact on the potential quality of decisions. There has been a great deal of public education on the effects of the consumption of alcohol on decision-making as it relates to driving performance. It is difficult for an impaired person to evaluate their level of impairment. The same could be said for someone suffering from lack of sleep or illness. In a study done by Coren (1996) on sleep deprivation, IQ was found to drop following successive nights of inadequate sleep. There was a cumulative effect when subjects had less than seven hours of sleep. So, as our physical state deteriorates, we become less able to make decisions and to evaluate the quality of the decisions that we make.

Perception plays a huge role in our analysis of the need for a decision. A lack of situational awareness may lead to the perception that nothing needs to be done. The perception of risk is dependent on the participant's previous experience with the activity, their assessment of the potential hazards, and the degree of confidence in their decision-making skills. Wilde (1994) suggests that we all have a target level of risk tolerance. This is the level of risk a person chooses to accept in order to maximize the overall expected benefit from an activity. He also suggests that risk homeostasis will occur. In essence, there is an optimal level of risk that we are willing to accept, and which we will seek to maintain. This brings up a question of whether improved or additional safety equipment will help us stay alive. Will having an Avalung and/or an ABS pack make you any safer? Both of these devices have the capacity to save lives in specific situations. Is it possible that a user may exhibit a tendency to take greater risks and ski steeper, more suspect slopes because of the addition layers of armour?

Weick (2001) identified the characteristics of High Reliability Organizations (HRO) using the term "mindfulness," which includes a preoccupation with failure where error reporting is encouraged and near-misses are examined for clues. These processes of reflection create more complete pictures of what is happening by looking for latent failures within the system. These are "loopholes in the system's defenses…whose potential existed for some time prior to the onset of the accident sequence, though usually without any obvious bad effect." (Weick 2001, p.13) It is important to recognize that errors are still going to occur, so keep them small and learn from them.

"Safety is elusive because 'it is a dynamic non-event – what produces the stable outcome is constant change rather than continuous repetition.' The problem is that when a system is operating safely and reliably there are constant outcomes and nothing to pay attention to. That does not mean that nothing is happening, even though it is tempting to draw that conclusion. Quite the opposite. There is continuous mutual adjustment." (Weick 2001, p.30-31)

The Outcomes— Training in Making Better Decisions

There are three essential components that must be included in order to optimize the learning environment: trainers that understand the process, learners that are open to learning, and terrain that is conducive to making "real" decisions.

One of the basic assumptions being used here is that experts make better decisions than novices. This brings up the question: "What is an expert?" Generally this is associated with many years of experience in a variety of situations. The critical component is the learning that has occurred as a result of the experiences. As it is entirely possible to develop false or misleading experience, the experiences must be referenced outside of the immediate situation in consultation with other seasoned decision-makers. As we have seen in the recent past with the Space Shuttle and other events, even expert decision-makers can sometimes be wrong and end up in catastrophic situations.

Good trainers must be selected carefully. They must be capable of making good decisions themselves and recognizing good decisions in others. Beyond this, they must be able to nurture the decision-making process in their students. This could be considered a coaching role. These trainers will probably need to be trained themselves. Specifically, they will need to develop highly sophisticated feedback skills. In addition to this, they will need to be able to train the candidates in receiving feedback.

The training of the learners begins with goal setting and the clarification of expectations. It continues with a process that helps them recognize the quality in their decisions. In post-trip debriefs, many candidates described their performances in positive tones that did not necessarily reflect the observations of the instructor. The most important attitudinal approach the candidate can take is to accept the existence of more elegant solutions. The greatest contribution that the instructor can make is to describe or even demonstrate these elegant solutions.

With candidates being coached toward an industry standard or certification, decisions will ultimately be assessed through a summative evaluation process. Prior to that point, decisions will be assessed using a formative approach. This necessitates a clear distinction between training days and exam days. On a training day, "OK" or "Adequate" is not good enough. It is essential to train the candidates to look for the elegant solutions. On an exam day the rubric may look something like this:

Pass: the decision is good enough. It exceeds the exam criteria.
Marginal Pass: the decision is on the line that separates pass and fail.
Fail: the decision is not good enough. It does not meet the criteria.

The exam process does not necessarily recognize the elegant solutions. In the big picture, however, this is an essential component of the candidate's growth. The tone during the training session needs to be one of "Yes, you are good, but you can also be better." This may help to address the ego needs of the candidates. They have worked hard to get into the training course and have high expectations of themselves. Unfortunately this can lead to a situation where the candidate feels the need to express a high level of confidence in his/her decision-making and may be reluctant to admit weakness. In this situation, the candidate's ego will negatively affect the potential learning. The question for the candidate is, "Are you coachable?" Ideally, the instructor can create an atmosphere of learning that separates the ego from the process. If the ground has been prepared well, the coach should not be afraid of hurting the candidate's feelings when giving an alternate solution.

Reflections on the decisions that are made during the day are an essential component of the process of developing better decision-making skills. Decisions can be debriefed at a variety of points during the day. There are pros and cons to each of these times.

It may be advantageous to make an intervention during the lead. If the candidate appears to be making a critical error that may lead to catastrophic consequences, the instructor must intervene to maintain an adequate safety margin. Another type of intervention is necessary when a candidate makes an error in navigation that will have serious logistical consequences for the rest of the day.

On a more positive note, subtleties in the management of micro-terrain are best described at the moment. This coaching of the more elegant solution is ineffective if left to the end of the day. It is a "teachable moment." Some level of reflection and debriefing at the end of each lead is of distinct benefit due to its timeliness and focus. The downside is that debriefing at the end of every lead may break up the flow of the day. If a stop is taken at midday for a lunch break, there is the opportunity to debrief a number of leads. This may make valuable use of down time.

The most traditional time for a debrief is at the end of the day. This may also include the components of a Guide's Meeting. The debrief may be formal or informal, but ideally will have some form of structure or format to follow.

The key to making a quality assessment of a candidate's ability is the creation of a situation that demands real decisions in real terrain with real, but manageable consequences. This involves getting inside the candidate's head on a regular basis, by asking the question, "What are you thinking about here?" It is important to ask the question both when things are going well and when they are not. The candidate needs to be allowed to assess a situation, come to a decision, and to carry through on it. However, it is a delicate balance whether to allow a marginal decision to be enacted vs. the overriding safety considerations of the group.

Decisions and Outcomes

We must ask ourselves the question, "Did we arrive at the right place for the wrong reason?" Inevitably there are times when this occurs. However, it is all too easy to jump to the conclusion we were right for the right reason and miss this invaluable learning opportunity.

"In that brief interval between surprise and successful normalizing lies one of your few opportunities to discover what you don't know. This is one of those rare moments when you can significantly improve your understanding. If you wait too long, normalizing will take over and you will be convinced that there is nothing to learn. Most opportunities for learning come in the form of brief moments. And one of the best moments for learning, a moment of the unexpected, is also one of the most short-lived moments." (Weick 2001, p. 41)

Acknowledgements

The University College of the Cariboo provided the bulk of the funding for this project. The Ecole Nationale de Ski et Alpinisme covered food and accommodation costs. Arcteryx provided a complete set of winter clothing and equipment. The Association of Canadian Mountain Guides Training and Certification Program assisted with accommodation costs. Glenmore Lodge in Aviemore Scotland provided food and accommodation. The American Mountain Guides Association assisted with travel costs.

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SUPPORTING GOOD DECISIONS

A Professional Perspective on Avalanche Accident Prevention in Canada

Story by Laura Adams

Editors' Note: *This article is a shorter version of the poster presented at the International Snow Science Workshop 2004. A full version is available upon request.*

INTRODUCTION

In the 10-year period of 1994 to 2003, avalanche accidents in Canada killed an average of 15 people annually (*Public Avalanche Safety Program Review*, 2003. p. 2). Recently, in the winter of 2002/03, 29 people died in avalanches while pursuing backcountry recreation in Canada – the highest annual backcountry avalanche-fatality rate in Canadian history. Since winter backcountry use is increasing significantly in Canada, there is an urgent need for effective prevention methods to support sound backcountry recreational decisions and to protect lives.

