



# Wānaka Mountain Guides

## Ski Mountaineering Course

*Late winter and spring is the prime time for ski mountaineering in NZs high mountains. Seasonal snow depths are high and crevasses are generally well bridged with supportive snow allowing fast travel and easy access to the classic peaks. Mountaineering on skis or splitboards require a good working knowledge of the full range of mountaineering skills including crevasse rescue, avalanche awareness and ropework.*

### Glacier travel on skis

#### *Navigating glaciers*

Any crevasse fall could potentially result in injury and at the least prove time consuming. Analysing the terrain will provide an idea of where crevasses are most likely to be encountered. Complex crevasse systems are likely to be found in areas of the glaciers that are steeper and the glacier is in tension (over convexities) or where there is more friction (towards the edges). Good route finding on snow covered glaciers will reduce exposure to falling in a crevasse.



Crevasse may be visibly indicated by cracks or slumps of the snow surface and it is possible to extrapolate outwards to give an indication of other areas. can be avoided or managed. Surface clues may however be masked by fresh snow or crust layers on or close to the surface.

The time of year and prevailing snow conditions will influence the supportive strength of any bridge. New snow, or snow that has had its strength weakened by cold temperature<sup>1</sup> commonly encountered mid winter, will be weak, whereas older snow that has consolidated through a number of melt freeze cycles will be stronger, more typical of the warmer spring season.

When travelling near visible crevasses, especially crossing them, it is important to have an idea of the shape of the crevasse. Bell shaped crevasse get wider as they get deeper and should be given a wide berth. Almost parallel or constricting crevasses can often be stepped over, if the edges of the crevasse can be clearly identified.

### ***Roping up for glacier travel***

It is not usual practice for ski tourers to rope up in good conditions. Route finding, visibility of any open crevasses and the increased surface area provided by skis provide some mitigation against the risk of falling in a crevasse. In unfamiliar and/or broken terrain or when visibility is limited by weather, roping up provides further security against unexpected crevasses falls.

It is usually practice for glacier ski tourers to carry 30-60 m of dynamic or light weight hyperstatic rope, primarily to be used in an emergency for crevasse rescue, but also to be used for roping up if required. Ski mountaineering objectives, especially those where some pitching or abseiling will be expected, may necessitate a longer dynamic rope.

There should always be at least two ropes in a party that are sufficiently separated in case one the carrier of one of the ropes, ends up in a crevasse. The leader, heading out in front to find the route, must not be the only one carrying a rope so all group members are susceptible to being surprised by a hidden crevasse hazard.

When roping up, a similar spacing to summer mountaineering on foot can be used of 8 to 12 metres, depending on what is known about the size of the crevasses and the distance between them in the area and number of people on the rope. The aim is to avoid more than one person being exposed to the same crevasse at the same time and maximise the chance of holding a crevasse fall.

### **Teams of more than two**

With more than two people on a rope, the chances of successfully holding a fall of any member of the party is increased. When roping up with three or more people, those not on the ends can

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<sup>1</sup> Snowpack metamorphosis also has implications on avalanche problem formation.



clip their harness belay loop into a bight knot in the middle of the rope. To prevent potential *cross-loading* a secondary gated carabiner (eg Black Diamond Gridlock®) or two opposed carabiners are recommended when clipping into a bight knot. Alternatively they could tie directly in with a rethreaded overhand knot but this is more difficult to escape. The distance between each person should still be between 8 to 12 metres but can be shortened due to the added security of more party members.

### Brake knots

Holding a crevasse fall when there are only two people on a rope is difficult, especially when the person falling into the crevasse is significantly heavier than the person holding the fall.

