Cork 12L Freeride World Tour Snow Safety Airbag Pack and Airbag Vest

Ryan M. Karow

M.S. Sports Product Design, University of Oregon

SPD 689: Thesis Capstone

Dr. Susan Sokolowski, Vanessa Preisler, Carly Mick

6/13/2024

Table of Contents

Research Section

Project Overview

Freeride skiing and snowboarding represent a recent evolution in extreme snow sports, embracing a diverse range of competitive disciplines. The Freeride World Tour stands as the pinnacle of competition for the most daring Freeride skiers and snowboarders, displaying their unparalleled skill, creativity, and style on some of the world's most challenging terrain. To meet the demands of such high-level performance, there is an urgent call for innovation to elevate the quality of equipment, as current offerings often fall short of expectations.

Each year around fifty top competing riders qualify for this intense competition and compete internationally at four to six stops with the ultimate goal of qualifying for finals in Verbier, Switzerland, the final stop of the tour (*WE ARE THE HOME OF FREERIDE*, n.d.). With this extreme level of riding comes the highest level of consequences. One bad fall and riders can tumble down 50° slopes over cliff bands, rock faces, and cause huge avalanche that can bury them.

To combat these risks, riders are now required to use back protectors, avalanche airbags, helmets, and other avalanche gear at a minimum, to protect against these hazards. Each of these products perform well but not in conjunction with each other. To embrace the fluidity of movement, the elevated stakes, the ever-present threat of avalanches, and address the existing issues of system integration, there's an imperative demand for a fresh line of safety equipment tailored for freeride skiers and snowboarders. This innovation is crucial to not only safeguard riders but also enhance their performance and overall enjoyment.

This research explores, substantiates, and proposes innovative solutions for backcountry skiing avalanche airbag packs and vests.

Sport History

Skiing is one of the oldest sports with the first original pair of skis found in Northern China around 8000BC. Throughout the years skiing was used primarily as a means of travel on snow until the 18th century when Norwegian, Olaf Rye, cultivated the sport of ski jumping which brought a new whimsical joy to snow that has lasted forever (History Of Skiing, n.d.). Over a millennia later, in 1965 Sherman Poppen developed the first snowboard (Torah, 2013). With the snowboard and skis fully imagined, riders were now able to transform the sport into a

form of expression, showing their skills in the air, on steep terrain, style, and technique which birthed the sport of freeride skiing and snowboarding.

The first freeride event to highlight these skills was held in 1991 in the Wasatch Range, Alaska by the World Extreme Ski Championships (WESC) (Freeride World Tour, n.d.). Five years later, 1996, the Freeride World Tour (FWT) was created in Verbier, Switzerland where riders year after year compete to face the famous slope on the Bec des Rosses (Freeride World Tour, n.d.). Today, men and women skiers and snowboarders compete in each different group for the podium with twelve total awards for the top three athletes in each category.

Figure 1: Bec des Rosses also known as the XTREME Verbier venue (starting area is on summit) (Freeride World Tour, 2022)

Target User

To cater to the unique requirements of riders, this product line is meticulously crafted for the pinnacle of freeride competition, specifically tailored for the Freeride World Tour (FWT). The line comprises an avalanche airbag pack and an avalanche airbag vest. Both products utilize the same ‘bag’ as a base but have non-interchangeable straps to save weight. The primary user, Freeride World Tour athletes are competing in this category range in age from 18- 35 with the majority of competitors being in the early to mid-20s (H. Samuels, personal communication, October 12, 2023). On the tour this year are 52 male and female snowboarders and skiers (*WE ARE THE HOME OF FREERIDE*, n.d.).

Indirect Market

The Cork 12L avalanche airbag product line is designed for the high-performance demands of Freeride World Tour (FWT) competitors, emphasizing innovation and cutting-edge features. While the FWT itself has a limited field of 50 athletes, the sport's reach extends far beyond this elite level. Over 4,000 individuals participate in qualifying and semi-professional events globally, primarily organized by the International Freeskier and Snowboard Association (IFSA). This robust community, with its shared values and competitive aspirations, represents a significant potential market for the Cork 12L. (*WE ARE THE HOME OF FREERIDE*, n.d.).

Crucially, many FWT athletes honed their skills in IFSA events, making the World Tour the ultimate goal for aspiring IFSA competitors. This close relationship creates a natural synergy, increasing the likelihood that IFSA participants will be drawn to the Cork 12L's advanced technology.

Furthermore, the broader backcountry skiing and snowboarding market, estimated at 1.3 million participants (Snowsport Industries America, 2023) presents a vast untapped opportunity. These enthusiasts, who frequently venture into avalanche-prone terrain, are a natural target audience for the Cork 12L's safety features.

To reach this wider market, the Cork 12L product line could benefit from more cost-effective models, utilizing less expensive fabrics and trims. This strategy would not only increase accessibility but also position the Cork 12L as a "halo product," with its advanced technologies potentially spilling over to other airbag applications across the market.

Golden Circle

Why: Elevate the safety and performance standards for freeride world tour competitors by providing cutting-edge safety products that seamlessly enhance the thrill of the sport, ensuring optimal protection without compromising performance and adhering to the rules and regulations of the Freeride World Tour.

How: Empower freeride world tour athletes to reach the pinnacle of competition, offering unparalleled protection and minimal disruption through advanced safety gear.

What: Introducing a comprehensive product line, featuring airbag packs and airbag vests that allow athletes to prioritize their performance while competing by alleviating all excess features and weight.

Product Classification

This project focuses on freeride competition snow safety equipment with an avalanche airbag pack and avalanche airbag vest.

Product Line Plan

This research focuses on creating a cohesive product line of ski safety equipment. Specifically exploring a combination of an airbag vest, along with an airbag pack. The pack and vest, although not interchangeable, are designed with the same bag that sits behind the user. This two-product plan allows for riders to choose between a normal pack, or a vest based off user preferences and strap configurations. The airbag system this project will use is provided by Black Diamond, an industry leading ski equipment company, using their JetForce Pro Airbag System with modifications.

How Can We Statement

How can we develop a line of Freeride World Tour snow safety equipment that provides athletes with the best visibility, prevents airbag pre-releases, and is lighter than competitors.

Rules And Regulation

Freeride World Tour athletes are also required to follow certain codes to ensure fair chance, safety, and maintain efficiency with the competition. During competition, athletes are required to ride with beacons, probes, shovels, avalanche airbag packs or vest, back protectors, and helmets (*Safety At The Freeride World Tour*, 2022). In addition, prior to the event, riders are only allowed to scope their lines via helicopter, hiking, or scouting from afar depending on the competition, conditions, and avalanche hazard. They employ fore runners that will ski and snowboard down the venue for riders to see how the snow reacts prior to the event.

Beacons are essential devices that continuously emit signals, allowing rescuers to locate a buried victim. Rescuers switch their beacons to receive mode to obtain a rough approximation of

the victim's position. Once the approximate location, typically within a one-meter by one-meter area, is determined, a probe is used to breach the surface and pinpoint the buried victim. Rescuers then deploy their shovels, often using collapsible shovels, to rapidly excavate and rescue the buried victim. Avalanche airbag packs and vests are purposefully designed to store these essential tools, except for the beacon, which is typically worn by athletes either in a harness system or commonly within their snowpants.

Avalanche airbags are essential for all athletes in avalanche terrain. These products allow riders who are about to get caught in an avalanche to pull a mechanism which deploys and inflates an airbag ballast or ballon. By the inverse segregation principle, meaning larger particles tend to ride to a surface of a mixture, riders who may otherwise be buried deep beneath a snowy avalanche can more effectively rise through an occurring avalanche (Kokelaar et al., 2015). In this situation, riders are the larger particles which tend to ride to the surface of the snowy mixture while the avalanche is occurring which can aid in survival.

In addition, helmets, and back protectors, also known as spine protectors, are required in competition. These items provide essential safety measures in the event a rider tumbles down the mountain and hits various obstacles.

Figure 2: (Top Left) Airbag, (Top Right) Beacon, (Bottom Left) Collapsible Probe, (Bottom Right) Shovel (*BSP & Airbag*, n.d.)

Figure 3: POC Men's VPD Back System (*POC Men's VPD Back System*, n.d.)

Figure 4: Sweet Protection Trooper 2 Vi SL Mips Helmet (*Sweet Protection Trooper 2 Vi SL Mips Helmet*, n.d.)

Success

Riders on the Freeride World Tour are ultimately judged based on line choice, control, technique, fluidity, and air and style on a scale from 0-100 (*Judging System*, n.d.). The higher the score they achieve, the greater their chances of securing a coveted spot in the Verbier finals held in Switzerland.

Line choice is scored based on difficulty and a variety of other factors like uniqueness and steepness. For example, a line through a cliff band jumping over various obstacles into a steep chute would score much higher than a lower angle line featuring easier terrain. Control is assessed on aerial and ground stability. If a rider almost or does fall over after landing a trick, this will result in a deduction of points. Technique relates most to rider style and skill such as turning, also known as carving. A rider that carves through a steep section with style rather than

uncontrollably sliding on their ski or snowboard edge down a hill will score highly in this category. Fluidity is judged on overall flow of the line without stopping. Air and style is what really makes the competition interesting with jumps, flips, spins, and more, the judges assess the difficulty of these tricks and score them based on takeoff, grabs, balance, aerial style, and landing (*Judging System*, n.d.).

Once riders are part of the tour, they enjoy guaranteed participation in competitions at all locations, except for Verbier. Over the course of the season, each event bestows riders with scores that can reach a maximum of 100. The top five competitors in each category, encompassing both women's and men's skiing and snowboarding, will earn the privilege of competing on the highly sought-after terrain known as the face of XTREME Verbier (H. Samuels, personal communication, October 12, 2023).

Environment

The Freeride World Tour takes place in a dynamic, ever-evolving environment characterized by steep, challenging terrain that is constantly susceptible to avalanches. This rugged landscape features both new locations and familiar faces, creating an atmosphere of both novelty and tradition. Each year, the tour introduces riders to fresh challenges, including a wide range of weather conditions, temperatures, and ground surfaces.

Unlike most skiers and snowboarders who often contend with harsh elements such as strong winds, overcast skies, and heavy snowfall, the Freeride World Tour athletes operate under unique circumstances. Due to the high level of intensity, inherent avalanche risks, and the need for optimal broadcast conditions, these riders typically only compete on sunny days, or when the weather remains mildly overcast or snowy. It's worth noting that these events are broadcast globally, and if the slope isn't suitable for camera coverage, riders won't take to the course (H. Samuels, personal communication, October 12, 2023).

On the other hand, surface conditions at each location can vary significantly, requiring riders to stay alert and adaptable. They may encounter various obstacles, including rocks, ice patches, wet snow that can unexpectedly impede their progress, water hazards, deep powder, wind crust (a hard, thin layer of ice over softer snow), and hard-packed snow that mimics concrete. Given the ever-changing environment, riders must continually assess their line choice,

engage in practice runs when available, and consult avalanche reports to ensure their success. Additionally, temperatures fluctuate between -20°C and 10°C depending on the specific location making it tough to plan for a line ahead of time (*Freeride World Tour Calendar With Temperatures*, 2023).

High elevation along with extended exposure at these heights also challenges athletes. Throughout the years, various location have peaks towering between 2100-4100m along with athletes spending sometimes close to eight hours in these conditions, waiting for a weather window (*Freeride World Tour Calendar With Temperatures*, 2023).

Performance Jobs to Be Done

Riders on the Freeride World Tour need to successfully scout, ascend, and descend while performing at the highest caliber at any given stop on the Freeride World Tour. This section addresses the performance jobs to be done and the necessity for new product innovation while abiding by the Freeride World Tour rules and regulations.

Prior to competition day, riders will spend a full day investigating the competition venue for their best line choice, snow quality, potential hazards, and avalanche stability. This scouting day is spent stagnantly in the snow waiting for forerunners to ski the face with hours of peering through binoculars.

Existing products fall short in meeting the diverse needs of riders during the ascent and descent portion of the competition. The ascent encompasses a spectrum of activities such as hiking, waiting to drop, scouting, transitioning, and more. Competitors must efficiently carry all their gear, including skis or snowboard, food, drinks, extra equipment, shovel, and probe, to and from the competition site and their residence. Access to the summit starting gate occurs through various means like helicopter drops, ski lifts, gondolas, hiking, or a hybrid of these methods. Any avalanche airbag pack or vest must be versatile, comfortable, and capable of performing seamlessly in these varied environments. Additionally, athletes need to transition smoothly from hiking to skiing or snowboarding before dropping in, involving the removal of skis or snowboards from the pack or vest and the donning of other competition equipment such as helmets or goggles (H. Samuels, personal communication, October 12, 2023).

The descent is the most important part of the competition with athletes navigating treacherous terrain, maintaining aerial and ground control, holding speed, spinning, flipping, observing surroundings, and executing their line plan. When dropping in, their airbag pack or vest needs to be comfortable, light weight, and maintain a small form factor close to the bodice.

While maintaining the utmost level of safety, riders need to seamlessly be protected in dangerous terrain while being unhindered. Many airbag packs and vests feature excessive trim items, unneeded storage, and unnecessary notions that slow down freeride competitors. A particular challenge lies in the retaining pocket, which houses the empty airbag ballast. This pocket must remain closed until the user triggers deployment, but most current designs rely on a zipper and a breakaway component, typically hook-and-loop, to secure the pocket. These breakaway components are intended to release the zipper when the airbag inflates, but they are often prone to premature separation, causing the airbag to deploy unintentionally. This can occur due to various factors, such as snagging on a chairlift, contact with trees, or impacts from jumps. The result is an uninflated airbag, acting as a cumbersome "windsail" that hinders rider performance and requires a time-consuming repacking process.

Despite numerous firsthand accounts from FWT athletes of these issues, to validate this claim further, competitor products airbag closure systems were evaluated for tensile strength testing outline in the “Testing” section of this paper. Currently, only one product has addressed this issue with airbag pre-releases. Ortovox and Arc’teryx, the two companies that accomplished this feat, utilize a mix of electronic components for inflating the airbag along with mechanical bike cables to unlatch a locking component holding two zippers closed (*Litric Airbag System*, n.d.). The complexity of this solution contributes to excess weight thus sparking the need for innovation within the space.