Researchers in the snow-avalanche field have focused extensively on understanding the physical properties of snow avalanches, e.g., snow metamorphism, avalanche release dynamics, weather, and terrain factors. Initiatives in public-safety avalanche prevention and education have been designed around these complex physical factors. However, due to the limited understanding of human factors and decision processes in avalanche terrain, education initiatives have yet to address key human components, and therefore may be lacking in their effectiveness. Avalanche practitioners and researchers are now recognizing the significant role human factors play in avalanche accidents, and several researchers have recently examined this area of avalanche phenomenon (see Fredston and Fesler, 1994; McCammon, 2002, 2000). "Since most avalanche accidents result from human errors, no description of avalanche forecasting is complete unless the human component is addressed" (McClung, 2002. p.1).

In this paper, I report the results of a survey of avalanche professionals and practitioners in western Canada. The objectives of my research were to capture the theoretical knowledge and experienced insight of Canadian avalanche experts, and to use this knowledge and insight to derive effective solutions for reducing avalanche accidents and improving the decision-making practices of winter recreationists.

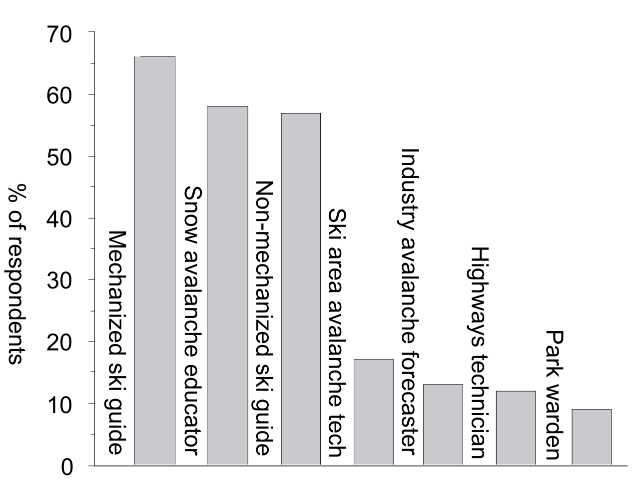

Figure 1. Area of expertise in the avalanche industry

METHODS

To examine recreational avalanche accident prevention from an avalanche experts' perspective, I surveyed Canadian avalanche practitioners in five topic areas: recreational avalanche accident factors, education, hazard communication, decision-support, and accident prevention. Respondents were asked to judge what they believed to be the:

- primary factors in recreational avalanche accidents
- core knowledge and skills for sound avalanche decision-making
- key areas of education that can improve avalanche decision-making
- effective methods to communicate avalanche hazard
- potential of a decision-support framework to improve decision-making and result in fewer avalanche accidents and fatalities

In the fall of 2003, I sent the survey by e-mail to all professional members of the Canadian Avalanche Association (CAA; n=284). As well, it was given in person to a group of experienced helicopter ski guides attending a pre-season training session. In total, I received 79 completed surveys. 72 surveys were from Canadian avalanche professionals representing 26% of the total CAA professional population at the time the survey was administered. The remaining seven surveys were from industry practitioners. Respondents represented a cross section of avalanche industry expertise (Fig. 1) and held a high level of industry experience with 40% of respondents having 20+ years of experience, 35% with 10-19 yrs, and 25% with 1-9 yrs.

The survey included both quantitative and qualitative questions. Quantitative questions involved ranking factors in the five topic areas using two methods: a five-step Likert type scale (1 = to a very great extent to 5 = Not at all) and ranking in order of importance (1 = most important to 5 = least important). To gain a comprehensive perspective for each question, I also asked respondents to include any additional factors they felt were important. A qualitative question culminated each of the study topics. For example, "Do you have any additional comments regarding decision-support methods/tools for recreational backcountry travelers?" These qualitative data were analyzed using meta-theme analysis, a procedure that captures the meaning in phrases and singular statements (Kirby and McKenna, 1989; VanManen, 1990). These meta-themes are shown throughout this paper.

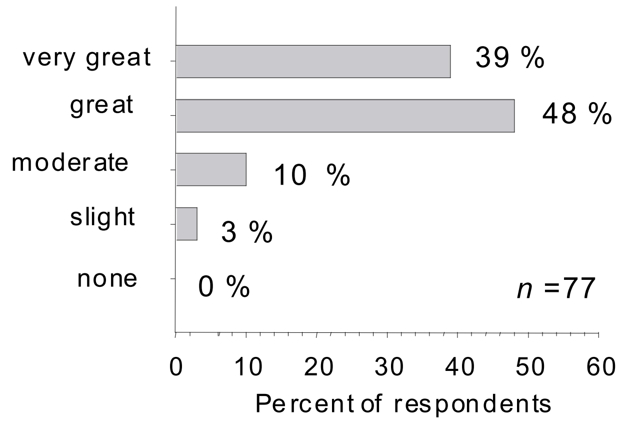

Figure 2. The extent that human factors influence recreational decisions resulting in avalanche accidents

RESULTS

Primary Causes of Recreational Avalanches

Respondents identified "human factors" and "choice of terrain" as the primary causes of recreational avalanche accidents followed by "inadequate snowpack assessment" and "failure to recognize meteorological effects on the snowpack."

Human Factors

97% of the respondents believed that human factors have a moderate or greater influence in recreational decision-making (Fig. 2). Human-factor meta-themes were:

- "Human factors and decision-making processes are the main hazard, not the snow."
- "Avalanche terrain is not a hazard until humans decide to go there."

Experience

84% of respondents indicated that level of experience has a very great or great impact in recreational decision-making (Fig. 3). Qualitative meta-themes included:

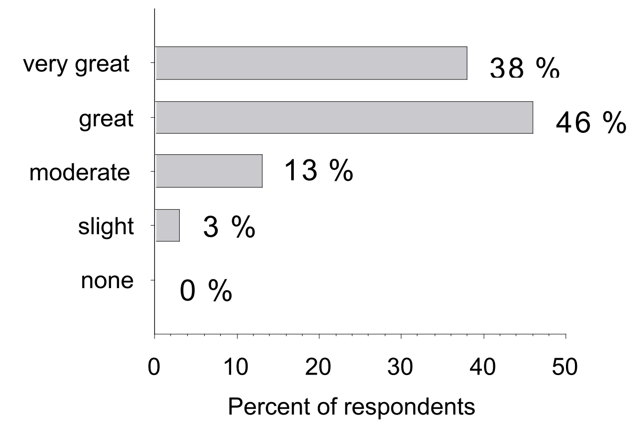

Figure 3. The impact of experience on recreational decision-making

- "Most decision-makers can't practically make good self-evaluations on the validity of their decisions until they have developed 'appropriate' experience."
- "Ultimately wise decision-making takes experience that comes with time."

Training and Education

67% of respondents felt that training and education has a very great or great impact in recreational decision-making. Two themes emerged from the qualitative responses: (1) recreational training in Canada could be more effectively designed to provide recreationists with better decision-making capacities, and (2) the curriculum currently taught in recreational avalanche training may provide recreationists with a false sense of security when making avalanche-related decisions. These themes will be addressed in detail in the following sections.

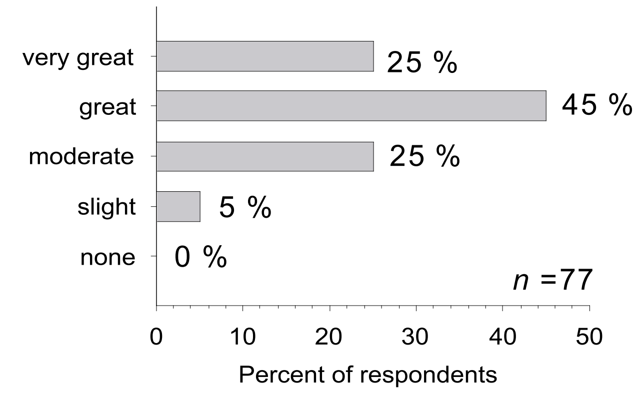

Figure 4. The extent that education in terrain and route-finding will improve recreational decision-making and reduce accidents

The Impact of Media

63% of respondents felt that "media extreme role modeling in snow terrain" had a moderate or greater impact on recreational decision-making. Meta-themes included:

- "The trend toward 'extreme' activities with the corresponding proliferation of videos and print media seems to be driving decision-making processes towards risk tolerance also in the range of 'extreme'."
- "Self-confidence and perceived risk levels in relation to terrain observation are greatly influenced by current role modeling of terrain use by mass media (text and video)."