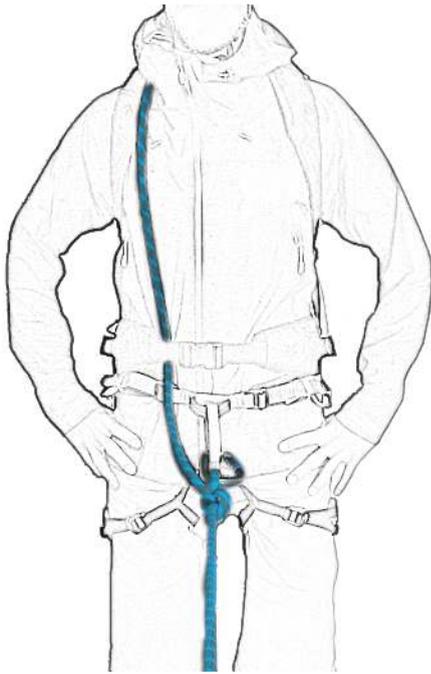
One way to increase the chances of holding such a fall is to tie brake knots (bight knot or an alpine butterfly) in the rope about 2-3 metres from each person. The knot will tend to drag through the snow or catch on the crevasse lip as the person falls into the crevasse and can significantly reduce the amount of effort needed for the person on the surface to hold the fall.

### Shortening the rope

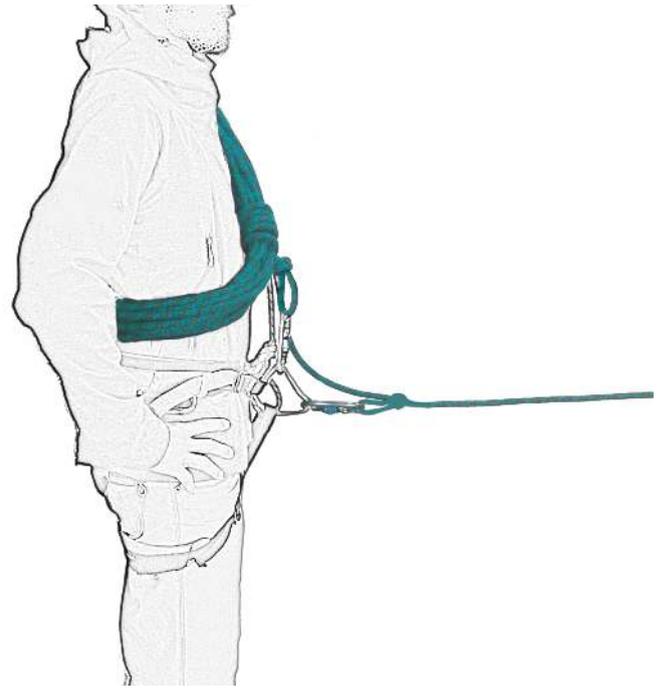
With a spacing of 8-12m between rope team members, the 30+m rope needs to be shortened. There are a number of methods for carrying the excess rope including stuffing it in a stuff sack and putting it in a backpack if it is already not too full or using Kiwi coils. Carrying excess rope in Kiwis coils draped over one shoulder is generally less comfortable but has the advantage of allowing the rope to be immediately accessible without taking off the pack and is a common and quick way for mountaineers to lengthen and shorten the rope between themselves as required.

The bight knots can be clipped directly to the belay loop of the harness. In the event of a glacier fall, a bight knot is easier to escape from than a clove hitch. By measuring out the required rope from the middle, the excess rope is divided and carried by those at the front and back and available for rescue. For larger rope parties, it is acceptable for most of the rope to be live (between team members) as there will still be rope available for companion rescue.





Rope in pack



Blocked Kiwi Coils

### Pre-rigging

Pre-rigging is the method of putting prusiks around the rope between members of a rope team so that they can be quickly and easily used for crevasse rescue if required. This is an added step but means that it is easier and quicker to react to any crevasse emergency.

Using the short prusik loop, tie a Klemheist or Classic prusik knot around the rope between you and your partner just in front of where you are attached to it. Clip the prusik loop into a separate screwgate carabiner attached to the belay loop of your harness. Using a clove hitch to attach the waist prusik to the carabiner prevents potential cross-loading.

