BRIGHTON RESORT GAZEX (RACS) OPERATIONAL HISTORY & CASE STUDY

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ABSTRACT: Brighton Resort, Utah is located at the top of Big Cottonwood Canyon in the Central Wasatch Mountain Range. Brighton Resort is designated a Level A avalanche hazard operation, receiving an average of 1200cm annual snowfall. In 1936 Brighton became the first Ski Area in the State of Utah and the 15th Ski Area in the United States. 1963 led to terrain expansion with the Millicent single chair lift and Brighton's introduction to avalanche hazard. This hazard was managed through terrain closures and use of a US Forest Service 75mm pack howitzer. As the years and technology progressed Brighton Resort transitioned to the 75mm recoilless rifle, followed by a tray loaded avalauncher, and finally the GAZEX remote avalanche control system (RACS). In 2005 Brighton installed a GAZEX control shelter and (2) 0.8 inertia exploders, followed by the installation of (1) additional 0.8 and (1) 1.5 inertia exploder in 2006. This case study will focus on improved safety and operational efficiencies recognized in the subsequent nineteen seasons of operation. It also provides a working database and historic reference for both current and future generations.

KEYWORDS: Remote Avalanche Control System (RACS), GAZEX, Brighton Resort, Avalanche Mitigation

1. INTRODUCTION

Millicent Peak (3,100 meters) rises six hundred meters above the satellite terminal of the Millicent lift. This terrain and upper start zones are steep, leeward, and predominantly rocky. The lower start zones or aprons are less steep, unsupported, poorly anchored and grass covered. The aspect is N-NE which offers shaded slopes and often promotes basal faceting of early season, shallow snowpacks. Season snowfall averages 1200cm, with a record snowfall of 2500cm during 2023 season.

Figure 1: Millicent Bowl Snow Covered

Upper chutes and aprons can be accessed only by "boot pack" hiking. This is a popular access point for recreational backcountry users of terrain beyond the resort's boundaries.

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Millicent Chair delivers users six hundred meters below the summit providing mid-slope access to the slope and avalanche terrain.

In the nearly 90 years since its humble, mom and pop, family-oriented beginnings, Brighton Resort and its home, Big Cottonwood Canyon BCC have experienced a massive increase in recreational use. Brighton Resort is 24km from Salt Lake Valley, situated between the Wasatch Front and Park City. The population of the Wasatch Front is well over two million. Brighton Resort sees over 500,000 user days per season.

2. OPERATIONAL CHALLENGES

2.1 *Early Season Access*

Sitting alone, yet just a few hundred meters and to the west, the Millicent chair is removed from the main body of the Ski Area. This creates early season access issues as the Millicent zone requires a deeper snowpack to access the satellite terminal, boot pack and starting zones.

Historically, access to these start zones has been operationally possible only after multiple early season storm cycles, which can unfortunately create a tricky combo- the development of basal facets and the formation of a stronger slab resting atop. Steep rocky terrain and cliffs prevent access to the starting zone aprons. Long distances reduced the likelihood of explosives, hand thrown from the

protection of the ridge, reaching the critical apron starting zones. The only possible access by avalanche mitigation teams is to skirt below the rocks and cliffs while gaining elevation by side-stepping uphill across the slope. This mitigation routine was typically deployed after the use of a long-range projectile explosives to "protect" the crews from the well-established weak layer and slab: beginning with the 75mm pack howitzer, transitioning to the 75mm recoilless rifle, and ending with the tray loaded avalauncher. The use of these remote weapons was time-consuming and personnel intensive, personnel which the Ski Area was often in short supply, particularly in the early winter season.

As a result, avalanche mitigation efforts began in late December or early January, roughly eight to twelve weeks after the first snowfall. Avalanche mitigation teams deployed all the tools available to them before accessing the terrain on skis. Reduction methods included long distance projectiles, hand thrown explosives, improvised trams, rope lowered case charges, and hand charges on a stick.