Physical Properties	To a very great extent	To a great extent	To a moderate extent	To a slight extent	Not at all
Meteorogical effects	5	44	38	13	0
Snowpack characteristics	5	23	41	30	1
Snowpack tests / site selection	5	33	45	16	1

Table 1. The extent to which snowpack education will improve recreational decision-making and reduce avalanche accidents. Values represent the proportion of respondents by factor (i.e., rows add up to 100%).

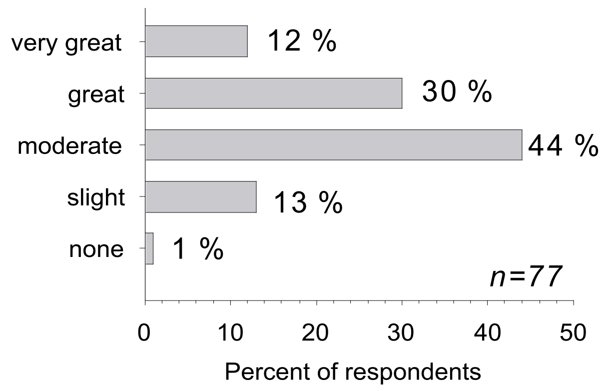

Figure 5. The extent that education in human factors will improve recreational decision-making and reduce avalanche accidents

Knowledge, Skills and Education

I asked respondents to identify the core knowledge and skill topics that would "effectively improve recreational decision making abilities therefore resulting in fewer avalanche accidents and fatalities." Terrain and route finding was selected as the area of greatest potential (Fig. 4), followed by human factors (Fig. 5).

- "Local courses in specific terrain are the best idea as it can increase specific terrain knowledge. Recreationists can also be encouraged to relate weather and avalanche events to specific terrain, build relevant local knowledge, and to encourage avoidance during avalanche cycles."
- "We should extend our educational focus in the realm of human factors, decision-making and situational awareness."

When asked about educating recreationists in the physical properties of the snowpack, qualitative and quantitative results were mixed. Quantitative results indicated that education in the physical properties of the snowpack will improve decision-making and reduce avalanche accidents as shown in Table 1. However, qualitative results suggested the opposite. These meta-themes included:

- "Striving to develop recreational understanding of deeper instabilities and how to judge when the snowpack is strengthening or weakening is ineffective. These complexities are challenging enough for professionals to understand.
- "Courses need to focus on terrain selection because snowpack structure is complex and too changeable over time and terrain."

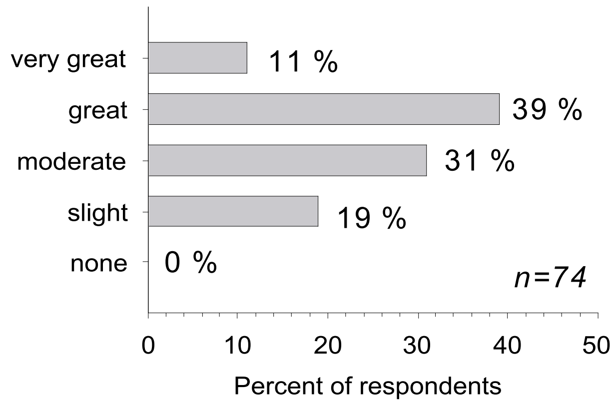

Figure 6. The extent that increasing the frequency and regions of avalanche bulletins will result in a decrease in recreational avalanche accidents

Hazard Communication and Graphical Mapping Tools

I asked respondents the extent to which "increasing the frequency and regions of avalanche bulletins would result in a decrease in the number of avalanche accidents and fatalities." 81% selected "to a very great" or "great extent" (Fig. 6). This question generated a great deal of comments from survey respondents:

- "Improve the scale of forecast areas from regional to local in high use areas."
- "Real results will only come from a complete re-visit to how the information is communicated to the public."
- "The best goal is to describe how to practically apply the bulletin to field decisions and to complement the bulletin with a basic factors checklist."

74% of the respondents felt to a moderate or greater extent that "identifying hazardous terrain on graphical terrain maps would simplify a recreational traveler's decision-making process and result in a decrease in avalanche accidents and fatalities." In addition, respondents commented that the use of graphics in general would be an effective augmentation to avalanche bulletins and as key decision information at high-use trailheads. Although there was strong support for increased use of various mapping tools by respondents (e.g. Geographical Information Systems (GIS), oblique and terrain photos), there were significant complexities associated with their implementation and use. Meta-themes included:

- "Detailed information describing the specific nature and terrain locations of existing snowpack instabilities provides a useful tool for terrain selection and routefinding decisions."
- "If mapping is provided in high use areas indicating hazardous and safe areas, the likelihood of accidents in those areas will be reduced."
- "It takes some sophistication to be able to accurately identify on the ground specific areas that are marked on a map."
- "This may lead to potential liability and limitations to professional practice."

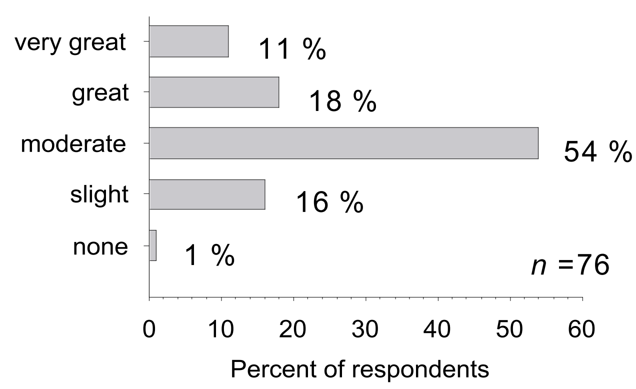

Figure 7. The extent that a recreational decision-support framework will improve decision-making and result in fewer avalanche accidents

Decision Support

83% of the respondents felt to a moderate extent or greater that the "design and implementation of a recreational decision support framework for Canadian recreational travelers will improve decision-making in snow-covered terrain and result in fewer avalanche accidents and fatalities" (Fig. 7). Qualitative meta-themes included:

- "There is great potential here. Tools that help make better decisions or impart discipline could have significant effects."
- "A decision-support tool may take some of the guesswork out of recreational decisions and make it easier to arrive at a decision without being influenced by other group or internal pressures."

These avalanche practitioners also articulated their concerns regarding the implementation of a decision support framework.

- "Such a decision making tool is of value to statistically reduce the number of accidents in the population that is not highly experienced and educated. These tools would oversimplify the process for more experienced people and would not be an improvement for professionals. We have to be careful about a possible double standard and be clear that the rule-based methods are applicable to less experienced people only as a substitute for experience."

Results of this study indicated two meta-factors that were identified by respondents as most important in recreational avalanche decision-making: human factors and experience. As well, three key themes emerged from this study for supporting sound decisions by recreationists: education and training, hazard communication, and decision support.

Meta-Factors in Recreational Decision-Making

Human Factors

Respondents believed that human factors are the key influencing factor in the decisions that recreationists make in avalanche terrain. Since human factors are comprised of knowledge, skills and attitudes, it is important to note that they are not a separate decision factor, but are inherent in all avalanche decision processes such as terrain selection or snowpack assessment.

Statistics from avalanche accidents in Canada between 1984 and 1996 state common failures in the decision process of recreationists include not recognizing the indicators of unstable snow and, either not understanding, or choosing to ignore fundamental principles of safe terrain choice (CAA, 2003b, ¶ 10, 12). Since decision-science research indicates that humans generally have the capacity to make systematic and methodical decisions (Kahneman, 2003; Slovic, Fischhoff & Lichtenstein, 1977), this situation perplexes avalanche researchers. Human factors appear to play a strong role in these avalanche accidents; from an avalanche professionals' perspective, these are primary basics of avalanche awareness.

While the presence of human factors in avalanche phenomena has been recognized in the past, the necessity to implement frameworks to cope with these complexities has only come to the fore recently. Social science research into human behavior in avalanche terrain is a critical missing element in the informed design of these frameworks, and is needed to complement the extensive knowledge of terrain and snowpack. Tremper (1991) states, "It is not enough to know the discipline, but how the discipline interfaces with people."