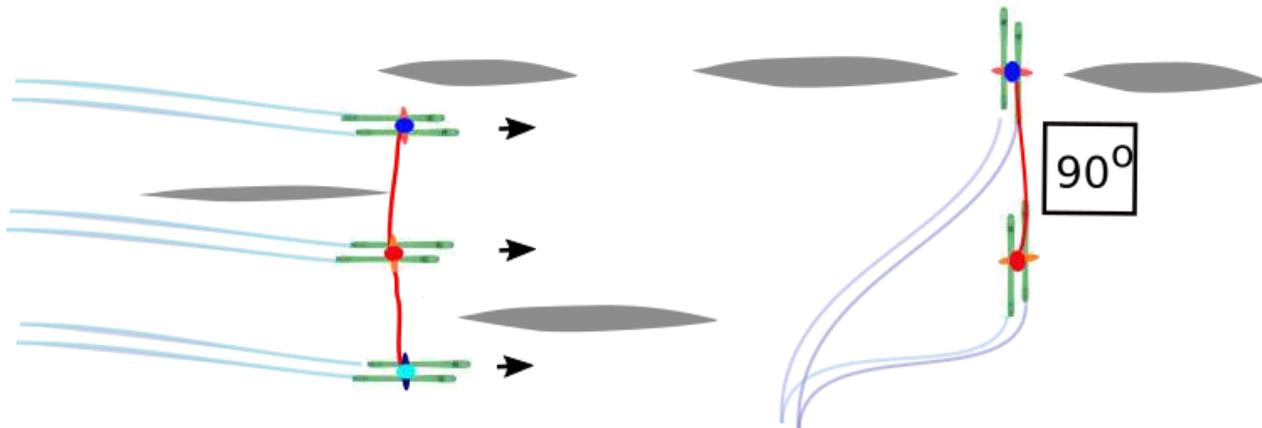
The long prusik loop can be placed similarly around the rope between the short prusik and the harness with the remainder tucked out of the way in your jacket or wrapped around coils.

### ***Roped travel on skis***

Roped glacier travel on skis as the slope angle starts to increase requires careful management. More so than on foot, ski tourers will have to zigzag which introduces issues with slack forming in the rope, and coming out of perpendicular with the fall line and crevassing, which has implications for the ability to hold falls. As with all mountaineering, there are often multiple hazards to be managed and as the slope angle increases, consideration needs to be given to the avalanche and slide hazards relative to any crevasse hazard.



When crossing obvious crevasses it is important to try to keep the rope between members of the team tight and as close to 90° to the crevasses as possible.



*Echelon formation*

*Crossing crevasses at 90 degrees*

If travelling parallel to the crevasses, it can be advantageous to travel in echelon formation with the rope perpendicular to the direction of travel. This is to avoid more than one person standing over the same crevasse at the same time and avoids pendulum falls that can be difficult to arrest. *With skis parallel to crevasses however can increase the risk of punching through hidden snowbridges.*

The rope between team members should not be too slack. A loose rope compromises the safety of the party as it increases the shock loading when a fall occurs and can dramatically reduce the chances of successfully holding a crevasse fall. Excessively loose rope can also pose a trip hazard. Too tight however can make it difficult for all members to maintain an efficient pace. A good tension is achieved when the rope is dancing along the snow surface at the bottom of its arc.

## Snowcraft

### *Walking on snow*

Before resorting to using crampons or for short sections of snow without consequence, it may be quicker to stay in boots. On low angled slopes, stiff boots with a good edge can swipe into the snow to create a secure platform even if it is firm. The most efficient way of ascending moderate slopes is to zig-zig. On steeper slopes, the toe of the boot may be able to be kicked straight in and the slope ascended directly.

When snow becomes softer, crampons do not add more security and it may be better to remove them. Particularly in soft wet snow when it can build up between the points of crampons rendering them useless, known as balling. Plastic anti-balling plates, supplied with all modern



crampons, help to avoid this becoming a problem but it still needs to be monitored and dealt with if need be.

In soft snow conditions, whether in crampons or not, it is most efficient to descend slopes facing out and directly down the fall line. Plunging heels into the snow will provide a positive platform. Alternatively facing in will be slower, less comfortable but feel more secure.

### Crampon techniques

When climbing snow or ice, every step counts. When using crampons, good technique must be well practised and intuitive to avoid dangerous mistakes, especially at the end of a long day in the mountains. Attention must be maintained especially on easier slopes where complacency can lead to catastrophic results.

When using crampons feet should be parallel to each other about shoulder width apart. This will help reduce the likelihood of a crampon catching the other leg and causing a trip. Ensure loose straps are secure and tidy. Having a crampon come off whilst climbing can be disastrous. Crampons must be put on securely at the beginning of the day and checked periodically throughout the day.