Fig. 2 & 3: Millicent Early Season Snow Cover

Despite these labor-intensive efforts and operational awareness of the hazard, these tools often proved ineffective at reducing the avalanche hazard until later in the season.

The problem was easy to identify: STRONG SNOW over WEAK SNOW. "*The ingredients are present, a slab, a weak layer, and a bed-surface."* However, safely, and efficiently finding the trigger proved much more difficult.

2.2 *Avalanche Forecasting and Mitigation*

Due to the forementioned access issues early season, forecasting efforts revolved around the available data from snow study plots and wind instrumentation. One thing was nearly guaranteed: early season snowfall would arrive, followed by days to weeks of clear cold weather, promoting basal faceting in the start zones, typically weeks before the arrival of larger snow and wind events. Long before teams could access the terrain the hazard was slowly increasing. When access became operationally possible the Ski Patrol mitigation teams would attack the hazard with the tools available to them. These missions often led to small variable pockets and sometimes underwhelming results. However, instability often lingered awaiting more load to trigger slides or for the snowpack to begin to heal overtime.

2.3 *Personnel*

Before long-range projectile and hand charge missions could begin, personnel must be transported via grooming machine or ski lift. This required at least one operator for a brief period before returning to other duties. Avalanche Mitigation Teams consisted of "gun team," (minimum two personnel) and "ridge team", (minimum two personnel). To be followed by "low route team" (2-4 personnel). Typically, the "ridge" and "gun" teams combined to form the "low route team" on a second mission from the top of the chair.

Figure 4: Brighton Patrol above Millicent Chair

This small number of personnel resulted in teams becoming “spread out” from each other by distance and terrain, complicating the ability for one team to rescue the other should an emergency arise. The need for lift or machine access further hinders acquisition of additional rescue resources leaving teams in a “self-rescue” situation.

Brighton Professional Ski Patrol consists of fourteen members and is responsible for all avalanche mitigation activities. The Pro Patrol is boosted by a substantial Volunteer Ski Patrol. Avalanche mitigation often required much of the Professional staff to focus their attention on Millicent and away from the busiest part of the resort. Often terrain or lift openings were delayed due to insufficient resources on avalanche control mornings.

2.4 *Time Constraints*

It is much easier, logistically, to gather necessary personnel at the start of the day before they are disbursed across the resort. Time of day challenges add complexity because avalanche mitigation almost always occurred in the early morning pre-dawn hours. The Wasatch Mountains are a busy range. Brighton Resort is surrounded by Alta and Snowbird Resorts to the West. Solitude Resort to the North, and Park City and Deer Valley Resorts to the East. Backcountry users routinely frequent the area surrounding Brighton Resort.

Backcountry population, proximity to other users, and limited personnel mandated shooting of long-range projectiles only take place during daylight hours, in the morning before lift openings.

While Brighton Resort was not alone in this challenge, many missions were cancelled due to weather conditions, lack of visibility, or poor timing.

Avalanche mitigation was conducted NOT when conditions *warranted*, but when factors *allowed*.

This presented only two solutions: terrain closure or explosive mitigation from the ridge.

2.5 *Terrain Closures*

Historically, terrain closures have been used as an avalanche mitigation tactic by Brighton. However, evidence, both anecdotal and scientific, has shown that skier compaction is beneficial to early season and storm snow.

Closures during and after storm events limit skier compaction and disruption of potential weak layers. In addition, safety closures must be enforced, requiring focused personnel time and frequently creating a tense atmosphere between violators and enforcement employees.

Brighton Resort, operating under agreements with the US Forest Service and Salt Lake County, is allowed to post “Avalanche Closed Areas.” Entry into these areas is a misdemeanor offence punishable by law.

Figure 5 : Large avalanche Millicent Bowl.