Experience

Respondents stated that recreational users do not have the same degree of knowledge and practical experience that enables avalanche practitioners to more consistently perform the complex "knowledge-based" processes that are fundamental for safe decisions in winter mountain terrain. These avalanche practitioners identified experience as being the key enabling factor in sound avalanche decision-making. A broad experience base enables decision-makers to identify and consider workable choices of action first and focus on assessing the nature of the situation, rather than comparing alternate courses of action (Klein, 1997, p. 241). Inexperienced decision-makers are often victims of a wide range of harmful biases, such as failing to recognize high-stakes problems ignoring the existing information about probabilities and responding to complexity by accepting status quo, i.e., what has worked for them in the past (Kunreuther et al., 20i2). While it is important to recognize that backcountry recreationists in Canada have a wide range of experience levels, experience is the key factor that differentiates between the decision-making capacities of recreationists and avalanche practitioners.

Key Themes for Supporting Sound Decisions

Three areas to support sound avalanche decision-making and recreational accident prevention schemas emerged from this study: training and education, hazard communication, and decision support.

Education and Training

Respondents spoke strongly for the need to revisit recreational avalanche curricula in Canada and focus core topics on meaningful outcomes that effectively enable recreationists to improve their decision-making. Respondents identified human factors and terrain as being the key areas in recreational education that would effectively improve decision-making and reduce avalanche accidents and fatalities. In addition, respondents suggested courses held in local terrain would enable recreationists to build local-terrain and snowpack knowledge and could have a dramatic impact on improving decision-making.

Continued on page 17 ➡

Learning to Decide:
On Becoming an Expert

Story by Steven Conger

Every action is a result of a decision, regardless of whether it is where to place your foot next on the sidewalk, what speed to enter the next corner, determining a solution to a partial differential equation, painting a landscape, or knowledgably standing in an avalanche runout zone. Some decisions are cognitive without awareness. Others require comprehension, thought, and reasoning. Each of the decision examples is an application or combination of knowledge, skill, experience, or guess. An individual gains the first three of these through some form of learning. Progression through learning builds expertise in a specific area.

In this article, I discuss the relevance of a learning-stage model to the structure of avalanche education and the primary role of decision-making skill development. Avalanche education can logically be divided amongst three categories: recreational pursuits, vocational training, and academic instruction. There is a respective similarity of each grounded in a generic goal. The generic goal of avalanche education is to improve the individual's decision-making outcome and application of knowledge. In the effort to reach expertise, the goal becomes specific with the addition of a context, i.e.: at the individual's respective level of interaction with the avalanche environment.

Learning Stages

Since learning is the basis for gaining the necessary framework for decision-making, it is reasonable to adopt a learning model in discussing avalanche education. Thoughtful writings and discourse (Dreyfus and Dreyfus, 1986; Dreyfus, 2001) offer just such a model in an exploration of the uniqueness between human and artificial intelligence and the probability of success for educational uses of technology such as the Internet. In the model Dreyfus describes, the steps that make up education are instruction, practice, and apprenticeship. These are the steps to becoming an expert. He divides these three steps across six learning stages: novice, advanced beginner, competence, proficiency, expertise and mastery.

The learning stages identified are appropriate for the field of avalanche education. The stages he defines have an unencumbered logic, allowing a correlation between their progression and an individual's development in learning the salient aspects of the avalanche phenomenon.

The novice stage is described as context free; it is the facts and procedures needed to learn about the topic, endeavor, or science to understand it. No skill is required in recognizing the components at this level. At the advanced-beginner stage, the learner faces real situations. Here, the learner begins to understand the context of the facts and procedures gained at the novice stage. Fundamentals are presented in a number of examples where they become meaningful maxims rather than rules. Though, at this point, the learner is missing a sense of what discerns importance.

Competence is developed through instruction and/or experience. The learner gains or develops a plan or perspective to determine what it important within the context. Any result depends upon the perspective adopted by the learner. Dreyfus suggests at this stage, choices often lead to confusion or failure since the learner does not know for sure how the plan they adopt will turn out. He also describes success at this level as invoking elation, which brings emotion into play. There is risk associated with reward of outcome. Brenner (1984) supported this concept with research in nursing skill development. Dreyfus also regards emotional involvement in the outcome of decisions as a necessary component to progressing further in the learning stages.

Dreyfus describes proficiency as the learner recognizing the problem and figuring out an answer based on an assimilated set of salient experiences. As a learner gains proficiency, rules and principles are gradually replaced by situational discrimination.

At reaching expertise, the learner has experienced a large number of situations and is able to simultaneously see the solution and the problem. It is characteristically reached through small holistic improvements of skill, acquired under apprenticeship. The difference between proficiency and expertise is reasoning, versus intuitively knowing the response. Dreyfus simplifies the description of the expert as one who, without the appearance of making decisions, ensures that "what must be done, simply is done." Klein (1998) provides an alternative perspective: "Experts see the world differently. They see things the rest of us cannot. Often experts do not realize that the rest of us are unable to detect what is obvious to them." Mastery is presented as the highest level of skill and development of individual style, as a result of working with multiple expert teachers. The relative stages and their respective components, along with their decision perspectives, types, and commitment are shown in Table 1.

Dreyfus's perspective is on the progressive decision-making stages leading up to expertise and the unique human attributes separating the ability to "know-how" from "know-that." There, the skill of intuition plays a role in distinguishing human intelligence from artificial intelligence and helps to explain why expert systems cannot replace experts. There seems to be a lack of awareness or consideration of this progression to expertise in the investigation of expert decision-making by Klein (1998) and others on High Reliability Organizations (Weick and Sutcliffe, 2001). Mistakenly, these efforts see the expert out of the sequential learning context.

Decision-making Levels

The learning stage narrative illustrates how decision-making is an acquired skill. Decision-making in avalanche matters often culminates in the activity of avalanche forecasting, with direct exposure to the consequences of actions taken from the decision. In this application, the six learning stages can be simplified to three classifications, each logically combining the underlying characteristics of two learning stages. These are: Basic (novice and advanced beginner), Intermediate (competent and proficient), and Advanced (expert and mastery).

In the novice stage of the basic level, context-free decisions are based on the facts of avalanches, e.g. aspect, elevation, angle, roughness, etc. In other words, the decision is whether something is, or is not, an avalanche fact. The meaningful maxims brought forth at the advanced-beginner stage would include the question: what range of slope angles is most commonly associated with dry-snow avalanches? The answer is found through the simple decision-making technique of measuring the slope angle. Basic-level decision-making is typically characterized by avoidance. Without advancing to a new perspective, a decision-maker would never get out of the basic level. In terms of avalanche matters, these basic style decisions are as close as one might come to "risk-free."

The learner, once having learned to discriminate the facts and fundamental environmental context of avalanche hazard, then becomes a "know-that." They can now begin to build their real-world practical experience of these fundamentals in a variety of situations and locations. The movement toward this more experience-based level of intermediate decision-making "know-how" can only be successful if targeted education is complemented with ample amounts of targeted experience. Here, targeted experience may take on many forms, from the intentional encounter

Skill level	Components	Perspective	Decision	Commitment
Novice	Context-free	None	Analytical	Detached
Advanced Beginner	Context-free and situational	None	Analytical	Detached
Competent	Context-free and situational	Chosen	Analytical	Detached understanding and deciding. Involved in outcome.
Proficient	Context-free and situational	Experienced	Analytical	Involved understanding. Detached deciding.
Expert	Context-free and situational	Experienced	Intuitive	Involved

Table 1. Learning stage components. (Dreyfus & Dreyfus 1986)

of avalanche terrain on their own, to traveling under the tutelage of an advanced decision-maker.

What type of decision-making is best learned and practiced at the intermediate level? Remember from the earlier description that the number of situational elements and context-free components to which the learner is being exposed often becomes overwhelming. Selecting a set of actions is no simple matter for the competent individual. There is no objective procedure like the basic context-free feature recognition. To perform at an intermediate level requires choosing an organizing plan. To make sense of this, it is logical for the learner to adopt a hierarchical procedure of decision-making.

Such a hierarchical decision-making procedure is not to be confused with a heuristic, which is a shortcutting rule-of-thumb, often substituted for reasoned decision-making. For a decision-making structure to be applicable by the intermediate level decision maker, it must address conditional probabilities, be adaptable to the interrelated factors of snowpack instability, and allow for persistent use in acquiring increasingly complex experiences. A goal of the decisions made at the intermediate level is to optimize the continued practice and experience acquired over a significant period, leading to the development of "know-how."