Addressing these challenges requires a holistic approach, focusing on a smaller overall form factor, reduced weight, preventing airbag pre-releases, and enhanced visibility. In redesigning snow safety gear, the goal is to offer Freeride World Tour athletes gear that seamlessly integrates, enhances performance, and provides uncompromising protection in the pursuit of freeride success.

Airbag Pack and Vest Competitors

Airbag packs have existed for over a decade with many brands exploring various means of shape of the pack, features, safety pockets, and various inflation sources. Since this research paper doesn't delve into redesigning the airbag system, the critique of competitor landscape will focus on system integration of the airbag within the pack or vest, weight, price, features, and benefits. Many riders are sponsored athletes which receive airbag packs or vests, protection products, and more for free, however, price is still included in this analysis.

The main brands in this space are Ortovox, Backcountry Access, Mammut, Black Diamond, and Arva. Airbag packs have steadily trended towards featuring an electronic airbag system, the ideal choice for Freeride World (*History Of Avalanche Airbags*, n.d.). The electronic airbag is the easiest airbag to travel with thus a better choice for FWT athletes. Interestingly, overall, most airbag vest brands have spent little time developing new electronic airbag systems in vest. This section explores the features and benefits of these products along with feedback on how they can be optimized for athletes on the Freeride World Tour. It is worth mentioning no product is specifically designed for freeride competition and instead is in an adjacent sector such as backcountry skiing and snowboarding, lift assisted backcountry skiing and snowboarding, and leisure freeride skiing and snowboarding.

Ortovox, a prominent airbag pack brand, rolled out the "Avabag Litric Freeride 18" in 2022 featuring an innovative freeride specific pack coming in at $1,250 and 2400g. This bag allows for optional zip on compartments, diagonal ski carry, snowboard holder, helmet carry, and a wide hip belt (*Ortovox Litric Freeride 18*, n.d.). A couple of issues are immediately apparent with this model, the awkward style of snowboard carry, large literage, high position on the back, and redundancy of the back protector is worth noting. To accommodate additional zip on section, a feature not needed by ultralight Freeride World Tour competitors, the bag sacrifices a vertical snowboard carry, and instead relies on an angled carry style.

Figure 5: Ortovox Avabag Litric Freeride 18 $1,250 (*Ortovox Litric Freeride 18*, n.d.)

The Backcountry Access "Float E2-25 Avalanche Airbag" pack, boasts 25 liters of space, vertical snowboard carry, diagonal ski carry, helmet carry, google sleeve, dedicated avalanche pocket, load lifters, a bottle pocket and hip pockets (*BCA Float E2-25*, n.d.). The pack comes in at $1,249.95 and 2662g and has a variety of features that the Ortovox bag misses. This bag is not specifically designed as a freeride skiing or snowboarding competition pack but is for leisure freeride skiing and snowboarding. The bulky straps, excessive pockets, large storage, and heavy weight, make this pack a tough choice for freeride competitors.

Figure 6: Backcountry Access Float E2-25 $1,249.95 (*BCA Float E2-25*, n.d.)

The Black Diamond "JetForce Pro 10L" pack is a solid choice for athletes coming in at 2860g and $1,499.95 (*JETFORCE PRO 10L AVALANCHE AIRBAG PACK*, n.d.). This bag has 10 liters of storage, modular zip on pieces, ski carry, helmet carry, dedicated avalanche tool pocket, and hip storage. This Black Diamond bag brings a minimalist approach to electronic airbags which is much more appealing to riders, however, the heavy weight and extremely stiff

back panel is a major drawback. In addition, it doesn't suit snowboarders since there is no option for snowboard carry on this pack.

Figure 7: Black Diamond JetForce Pro 10L $1,449.95 (*JETFORCE PRO 10L AVALANCHE AIRBAG PACK*, n.d.)

Backcountry Access also makes an electronic vest airbag designed for snowmobile use with extra padding for riders called the "BCA Float E2 MtnPro Airbag Vest" (*BCA Float E2 MtnPro Vest*, 2023). This vest comes in at a whopping $1,499.95 and a hefty 3674g making it one of the heaviest products in this category. It features 15 liters of space, hip pockets, a dedicated probe and shovel pocket, modular straps, goggle sleeve, internal frame, and an electronic airbag system. This bag really is only designed for snowmobiling; it lacks ski or snowboard carry straps, helmet carry, and load lifters (*BCA FloatE2 MtnPro Vest*, 2023).

Figure 8: Backcountry Access Float E2 MtnPro Airbag Vest $1,499.95 (*BCA FloatE2 MtnPro Vest*, 2023)

In early 2015 Mammut released their “Alyeska Protection Airbag Vest”, an 889.99 and 1950g a fantastic gas-powered airbag vest choice for competitors back in the day. This bare bones vest stripped away all possible features with just one pocket, 5 liters of storage, and Mammut’s then innovative “trauma protection” which has since been discontinued due to unpopularity and questionable claims (*Mammut Airbag Vest*, n.d.). The “Alyeska Protection Airbag Vest” started down the road but fell short regarding back protection, electronic airbag capability, and any carry capability.

Figure 9: Mammut Alyeska Airbag Vest from 2015 $899.99 (*Mammut Airbag Vest*, n.d.)

Dakine’s “Poacher R.A.S. Vest” is a popular ever evolving airbag vest system that relies on compressed air to deploy the airbag system using Mammut’s removable airbag system R.A.S. (*Poacher R.A.S. Vest*, n.d.). This vest is for backcountry skiers and snowboarders who rely on lifts or vehicles to bring them out to their zone, rather than hiking intense ridgelines like FWT athletes. The vest has 15 liters of storage, a ski carry, snowboard carry, and main pocket. It comes in at an ultralight 1400g and costs $1074.90 with an optional back protection insert of another 50$ and is certified EN 1621-2 Level 2. The slide in padding system and full array of features seems like an alluring option but is difficult to transition from ascending and descending on ridgelines which freeride athletes frequently do. The vest must be removed to mount or dismount a board and snowboard which is cumbersome for riders. In addition, the padding system is a thermoplastic polyurethane and nylon blend which has a high safety rating but at a large cost. The padding is 10mm thick with no holes for breathability making hiking a sweaty and troublesome task, an unneeded disadvantage for Freeride World Tour athletes.

Figure 10: Dakine Poacher R.A.S. $1,074.90 (*Poacher R.A.S. Vest*, n.d.)

Avalanche Airbag Anatomy, Parts, and Jobs to Be Done

Avalanche airbags are either gas or electric fan powered devices that inflate an airbag ballast to help riders stay more afloat in an avalanche. Gas powered avalanche airbags are designed with a high-pressure canister and a mechanical release mechanism that allows the pent-up gas, usually oxygen, to disperse into a large airbag ballast. The primary drawbacks of gas-powered avalanche airbags are their single deployment along with issues with traveling. Compressed air canisters must be emptied prior to flight and despite being empty, sometimes still get confiscated by transportation security (H. Samuels, personal communication, October 12, 2023). Due to the frequent nature of travel for Freeride World Tour athletes, the ideal avalanche airbag system is an electronic powered system since no parts must be removed, refilled, or adjusted for flight.

The electronic airbag versions rely on ambient air intake to fill the ballast, another reason why airbags need to be deployed during an avalanche, not after the victim is buried. Electronic airbags are comprised of a battery, supercapacitor, or combination of the two, along with a fan, air intake, deployment mechanism, and airbag ballast. The battery, supercapacitor, or combo all function as the energy system for this product and store energy which can be transferred to the fan to inflate the ballast. The fan is either radial compressor style, like a turbo fan, or axial fan style, like a propeller fan, which blows ambient air through tubing to inflate the ballast (Reiter, n.d.). The job to be done for the fan is provide air to fill the airbag ballast. The air intake is a region in the system where ambient air can be pulled in via the force from the fan. This part's job

enables ambient air to be used within the system compared to compressed gas versions that don't rely on electronics.

The ballast is a key part in the system which holds the air and is commonly what people refer to as the bladder, ballast, airbag, or pressure vessel (Reiter, n.d.). An electronic deployment mechanism, or pull trigger, is also used to initiate this system from a 'stored' state to an 'inflated' state. This pull trigger serves as the activator switch and provides an electronic signal that enables the fan to be spun for inflation (P. Gompert, personal communication, April 24, 2023).

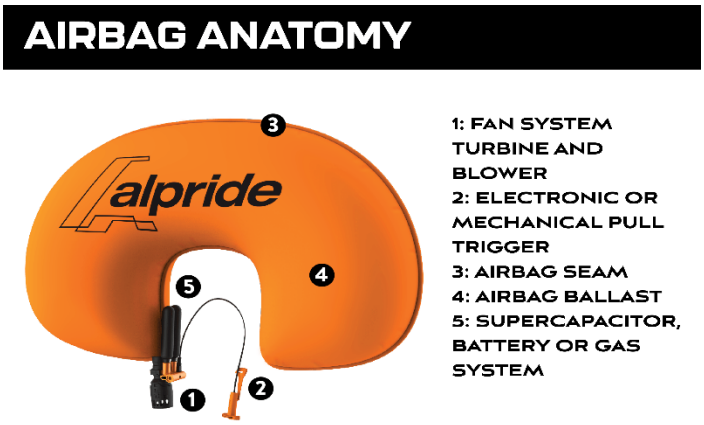


Figure 11: Airbag Anatomy (*Alpride System*, n.d.)

Airbag Pack and Vest Anatomy, Parts, and Jobs to Be Done

Airbag packs and vests have similar anatomy that creates the structure of the bag. There are six main components for these pieces of equipment, a back panel, main compartment, dedicated probe and shovel pocket, hip straps, shoulder straps, and trim pieces. Each pack and vest slightly vary with additional trim pieces, extra pockets, more storage, helmet carries, ski mounts, snowboard mounts, and more. For avalanche airbag packs and vests, almost every component is crafted with synthetic materials with waterproofing, durability, and abrasion resistance held paramount.

Figure 12: Pack and Vest Parts (*BCA Float 32*, n.d.) (*POC Men's VPD Back System*, n.d.)

The back panel serves to add breathability and comfortability for the user and provides structure for the bag. In addition, the panel is made with woven nylon or a knit polyester spacer mesh. This panel job is to protect the user from the contents of the pack or vest. The main compartment of the pack or vest provides athletes with a space to store clothes, water, and other items. This compartment almost always features a nylon coil zipper, knit or woven waterproof exterior fabric, and knit nylon grosgrain to bind the unfinished edges. The seams aren't seam taped to save weight.

After the main compartment, most packs and vests feature a dedicated probe and shovel pocket. This pocket serves to separate lifesaving snow safety equipment from the rest of the pack so athletes, in the case of an emergency, can quickly find, deploy, and unbury a victim. The hip straps keep the pack secure on the user and serve to hold most of the weight of the pack or vest. The straps are made from synthetic nylon with EVA foam sandwiched in between an interior spacer mesh like knit polyester. The edges are bound with knit nylon grosgrain and a thick knit nylon 1.5" to 2" hip strap is bar tacked on. Depending on the brand, some different aluminum, nylon, or abs plastic closures are used to secure the straps (*BCA Float E2-25*, n.d.).

Shoulder straps are made similar to hip straps, comprising of a ¾" knit nylon webbing, nylon or aluminum ladder locks, polyester spacer mesh, EVA foam, and the main synthetic pack material. The shoulder straps provide a means to carry the pack and have the weight suspended in a vertical orientation (*BCA Float E2-25*, n.d.).

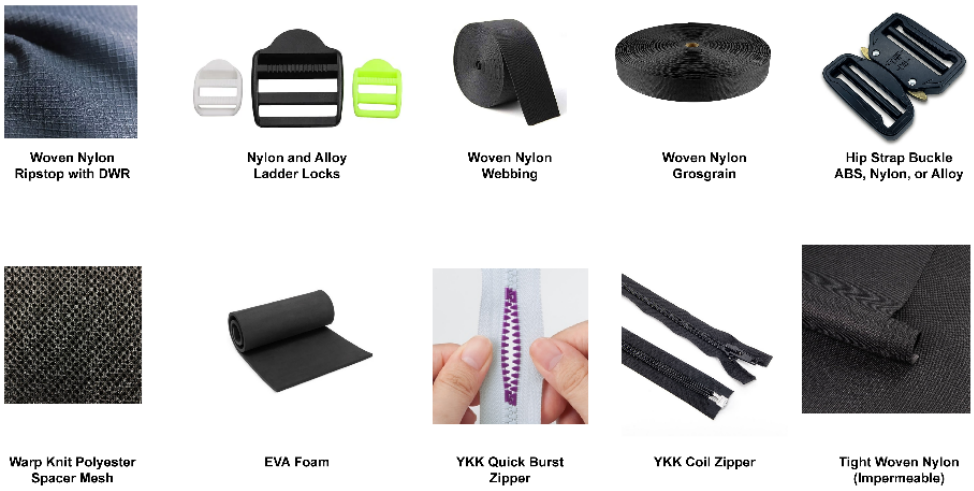


Figure 13: Materials Palette

Airbag Integration

The Black Diamond JetForce airbag system relies on a securing mechanism, pull trigger, venting, and ballast storage to integrate successfully in a pack or airbag. To fully integrate the JetForce system, a securing mechanism must be designed to hold the airbag onto the pack and vest. A pocket with a Quick Burst YKK zipper is traditionally used to hold these products in place. The Quick Burst YKK zipper is a partially closed zipper that under pressure will open allowing the airbag to expand out of the pack (N. Alicia, personal communication, November 2, 2023). Given the low-pressure deployment, 1.5psi, the JetForce system cannot use a Quick Burst zipper. A new retention pocket must be designed to allow the airbag to release but also prevent uncontrolled pre-release of the airbag ballast.

This low-pressure criterion along with the need to prevent airbag pre-release is what sparked the creation of the Retaining Airbag Pocket, also known as the R.A.P. System.

The airbag system is held in place via 12kN rated Nylon webbing and a 14kN rated UHMWPE 5mm cord. The webbing from the shoulder straps and hip straps of the pack and vest extend inside the back panel allowing for the 5mm cord to create a closed loop system. This closed loop also features webbing loops from the Deploy 1.0 Airbag that allows the 5mm cord to

slot in between thus securing the shoulder straps, airbag, and hip straps to the user. The diagram below shows a ghosted view of the airbag threading method along with views showing the threading process for the Deploy 1.0 Airbag System.

