# WEST TWIN AVALANCHE HELICOPTER INVOLVEMENT-

# HOW SAFE ARE OUR PICK-UP LOCATIONS?

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ABSTRACT: On Feb 19 2014, a Bell 205 helicopter of Selkirk Tangiers Heli Skiing (STHS), was shut down at one of the most highly used pick-ups within their tenure East of Revelstoke, British Columbia. This landing site, located 60 vertical meters above the creek, was generally considered "safe" and commonly used during periods of high avalanche hazard. At 09:55, a size 3 avalanche released naturally on the steep rock face high across the valley. Even though the debris of the avalanche never reached the landing site, the helicopter was lifted into the air by the air blast, flipped mid-air, and dropped back onto the ground upside down 10 meters from the landing. The air blast also knocked down mature timber for 500 m down the valley.

While nobody was seriously injured, this event raised a number of serious operational questions: What did our hazard evaluation miss that morning, or many other similar mornings when this spot was deemed safe? What kind of air blast speeds/forces are required to flip a 3200 kg helicopter? How many landings in our operation are threatened similarly?

In this presentation, we apply a mixed flowing/powder avalanche model to numerically simulate this incident in detail and explore the impact of different scenarios on the safety at this landing site. We will then discuss the operational implications and make recommendations for improving the assessment of landing sites.

KEYWORDS: Avalanche, Helicopter, Heliskiing, Avalanche Modeling, Air Blast

## 1. INTRODUCTION

Commercial helicopter skiing in Canada consists of groups of four to twelve guests and one to two guides being lifted to the top of their run via helicopter. They typically complete between three and sixteen runs per day. The size of the company, and the operation varies, but between one and ten helicopters are used on a daily basis to service between twelve and one hundred and thirty guests. On any given winter day in the BC backcountry, you may find dozens of helicopters, hundreds of professional Ski Guides, and thousands of guests from across the globe. The areas that are used, are uncontrolled backcountry wilderness. Typically, pre-defined helicopter landing and pickup locations are used and are common from year to year. Many of these locations have been used for decades, and are selected based on proximity to a ski run or good ski terrain, their ability to physically accommodate a helicopter, and often the safety that the location provides with regards to nearby avalanche and mountain hazards. Safety is the top priority for heli skiing companies, and while 100% safety is never guaranteed, great effort, money, and resources are focused on creating as safe of an experience as possible for guests, while still delivering the experience they came for. Avoiding avalanche incidents while skiing in the wilderness is a primary focus of these operations. The avalanche accident on February 19, 2014 at STHS proved to be a very unexpected, and noteworthy incident. This incident highlighted the challenges heli ski guides and operations face while trying to forecast for large areas, and raised some difficult questions regarding assessing avalanche size potential, air blast capabilities, and avalanche runout zones.

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In this paper we will first discuss the incident, we will then discuss and present the modeling approach and results, and finish by drawing some general conclusions to this challenging issue.

## 2. INCIDENT DESCRIPTION

At 0955, February 19, 2014 two groups of heli skiers being serviced by a Bell 205 helicopter were enjoying the second run of the day in a valley just East of Revelstoke BC. These groups were part of the STHS program that day which included 86 guests, 17 guides, and 7 helicopters. The helicopter was sitting shut down at the pick up waiting for its next lift. On board there was the pilot, and one guest who was sitting out a run. The guides on the upper part of the run heard a large rumble from the opposite side of the valley, which is not uncommon as it is extreme terrain that regularly produces avalanches especially during storm cycles. However, this time the rumble was louder and longer than normal, and the guides knew something big was running. They radioed the pilot to let him know, but they were not really concerned about his location as it is a common pick up spot during times of high avalanche hazard. Seconds later, the guides on the run heard the pilot on the radio calling “Mayday, I have been hit by an avalanche”. Fearing the worst, they immediately called into base to start a rescue response, and then quickly skied down. They were at the pick up site within only 1-2 minutes of the mayday call. Luckily the helicopter had not been buried, and the guides were able to get into it quite quickly to help the pilot and guest who were banged up, with some cuts and bruises, but basically uninjured (pilot had seat belt on, guest had just removed belt before avalanche struck). Meanwhile, the base in Revelstoke was organizing a response and another helicopter with 4 guides was on its way to the incident site very quickly. By the time that helicopter arrived to the scene, the pilot and guest had just been removed from the affected helicopter. Yet another helicopter arrived to the incident site shortly after and all remaining guests, and staff were transported out of the incident site. The pilot and guest were taken to the hospital, and released shortly thereafter, with only minor lacerations, bruising and whiplash. Once the site was cleared, some photos were taken of the helicopter and the avalanche. (Fig 1 to 6)