The focus of decisions at the advanced level is operating or recreating within an optimal range of risk, much as alpinism is defined as "the art of climbing mountains in such a way to face the greatest risk with the greatest prudence." (Daumal, 1959) For the advanced decision-maker, a fixed set of simple, unconditional rules would be too strict and result in too conservative of decisions. An importance-filtering and organizing structure may seem too cumbersome to the advanced decision-maker. That person has adequate targeted experience to the level that not only is a situation, when seen as similar to a prior one, understood, but the associated decision, action, or tactic simultaneously comes to mind. Such an experience-based holistic recognition of similarity produces a deep situational understanding where, "When things are proceeding normally, experts don't solve problems and don't make decisions; they do what normally works." (Dreyfus & Dreyfus, 1986)

While experience-based holistic recognition of similarity produces a deep situational understanding at the advanced level, this does not imply all expert decision-making is intuitive. Clearly, though most demonstration of expertise is ongoing and non-reflective, when time permits and outcomes are crucial, the expert will deliberate before acting. At this level, decision-making education focuses on the manner in which the expert seeks to avoid loss of this situational awareness, or lapses into shortcuts. At the intermediate level, experiencing many situations from a single perspective provides the opportunity for increasing skill. At the advanced level, the decision-maker must be vigilant for bias creeping into the perspective.

McClung (2002) provides an examination and suggested framework to solve this problem. He presents the concept of a fundamental operational risk band, which defines the range where appropriate decisions should fall, thereby avoiding errors that might include actions too risky or too conservative. Examples of common biases affecting human factors and perception at the advanced decision-making level, along with McClung's recommended resolution model, provide a core for the type of continued education design for the advanced decision-making level.

In conclusion, the core focus of avalanche education is best realized in teaching the process of decision-making—imparting the ability to make skilled decisions followed by appropriate actions. The decision-making level with the broadest spectrum of skill levels is that of the intermediate. It is here, especially for recreational pursuit skill development, where the education provider must give careful thought in preparing targeted education. The decision structure necessary to address the risk-based actions taken by individuals along the progressive learning stages is not the same for the basic, intermediate, and advanced levels of decision-makers. This indicates a need to convey a clear understanding of the three relative stages to those participating in avalanche-education courses. This would help avoid slips into common decision traps or biased decision-making in the drive to experience maximum reward from the combination of gravity and inclined snow.

Acknowledgements

I thank Canadian Mountain Holidays for their generous support of this research and acknowledge the contribution of Natural Sciences and Engineering Research Council of Canada, and the Vice President of Research of the University of British Columbia.

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Natural Born Risk Takers

The NivoTest™ — 25 Questions That May Just Save Your Life

Story and Photo by David George

French snowshoe guide Steph Ledauphin consults a NivoTest card on la Rochail in the French Ecrins.

Humans are natural risk takers. If this were not so we would never had come down from the trees and spread out from Africa into the frozen wastes of Europe. There is obviously an evolutionary advantage to taking some risk, and one would think that after all this time we would have become quite good at it. However, studies in the domains of finance, man-made disasters, and avalanche accidents show that we are poor at analyzing just how much risk we are taking.

Prospect theory shows that we weigh the same risk differently depending on whether we believe we are gaining or losing something. Other research has found that individuals with some knowledge are often overconfident, especially in a familiar environment. Safety systems such as Avalungs, ABS, and avalanche transceivers often mean that we take more risk; Bruce Tremper even postulates that avalanche transceivers have cost more lives than they have saved.

We know a lot about avalanches, both scientifically and statistically. We know that the victims or members of their party trigger 90% of fatal avalanches. We know the weather conditions that lead to avalanches, the different types of avalanches, and the slope angles and aspects that are most dangerous. We know a great deal about group dynamics and human factors. And yet around 130 people are still killed annually in the big-four alpine countries and North America.

In light of a number of avalanche accidents involving some very experienced backcountry travelers including guided groups, researchers in Europe and North America have looked at the decisions that led these groups to enter avalanche territory. In Switzerland over the 10-year period between 1981 and 1991, there were 52 avalanche fatalities in nine professionally guided ski tours. In France, Alain Duclos and Claude Rey noticed that, although the overall trend of avalanche deaths was decreasing, for guided groups it had begun to increase. Even non-guided but experienced backcountry users seem to be taking a lot of risk. Of the 25 deaths last year in France, six involved snow professionals and eight were experienced amateurs. The 2004 season kicked off with the death of a member of the Mountain Police (PGHM) and a near miss for one of France's best-known backcountry skiers.

Clearly there is a problem with avalanche education. In both Swiss and French training there is now a move away from complicated scientific approaches toward a better understanding of human and terrain factors when assessing risks.

In his excellent articles published recently in *The Avalanche Review*, Ian McCammon suggests that most backcountry travelers short-circuit an extended thinking/analysis process by applying heuristics, simple rules of thumb used to summarize complex situations. What could be more complex than deciding if a particular slope is going to slide or not? Even the experts say, somewhat ironically, they are only right 50% of the time. Possibly the most basic of these is the avalanche bulletin with its 1 to 5 danger scale. Rather than understand the details, many skiers apply the following rule to summarize the situation: 1-2 go, 3 take care, 4-5 no go. This is perhaps one reason why nearly three quarters of avalanche fatalities occur at risk 2 to 3.

Reducing the many complex factors that make up avalanche risk to a simple go/no-go decision is not such a bad idea as long as it is based on a sound analysis of that risk. Avalanche scoring systems do exactly this, and they are starting to be used as a standard part of guide and ski-leader training in Europe. A scoring system applies a calculation to various aspects of weather and snow-pack, terrain, and group experience.

A number of scoring systems have been developed in tandem in various geographic zones: Stop/Go (Austria), SnowCard and Factorcheck (Germany), Red/Yellow/Green Light (North America), Münter 3x3 and Reduction methods (Switzerland) and NivoTest (Switzerland/France). The fact that three different approaches have originated from Switzerland probably has a lot to do with that country's long history of avalanche research and the fact that it is split into two main linguistic zones.

The most famous of the above are the 3x3 and Reduction methods, which were developed by Swiss guide and avalanche researcher Werner Münter with the aim to cut avalanche deaths in guided groups by 50%. Münter's methods are currently used in Swiss and French mountain-guide training. The NivoTest was developed by Robert Bolognesi in conjunction with ANENA (www.anena.org), the French avalanche research institute, and other experts. It is being adopted in the avalanche curriculum of French ski group leaders.

Bolognesi is an expert in environmental risk evaluation and has used this knowledge to devise a system for calculating the overall risk presented by an itinerary for given snow and weather conditions, taking into account the strengths and weaknesses of the group.

The NivoTest is based on the classic risk expression: R = Ht x D

This formula is used to calculate the risks associated with natural hazards. For any Risk (R), Ht is the probability of the event (usually associated with a return period) based on statistical data and D is the potential damage expressed in terms of the vulnerability and value of the objects at risk. Compare this with Münter's Reduction method which defines risk as: Risk = Danger ÷ Reduction Factors.

NivoTest is a catalogue of 25 questions which take into account the weather, the snowpack, recent avalanche observations, the route, and the participants; the classic Avalanche Triangle with the addition of human factors. The NivoTest consists of a card holding a rotary dial (see photo) and two rules used for calculating 30-degree slopes on Swiss and French 1:25,000 series maps. If the answer to a question is yes, then you add the points indicated on dial. Once the user has completed the test, the reverse side gives the risk the user is assuming. The higher the total score, the higher the risk.

However, to fully understand the questions that make up the NivoTest, it is necessary to read an accompanying short book called *Attention Avalanche!* that explains each of the questions in a couple of paragraphs, giving the probability of an avalanche and the potential damage. The book can easily be slipped inside a pocket for reference while on the terrain. Each question has its own risk factor, ranging from 1 (lowest) to 5 (highest). By reading the explanations that Bolognesi gives it is possible to deduce the associated risk factor.