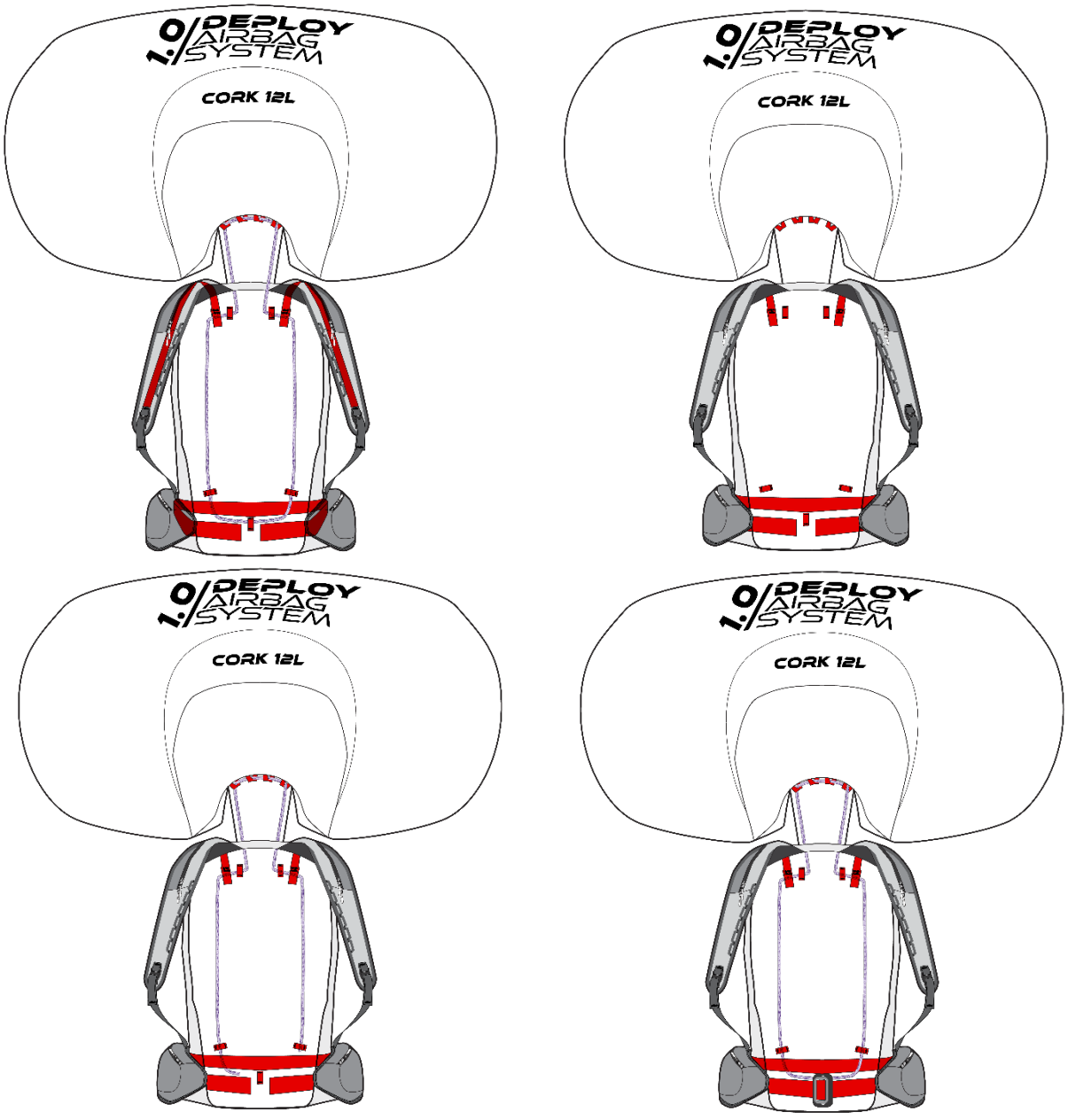


Figure 14: Deploy 1.0 Airbag System Threading Process (Top Left: Ghosted View, Top Right No Rope View, Bottom Left Partially Threaded View, Bottom Right Fully Threaded View)

Pack and Vest Manufacturing

Packs and vests are both cut and sew constructions with the primary focus on trim, hardware, and notion placement. The biggest exception comes with the back panel which is usually a woven nylon fabric with a foam backing, traditionally Ethylene-vinyl acetate copolymer foam (EVA) and thermoformed or vacuum formed. The packs are first cut from fabric sheets then trim, hardware, logos, tags, airbag parts and other printed items are added. The final product then gets all raw edges binded and tested for quality control (Dipanwita, 2022). Most airbag packs and vests are made from nylon, aramid, or other synthetic blends typically treated with a durable waterproof resistant (DWR) finish. If the fabric isn't treated with a DWR finish, it usually contains a polyurethane backer or in the case of the Dakine "Poacher R.A.S." vest the fabric is woven closely enough that it makes water impermeable (*Poacher R.A.S. Vest*, n.d.).

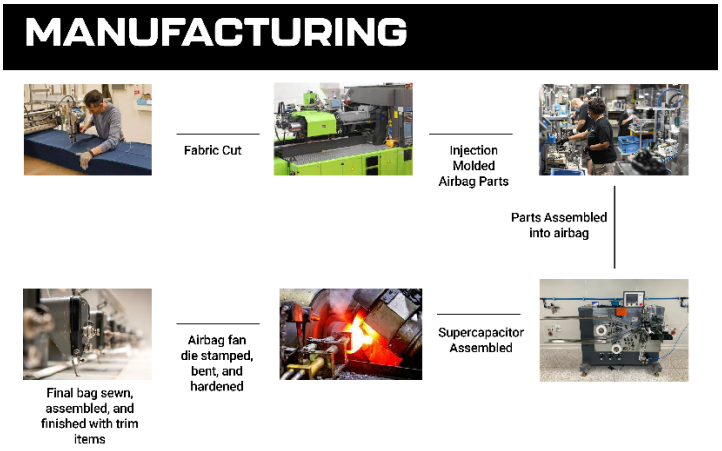


Figure 15: Pack and Vest Manufacturing (Dipanwita, 2022)

Intellectual Property Research

The avalanche airbag pack and vest space are rich with patented technologies with each company slightly differentiating themselves with minute details. Since this airbag vest and pack will be using the Black Diamond JetForce airbag, this "Intellectual Property Research" section will not cover their specific patents over their technology. The intellectual property analysis will

be focusing on airbag system integration, back protection integration, pack construction, and airbag deployment zoning.

Patent number WO2004107888A1 is an airbag vest claim that needs to be avoided for this research project. The patent covers “a vest with airbag, comprising: a shell defining a neck opening, a torso opening, and a pair of opposed arm holes; a chest protector attached to said shell; and an air bag attached to said chest protector, wherein said air bag is configured to expand in front of a torso of a user” (Haddacks, 2004). The most important claim in this patent is over chest protector. The proposed product cannot act as a chest protector with an airbag inflating in front of the bodice. It is worth noting that the proposed solution doesn’t tackle chest protection as is proposed in the patent.

The *Protective clothing for upper half of* body patent number WO2015046205A1 claims “a plurality of protective layers formed between the front surface and the back surface of the protective clothing. It consists of a front side protection plate, an airbag connected to the gas supply means, and a back side protection plate…” (若槻彰浩竹内健詞, n.d.). This patent will be avoidable by implementing the proposed electronic airbag system supplied by Black Diamond. Due to the multitude of claims contingent on gas cylinder airbag systems, the electronic airbag will avoid infringing on this claim.

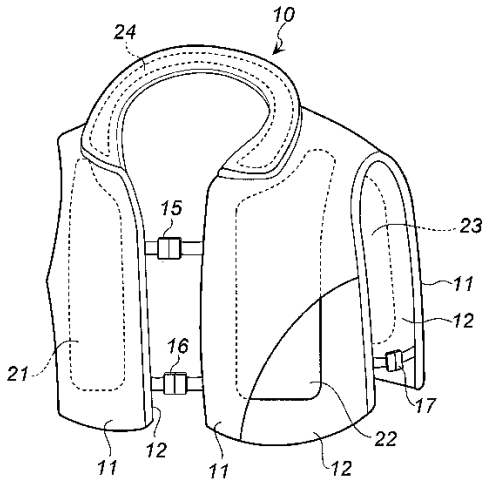


Figure 16: WO2015046205A1 Patent (若槻彰浩竹内健詞, n.d.)

Mammut, a prominent avalanche airbag company, has patented the *Portable airbag for people* patent number US9585425B2. This patent has an important method of fixing the airbag to

a pack or vest which is important to highlight in this research. The patent claims, “The airbag system according to claim 1, wherein the fixing elements are in a T-shape and the fasteners are in the form of slots.” (Berchten & Guernier, n.d.). To avoid infringement on this patent, a new method of fixation must be created to adhere the airbag system to the pack and vest.

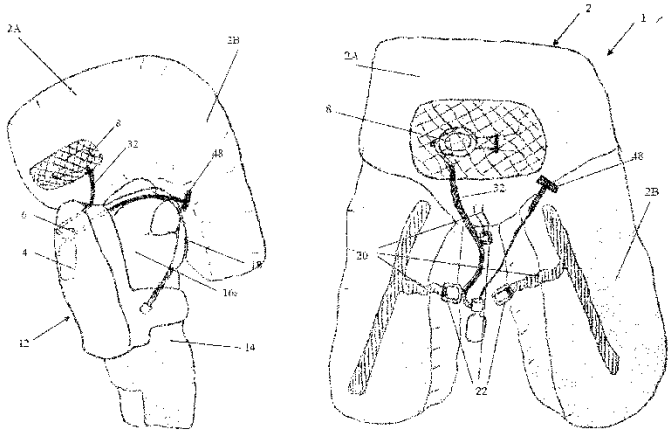


Figure 17: US9585425B2 Patent (Berchten & Guernier, n.d.)

Backcountry Access, another brand highlighted in the Airbag Pack and Vest Competitors section, has a claim regarding the grab handle location on an airbag pack. The claims highlighted in *Airbag system for use in an avalanche* per CA2750288C are over; “… the harness comprises a retainer for the handle that prevents the handle from being moved in a manner that causes an unintended placement of the valve in the open condition.” (Edgerly et al., 2010). This patent must be avoided and will prove difficult to relocate the grab handle of the pack.

Current and Future Color Trends

Airbag vest color trends for state-of-the-art products along with first generation models have not changed at all. Interestingly, all avalanche airbag vests are crafted in black with small trim color in bright contrast, best seen on the industry leading *Dakine Poacher R.A.S.* vest mentioned in the Avalanche Airbag Pack and Vest Competitors section (*Poacher R.A.S. Vest*, n.d.). This vest comes with hints of red for important features and zipper pulls but otherwise remains black for most of the construction. The future color trends in this category showcase similar trends of primarily black construction but the use of more secondary colors and trim piece. World Global Style Network (WGSN) forecasts a trend in “upbeat bright colors with

black and white… cyber lime used with other pastel colors" (Kostiak, 2023). This is completely in line with the *BCA Mtn Pro Vest* featuring more bright colors but with a primarily black construction that released fall 2023 (*BCA FloatE2 MtnPro Vest*, 2023).

Figure 18: Current Airbag Colorways

The airbag pack market surprisingly has consistently experimented with bright highlighter colors compared to the vest or back protection market. The current landscape has packs with one primary highlighter or black main face fabric and usually one secondary color with matching or contrasting trim items. This sector also follows the same trend from WGSN with a continuation of highlighter colors and contrasting blacks and whites. The use of cyber lime has been most prominent with European brands and can best seen in the ISPO S/S 2024 with Dynafit featuring new ski highlighter products.

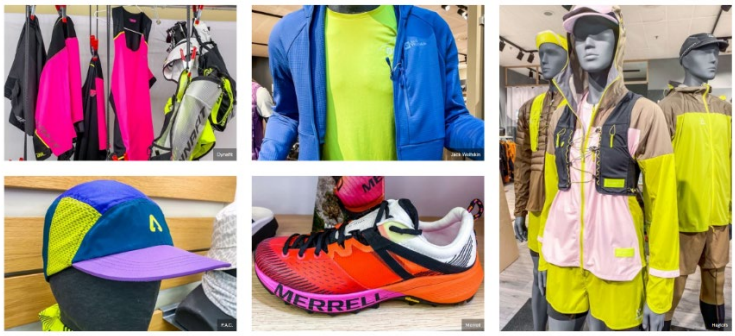


Figure 19: ISPO S/S 2024 Color Trends (Kostiak, 2023)

Current and Future Graphic Trends

Throughout the avalanche airbag pack and vest along with back protection market, most graphics are currently defined by material manufacturers and the end use of the product. For example, most airbags feature ripstop nylon or PU coated nylon with a high denier to last extended periods.

Figure 20: Current Graphic Trends

Looking out at future graphics, WGSN forecasts that “nature and mineral patterns” will start being used in S/S 2024 which is best seen in figure 21 (Kostiak, 2023). These products abstract natural designs such as waves, trees, and bushes into a more muted style that could be seen on future airbag packs and vests. In addition, UHMPWE composites with a plain weave polyester facing are now being used on a substantial number of technical packs and vests. These fabrics reflect performance, lightweight construction, and are being commonly used in other spaces like backcountry skiing packs but not airbags.

Figure 21: ISPO S/S 2024 Graphic Trends (Kostiak, 2023)

Current and Future Logo and Branding Trends

Logo trends for current airbag vests and packs are very similar with all brands featuring their brand logo on the rear panel, a product or technology name on the side, and a name for their airbag ballast. Some brands with longer names like Ortovox feature their brand name vertically on the rear panel, a new trend, compared to conventional horizontal or logo imagery. Almost all packs and vests print the litreage on the center bottom of the rear panel. Airbag retaining pockets normally print the airbag system as a wordmark on the pocket. The airbag ballast is common to show off the company along with the airbag technology name, commonly also on the airbag retaining pocket.