Later that day avalanche control via heli bombing was performed on the remaining hangfire threatening the location of the damaged helicopter. Several smaller avalanches size 1-2.5 were released, but none affected the location of the helicopter. In subsequent days, a salvage team was flown to the site to disassemble the helicopter, and it was slung out. The helicopter sustained serious damage. The main rotors and tail rotors were broken and bent, the tail boom and cabin suffered some broken and dented panels, and the transmission and engine were damaged.

Fig 1. Flipped, rolled, and damaged helicopter

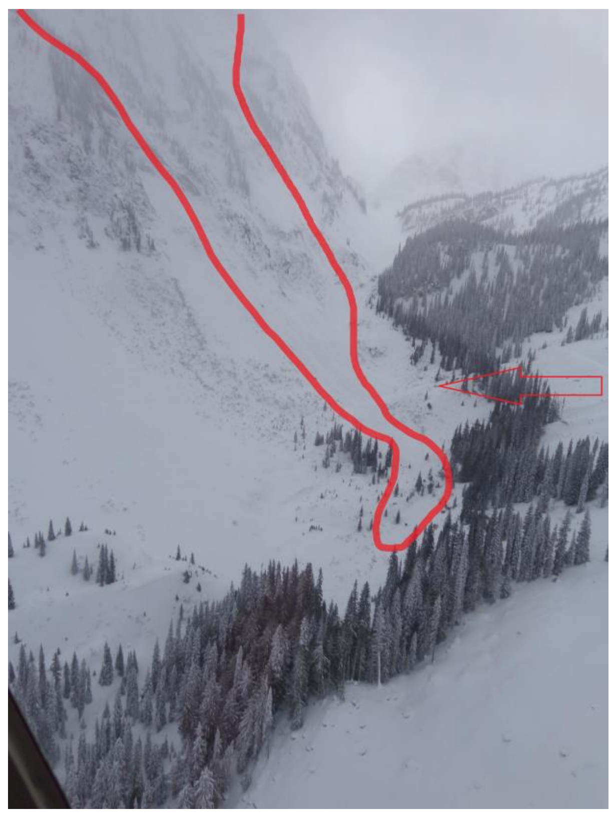

Fig 2. Avalanche overview, and helicopter location (red arrow)

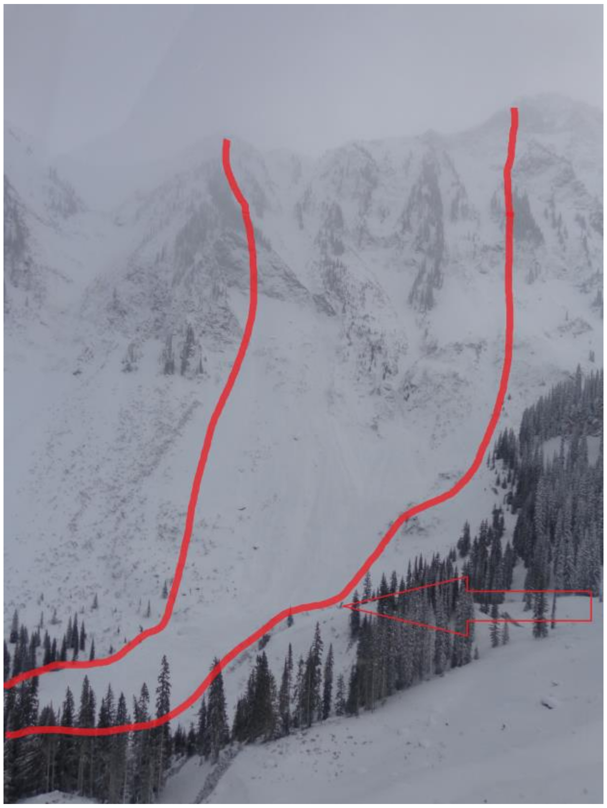

Fig 3. Avalanche overview, and helicopter location (red arrow)

Fig 4. Location of Pick up and helicopter (red circle) on elevated terrain. As well margin of debris shown in red line.