Both the NivoTest and Münter methods are heavily based on statistical observations about avalanches in the European Alps. NivoTest has been evaluated by a large number of snow professionals. Snow Dynamics, based in the Chugach range in Alaska, used the system over two seasons and fed their results back to Bolognesi. However, the weightings attached to various terrain and snowpack risks may not translate precisely to other latitudes or to the dryer climate of the American and Canadian Rockies. Research by Schweizer and Jamieson shows that risks on northern slope aspects are roughly similar for Canada and Switzerland. Given good statistical measurements for aspect and slope angles it should be possible to adapt both systems for American use.

We used the NivoTest on a ski tour we made during the late winter in the Belledonne mountains in the French Alps, then cross checked the results with the Reduction method.

Answering the NivoTest questions takes about five minutes; it is a good idea to involve all members of the group in this process. We answered yes to the following questions out of the 25 with our running total (shown by the disk) in brackets:

- **More than 20cm of snow?** [3]
- **Blown Snow?** [6]
- **Deep Snow (a foot can penetrate 20-40cm)?** [9]
- **Cornices or other wind created snow structures?** [14]
- **Fragile Internal Snow Structure?** [17]
- **Avalanche during the same day?** [21]
- **Itinerary without shelter?** [25]
- **Steep Slope (greater than 30 degrees)?** [29]
- **Group Size less than 3 or more than 5?** [total = 30]

The NivoTest says that a score of 1-7 is a Go, 8-25 is Doubtful and greater than 26 is a No Go. These are indicated by a series of "smilies" on the reverse of the disk: L, K, J.

The risk figure given in the avalanche bulletin is the basis of the Reduction method. In Europe, avalanche bulletins are issued daily and cover fairly small geographical areas. The idea of the Reduction method is to take this headline risk and see if it can be reduced to an acceptable level—less than 1. A risk of 1 is statistically equivalent to one death per 100,000 person/trips. During the 1980s Switzerland saw one death per 50,000 person/trips so this equates to a 50% reduction in fatalities.

For our trip to the Selle du Puy Gris, the avalanche hazard was considerable. For each level on the avalanche scale Münter doubles the risk, 2-4-8, so this gives a danger value 8. The steepest slope angle was 33 degrees (reduction 4). The slope is north facing (no reduction – 1), the group is large (no reduction – 1) but the slope is regularly skied so is compacted (reduction – 2). Plugging this into the calculation we get: **8 ÷ (4 x 1 x 1 x 2) = 1**.

With this risk value we should try to look at other reduction factors such as improving group spacing. The calculation took less than a minute.

It is worth examining the questions asked by the NivoTest in more detail. They are divided into five areas: weather, snow conditions, avalanche activity, route choice, and group. These equate roughly to the three filters of: conditions, terrain, and human used in Münter's 3x3 method. For example, under group factors we are asked if one of the group members has poor ski technique. In the corresponding book we learn this has several consequences: the person may be slower leading to a greater exposure to danger, the person may fall more often which puts a greater trigger load on any instabilities, the person may be less attentive to danger signs and will probably be less able to organize a rescue in the event of an avalanche. This clearly increases the chance of triggering an avalanche and increases the consequences of any slide. Bolognesi sees the NivoTest as a learning tool that will instill good backcountry practices in its users. It also enables direct comparisons between route choices. This is one reason it has been adopted in training ski leaders in France.

When we got to our proposed route, rather than our compact group of four, we found there were another 17 people ahead of us on the slope; this is a frequent problem on popular routes in the crowded European Alps. Bolognesi says that because NivoTest consists of a large number of questions, none of them with a significant weighting, it is tolerant of these factors and this won't change the overall conclusion. In this case, after applying the Reduction method and not being able to find a further reduction factor such as good group spacing, we headed for a less crowded climb.

It is obvious that both NivoTest and the Reduction method cut down skiing on steep, shady slopes. Statistically these are the most dangerous, but they are often the very slopes we would like to ski. There is a danger that users will consider this conservatism unrealistic in the real world. With the NivoTest it can be seen that it only takes a few risk factors to get a doubtful prognosis. In their tests, *Snow Dynamics* considered the risk to be moderate at the lower end of the doubtful scale. Bolognesi says that his test should be seen more as a pause for reflection by the user who should either consider an alternative route or think carefully about the factors increasing the risk. His book has a complete section on risk reduction covering group management and search and rescue.

Despite the introduction of the NivoTest into ski-leader training, there still seems to be some reluctance to explicitly adopt scoring systems. In his work on heuristic traps, McCammon found that 73% of accidents occurred when there were three or more obvious indicators of hazard. Clearly there are some serious errors being made in risk assessment, at least in the groups caught by avalanches. Scoring systems such as the NivoTest can be viewed in a similar way to pre-flight checklists used by pilots. They can ensure that obvious hazard indicators are not overlooked by a group. In the future a more formal adoption of these techniques may need to be mandated for certain backcountry users. For example, club ski leaders could be required to keep a log-book showing their decision-making process.

David George runs the French backcountry Web site www.PisteHors.com. A keen ski tourer since 1991, he holds the French Mountain Federation level 2 snow and avalanche certification.

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SOUND DECISIONS

continued from page 13

As the results in Table 1 suggest, respondents believed educating recreationists in physical properties of the snowpack offers the potential of reducing accidents. However, this was the one area of the study where the quantitative results did not correlate with the extensive qualitative responses articulated. In fact, the results were the opposite. Respondents emphasized the complexities of snowpack analysis and indicated the concern that recreationists may be mislead by inaccurate snowpack assessments in poorly selected locations. These study results suggest that the snowpack curricula in recreational courses should be carefully assessed to identify the core learning outcomes that can effectively and practically improve recreational avalanche decision-making capacities. In addition, this finding shows the importance of recognizing the cognitive and experiential differences between recreationists and practitioners when designing effective educational curricula and when communicating avalanche hazard and risk.

A second theme identified by respondents was the need to set higher standards for Canadian recreational avalanche course instructors in order to ensure high quality of instruction, the instruction of informed and relevant field curriculum and the appropriate modeling of terrain use and safe travel practices.

Hazard Communication

Communicating avalanche hazard and risk in a variety of forms was identified as having the potential to improve decision-making and reduce avalanche accidents. Respondents suggested that the scale of avalanche bulletins be modified from regional to local in high-frequency areas and that hazard information be linked to specific use of terrain features. Opportunities then exist for recreationists to practically apply bulletins directly to the decisions they make in the terrain—a primary theme of this study.

Other comments included the addition of graphical-mapping applications and hazard icons to complement the current text-based products and that these decision aids be made more widely available in a variety of locations, i.e., on the internet and in public areas frequented by recreationists. Broadening the range of strategies utilized for avalanche hazard and risk communication appeals to different cognitive processes and learning styles, therefore has the potential of reaching a greater proportion of backcountry recreationists with more meaningful effect.

The communication of hazard and risk to the public is a matter of growing concern and debate and is the subject of extensive literature. One theme that resonates throughout the literature is the critical importance of providing meaningful information, a theme consistent with my study. Respondents articulated a concern that the technical language and complex concepts used

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Integrating Strength, Energy & Structure

INTO STABILITY DECISIONS

So you dig a pit and then what?

Story by Ian McCammon and Don Sharaf

Illustration by Mike Clelland

"You get in zee pit, you get zee information, you get out," Peter Schaerer told one of us during a training course. Along with his advice that you should never stop observing changes within the snowpack was the stern admonition that snow pits should be focused, efficient, and QUICK.

For years, avalanche educators have taught students to dig snow pits to look at stratigraphy, identify snow crystals, and perform stability tests. But correlating snow profiles with stability has never been an exact science, and many students came away unsure of exactly how they were supposed to use snow stratigraphy in their stability decisions. Moreover, many of them lacked clear objectives for their pit analysis and ended up wasting time collecting tedious and semi-relevant information. The result fell far short of Peter Schaerer's sage advice. Rather than training people to make quick informed decisions, we seemed to be creating an army of winter recreationists who could spend half an hour or more in one snow pit but couldn't tell you how, why, or when they would use the information they found.

Two years ago, we began teaching a simple approach to interpreting snowpit results on upper level avalanche courses and professional training seminars. Many students said the approach produced an "a-ha!" moment for them, and they were excited to learn a simple way to focus their efforts in their snow pits. In this article, we'll describe our approach and how we teach it, in hopes that others may find it useful in helping their students to make quick and informed stability decisions.