Figure 22: Competitors Branding Trends

BREAKDOWN

AIRBAG WORDMARK

- Purpose: highlight this bag is an airbag
-Reference technology (b or w)
- 40 Ish point font with no logo
- On airbag pocket

BRAND LOGO

- Purpose: highlight brand that built product
- Usually mountain reference
- Varied scale logo and wordmark usually (b or w)
- On front panel and sometimes strap

BALLAST BRANDING

- Purpose: highlight brand and airbag tech
- Always black and huge font with massive brand logo
- Symmetric front & back branding on airbag ballast

Figure 23: Competitors Branding Breakdown

PRODUCT NAME

WORDMARK

- Purpose: tell product name and always be visible from rear view

- Can be seen even if using ski, snowboard, or ice ax carry

- Product name always ties into reference from sport or technology with colors being (b or w) or occasionally in a secondary trim colorway

- 4-6" long usually with no logo

- Located on front panel and side panels traditionally with a reference logo on shoulder straps

Figure 24: Product Naming

Another key component is the product name and associated wordmark or logo. Each product name for airbag vest or packs ties into one of three components; mountain related, airbag related, or brand related. Existing products like the *Ortovox Litric Freeride 18L, BCA Float 32,* and the *Black Diamond JetForce 10L* are all examples following this trend.

Looking at future logos and branding trends for airbag packs and vests, mostly abstract logos in black and white along with vertical lettering will likely be used. In addition, the continuation of pack or vest name and litreage will remain on side panels and the center bottom of the rear panel. A key area is also the airbag technology name being printed on the airbag pocket and airbag ballast.

Figure 25: Future Logo and Branding Trends

Biomechanical Research

The intricate biomechanics of load bearing, especially when it comes to packs and vests, have been the subject of meticulous scrutiny in numerous studies. This section explores the biomechanics of freeride skiing and snowboarding competitions pertaining to airbag packs and vests.

One key issue highlighted in the journal article is shoulder strap design. The authors pointed out how poor shoulder strap design can result in tissue damage beneath the shoulder

straps. In addition, they went into detail about hip straps being an essential piece to prevent movement in the sagittal plane (Ren, L., Jones, R., & Howard, D., 2005). The hip strap plays a pivotal role in preventing movement and is extremely important for packs.

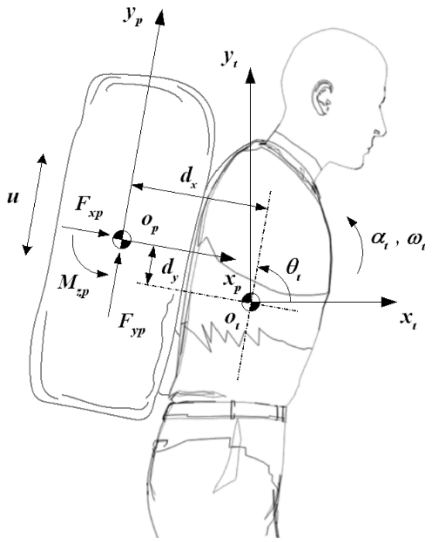


Figure 26: Force Diagram for Packs (Ren, L., Jones, R., & Howard, D., 2005)

In addition, the authors concluded that a soft suspension system can reduce nerve and tissue damage for athletes (Ren, L., Jones, R., & Howard, D., 2005). A soft suspension system can be helpful for FWT athletes by preventing this damage especially since they are constantly doing aerial tricks like flipping and spinning.

Another key factor to consider is spine flexion and extension. During any of these movement, as seen in figure 27 a back panel and overall airbag system must be able to bend to these extreme angles (MD Savlovskis, 2022). If any of these products don't contort to these extreme movements, the athlete could be prevented from moving and result in poor performance. One example of these movements is performing front flips and back flips which involve spinal flexion and extension, essential for starting rotation. If the athlete can't bend their back, they won't be able to flip.

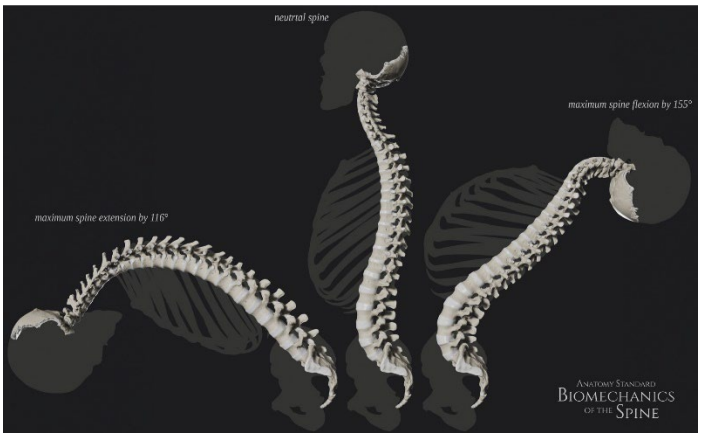


Figure 27: Spine Biomechanics (MD Savlovskis, 2022)

Physiological Research

Each rider is faced with serious physiological challenges they need to overcome to compete on the Freeride World Tour. Riders are tasked with upholding some of the highest anaerobic power and endurance, maintaining incredible levels of stability, being ultra-flexible, and not to mention high muscular strength in order to compete on the Freeride World Tour (Andersen & Montgomery, 1988). In addition, the highest performing athletes have the highest VO2max compared to other skiers. The VO2max or maximal volume of oxygen uptake is a means of measuring anaerobic power and endurance (Winn, 2022a).

As highlighted in the “Environment” section, FWT athletes face temperatures ranging from -20°C and 10°C. These frigid conditions will lower the maximal oxygen uptake max (VO2max) for athletes along with other physiological factors. For context, VO2max is measured via the Fick equation: VO2max= Q_{max}*(a-v)*(O_2 difference max) (Winn, 2022b). The variable, Q_{max}, stands for the cardiac output from the heart. The (a-v) component of the equation is the arterial venous oxygen difference which is strongly affected by cold temperatures. When an athlete gets cold, less oxygen can get pumped by the muscles resulting in a lower over VO2max, impairment of dexterity, and lower maximal capacity (Winn, 2022b). To recap, with lower temperatures, riders will have a lower overall cardiovascular fitness which will result in poor performance.

Sustaining rider stability plays a pivotal role in the Freeride World Tour (FWT). As highlighted in the "Success" section of this study, rider control represents a crucial judging

criterion for the tour. Riders are expected to showcase exceptional stability, both while grounded and airborne. Achieving such a high level of stability can be quite challenging without the aid of appropriate balance training, the confidence acquired through years of dedicated practice, and mastery of aerial control.

Flexibility represents a somewhat overlooked facet of competition. While executing various aerial maneuvers, athletes often grapple with the challenge of potentially over-rotating, under-rotating, or miscalculating a landing, leading to significant flexion and extension of leg muscles. These unforeseen movements can be particularly unwelcome for athletes who have not undergone the necessary training, potentially resulting in severe injuries such as torn ligaments, muscles, and tendons.

Hence, it is of paramount importance for athletes to engage in offseason "dry training" regimens. This preparatory phase is essential for them to attain peak physical condition as they gear up for the winter competitions (Andersen & Montgomery, 1988).

Psychological Research

Freeride World Tour athletes face major psychological challenges when competing. Dropping in at the top of the venue, riders have a ton on their mind. Will I land this run? Will I have sponsors for next season? Is my career over if I crash? Is my run good enough? Will the snow hold from avalanching?

Fear and anxiety are two of the biggest psychological challenges to overcome. Athletes fear falling, potentially lifelong injury, losing sponsors, not performing to their highest potential. These fears lead to longer lasting stress and anxiety all season (Brymer et al., 2020). Additionally, they are compelled to perpetually assess risks and make rapid decisions in high-speed, unpredictable environments. Often, as they descend a line, they encounter unforeseen and treacherous terrain, and it is in these moments that only the mentally strongest athletes prevail.

The incessant pressure to deliver exceptional performances and the inevitable pre-competition nerves further compound the challenges faced by these remarkable athletes. Moreover, the extended periods of travel, rigorous training, and relentless competition can foster feelings of isolation, making this pursuit a solitary journey at times. In sum, these athletes

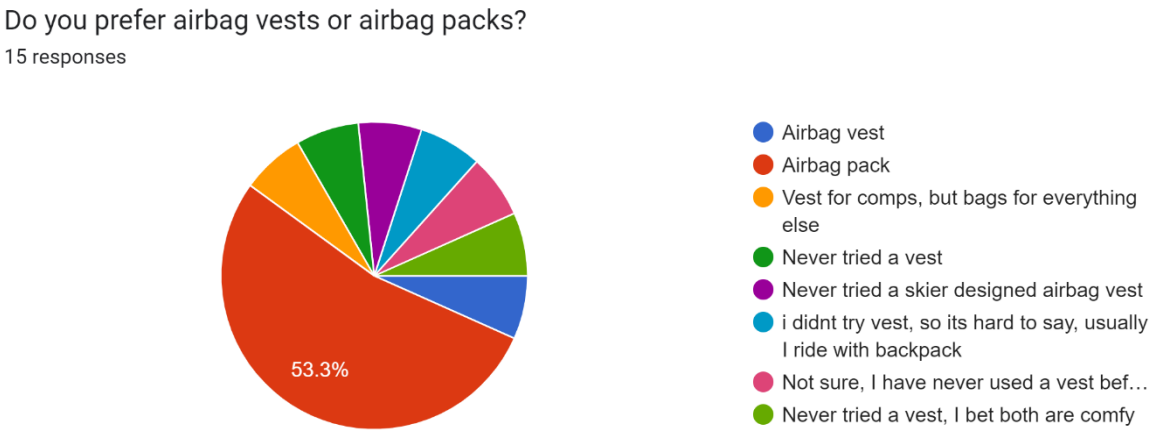
navigate a formidable mental obstacle course, one that demands resilience and unwavering determination to achieve success on the demanding Freeride World Tour.

Consumer Information

This research project employs preliminary athlete feedback, in-field learning with athletes, rigorous testing, and comprehensive validation procedures to substantiate the project's findings and conclusions.

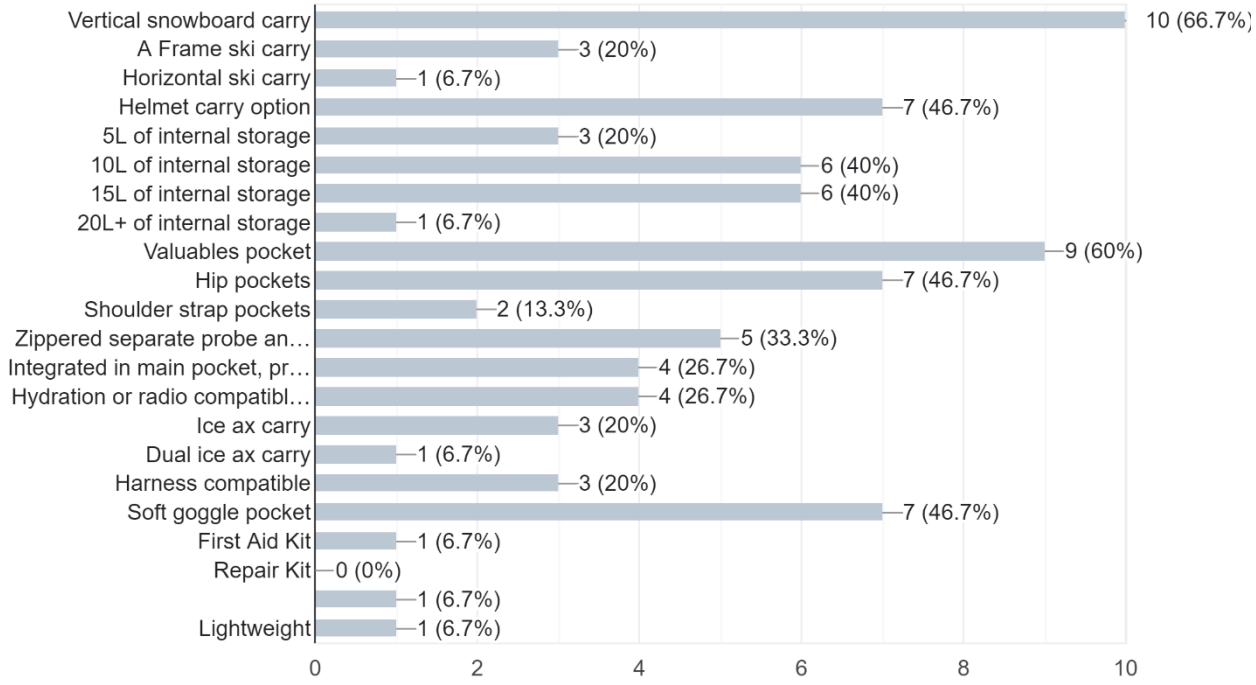
Initial insights involved a survey and interviews of various Freeride World Tour and IFSA athletes in early fall of 2023 to January 2024 to learn more about user needs in addition to interviews. The survey was targeted at IFSA and FWT athletes with 13 FWT athletes responding.

This research progressed through in-depth interviews aimed at gaining a comprehensive understanding of the Freeride World Tour competition day and collecting other relevant information. Tailored to current or former athletes who have participated in the tour, these interviews were conducted through social media and email, employing refined questions based on the insights gathered from the initial survey. The insights derived from this process were instrumental in shaping an understanding of essential features, determining optimal product size, identifying user preferences, and more.



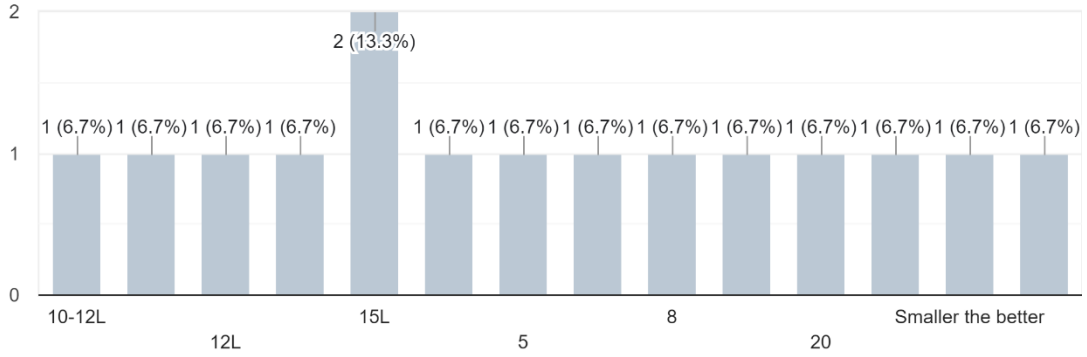
What features for a pack or vest are essential for your competition days? (includes arriving to comp, competing, and after comp) [Select all that apply]

15 responses



How many liters of storage do you need in a airbag pack or vest for competition?