When descending firm snow, all the crampon points must be engaged. Leading too much with the heel points (which is the usual technique for soft snow) may cause the heel points to skid.



Flat-foot technique (also known as French technique) maximises the number of crampon spikes that are in contact with a snow slope and can be used on low and moderate angled snow (up to 45°). When flat-footing it is important to roll ankles so that all vertical points are penetrating the snow, which can feel awkward at first.



Mixed technique (also known as American technique) uses one foot flat-footing and the other foot front-pointing (see below). Mixed technique is an efficient way to move directly up moderately steep snow (30° to 45°) that is too steep to comfortably flat-foot with both feet, and for which front pointing would be tiring. It is commonly used in combination with the daggering ice axe technique



(see below). The front-pointing foot can be alternated to minimise strain.



Front pointing is a secure method for ascending or descending steep snow, (steeper than 45°) and ice but requires stiff soled boots otherwise it quickly becomes tiring. The two front points of the crampons are kicked into the snow. Feet should be parallel, shoulder width apart, perpendicular to the snow, and the soles of the boots should be horizontal. On snow, this technique is often used with the daggering ice axe technique.

## ***Ice axe techniques***

### **Walking with the ice axe**



When walking on low angled snow where a slip or stumble could lead to a slide, the axe is held in the uphill hand with the adze facing forwards and the pick backwards. This is the best position from which the self-arrest position can be easily adopted (see below). How much the axe is used for support and balance will depend on the angle of the slope and the hardness of the snow. On moderate slopes a slightly longer axe is useful as it encourages a balanced, upright stance.

Ascending low and moderated angled snow with an ice axe requires a stable rhythm that keeps two points in contact with the snow at all times. This

means the ice axes are placed then both feet are moved up in turn before moving the ice axe again.

When ascending low and moderated angled snow it is most efficient to zig-zig. To change direction, stand in a secure and stable position before swapping the ice axe into the other hand and manoeuvring your feet round to point in the other direction. The leash must be used or stowed around the shaft of the axe to avoid getting it snagged on crampon points.



## Self-arresting

Self-arresting is the process of using an ice axe for stopping an uncontrolled slide on snow. Good movement skills and situational awareness should avoid ever having to do it for real but it is still a fundamental skill for moving safely on snow. There is no substitute for practising a range of scenarios in a safe location until it becomes instinctive.

In the event of a slip:

1. The initial reaction should be to dig everything in to stop the slide accelerating;
2. If this does not arrest the slip and it accelerates into a slide, manoeuvre into the self arrest position with chest facing the snow and head pointing uphill. If you have a tool in each hand or a walking pole, these need to be discarded so that both hands can be used on the axe. Especially on firmer snow, crampons can catch and cause a falling climber to catapult uncontrollably down the slope. It is therefore important, after committing to a self-arrest, to lift your feet and point your toes in;
3. Place the head of the ice tool under your shoulder and hold the shaft near the spike with your other hand;
4. Arch your body with knees apart and use your weight to drive the pick in and slow you down. The spike must be lifted clear of the snow, and to protect your face, look away from the head of the ice axe.

A slide can initiate from a variety of positions, on the back or front, head facing uphill or downhill. It is therefore important to practise getting into the self arrest position from all these variations. A key step is to use a widely placed ice axe to pivot legs around so they are pointing downhill and to roll towards the hand holding the head of the ice axe to get into the front on self arrest position.

## Step cutting

Cutting steps with the adze of the ice axe can also increase security in firm snow with or without crampons. Especially to change direction when zig-zagging up a slope. With each swing, cut the step away so that the ice is free to fall out of the step. The same techniques can also be used to create rest ledges when climbing steep snow or more comfortable stances when doing pitched climbing. If donning crampons is inevitable, it is much easier to stop early to put crampons on rather than persevere without.

## Dagging

Dagging (also known as north wall technique) is commonly used in combination with mixed crampon technique or front-pointing on steep snow (40° to 60°). The ice axe or axes are held near the top of the shaft, just under the pick, and the pick is 'punched' into the snow at waist level,



about shoulder width apart. Once the snow becomes too steep to keep your balance or too hard to push the pick into the snow then it is time to resort to swinging the axe above the head as for ice climbing.