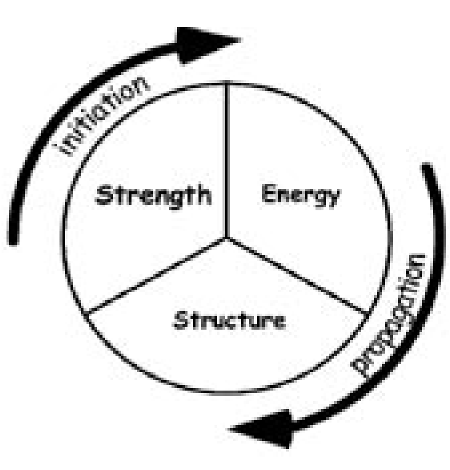

Figure 2. A fracture mechanical model of slope stability.

A three-part model

The discipline of fracture mechanics tells us that three things need to happen in order to produce the large-scale shear fracture that initiates a slab avalanche: 1) the fracture must begin at some point under the slab where the shear strength of the weak layer is overcome by applied stresses, 2) the shear fracture must liberate enough energy from the snowpack to sustain its own propagation, and 3) there must be a "path of least resistance" in the snowpack structure along which the shear fracture can propagate.

Weak Layer Depth	**≤ 1 m**
Weak Layer Thickness	**≤ 10 cm**
Hardness Difference	**≥ 1 step**
Weak Layer Grain Type	**Persistent (SH, DH, FC)**
Grain Size Difference	**≥ 1 mm**

Table 1. Five Structural "Lemons"

These three components of strength, energy, and structure are a simplification of the complex interrelationships that produce slab avalanches. But from a teaching standpoint, they provide an effective way of summarizing important stability information that students can gather from a few simple field procedures.

Strength

The backbone of most Level 1 stability classes is the standard stress-strength model. This model says that a weak layer will fail when you apply enough stress to it. An important implication of this model is that when stress and strength are very nearly balanced, unstable conditions will exist and slabs may be easily triggered by the weight of a skier or snowmachine. In this model, the role of stability tests is to assess whether stress and strength are in a critical balance. If your stability test scores are low, the weak layer is in a critical state of balance. But if your stability scores are consistently high, the weak layer is less likely to be triggered. Many students come away from avalanche courses with a simple rule of thumb: low scores are bad, high scores are good. Thus it's no surprise that some of them come to base their go/no-go decisions almost entirely on cursory avalanche observations and test scores from one or two snow pits.

Research has shown that the stress-strength model works pretty well most of the time—high test scores generally do correlate with stable conditions. But not always. A disturbing number of accidents occur during "false stable" conditions, where tests indicated stability but avalanches were still triggered by a skier or rider. In these cases, practitioners in the know say, "Well, that's spatial variability for you," and shake their heads in recognition of the tough job they have chosen. But for decision makers who rely on stability tests, the message is deeply troubling—the stress-strength model is not the whole picture.

Energy

In 1998, Ron Johnson and Karl Birkeland described a formal rating system for a phenomenon that field practitioners had noticed over the years: when stability tests fractured with a clean and fast shear, triggered avalanches were more likely. In 2001, Schweizer and Weisinger described a similar system used with rutschblock tests in Switzerland, and in 2002, van Herwijnen and Jamieson described a system of fracture character used in Canada. Exactly what these schemes are measuring remains unclear, but one trend stands out: fast and clean shears release their fracture energy quickly and are more frequently associated with unstable conditions. See Karl Birkeland's article on stability, shear quality, and fracture character in the previous issue of *The Avalanche Review* for more details.

Fracture mechanics tells us that the higher the fracture-energy release rate, the greater potential the fracture has for propagation. Shear quality and fracture character may only provide a very rough estimate of the fracture-energy release rate, but when used in conjunction with stability tests, shear quality seems to provide valuable information regarding the likelihood of avalanche triggering.

Structure

Imagine two snow profiles. In one, an interface between light-density storm layers produces a moderate and clean shear 30 cm from the surface. In the second, a layer of facets beneath a hard wind slab produces the same shear quality and score at the same depth. Even though the two weak layers have the same strength and release their energy at the same rate, few practitioners would treat the two snow packs the same.

In an effort to characterize some of the "red flags" that professionals use in comparing such profiles, McCammon and Schweizer (2002) described five stratigraphic features of weak layers that statistically correlate with skier-triggered avalanches (Table 1). These features, referred to here as "lemons," appear to be rough indicators of how well a snowpack might concentrate shear stresses in a weak layer. The more lemons in a weak layer, the more structurally weak the snowpack. Schweizer, et al., (2004) extended the initial concept, and refinement of the system continues.

Taken alone, strength, energy, and structure only do a fair job of predicting skier triggered avalanching. But fracture mechanics tells us that when all three factors are present, shear fractures are more easily initiated and are more likely to propagate large distances. Bruce Tremper uses the analogy of a combination lock; when all three tumblers of strength, energy, and structure fall into place on a particular slope, conditions are primed for avalanching. False stable conditions exist when the tumblers of energy and structure are present, but strength tests indicate stability. Under these conditions, wandering onto an isolated weak spot can cause localized fracture that can propagate into an avalanche.

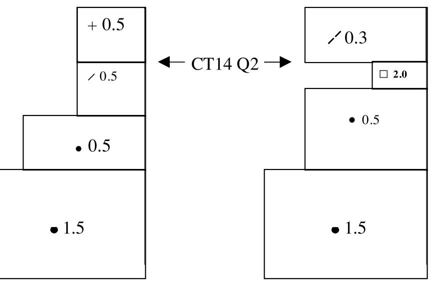

Figure 3. Two profiles with similar strength and energy, but different structural properties.

Teaching

The standard way that we approach teaching mechanics and stability assessment using strength, energy, and structure typically goes like this:

1) Review the stress-strength model and its limitations.
2) Describe shear quality as a way of quantifying elastic energy release.
3) Introduce the lemons as a method of analyzing snow structure.
4) Incorporate the lemons into a quiz for strength, energy, and structure. (Table 2: R,Y, G & false stable results)
5) Introduce the concept of the "Test+" pit as an efficient way to analyze snow strength, energy and structure in a snow pit.

As always, information from a snowpit shouldn't override Class 1 information

Test Results	Strength	Energy	Structure	Stability
RB6 Q3 L2	Strong	Slow	Strong	Good
RB2 Q1 L4	Weak	Fast	Weak	Poor
RB6 Q1 L5	Strong	Fast	Weak	False Stable

Table 2. Examples used in introducing the fracture mechanics model of slope stability. Students are encouraged to consider all three aspects of stability in their snow pits.

The Test+ Pit

In *Snow Sense*, Jill Fredston and Doug Fesler describe three questions to ask when digging a test pit:

1) What is the weakest (significant) layer?
2) How much force does it take to make that weak layer fail?
3) What is the depth and distribution of that weak layer?

These are very good questions to help focus snow pit observations and keep the observer from analyzing layers that are unimportant for an immediate go or no go decision. A test + pit takes the three questions and then asks you to get more structural information about the weak layer. To answer the five lemon categories, you need this additional information about the weak layer only. Obtaining this information shouldn't take more than a few minutes.

1) What is the hardness of the weak layer and the layer immediately above it?
2) What is the grain size of the weak layer and the layer immediately above it?
3) What is the grain type of the weak layer? Persistent?
4) What is the weak layer depth (answered before with the previous questions)
5) What is the weak layer thickness?

Helpful hint: When teaching about the lemons we strongly encourage the students to write down the lemons into the back of their field books (along with the three objectives of a standard test pit).

(natural avalanches, recent loading, shooting cracks). However, we have found that when students look at snow pits within a larger mechanical framework, their efforts are more focused, efficient, and productive. So get in those snowpits and then…get out!

Don Sharaf is an avalanche educator and guide who divides his time between skiing, snowboarding, and digging. He is constantly in search of faster ways to ski, snowboard, and dig. So far he has found caffeine and impatient partners/clients help the cause, but draws the line at bringing a grain scoop in to the field.

Ian McCammon is continuing his avalanche research in the hallowed halls of Harvard University and MIT. The mountains of Boston create unique learning opportunities, though he laments missing the 3 meter crowns of the Wasatch this season. Ian is traveling a lot this winter helping CMH, the CAA, and others with their avalanche training and education efforts. Ian insists that Boston is a temporary phase and that he will grow out of it soon.