15 responses



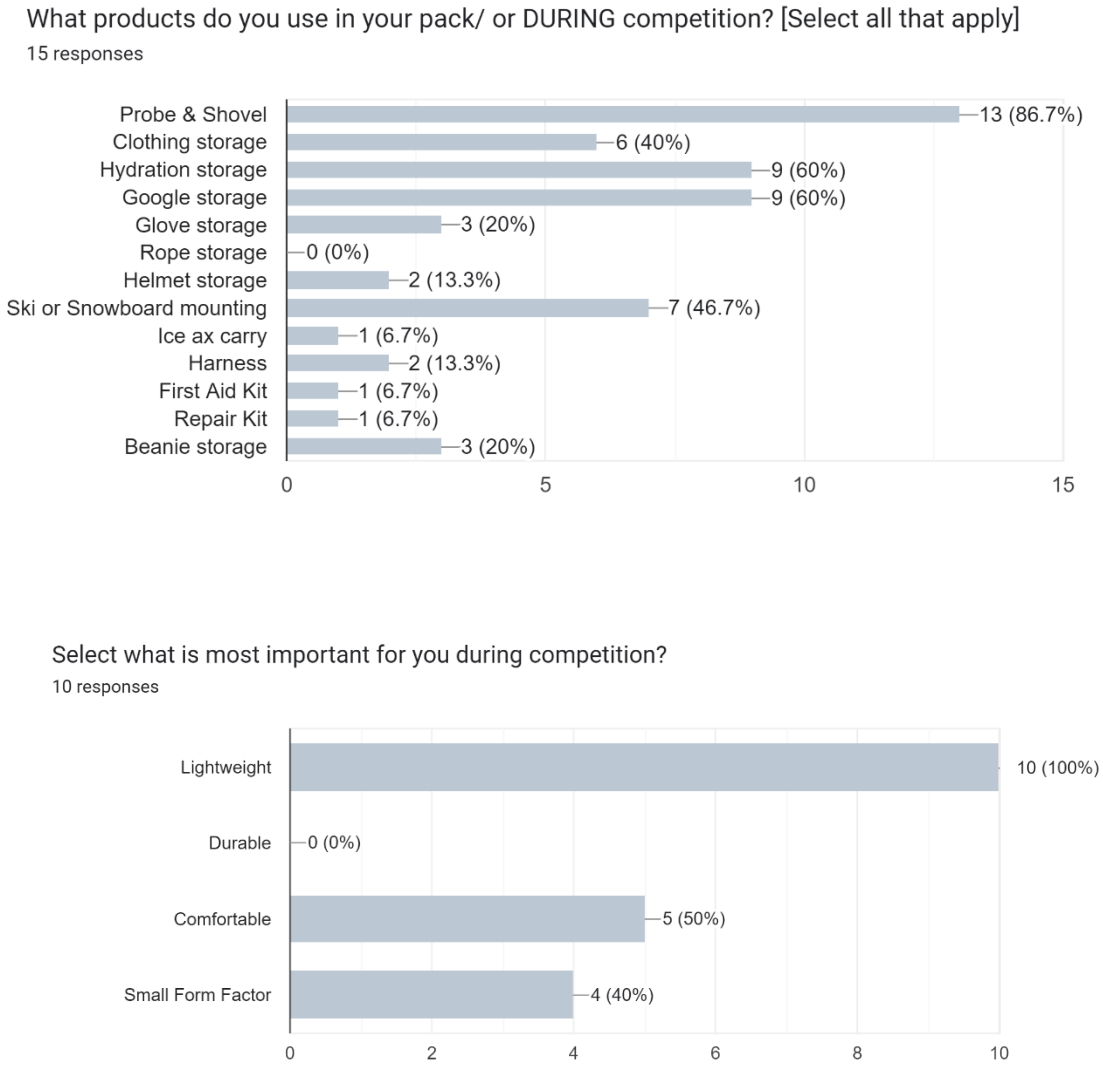


Figure 28: Google Forms Survey from January 2024

Athlete Insights

Athlete insights were meticulously gathered through a combination of expert interviews and surveys involving prominent figures from the IFSA and Freeride World Tour. These interactions unveiled a wealth of information encompassing diverse training methods, athlete preferences, and key features. The initial segment of the analysis delves into airbag packs and vests.

The survey data represents the 13 seasoned athletes from the Freeride World Tour and three IFSA athletes, complemented by in-depth interviews with notable figures such as Holden Samuels, a current Freeride World Tour competitor, and Shepard Delong, a retired athlete from the same tour.

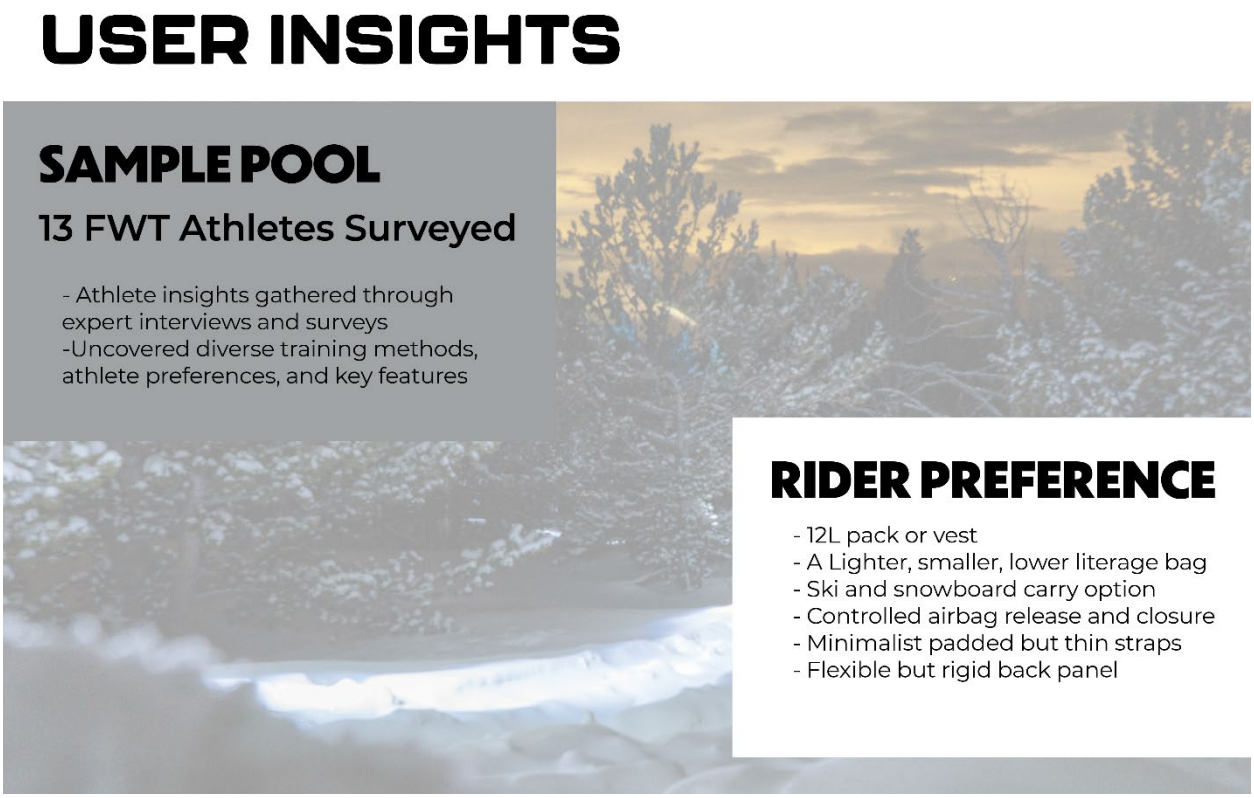


Figure 29: User Insights

This analysis summarizes the results from the survey along with insights from expert interviews. Most athletes currently favor airbag packs, yet there is a notable absence of a specialized product for competition versus training. Intriguingly, just under half of the athletes expressed interest in using an airbag vest for competitions and a dedicated airbag pack for training purposes. The survey and interview outcomes concluded, 12L of storage was the prefect size for a pack or vest.

Regarding features needed for competition days, most athletes prefer a small valuables pocket, a space for their probe and shovel, vertical snowboard carry, a flexible but rigid back panel, helmet carry, horizontal ski carry, and hip pockets. During the expert interviews, athlete

Holden Samuels pointed out the need to have a “flexible yet stiff back panel that limits movement to prevent scorpions but allows backflips. I’d prefer something that is most protective of the mid spine. Tapering laterally and vertically as you get closer to the tailbone and neck”. These preferences in the back panel stiffness and zoning were essential considerations that were explored during the prototyping stage. In addition, athletes noted the deficiencies in airbag closures and recalled numerous times the airbag pocket had accidentally opened. Given this criterion, this was another key point the Cork 12L addresses.

One of the final areas to address in moving forward is pack and vest location on the back. One athlete concluded that: “The straps of my current pack are too stiff and get in my way when I try to turn my head. I would like a pack that fits high on my back without being so high that my head hits it if I tilt my head all the way back. So middle of the back and be able to tighten the straps so that it stays there”. This insight led to the development of Facet Fit Technology, to maintain an overall low-profile solution for riders.

SWOT

For this comprehensive analysis, I opted to categorize distinct products sharing common features and advantages into SWOT analyses. Airbag packs were collectively assessed due to their shared characteristics, such as entry methods, hip and shoulder straps, back panels, and strap configurations. Similarly, Airbag Vests were grouped together, focusing on their zippered entry and analogous features like pockets and strap configurations.

Another key area this SWOT analysis focuses on is the airbag ballast closure system, commonly referred to as the airbag retention pocket throughout this paper. It is worth noting that the Ortovox Litric Freeride 18L airbag pack is the only product in the competitor analysis that effectively holds the airbag as described in the *Performance Jobs To Be Done* segment of this research paper. This section addresses the extremely innovative but heavy solution designed by Ortovox and Arc’teryx team apart of the Litric airbag project.

AIRBAG PACK SWOT

Item	Strength	Weakness	Opportunity	Threat
Shoulder Straps	- Soft Padding	- Stiff material	- Storage pocket - Suspension system for comfort	- Increases vibration with suspension system
Hip Straps	- Pockets	- Pockets are small and don't fit a harness	- Better closure system - Spacer mesh for breathability	- Closure must withstand 3kN and could fail
Airbag Ballast Closure System	- Ortovox mechanical closure never opens unintentionally	- Cumbersome to re-zip up	- Better mechanical closure system with single zipper closure and re-zip	- Could weigh more
Probe and Shovel Pocket	- Large main zipper for easy top access	- Doesn't fit all probe and shovel sizes	- Waterproof zippers	- Weight
Ski Carry	- Cam buckles that prevent skis from loosing tension in system	- Bounces around while descending	- Store-able carry	- Could weigh more than other options - Might dangle more than others

Ortovox Litric Freeride 18L

- $1,250
- 2,400g

Black Diamond JetForce 10L

- $1,499.95
- 2,860g

BCA Float E2-25L

- $1,249.99
- 2,662g

AIRBAG VEST SWOT

Dakine Poacher R.A.S. Vest

- $1,074.90
- 3,000g

BCA Float MtnPro

- $1,499.95
- 3,674g

Mammut Free 15 Vest

- $1,009.99
- 2,265g

Item	Strength	Weakness	Opportunity	Threat
Shoulder Straps	- Soft Padding	- Stiff material	- Suspension system for comfort	- Increases vibration with suspension system
Vest System	- Easy zippered entry	- Too heavy	- Better closure system	- Quick release could be faulty
Airbag Ballast Closure System	- YKK QuickBurst is easy to use	- Constantly opens if Vest is filled	- Mechanical closure system to prevent unintentional opening	- Could be a failure point if doesn't open
Probe and Shovel Pockets	- Separate Probe and Shovel pocket	- Doesn't fit all probe and shovel sizes	- Pleated pocket for added space	- Weight and ease of opening with different closure options
Ski & Board Carry	- Store-able diagonal carry	- Bounces around while skiing down	- Permanent ski storage system without removing vest from back	- Could weigh more than other options

Figure 30: SWOT Analysis

Research Goals

The research goals encompass the creation of more comfortable, confidence-inspiring, low-profile, and weight-optimized snow safety equipment tailored specifically for riders in the Freeride World Tour. The objectives for pack research involve understanding athlete preferences in features, determining optimal size, assessing comfort, and validating product performance through extensive on-snow and environmental chamber testing. The vest research focuses on analyzing athlete-preferred features, determining the ideal size, assessing comfort, and validating performance.

The testing and validation phase involves confirming product performance, assessing on-snow features, measuring airbag releasability, measuring improvements in peripheral view, and evaluating weight. Together, these efforts aim to contribute innovative and high-performance snow safety equipment to the Freeride World Tour.

Cork 12L Product Creation

Working Prototype (Cork 12L)

During a nine-week period, 67 versions of the Cork 12L were iterated through to test features, fit, reduce weight, increase peripheral vision, and prevent airbag pre-releases. These prototypes were an essential part of the project that employed Facet Fit, the Retaining Airbag Pocket (R.A.P.) system, and the Deploy 1.0 Airbag System technology to create a seamless product. The culmination of this round of iterations was the Cork 12L avalanche airbag vest coming in at 2465g. This bag successfully inflates the Deploy 1.0 Airbag with the aid of the R.A.P. system to always have controlled airbag release.

The Cork 12L initial prototyping focused mostly on user fit, back panel shape, and strap configurations. The early prototyping also focused on refining the airbag shape, size, and method of deployment. The airbag shape works around existing patents to create a shape that provides athletes with superior trauma protection in the event they are in an avalanche. The extra 'pillow' that sits behind their head is meant to reduce the risk of neck hyperextension also known as whiplash in the neck.