Brighton Resort is in the business of selling terrain access. Terrain access is two-fold, it makes customers happy and delivers the benefit of skier compaction. Prohibiting access to terrain is contrary to successful business model and is labor intensive. Installing, maintaining, and enforcing closures is demanding work. But, enforcing closures is critical to protecting the Brighton Resort legally, for the safety of personnel, and for sending the message that violations will not be tolerated. Resort operators are obligated to ensure closures are warranted and enforced.

Reducing closure duration and frequency is in the best interests of Brighton Resort and their customers.

2.6 *Worker Safety and Hand Charging*

Avalanche mitigation work is inherently dangerous, combining a mountainous environment with extreme weather, hazardous terrain, avalanche conditions, explosives, long-range weapons, and people. Despite the best efforts and due diligence, Brighton Resort incurred work-related injuries in the Millicent

Bowl terrain. Over 10 years (4) Ski Patrollers were caught, carried, buried (fully or partially) and injured while conducting mitigation work in Millicent Bowl.

Close calls occurred primarily when use of long-range projectiles was not possible due to factors previously discussed. These incidents involved early season, wind slab, and new snow avalanches. Avalanche mitigation teams were more likely to trigger avalanches and be injured on days with lower snowfall totals and less persistent avalanche problems. Operationally, this data makes sense. During times of higher avalanche hazard, terrain was managed with long range projectiles or closures. However, as hazard decreased, the terrain was managed by personnel on the ground, on skis, thus in harm's way, resulting in higher likelihood of injury.

2.7 *Long Range Projectiles*

Brighton Resort, like many resorts of the era, progressed with the weapons and programs of the US government. Transitioning from the occasional firing of the 75mm pack howitzer by US Forest Service personnel to routine firing of the 75mm recoilless rifle. High dud rate, ammunition supply shortages and the cost of storage magazine construction led to replacement by tray loaded avalauncher.

The avalauncher, a "Fast Ball" baseball pitching machine in its former existence, did not offer the power, reliability, or accuracy of its predecessors. In addition, firing missions were time-consuming. Explosive rounds were retrieved from the magazine, assembled, packaged, transported by lift, transported by skis, delivered to the gun tower. The Avalauncher must be prepared before use. Due to outside storage, water, ice, and freezing issues were ever present. These processes consumed hours for each mission. Target accusation proved difficult. Limited azimuth and elevation configurations combined with strong gusty winds made hitting objectives impossible. Small payloads made the power of avalauncher rounds less effective, particularly when deployed into the snowpack. Standard practice was to aim for "rock shots" to increase effectiveness. The avalauncher clearly lacked the power of the Howitzer. However, a switch to newer artillery was neither financially probable, nor likely to receive approval from the US Military and / or US Forest Service.

2.8 *Deep Instability / Late Season Avalanches*

Questions should be raised when persistent weak layers lead to mid to late season, deep slab avalanches. In fact, Brighton Snow Safety Teams had triggered late season avalanches with crown heights of 4-5 meters and massive debris fields in terrain previously opened to the public.

Brighton Resort was faced with a classic dilemma, increasing demand on personnel for timely terrain openings along with more accountability for accurate avalanche forecasting. Coupled with difficulty using the historical tools and personnel in a traditional manner to accomplish its growing needs. After visiting GAZEX installations in Europe, John Kircher, Boyne Resorts owner, decided to install and evaluate a GAZEX system at Brighton Resort.

3. INSTALLATION AND INTRAGRATION OF THE GAZEX SYSTEM

In the Fall of 2005 Brighton Resort purchased (2) 0,8 inertia exploders, (1) 1.5 standard exploder and steel shelter (formerly used by WYDOT at Teton Pass). The control shelter and (2) 0.8 exploders were installed, and test fired just as winter and snowfall arrived. The first winter was a learning curve, but one thing was clear, the explosive power created by these units was enough to trigger avalanches. The GAZEX system was fired before the avalauncher. Teams would access the terrain from the ridge to complete hand charge missions and verify results. Fall 2006 saw the installation of the 1.5 exploder in "the elevator chute" and (1) additional 0.8 inertia exploder.