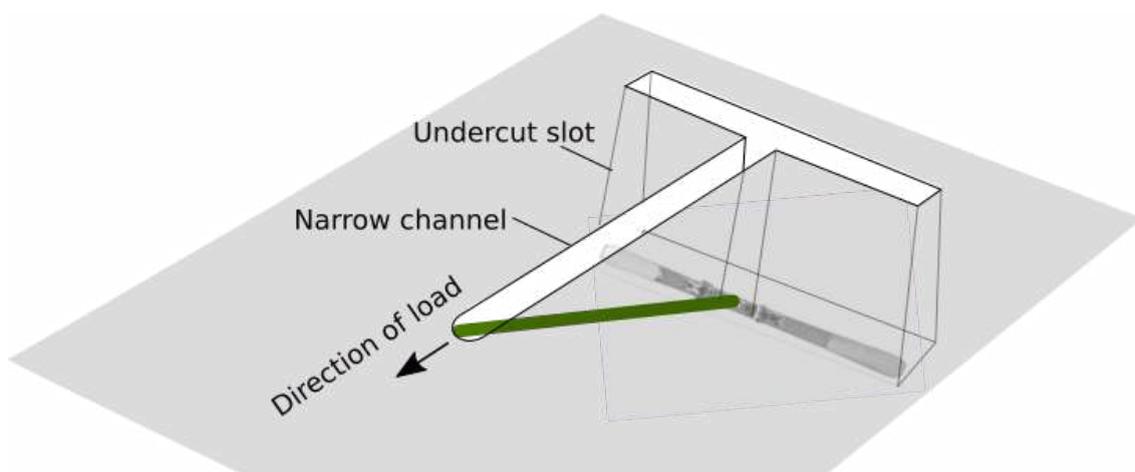
### **Snow protection and anchors**

Snow protection is most commonly used in NZ to abseil or belay over crevasses and bergschrunds and in the event of a crevasse fall, building rescue anchors. They are occasionally used for pitching moderate angled snow slopes but climbers need to be aware of the anchors limitations in this application. In the event of a fall, forces generated could exceed the maximum strength of any snow anchor. It is therefore important to understand likely loads, be able to recognise the factors that affect snow strength and be able to choose the best solution from a variety of snow protection options.

Unlike rock protection, the strength of snow can vary to a large degree and can change on an hourly and daily basis. Snow can be hard and almost ice through soft powder or wet snow. The only way to develop an awareness of snow anchor strength is to practise building and testing them in different snow conditions over and over again. Any snow anchor relies on experience and judgement. As they are often used singularly, when they fail, they do so catastrophically.

#### **Buried object**

In soft snow, the strongest possible anchors are created by placing an object with the **biggest surface area as possible, as deep as possible**. In the ski touring context, skis are the most obvious solution in a T-slot. Two skis should be placed with bases facing each other or using skins or some other padding to protect the sling from getting damaged on the edges if using one ski and with a sling hitched around the midpoint of the ski for an attachment. Other options include burying backpacks, stuff sacks filled with snow.



*Buried object (or ski T-slot)*



Whilst digging the slot, observe the snow hardness and any weak layers that will affect the strength of the placement. The channel for the attachment must be as narrow as possible and the front face of the slot can also be undercut. The channel must be deep enough for the attachment sling to run straight and not inadvertently pull upwards on the skis.