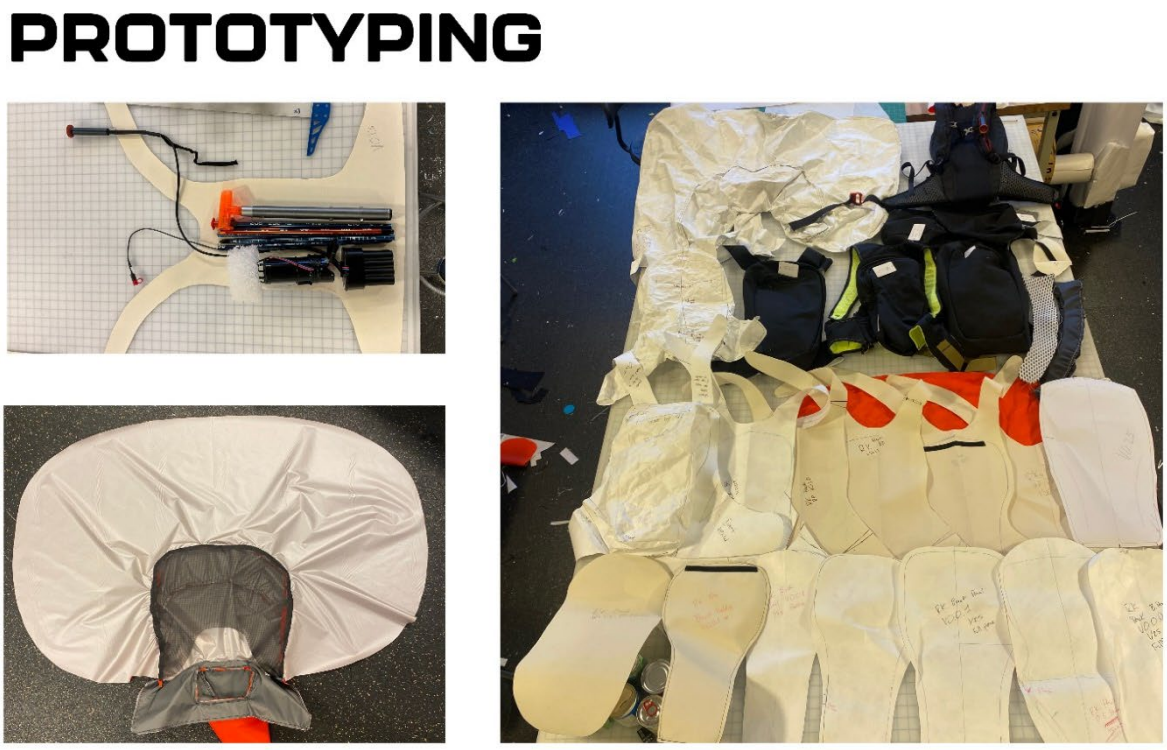


Figure 31: Prototyping Cork 12L

Work on the prototypes steadily increased till version 27 which was brought to Kicking Horse, BC for the second stop on the Freeride World Tour. While there, athletes provided in-depth feedback about the product, features, size, and more.

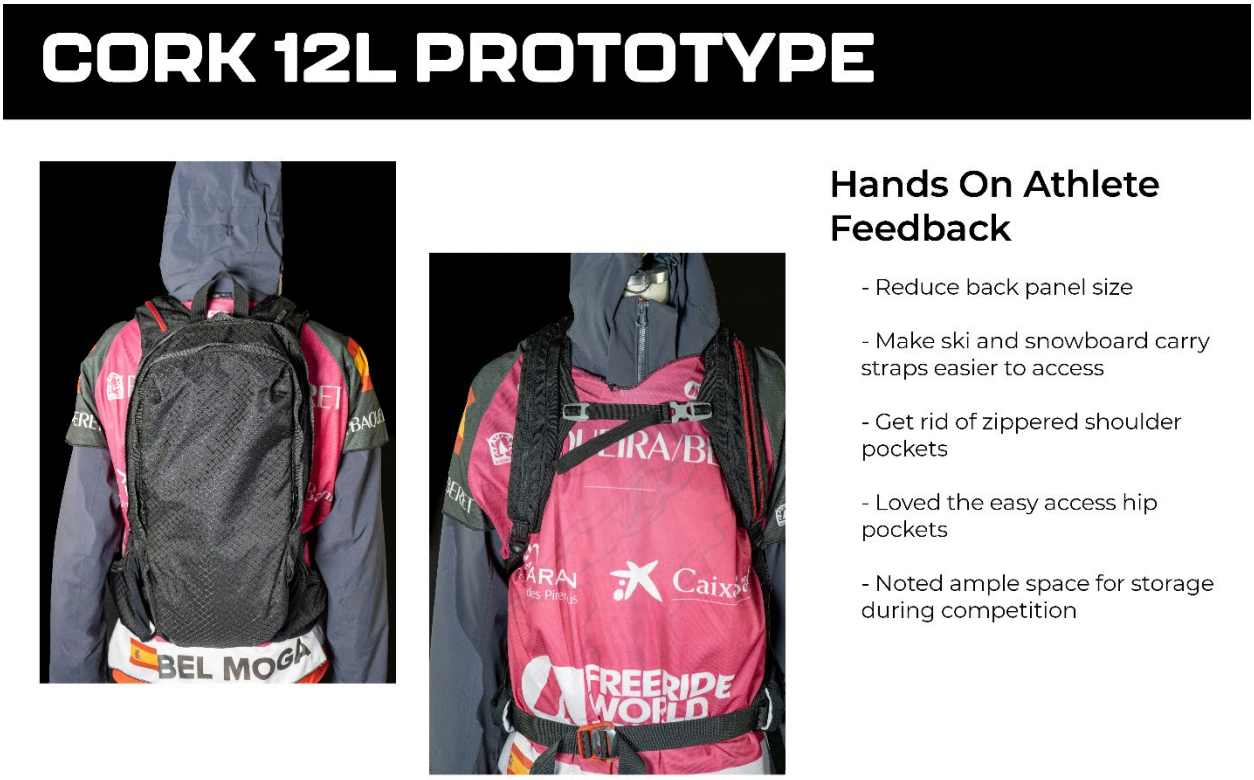


Figure 32: Cork V27 + Feedback

The culmination of athlete feedback, new refinements, and a clearer working prototype made version 67, the Cork 12L working prototype. This product was tested on snow and all technologies, features, and functions performed operational. The next steps were refining the R.A.P. system and creating an even lighter weight version. The new construction primarily focused on utilizing cutting edge composite UHMWPE with a Polyester face fabric to save weight.

Figure 33: Cork 12L Vest Prototype

Cork 12L Final Prototype

The final iteration of the Cork 12L vest and pack takes into consideration all feedback from FWT athletes, lightweight construction, enhanced peripheral view, and controlled airbag deployment.

This iteration employs advanced composite materials from Dyneema, a custom airbag ballast fabric from NUWA Textiles, Derwei Textiles innovative back panel material, along with trim items supplied from DuraFlex. These brands were sponsors of this project and played a pivotal role in the success of the Cork 12L airbag product line. Below are finally photographs taken in East Portal, Colorado Front Range. Photographer: Jacob Houser. Models: Henry Cutting, Tadija Ilic, Drew Frank, and Sami Bud.

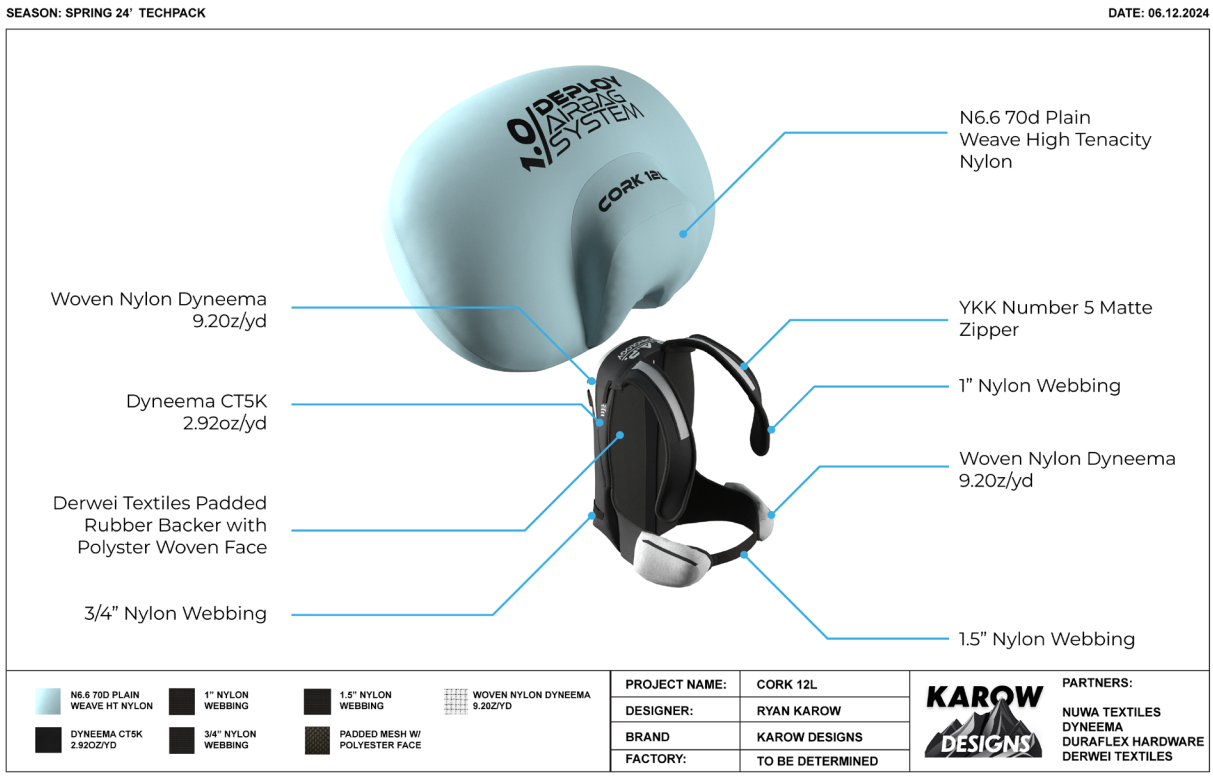


Figure 34: Cork 12L Final Product Photography + Materials

Technologies

Facet Fit

Facet Fit is a technology employed to provide users with a low-profile strap system, a flexible back panel, and low literage bag for maximum visibility when checking shoulders. Facet Fit focuses on reducing weight as the true cornerstone of technology. The minimalist design gives riders the best mobility and plays perfectly into their rider preferences as learned from the survey.

The custom back panel, constructed from 1/8” ABS with strategically placed holes, facilitates flexibility. Red areas in Figure 33 indicate zones optimized for spinal flexion during front and back flips, targeting the lower back. Blue areas, conversely, target rotational spins, accounting for the upper body initiation of these maneuvers.

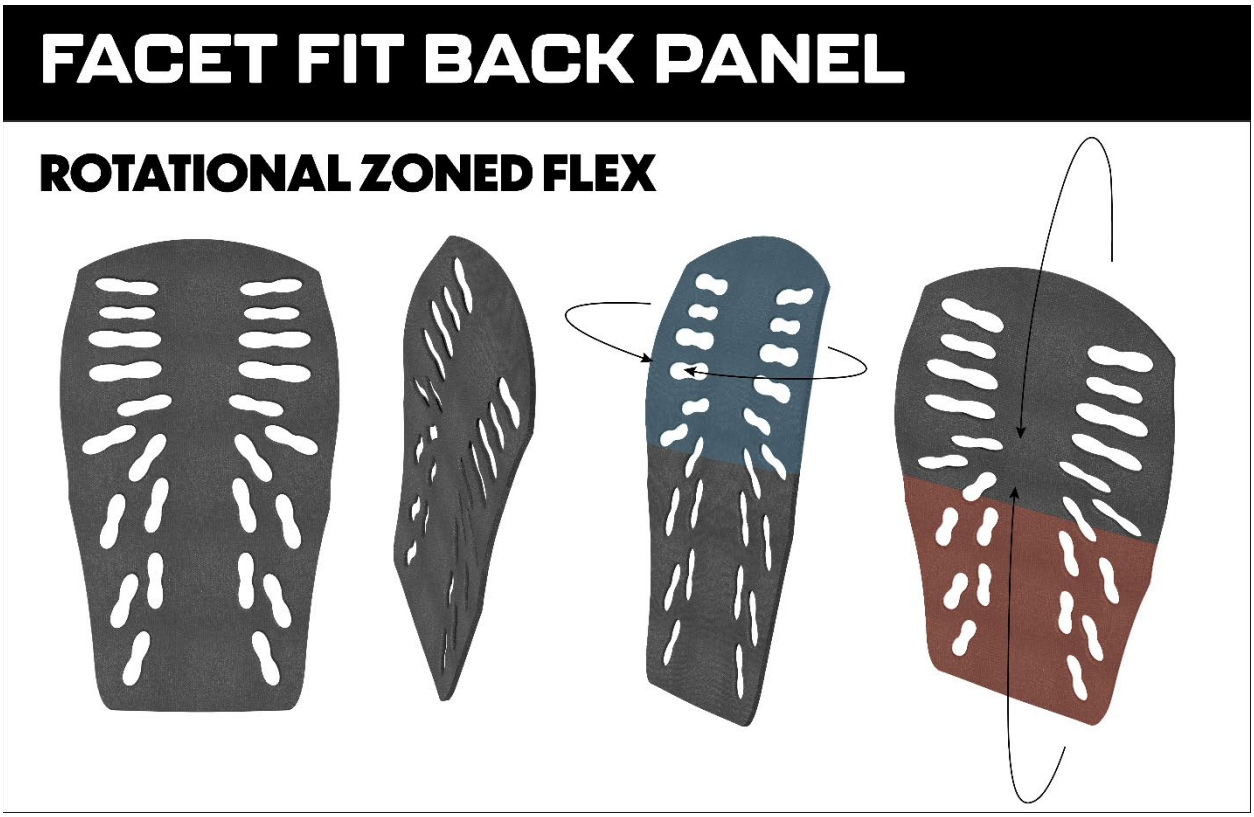


Figure 35: Back Panel

R.A.P. System

The Retaining Airbag Pocket (R.A.P.) system offers a secure, zipper-less solution for avalanche airbag deployment, ensuring consistent 5-second activation under all conditions. The R.A.P. system employs a dual-flap design, utilizing two elastic webbing straps with G-hooks to maintain a secure closure. The primary flap protects the airbag from external elements and acts as a "lid" for the pocket. The secondary flap, sewn to the back panel side of the bag, ensures the primary flap remains closed unless the airbag deploys. This secondary flap is held in place by two G-hooks attached to tensioned elastic webbing, creating a constant force that keeps the pocket closed. During deployment, the airbag pushes against both flaps, utilizing the elasticity of the webbing to escape the pocket.