Over the next few years, Brighton Snow Safety integrated the GAZEX system. Standard storm snow morning missions initiated largely unremarkable results. Loose storm snow or small size 1 and 2 results were recorded with each mission. The steep terrain of the upper zones was "cleaned-out" with each mission. This debris piled in the apron starting zones creating deep depositions.

Previous avalanche mitigation efforts were limited to early mornings before lift openings. GAZEX allowed the teams to shoot in the evening after a stormy day, or more importantly, GAZEX allowed midday missions. Ski Patrol could close and sweep the effected terrain. The

(4) GAZEX exploders could be fired in 10 minutes, and the terrain could be reopened to the public. This practice allowed for avalanche mitigation from above and ski compaction and disruption below, reducing closures and increasing guest access and satisfaction.

4. LESSONS LEARNED

December 2008 started like many seasons before, early season brought substantial snowfall in late October followed by cold clear weather into early December. Millicent Lift and Millicent Bowl had not yet opened to the public due to early season conditions. The GAZEX system was not yet operational for the winter. Snow Safety Teams accessed the Millicent Bowl terrain for the first time on December 11th conducting an avalauncher mission and hand charge mission on the upper apron. December 12th mitigation teams returned for another avalauncher and hand charge mission. The snowpack was approximately one meter deep, consisting of 0.5m basal facets covered by a strong crust and wind slab. This scenario was not a new one and, in the past, patrol personnel had been injured under similar circumstances. An avalauncher mission was conducted. Teams would then throw hand charges from the ridge. They would next enter the exposed terrain on skis “side-stepping” uphill while crossing below the cliffs. They would stop periodically to throw additional hand charges below them. Team members might stop to dig a quick snow pit before proceeding. Two things were clear, first, there was avalanche hazard, second, the slab and slope the teams actively prodded with explosives was the same slab and slope they stood upon. Results from two days’ worth of missions produced only limited loose snow avalanches. After the mitigation on December 12th, a team hiked the ridge to the GAZEX shelter to access and make it operational for the season. The Ridge Team retreated down the bootpack due to avalanche hazard and early season conditions.

December 13th arrived with 50cm of new snow and wind. The GAZEX system was fired in early morning pre-light conditions. As the clouds cleared, and the light improved the Ridge Team reported widespread avalanches 1.5 - 2 meters deep on all Millicent Bowl apron start zones. This was the first large avalanche since the installation of the GAZEX system and an event to learn from.

Figure 6: Large avalanche crown-face. Millicent Bowl 12/13/08 Explosive residue from previous days missions visible.

On two consecutive mornings after hand charge and avalauncher missions, personnel had entered a slope with obvious avalanche hazard to deploy explosive charges. However, this go ‘round, that was unnecessary as the GAZEX system worked. A large, early season avalanche was triggered, hazard reduced, and terrain opened without significant exposure to patrol personnel. In fact, avalanche hazard was reduced from this event and for the rest of the season.

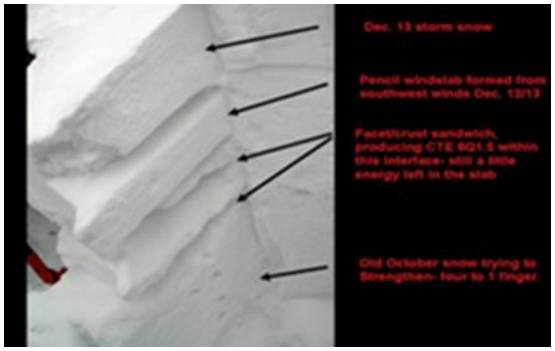

Figure 7: Snow profile Dec 13th incident. Photo UAC Incident Investigation Report.

The same morning in the Central Wasatch avalanches caught, carried, and injured one skier and killed another on slopes with similar aspect, elevation, and snowpack structure.