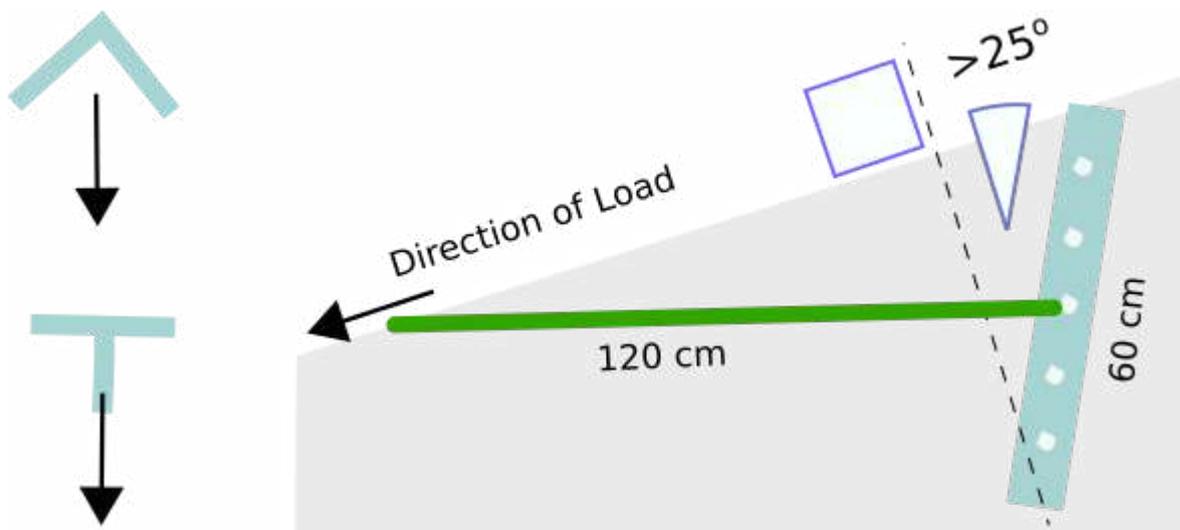
If wet snow can be formed into a snowball, it can be made stronger through compacting with hands. Otherwise, or if the snow is dry, it is best not to disturb the snow in front of the anchor. Unless the snow is compatible, the snow in front of the T-slot should not be disturbed. Backfilling the slot does not increase the strength of the placement. Whilst digging the slot, observe the snow hardness and any weak layers that will affect the strength of the placement.

There are other quicker ways of using skis as snow anchors but require more experience to be confident in their strength.

### Snow stakes

If firm conditions are expected, usually encountered early in the morning during an established spring diurnal or melt-freeze cycle before the snow surface has released, snow stakes may be carried for snow anchors. The strongest possible orientation of snow stake anchors is the vertical mid-clip requiring a sling or cable to attach to the middle of the stake.

The stake should be placed at least  $25^\circ$  back from perpendicular to the surface. For a V shaped snow stake, the open part of the V points in the direction of load. The channel for the attachment should be cut as narrow as possible with an ice axe pick or a snow saw and deep enough so it doesn't inadvertently pull upwards on the stake. Also try not to disrupt the snow in front of the stake unless the snow in front of the stake can be compacted to increase strength.



*Vertical mid-clip*

The wire cables and double length slings are both 120cm long, twice the length of a typical snow stake. This is useful because if the top of the snow stake and the end of the wire/sling is flush with the surface of the snow and the wire/sling is not kinked, the stake will be positioned at the correct angle back from perpendicular.

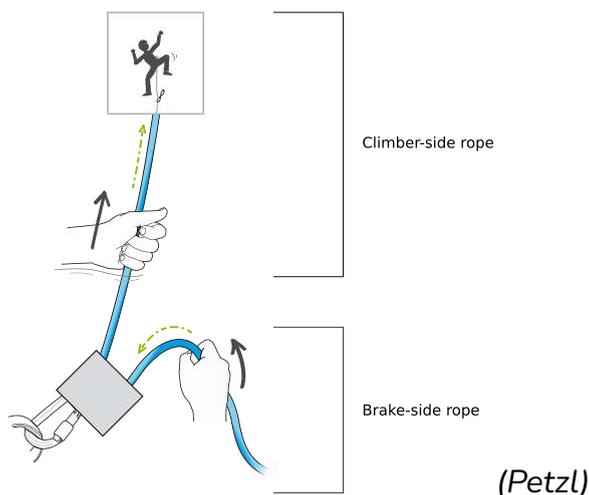
## Bollards

Other snow protection commonly used include snow bollards, body stances such as bucket seats dug in the snow and quickly and efficiently counter balancing terrain features such as bergschrunds, wind scoops and ridge crests.