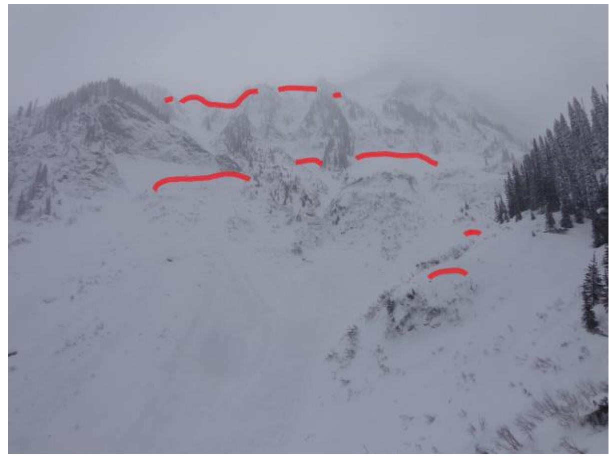

Fig 5. Approximate location of various crown lines.

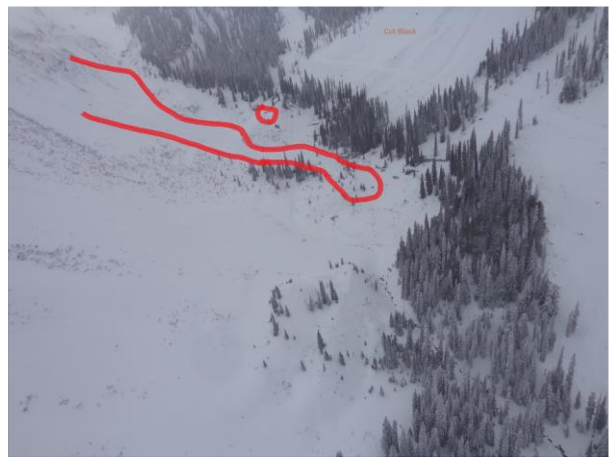

Fig 6 Location of Helicopter (red circle), and extent of debris flow. Note broken trees, and snow removal from trees well downstream.

## 3. TECHNICAL DETAILS OF AVALANCHE

Size 3 natural trigger, start zone elevation 2260m, deposit elevation 1432m, start zone incline average 45-50 degrees, total crown width 250m (several pockets), crown line average depth 60-150 (several pockets up to 500cm), deposit 250m long x 80m wide x 6m deep (all deposit dimensions estimated).

## 4. AVALANCHE SIMULATIONS

The purpose of the avalanche simulations was to recreate the event, and to determine how much force, wind speed, and pressure were likely present in order to lift, flip, and roll the helicopter.

### *4.1 Numerical simulation tool RAMMS powder*

The numerical avalanche simulation tool RAMMS (Christen et al., 2010) enables the calculation of runout distances, velocities, deposition heights and pressures of extreme avalanches in the three-dimensional terrain based on digital elevation models DEM. This model is running on a state-of-the-art personal computer and is applied for hazard mapping and mitigation measure planning in alpine regions around the world. Currently the WSL Institute for Snow and Avalanche Research SLF is refining and further developing this numerical model to simulate powder (Bartelt et al., 2013) and small avalanches (Dreier et al., 2014).

The extended RAMMS model divides the avalanche into the flowing core and powder cloud. Formation of the cloud involves the internal dynamics of the core. However, once formed the cloud can move independently of the core long distances. For details of the cloud formation, see (Bühler et al., 2014).

The well-documented case of a large-scale powder avalanche, presented in this paper, is very valuable to test the new model approaches currently under development at SLF.

### *4.2 Simulation setup*

We obtained a digital elevation model from GeoBase Canada (http://www.geobase.ca) and satellite imagery from ArcGIS World Imagery. To simulate the accident we defined two independent release zone with a release depth of h = 1m and average density of 200 kg/m3 (Fig. 6). The release volume was $V_0$ = 37'500 $m^3$ and mass $M_0$ = 7.5 t. The location of the release zones was defined based on slope angle, satellite imagery and event photos. We assumed the avalanche entrained an additional 25 cm of new snow (density 200 kg/m3). Temperature effects were judged to be unimportant due to low temperatures (T = -10C). The simulation resolution was set to 10 m. We applied model parameters similar to values used to simulate powder snow avalanches in Vallée de la Sionne (Bartelt et al., 2012). Cohesion was considered to be small ($N_0$ = 100 Pa) because of the low snow temperatures.