5. GAZEX - OPERATIONS

As Brighton continued the transition away from long range projectiles, avalauncher use decreased each year until the final mission in 2011. The GAZEX evolved into the “Work Horse” of Brighton’s Milly avalanche mitigation

program. The process, start to finish, firing four exploders was completed in just 10 minutes, proving GAZEX was easy to use. The morning routine was seamless: access the software, clear the start and runout zones, fire the exploders, open the terrain, grab a coffee! A transition had occurred.

Avalanche mitigation could be conducted when conditions *warranted*, not just when outside factors *allowed*.

5.1 *Maintenance*

Yearly maintenance and attention to gas supply is critical. Thoughtful installation and protection of the gas lines to the exploders is crucial for longevity. Brighton Resort dedicated many manhours to support, anchor, and cover the gas-lines. Taking this time proved a worthwhile investment. Nineteen operational seasons later, the gas lines are in particularly good condition.

The GAZEX system, like any tool, needs service, maintenance, and attention to maintain performance. The available gas supply is the only factor limiting how many shots are available. Oxygen is re-supplied as needed using the chairlift. The shelter on the ridge is supplied with high pressure oxygen from the top lift station. Propane is supplied every 3-5 years by helicopter. Maintaining and supplying gas takes place during the fall season. With proper planning and precautions resupplying gas is not necessary during the winter. Ignition batteries are replaced each year. After nineteen seasons of heavy use, this system is currently undergoing major maintenance. Replacement of the gas shelter and communications system upgrades are planned for next year.

Figure 8: Gas-lines after 19 seasons

5.2 *Communication System*

GAZEX operational data and communication system is managed by GAZEX MANAGER Evolution software. Communication is currently established using Ultra High Frequency radios. ***Safety-cs*** is a redundant cloud-based communication system using cellular network and Freewave radios will be implemented with shelter replacement in 2025.

6. AVALANCHE MITIGATION TOOLS

Comparing different avalanche mitigation devices and techniques across timelines and eras is complicated. For this paper, we will focus on comparing the Number and Type of shots vs. Size and Frequency of avalanches.

6.1 *75mm Recoilless Rifle*

Brighton 75mm rifle data existed from 1985 to 1995. It was replaced due to the high dud rate and limited ammunition for 1995/96 winter.

- 1,283 recorded firings
- 128 average shots / year
- 16 average missions / year
- 8 average shots / mission
- 106 recorded duds
- 8.25% dud rate

6.2 *Fast-pitch Avalauncher*

Beginning in 1995, an avalauncher was repurposed for use on Millicent Bowl. The avalauncher was used from 1995 to 2010.

- 4,123 recorded firings
- 312 average shots / year
- 26 average missions / year
- 12 average shots / mission
- 78 recorded duds / overshoots
- 1.89% dud rate

Figure 9: 0.8 Inertia exploder

6.3 *GAZEX System*

- 3,657 total detonations (as of 7/2024)
- 192 average detonations / year
- 48 average GAZEX missions / year
- 915 average detonations / exploder
- 19 operational seasons

7. GAZEX - AVALANCHE OUTCOMES

For this comparison, we looked at 33 years of recorded data. Each device was given an 11-year time span. First, we will consider the average number of recorded class 3 or larger avalanches initiated by each control measure over the respective periods. We will refer to these as “large events” in this document.

Large Event Avalanches (11-yr average)

75mm Rifle – 58 events, 5.27 / year (85-96)

Avalauncher- 85 events, 7.72 / year (96-07)

GAZEX- 39 events, 3.54 / year (07-18)

Frequency of Large Events

75mm Rifle 3.03 missions / event

Avalancher 3.36 missions / event

GAZEX 13.55 missions / event

Data supports the anecdotal evidence that conducting avalanche mitigation more frequently reduces the size and scale of subsequent avalanches. The terminology “cleaned-out” appears very frequently in the logbook as results for GAZEX missions. This term means the new snow avalanched or sluffed leaving debris or old snow surface. These missions are noted as size 1 and 2 results.