Figure 36: R.A.P. System

The R.A.P. system's active closure mechanism distinguishes it from competitor systems that rely on breakaway hook-and-loop or friction fittings. These breakaway mechanisms are prone to premature release, compromising the airbag even without user intervention. In contrast, the R.A.P. system's constant tension prevents unintended openings, even in situations where the pocket is snagged. The system's design ensures that any snagging only exposes a partial portion

of the primary flap, with the secondary flap immediately retracting the closure upon release. This eliminates the need for user intervention or resetting, simplifying the overall process and enhancing reliability.

Deploy 1.0 System

The Deploy 1.0 Airbag System offers a novel approach to mitigating trauma during avalanches. The system's unique shape, with added volume in the neck area, helps reduce spinal flexion during the "scorpion" tumbling motion common in avalanche events, lessening the impact of whiplash. The airbag is secured to the bag only via front-mounted webbing straps, preventing unwanted forward pressure on the head during deployment.

The Deploy 1.0 utilizes a custom, lightweight Plain weave High Tenacity 6 filament Nylon fabric with a dual-sided Silicone coating and near-zero air permeability, sourced from NUWA fabrics. This innovative fabric significantly reduces the overall weight of the Cork 12L airbag line. The bag is not seam-sealed, as the JetForce Airbag system continuously cycles air into the bag for five minutes, ensuring consistent inflation.

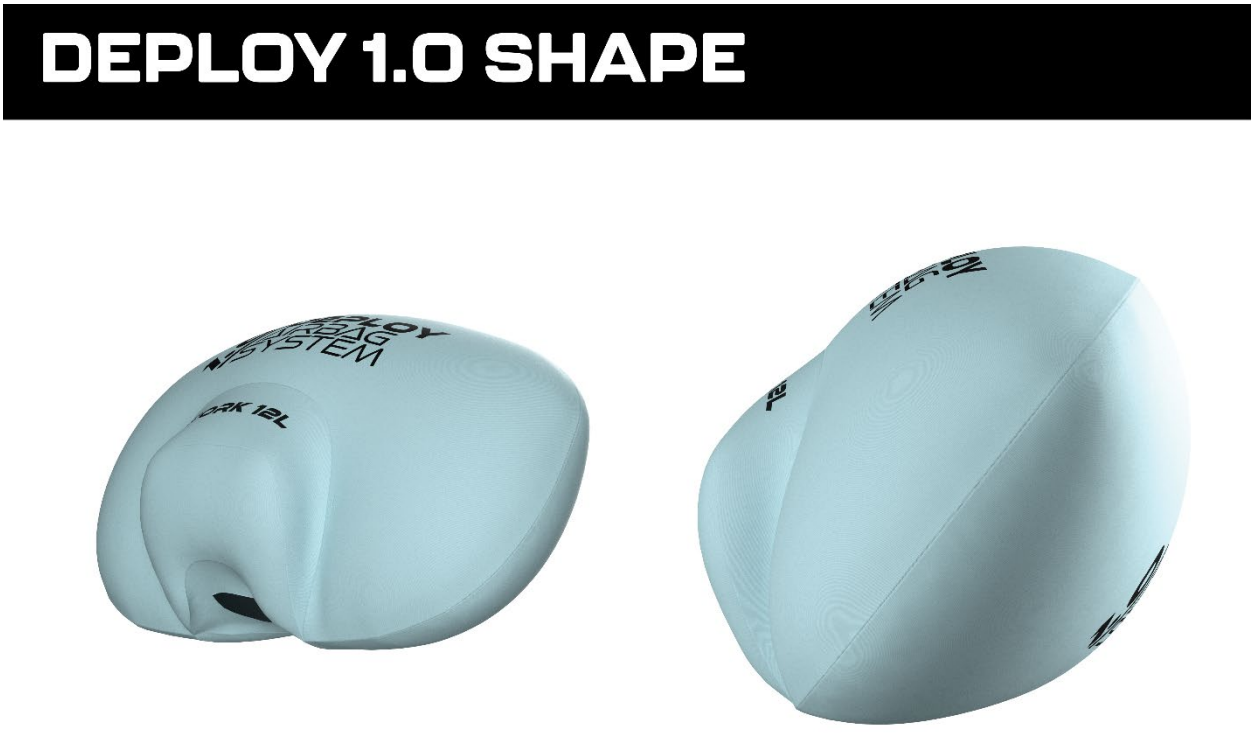


Figure 37: Deploy 1.0 System

Testing Plan

Overview

This project aims to develop innovative avalanche protection gear that prioritizes both safety and performance. To achieve this, a rigorous testing protocol was implemented to thoroughly evaluate each component: the pack and the vest.

Comp Products

In January 2024, multiple tests were conducted on competitor products to gain valuable insight on construction, features, materials, and more. The primary competitors to test are the Mammut Free 15L Vest, BCA Float 32L airbag pack, and BCA Float 22 airbag pack. These products are commonly used on the Freeride World Tour and were accessible for this project given the price of many other competitors.

Metrics For Testing

The research goals encompass the creation of more comfortable, confidence-inspiring, low-profile, weight-optimized, and sustainable snow safety equipment tailored specifically for riders in the Freeride World Tour. The objectives for vest and pack testing involve weighing, establishing peripheral visibility, and airbag tensile testing for the airbag retention pocket. For all athlete feedback and testing, a human subject release form was signed.

One of the tests that was constantly performed per prototype created, is whether the product can inflate in under 5 seconds. This involves the successful integration of the airbag unit along with a method to deploy the airbag. While developing the Retaining Airbag Pocket R.A.P. system, airbag inflation was continuously evaluated to ensure the airbag system was capable of inflation in all conditions. Testing results can be found below for inflation testing. A user pulled the airbag release mechanism and successful deployment was evaluated as a yes or no. Yes, indicates successful inflation of the airbag ballast in under five seconds, an EU standard. No, indicates a longer period or unsuccessful inflation. but product validation will involve successful deployment of the ballast and inflation while meeting the EU standards for airbags (*CSN EN*

16716 Mountaineering Equipment - Avalanche Airbag Systems - Safety Requirements and Test Methods, n.d.). After averaging multiple tests, the average inflation time for the Cork 12L was 4.52 seconds deeming this test successful.

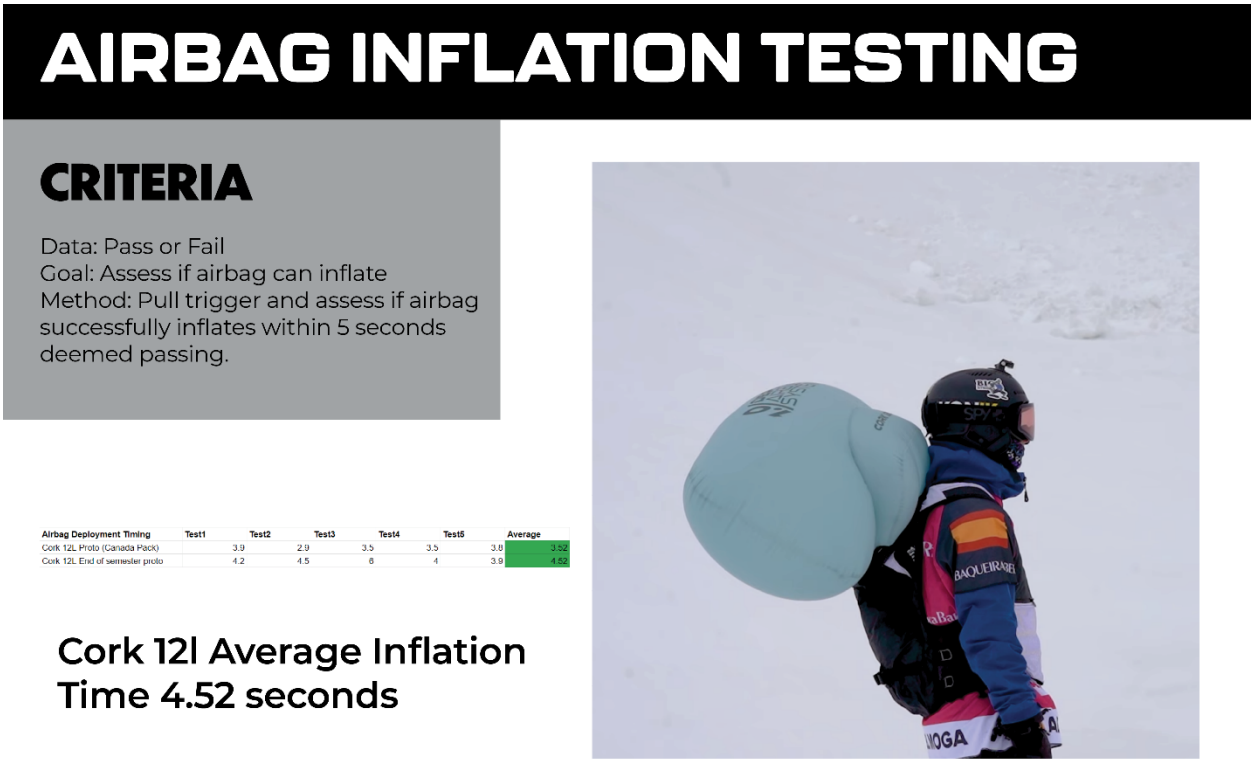


Figure 38: Airbag Inflation Testing

To evaluate the R.A.P. system's secure closure, tensile testing was conducted to determine the peak force required for opening the airbag pocket. This involved identifying the weakest breakaway component of competing airbag systems and subjecting them to a tensile force test using a force gauge. The test involved pulling on the weakest point until the component released or until the force exceeded the tester's single-hand capacity. Competitor systems exhibited an average peak force between 33N and 6N. In contrast, the R.A.P. system consistently required an average of 87.4N to initiate opening. During testing, the R.A.P. pocket never fully opened, and immediately closed upon release of the force. The actual force needed to fully open the R.A.P. system was not fully determined due to the tester's physical limitations,

indicating a significantly higher resistance to accidental deployment compared to competitor systems.

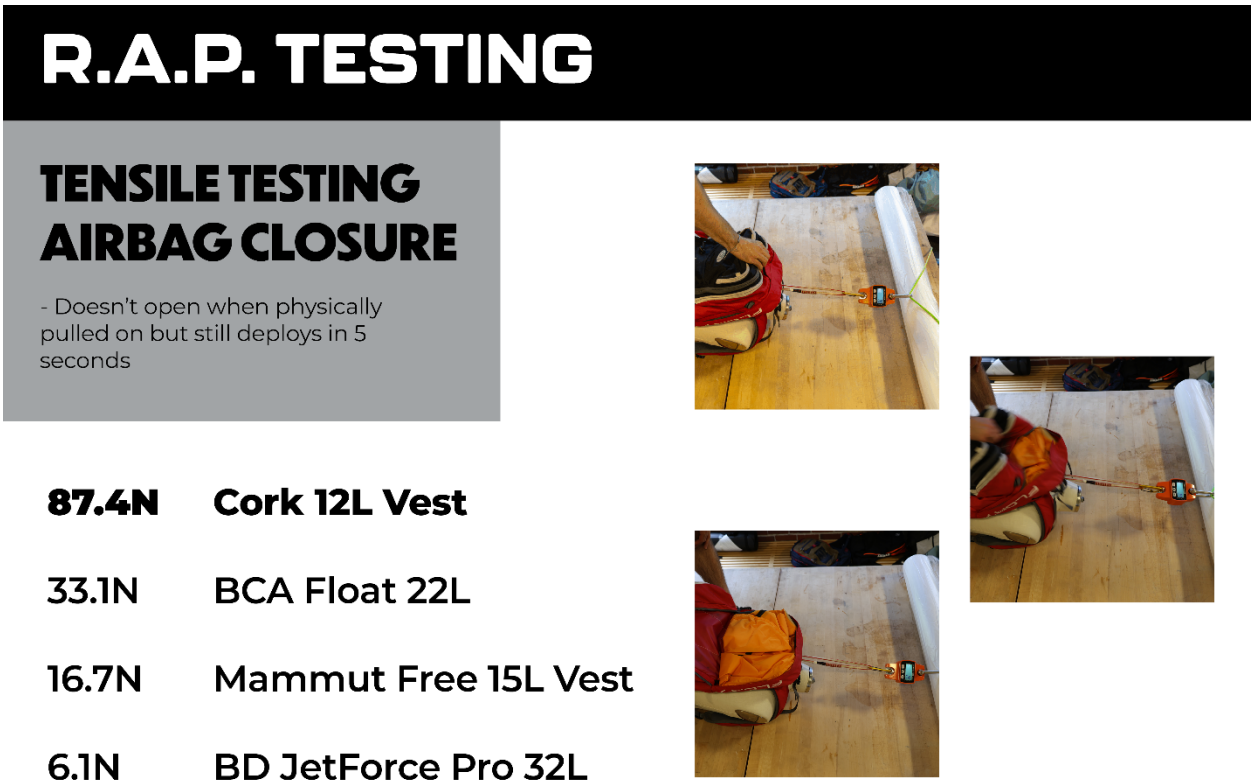


Figure 39: R.A.P. Testing

To assess the efficacy of the Facet Fit technology, a comprehensive evaluation was conducted, focusing on both weight and visual field improvement. This evaluation aimed to determine how the technology's design contributes to a lighter overall weight and enhances an athlete's ability to survey their surroundings. The Cork 12L vest emerged as the lightest vest-style electric driven airbag system on the market, weighing a mere 2133g with the vest itself contributing 880g. The Cork 12L pack, at 2261g, secured the position of third lightest electric-powered avalanche airbag when compared to current market competitors. The table below provides a detailed comparison of the Cork 12L pack and vest against other leading avalanche airbag systems, highlighting the significant weight advantages offered by the Facet Fit technology.