As a control calculation, we calculated an avalanche with half the release zone depth (h = 0.5 m) using the same conditions and parameters. Because of the steep terrain and entrainment a powder snow avalanche developed but propagated with much less intensity.

### *4.3 Simulation Results*

The powder avalanche simulations revealed that the avalanche core flowed past the helicopter landing position, missing the helicopter by 30 m to 50 m. The core flowed in three main arms from the release zones (Fig. 7). The fastest arm moved at a speed of excess 50 m/s. Fortunately, the helicopter was not directly in the flow path of this avalanche arm, which was deflected by the terrain below the landing zone, following the creek. Trees well beyond the helicopter landing position could have easily been destroyed by the air blast of this major flow arm (Feistl et al., 2014). This corresponds to the observations. The other flow arms passed closer to the helicopter, but were moving slower and were also deflected by the terrain.

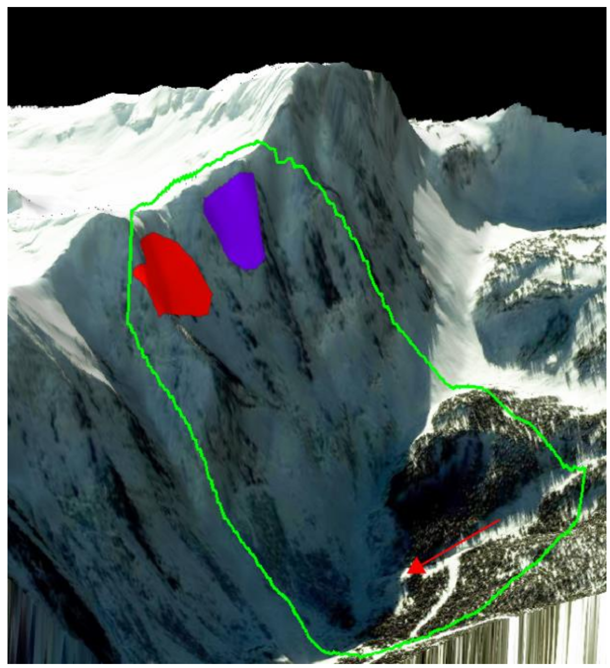

Fig 6. Three-dimensional view of the two simulated release zones and the calculation domaine (in green). The landing zone of the helicopter is indicated by a red arrow.

The numerical simulations revealed that a powder cloud was formed from all three flow arms. The height of the fluidized core was between 2 m and 3 m, with mean flow densities of 200-300 kg/m3. The powder cloud heights reached 20 m at the front of the avalanche. The leading edge velocities of the powder cloud reached over 50 m/s with a maximum density of between 3 kg/m3 and 6 kg/m3. The helicopter was not struck directly by the most intensive and violent powder blasts originating from the core. The simulations show the helicopter was struck from the back and side by a lateral blast originating from the major flow arm (1 in Fig. 7a). The maximum pressure arising from the blast was calculated to be over 5 kPa (Fig. 8). The cloud arrived at the landing zone 30 s after the fracture zones released; the lateral blast arrived less than one second after the core passage. The pressure exerted on the helicopter had an intensity of over 3 kPa for at least 5 s. The magnitude and duration of the air blast would explain the flipping and violent transport of the helicopter. During the air blast the height of the cloud was 20 m and probably contained significant turbulent eddies. The model assumes the powder cloud is formed from jet-like expulsions of air induced by granular collapse and compression mechanisms at the avalanche front (Bartelt et al., 2013).

The powder avalanche calculated with half release depth (h = 0.5 m, control calculation) also engulfed the landing location, but exerted only a maximum pressure of 1 kPa (Fig. 9), which is insufficient to flip the helicopter.  The fact that a powder avalanche with less mass reached the valley bottom is an indication of extreme terrain steepness.