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SOUND DECISIONS

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in bulletins are relevant to practitioner-level understanding, yet are not effectively and practically communicated to recreationists who often have limited technical and experiential background. Larkin and Pallister (1976) likened this communication gap as "reciting Gaelic poetry to deaf seagulls." (p.3)

Media is also involved in avalanche communication, and media extreme role modeling was identified as a significant influencing factor in recreational decision-making. Respondents felt this factor may be encouraging the increased extreme use of terrain that they have been observing in the field. Since avalanche-accident statistics in Canada from 1984 to 2003 identify males in their 20s as the typical accident victim (CAA, 2003b), this factor is worth consideration. Effective role modeling and use of mountain terrain is critical to positively influence safe practices within this demographic group.

Decision Support

Strong support was given by respondents in this study for the design and implementation of a recreational decision-support framework in Canada (Fig. 8). Respondents perceive recreationists are making decisions in isolation and are basing their decisions on passive, subjective interpretations of hazard terminologies such as "considerable" or "moderate." Decision Support Systems and Naturalistic Decision Making methods involve users in an active process of decision-making, therefore reducing the influence of human factors and subjective perceptions in the decision process. Decision-support frameworks for winter recreationists have been successfully used in Europe over the past decade (e.g., Münter's 3X3, NivoTest). Canada does not have a framework in place although interest in the concept has gained momentum over the past few years. Respondents also emphasized their concerns that a recreational-decision framework may pose perceived limitations to professional practice. However, respondents suggested stating the target audience on all tools, and clearly articulating the application for less experienced users as a substitute for experience could mitigate this.

Recommendations

The following recommendations summarize the suggestions advocated by survey respondents for improving recreational decision making and reducing avalanche accidents and fatalities.

Training and Education

- Focus curriculum around factors that support and enable sound decision making, for example:
  - terrain analysis
  - route-finding principles
  - human factors
  - trip planning
- Integrate decision skills training
- Emphasize courses in local terrain
- Ensure high instructional standards
- Teach methods to practically apply avalanche bulletins to field decisions
- Foster opportunities for mentoring
- Build knowledge foundations in youth
- Integrate education within a systemic decision support framework

Hazard Communication

- Improve the scale of bulletins from regional to local in high-frequency areas
- Use language that is meaningful to recreationists
- Describe how to practically apply bulletins to field decisions
- Broaden communication methods to include graphics, icons, and mapping tools
- Use graphical mapping to identify terrain traps, frequent performers, exposure from above, and existing snowpack instabilities
- Identify non-avalanche terrain
- Describe the probabilities and consequences of involvement
- Utilize media for information dissemination and good role modeling
- Integrate hazard communication within a systemic decision support framework

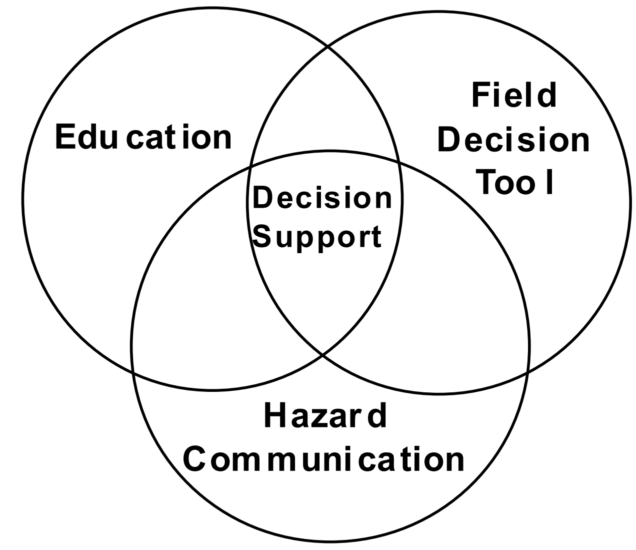

Figure 8. A proposed systems approach to decision support and recreational avalanche accident prevention in Canada

Acknowledgements

My gratitude is extended to the avalanche practitioners who offered a great deal of thought and insight to this study. I am grateful to Canadian Mountain Holidays, the Selkirk Geospatial Research Centre, and the Social Sciences and Humanities Research Council of Canada for supporting my research. I thank R. D'Eon, B. Jamieson, R. Stevens and J. Tweedy for reviewing my draft, and the faculty of Organizational Leadership and Learning at Royal Roads University for graduate student support.

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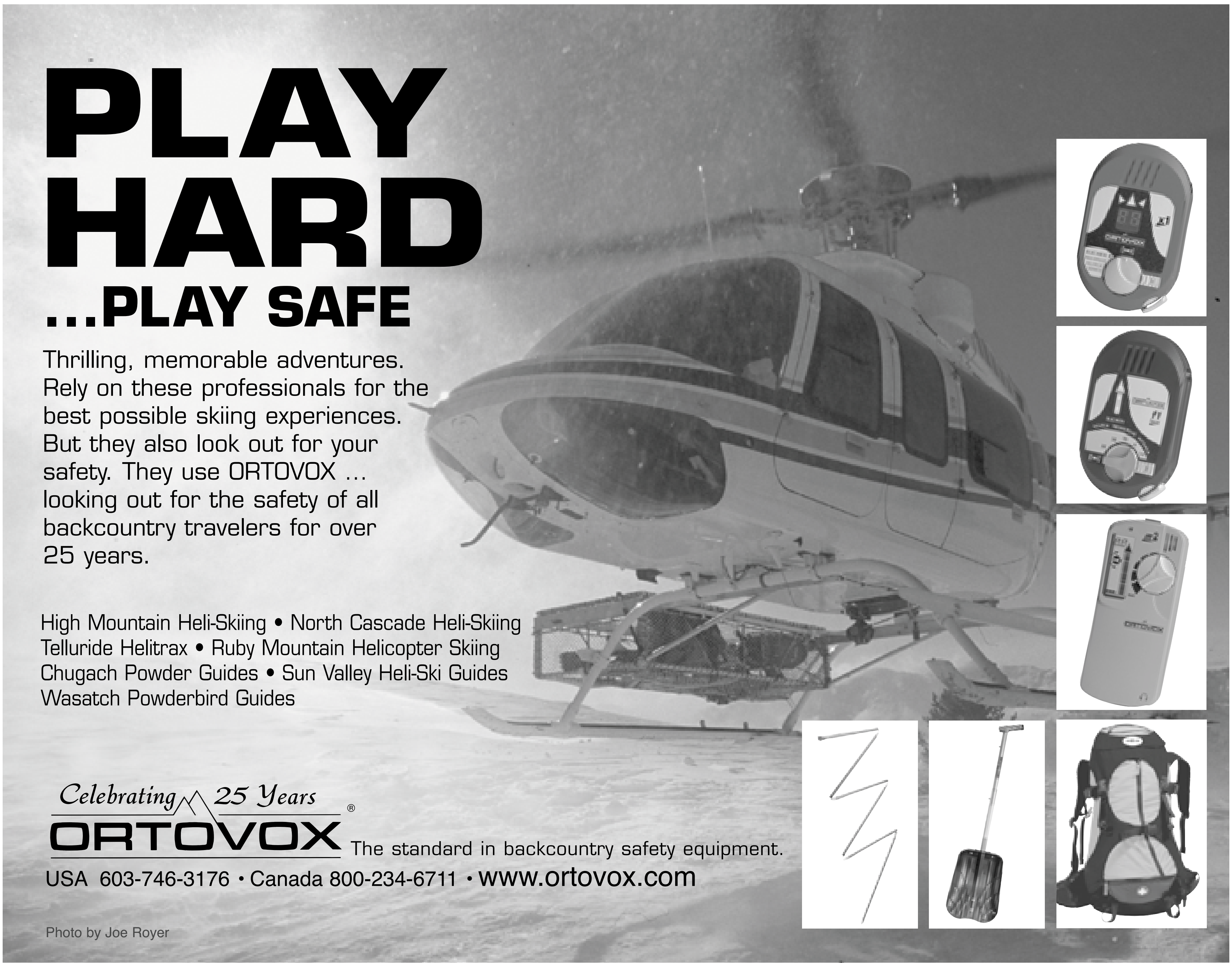

THE Avalanche REVIEW

A Publication of the American Avalanche Association

VOLUME 23, NO. 3 • FEBRUARY 2005

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