FACET FIT TESTING

PACK **VEST**

2133g **2133g**

- Lightest avalanche airbag vest and third lightest pack

Ortovox Litric Freeride 18L

Total 2400g

Mammut Free 15L Vest

Total 2467g

BD JetForce Pro 10L Pack

Total 2858g

FACET FIT DATA

Rank	Brand & Model	Type	Total Weight	Weight (without airbag)	Airbag Weight	Literage	Inflation Method (Electric or Gas)
1	Arc'Teryx Macron 16L	Pack	1850 g	770 g	1080 g	16	e
2	Ortovox Litric Zero 27l	Pack	1970 g	890 g	1080 g	27	e
3	Black Diamond JetForce UL	Pack	1991 g	N/A	N/A	26	gas
4	**Cork 12L Vest**	Vest	**2133 g**	880 g	1253 g	12	e
5	**Cork 12L Pack**	Pack	**2261 g**	1008 g	1253 g	12	e
6	Ortovox Litric Freeride 18L	Pack	2400 g	N/A	N/A	18	e
7	Ortovox Avabag Litric Tour 30	Pack	2400 g	2400 g	N/A	30	e
8	Cork 12L Old Proto	Pack	2410g	N/A	N/A	12	e
9	Cork 12L Works Like Proto	Vest	2465 g	1100 g	N/A	12	e
10	Mammut Free Vest 15L	Vest	2467 g	2140 g	700 g	15	gas
11	Arva Airbag Tour 28 UL	Pack	2495 g	N/A	N/A	28	gas
12	Ortovox Avabag Mezzo 22	Pack	2495 g	N/A	N/A	22	e
13	Mammut Free 22 Removable Airbag 3.0	Pack	2527 g	2217 g	310 g	22	gas
14	Pieps Pro Light	Pack	2653 g	N/A	N/A		e
15	BCA Float 22 2.0	Pack	2670 g	N/A	N/A	22	gas
16	Dakine RAS Vest	Vest	2806 g	1400 g	1406 g		gas
17	BCA Float E2-35	Pack	2835 g	2835 g	N/A	35	e
18	Black Diamond Jetforce 10L	Pack	2857 g	N/A	N/A	10	e
19	Osprey Soelden Pro E2 Airbag Pack 32	Pack	2948 g	N/A	N/A	32	e
20	Black Diamond Jetforce 32L	Pack	3000 g	N/A	N/A	32	e
21	BCA Float 32	Pack	3014 g	N/A	N/A	32	gas
22	Mammut Pro 35 Removable Airbag 3.0	Pack	3086 g	N/A	700 g	35	gas
23	BCA Float 40	Pack	3260 g	N/A	N/A	40	gas
24	BCA Float 22L	Pack	3360 g	N/A	N/A	22	e
25	Scott Patrol E1 30 Backpack Kit	Pack	3525 g	N/A	N/A	30	e
26	Scott Alpin Airbag Vest	Vest	3540 g	N/A	N/A		e
27	BCA Float MtnPro Vest 2.0 (S)	Vest	3899 g	2018 g	2712 g		e
28	BCA Float MtnPro Vest 2.0 (M/L)	Vest	4173 g	2972 g	3719 g		e
29	BCA Float MtnPro Vest 2.0 (XL/XXL)	Vest	4247 g	3048 g	3855 g		e

Figure 40: Weight Data

Peripheral view testing is another key metric for this product to improve rider line sight. This was conducted with the user standing still with all gear and associated airbag vest or pack being worn. The user will stand in cross section to visually identify if the Cork 12L pack sits lower on the back.

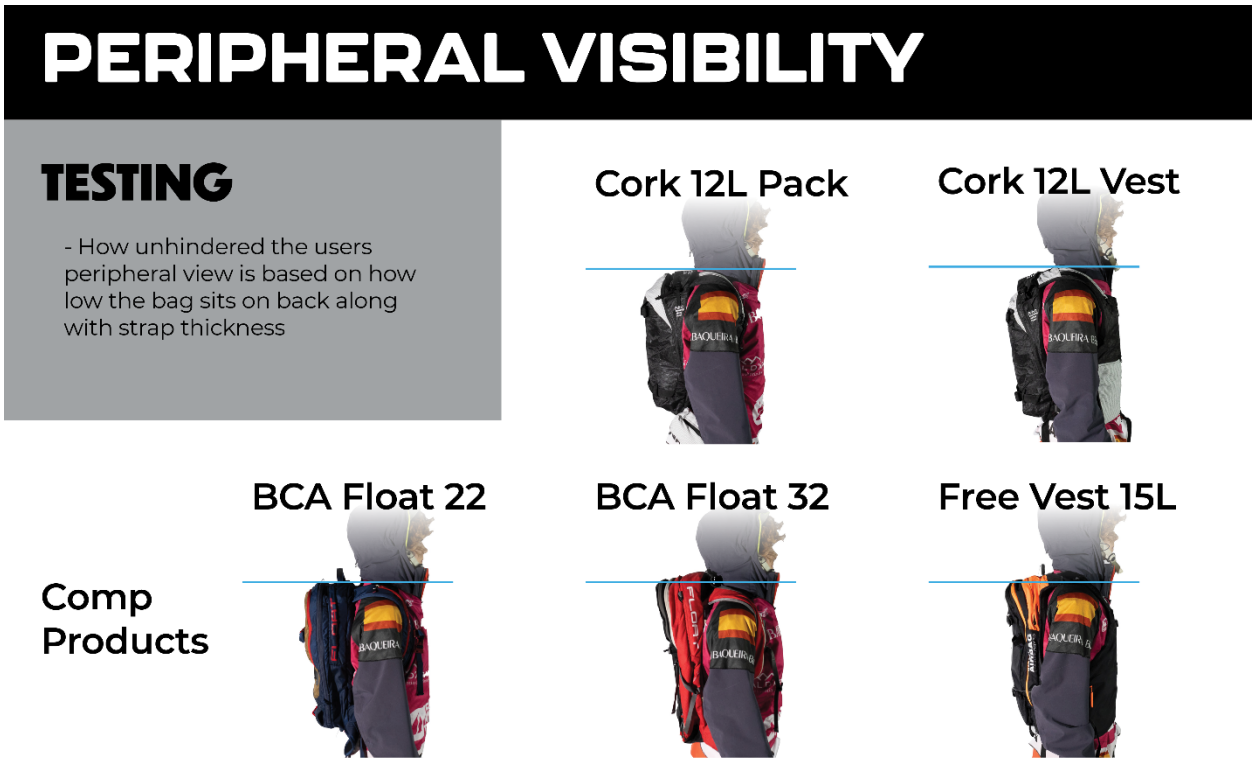


Figure 41: Visibility Testing

Further testing needs to be conducted to validate the 3kN tensile strength for this airbag system. The test will pull an inflated airbag ballast against a wooden mannequin and the test will be deemed successful if the system holds more than 3kN when pulled on. Given the testing equipment needed to conduct this test, the Cork 12L anchoring system was thoroughly overbuilt with materials rated at a minimum of 12kN as outlined in the *Airbag Integration* section.

Analysis

This research project has comprehensively evaluated the design and performance of the Cork 12L avalanche airbag system, revealing a promising solution for freeride athletes seeking the ultimate combination of safety and performance. The Cork 12L has consistently exceeded

expectations in rigorous testing, demonstrating its potential as a market-ready product. While further testing, specifically focusing on EU standards for 3kN tensile strength, is required to finalize validation, the initial results are highly encouraging.

Developed in close collaboration with Freeride World Tour athletes, the Cork 12L emerges as one of the lightest, most comfortable, and performance-oriented avalanche airbags available. This innovative design, built to meet the rigorous demands of professional freeride competition, promises to redefine the landscape of avalanche safety in the upcoming season.

Professional Goals

How This Project Aligns with My Clifton Strengths

The strengths highlighted in my Clifton assessment are particularly well-suited to this project, with focus emerging as a standout quality that ensures meticulous time management and project completion. Leveraging my achiever strength, I set ambitious expectations for the project, aiming for validation and collaboration with top athletes to meet both their standards and industry guidelines. Moreover, my learner strength proves invaluable, driving my deep dive into understanding avalanche airbags. This pursuit not only enriches my knowledge but also fosters professional connections, enhancing my prospects for securing a position in this field post-graduation (*Clifton Strengths*, n.d.).

Thesis Project and Professional Goals

This project explores the equipment space of skiing and snowboarding which perfectly coincide with my professional goals leaving the Sports Product Design masters program. Post graduating, I would love to work in the skiing or snowboarding space. Working in the industry I would love to start in the snow space focusing on technical equipment or technical apparel. The area I'm most interested in is avalanche airbags which is the crux of this thesis project.

By aligning my thesis project with my professional goals of working in the skiing and snowboarding equipment and apparel space, I hope that this project will enable me to learn about the space, make valuable connections, and expand my knowledge in this realm of design.

Special Thank You

This project wouldn't have been possible without brand help from NUWA Fabrics, Derwei Textiles, Dyneema, and Duraflex. I would also like to thank Pete Gompert from Black Diamond, Carly Anderson from Black Diamond, Jacob Houser for photography + videography + editing, Tadija Ilic for modeling, Drew Frank for Modeling, Henry Cutting for modeling, and Sami Bud for modeling.

Bibliography

Alicia, N. (2023, November 2). *YKK Quick Burst* [Personal communication].

Alpride System. (n.d.). https://www.scott-sports.com/us/en/page/avalanche-pack

Andersen, R., & Montgomery, D. (1988). Physiology of Alpine Skiing. *Sports Medicine*. https://doi.org/doi: 10.2165/00007256-198806040-00003

BCA Float 32. (n.d.). https://www.campsaver.com/backcountry-access-float-32-avalanche-airbag-2-0.html

BCA Float E2-25. (n.d.). https://backcountryaccess.com/en-us/p/bca-float-e2-25-avalanche-airbag-2024

BCA FloatE2 MtnPro Vest. (2023). https://backcountryaccess.com/en-us/p/bca-float-e2-mtnpro-vest-2024

Beacon, Shovel, Probe, Airbag. (n.d.). https://silvertonmountain.com/shop/rentals/beacon-shovel-probe-airbag-pack/

Berchten, Y., & Guernier, P.-Y. (n.d.). *Portable airbag for people* (Patent US958542B2). https://patents.google.com/patent/US9585425B2/en?oq=US9585425B2

Brymer, E., Feletti, F., Schweitzer, R., & Monasterio, E. (2020). *Understanding Extreme Sports: A Psychological perspective*. https://doi.org/10.3389/fpsyg.2019.03029

Clifton Strengths. (n.d.). https://www.gallup.com/cliftonstrengths/en/252137/home.aspx

CSN EN 16716 Mountaineering Equipment—Avalanche airbag systems—Safety requirements and test methods. (n.d.). https://www.en-standard.eu/csn-en-16716-mountaineering-equipment-avalanche-airbag-systems-safety-requirements-and-test-methods/

Dipanwita, R. (2022, December 12). *Backpack Manufacturing Process*. https://www.onlineclothingstudy.com/2022/12/backpack-manufacturing-process.html

Edgerly, B. J., Moore, E. S., Cloyd, J. H., & Paynton, D. R. (2010). *Airbag system for use in an avalanche* (Patent CA2750288C). https://patents.google.com/patent/CA2750288C/en?oq=CA2750288C

Freeride World Tour. (2022). *Xtreme Verbier*. https://www.freerideworldtour.com/events/2022-xtreme-verbier/

Freeride World Tour Calendar With Temperatures. (2023). https://www.snow-online.com/skimag/freeride-world-tour-competition-calendar.htm

Gompert, P. (2023, April 24). *Airbag Parts, Construction, and Testing* [Personal communication].

Haddacks, W. (2004). *Vest With Airbag*. https://patents.google.com/patent/WO2004107888A1/en?oq=WO2004107888A1+

History Of Avalanche Airbags. (n.d.). https://www.snowsafe.co.uk/history-of-avalanche-airbags-and-how-they-have-evolved/

JETFORCE PRO 10L AVALANCHE AIRBAG PACK. (n.d.). https://www.blackdiamondequipment.com/en_US/product/jetforce-pro-avalanche-airbag-pack-10l/?colorid=6281

Judging System. (n.d.). https://www.freerideworldtour.com/judging/#Judging-System

Kokelaar, P., Gajjar, P., & John Mark Nicholars Timm, G. (2015). *Particle-size segregation in dense granular avalanches*. https://doi.org/10.1016/j.crhy.2015.01.004

Kostiak, Y. (2023, June 13). *OutDoor by ISPO S/S 24*. https://www.wgsn.com/fashion/article/64806835114d98d868217f7e

Litric Airbag System. (n.d.). https://www.litricavalanchesafety.com/

Mammut Airbag Vest. (n.d.). https://www.evo.com/outlet/airbags/mammut-alyeska-protection-airbag-vest-set-with

MD Savlovskis, J. (2022). *Range of the Motion (ROM) of the Cervical, Thoracic and Lumbar Spine in the Traditional Anatomical Planes*. https://www.anatomystandard.com/biomechanics/spine/rom-of-spine.html

Ortovox Litric Freeride 18. (n.d.). https://www.ortovox.com/us-en/shop/backpacks/p496624-litric-avabag-litric-freeride-18

Poacher R.A.S. Vest. (n.d.). https://www.dakine.com/collections/snow-backpacks/products/poacher-ras-vest?variant=39772855205968

POC Men's VPD Back System. (n.d.). https://na.pocsports.com/products/vpd-system-back?variant=43320194859174

Reiter, A. (n.d.). *Avalanche airbag system* (EP Patent EP3956038B1).

Ren, L., Jones, R., & Howard, D. (2005). *Dynamic analysis of load carriage biomechanics during level walking*. *Journal of biomechanics*.

Safety At The Freeride World Tour. (2022). https://www.freerideworldtour.com/safety/

Samuels, H. (2023, October 12). *FWT Competitor Interview* [Personal communication].

Snowsport Industries America. (2023). 2023 Report on Global Ski & Snowboard Participation. *Snowsports Industries America*. https://www.snowsports.org/report-on-global-ski-snowboard-participation-released/

Sweet Protection Trooper 2 Vi SL Mips Helmet. (n.d.). https://www.sweetprotection.com/se/en/trooper-2vi-sl-mips-helmet-gloss-white/

WE ARE THE HOME OF FREERIDE. (n.d.). https://www.freerideworldtour.com/who-we-are/

Winn, B. (2022a, October 4). *Work and Energy Human Physiology*.

Winn, B. (2022b, November 8). *Cold Stress Human Physiology*.

若槻彰浩竹内健詞. (n.d.). *Protective clothing for upper half of body* (Patent W02015046205A1). https://patents.google.com/patent/WO2015046205A1/en?oq=WO2015046205A1