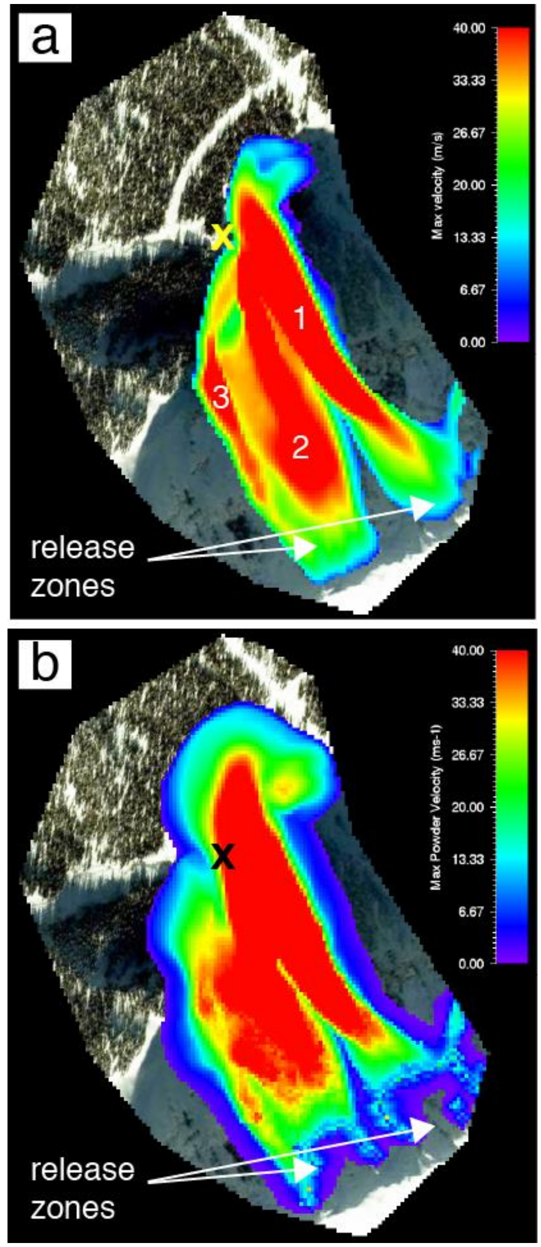


Fig 7. Simulated maximum velocity of the avalanche core (a) and the powder cloud (b). The landing zone of the helicopter is marked with an X, the flow arms are numbered in (a).

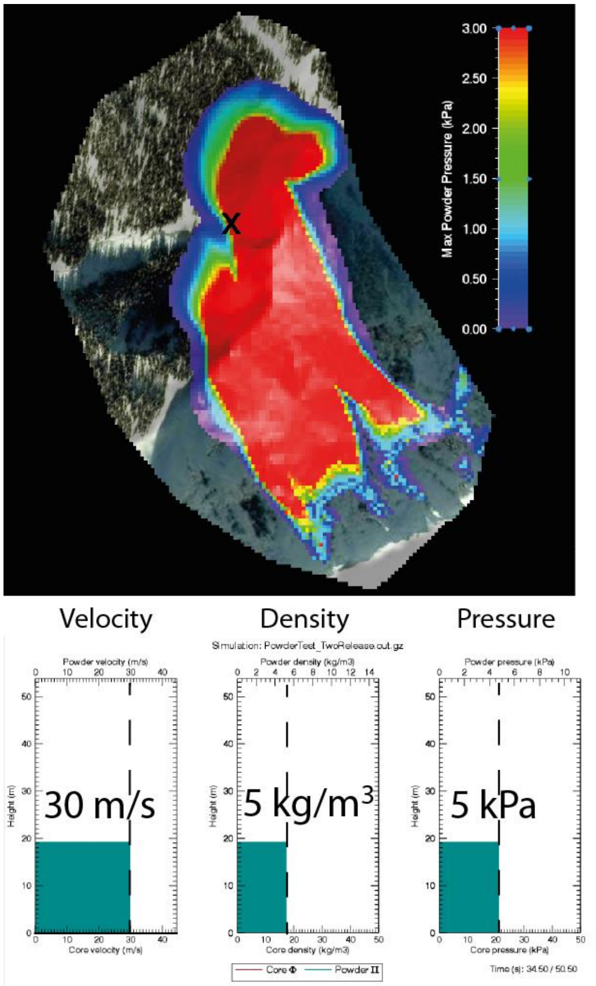


Fig 8. Simulated maximum powder pressures (top) and values extracted from the powder cloud simulation at the landing location of the helicopter.