A further study into the timing of these “large events” could be interesting. Primary data suggests after the GAZEX program, these large events happened in clusters. Due to increased loading from storm snow and wind events. Historically, these events are more random. It appears these large events revolved around the inability to access and mitigate known avalanche hazard in deep, unstable snowpacks, occurring later in the year with less predictability. Initial observations suggest this situation happens less frequently with GAZEX and larger events are tied to increased snow loads prior to mitigation missions.

CASE STUDY

Consider this phrase “*We just don’t see big avalanche results up there like we did in the past*”, an ongoing comment since the GAZEX program began.

Option 1- The (4) GAZEX locations are insufficient to manage the zone previously managed with 6-15 explosive projectiles. Hazard is present, however the GAZEX operational program is insufficient to trigger.

Option 2- The ability to better manage the snowpack with the GAZEX system, from the first snowfall through the daily operations of the season, has effectively led to an overall reduction in avalanche hazard, reducing “large event” probability by the creation of multiple smaller slides and structural changes to the snowpack.

Option 3- The reality is somewhere in the middle. However, the ability to actively mitigate a difficult to access snowpack in under 10 minutes, in any weather, at any time of day makes operations more efficient.

Figure 10: Early season GAZEX results.

8. GAZEX– OPERATIONAL OUTCOMES

8.1 *Influencing Early Season Snowpack*

Early season snowpack can be influenced vastly by time-sensitive use of the GAZEX system. Early season snow on the high north aspect “rots” and facets with periods of dry, clear, cold weather. The upper start zones of Millicent Bowl are steep and rocky. Firing GAZEX with each new snow event creates loose “sluff” avalanches. These events “clean-out” the upper starting zones and overrun snowpack on the lower apron starting zones below. The dense avalanche debris created by these frequent small avalanches is much more resistant to faceting than lower density new

snow on the ground. Reducing or eliminating the faceted snow in these start zones reduces the problem before it begins. The ability to fire GAZEX early and often creates the opportunity to begin mitigation efforts with the first snowfall.

8.2 *Increased Safety*

Early winter avalanche mitigation in this terrain has increased worker and public safety. Historically, these slopes could only be accessed after the formation of an early season snowpack which often offered the dangerous combo of a slab and a weak layer.

Since the inception of the GAZEX system, this terrain can now be influenced early and often. In fact, Brighton Ski Patrol reported zero avalanche related injuries to avalanche workers in the Millicent zone. This reduction in injuries influences the resorts insurance cost and bottom line. More importantly injured personnel never fully recover. Avoiding injuries is paramount to the long-term health and success of avalanche workers.

8.3 *Terrain Closures*

Brighton Resort has experienced a significant decrease in closures. These reductions are manifest in the form of shorter closure times for daily storm snow mitigation, also drastically reducing the number of pre-season Avalanche Closure days. This reduction has led to reduced time spent policing closures and citating violators. It means guests access more terrain faster, skier compaction and disruption significantly reduce avalanche hazard before the next storm.

8.4 *Reduced Manpower*

GAZEX reduces the operational manpower needed to complete mitigation of Millicent Bowl by 50% with elimination of the gun team. Most days the manpower is further reduced by firing only the GAZEX without teams accessing the upper apron due to conditions and/or avalanche results.

The ability to access and mitigate these zones with increased safety and efficiency has led to a reduction of both terrain closures and their duration.

Operational efficiency is the net gain, allowing Brighton Ski Patrol to focus on other demands, especially on big storm days.

CONFLICT OF INTEREST

Brandon Dodge, the author, is an employee of Brighton Resort, The MND Group and MND America. MND Group manufactures GAZEX. Brandon is a resolute supporter of RACS systems to provide better safety, increased decision-making capacity, and efficiency to avalanche workers.

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