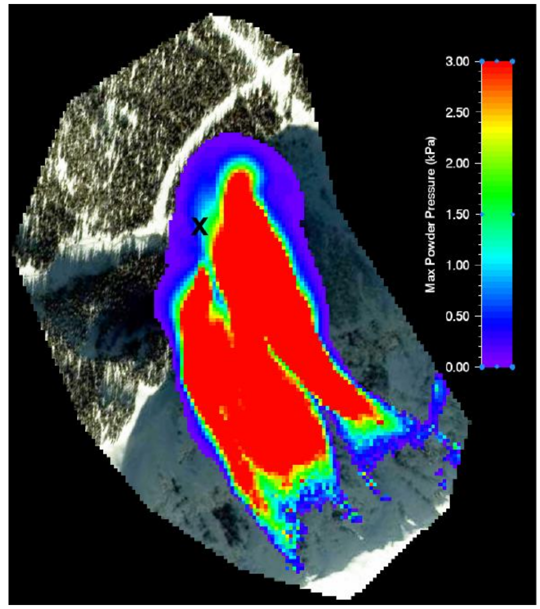


Fig. 9 Powder pressure of the small avalanche scenario simulated with half of the release depth (d = 0.5 m). The powder pressure at the helicopter location is around 1 kPa, which is insufficient to flip the helicopter.

## 5. POWDER PRESSSURE TO FLIP THE HELICOPTER

We calculated the force required to flip the BELL 205 helicopter by determing the moment needed to turn over the helicopter on one of its landing gear in a simplified model (Fig. 10).

The helicopter has a total weight of 3200 kg or 32 KN. The total weight is divided equally between the two landing gears. Moreover, the overturning moment must supply a force of W= 16 KN to overcome the weight of the helicopter. The simulations indicate that the powder blast struck the helicopter from the side (Fig. 7). Therefore, we applied the pressure over an effective area of A=10 $m^2$. Larger areas would reduce the minimum pressure necessary to flip the helicopter. We assume that the pressure distribution over the entire helicopter side surface area (A = 23.2 $m^2$) is not homogeneous, but consists of concentrated gusts that act over a smaller effective area. The moment arm was assumed to be h=1.5 m above the ground (approx half the total height) and the landing gear is separated by a distance of d=2m.

Thus, the minimum pressure is

$$p = \frac{Wd}{Ah} = 2.2kPa \quad (1)$$

This shows that the larger avalanche (p = 5kPa) could easily flip and carry the helicopter, while the smaller avalanche (p = 1 kPa) would not have damaged the helicopter.

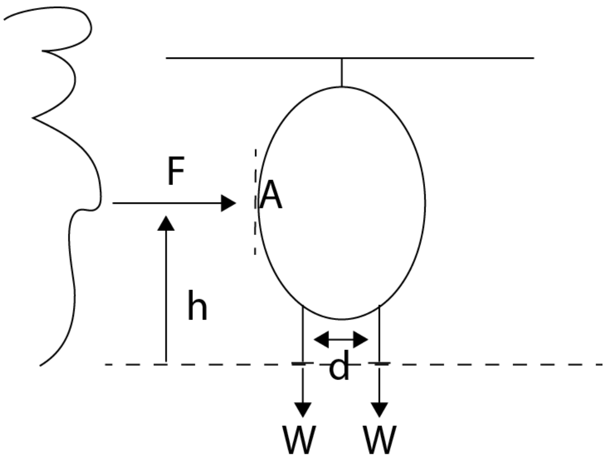


Fig. 10 Simple calculation model for the minimum pressure needed to turn over the helicopter.

## 6. CONCLUSIONS

### *6.1 <u>This avalanche in the context of the snowpack and season</u>*

While large natural avalanches are commonplace in the interior mountains of BC, such deep lingering and sensitive instabilities as were present in the 2013-2014 winter are not. This season saw many "surprise" or "anomalous" avalanches that caught many avalanche practitioners off guard. The depth and propagation propensity of many slabs this season were out of the normal range. As such, there were many avalanches that exceeded normal or historic run outs in areas, and many ran into and destroyed mature forests. In this type of avalanche season, "surprises" can be anticipated, and one must reconsider what is possible, and treat things with even more respect, and wider buffers than normal.

### *6.2 <u>Contributing Factors</u>*

As with any incident, there are several factors which contribute to the outcome of this avalanche. Due to the fact that the failure plane was a deep persistent weak layer, the volume of snow moving was larger than normally expected from this type of terrain. Many pockets below the upper cliff bands released very deep, (5 meters), due to the fact that these pockets had been previously loaded from spindrift avalanches.

The orientation of the helicopter almost certainly played a considerable role in its susceptibility to being lifted. Our calculation is based on finding the minimum possible pressure, which assumes a straight side, hit. However, with the tail hanging out over the high ground it was parked on, and the fact that the air blast would have been redirected upwards as it hit this terrain, the actual direction the wind blast contacted the helicopter was likely from underneath. The Bell 205 has 2 large surface area horizontal wing like stabilizers located right near the tail rotor which would have provided additional surface area combined with the surface area of the belly of the aircraft, and underside of tail boom. Additionally, we believe one of the 2 main rotor blades was positioned at the 7 o'clock position at the time of impact, which would have provided even more surface area for the upward direction of the air blast. However, higher pressures would still be required to flip the helicopter tail over nose. The calculations reveal that these pressures, probably in excess of 3 kPa, could arise.

It is also possible that the distinct and abrupt transition from the track to the runout contributed to a "piston like" affect. While such an effect would be hard to model, it is imaginable that the descending powder cloud and air blast could be forced into the confined valley bottom with such a force that it actually accelerated the velocity of the powder cloud as it was forced upwards by the terrain towards the helicopter

### *6.3 <u>Air blast forces</u>*

It is also very important to note the increased pressures on the aircraft due to the fact that a powder cloud has higher density than strictly air. A 100km/hr powder cloud air blast has more pressure, and destructive power than a 100km/hr wind speed on its own due to the solid component of the suspended snow crystals. The calculated densities of the powder cloud at the pick-up were a maximum of 6 kg/m3. Thus, the wind blast from the avalanche is approximately six times the wind blast from air.

### *6.4 <u>How far can an air blast travel?</u>*

While it is common knowledge that air blasts and powder clouds can travel much further than the associated debris core of avalanches, more work is needed to determine exactly how far, and with what force. The calculation model assumes that the powder cloud arises from core. In the beginning the core and cloud are moving at the same speed. Drag forces on the cloud cause it to slow down. When the cloud separates from core (in the runout zone or by terrain deflections) the cloud is already moving at a slower velocity. In this particular simulation, the cloud disengaged from the core approximately 30 m in front of the helicopter. In this distance the cloud decelerated from 50 m/s to 30 m/s (=100 km/hr) when it hit the helicopter. Behind the helicopter the powder blast would still be violent enough to knock down trees (Feistl et al., 2014). The current version of RAMMS model assumes that powder clouds are treated as inertia flows. The initial momentum imparted to the cloud from the core controls the cloud dynamics, including the magnitude of the impulsive pressure.

### *6.5 Forecasting air blast*

When forecasting potential air blast zones relating to avalanche paths, several factors need to be considered. What size of avalanche is possible in the current conditions? How does this size compare to the relative size of the path? For example a path that is able to produce avalanches to a maximum of destructive size 3 should be treated with extra caution with regards to air blasts when the conditions are ripe for avalanches of the maximum size. In these situations, further respect and extra berth should be given to the avalanche path. Shape and orientation of start zone, track and run out should also be considered. In terrain with large vertical relief, and rapid transition to the run out, air blast forces could be compounded as the speed and force of the blast does not have time/ space to decrease as it approaches the end of the run out.

### *6.6 Operational Changes*

When assessing helicopter landing and pick up locations, as well as terrain guests and guides will be traveling in, continued vigilance is required to consider potential consequences that air blasts from nearby avalanche paths may produce. Air blast zones are typically obvious due to lack of vegetation, and or broken timber but exceptionally large avalanches can produce air blasts that easily exceed normal run out zones. This must be clearly taken into account for terrain selection during times of persistent deep instabilities.

### *6.7 Potential role of numerical simulations for hazard/ safety assessment*

This paper clearly shows that the use of numerical simulations can be a valuable tool for assisting exposure assessment to avalanche hazard in backcountry settings. Specifically for mechanized ski operations, these simulations could be used to assist with risk determination for specific key locations. While it would be unrealistic to assess the exposure of all heli ski runs and helicopter landing locations, high use locations, infrastructure locations or areas frequently used during elevated avalanche hazard could benefit from modelling assessments as presented in this paper. However as with any numerical modeling, there would be room for error, and potential would exist for avalanche events that were outside of the models capabilities (or the parameters that were used to develop the model for that location). Determining the location of the release zone(s), and the release volume, (building the scenario), would be critical to any simulation results. Benefits of this type of model compared to traditional forecasting include the ability to calculate different scenarios with the ability to alter setup even for very extreme events, reproducible simulations, and visualization of hazards.

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