# Ropework

## Belaying

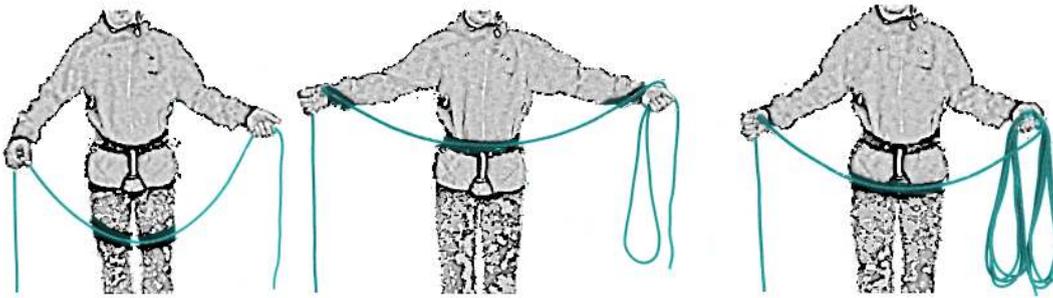
Belaying is the process of controlling the length of rope in a roped climbing system using a belay device.



Top roping is commonly used at crags with fixed anchors at the top of the established climbs. The rope is attached to these fixed anchors either by accessing the top of the crag from above or by the first climber lead climbing upwards from the ground. Subsequent climbers are then belayed from the ground or bottom belayed.

The live or climber-side rope refers to the length of rope between the climber and belay devices and the dead or brake-side rope refers to the rope that is on the other side of the belay device. It is important to have at least one hand on the dead rope at all times regardless of the device being used.

Coiling ropes in loops introduces twists that can make handling difficult. It is preferable to lap coil or flake ropes in a back and forth motion across the hand or shoulders so that there is always a gap in the loops. These coils can then be tied off into a rucksack coil for carrying or a single butterfly coil that is useful for strapping the rope to a pack for carrying.



*Lap coiling rope*

## **Anchors**

### **Anchor systems principles**

Two or more pieces of protection can be combined into an anchor system that can be used for pitching or abseiling. In these situations reliability is paramount as climbers will often have their entire weight on an anchor and its failure can be catastrophic.

When creating an anchor system the following 5 principles apply:

**Secure** - Each piece of protection used within an anchor system must be secure. This means that there is good confidence in its strength and reliability.

**Independent** - Each piece of protection must be independent.

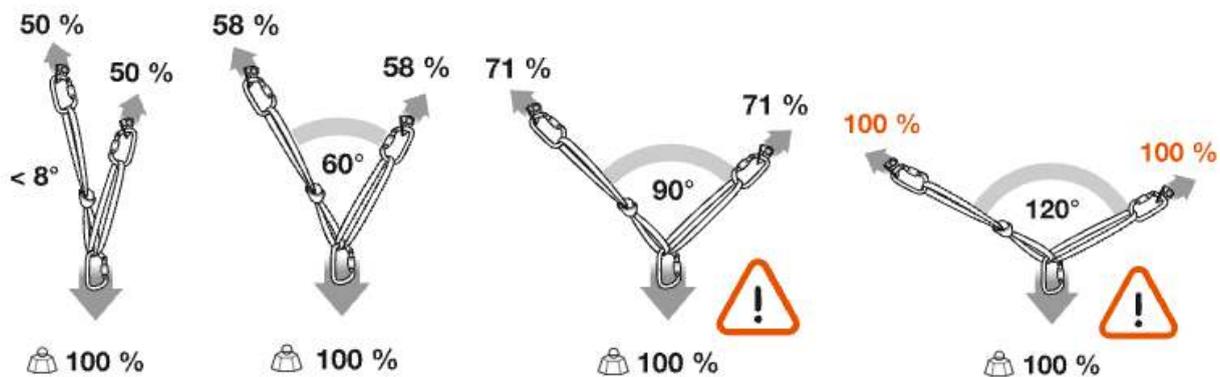
- This means that for rock protection, each piece should be in separate cracks (ie, if the crack widens, only one piece of protection is affected).
- For snow anchors maximum strength and independence is achieved by separating each piece of protection by at least twice the depth of the deepest piece.
- On good water ice, 2 well spaced ice screws are usually sufficient to create a suitable anchor. To avoid the ice screws affecting the strength of each other and the ice fracturing around the entire anchor system, separate each screw by at least 2 screw lengths and in different horizontal and vertical planes.

**Equalised** - To minimise the force on individual pieces of protection and maximise the strength of an anchor system, it is important that the initial load is equalised or shared between all of the individual pieces of protection.

**Redundant** - If a protection piece within the anchor system fails, then there must not be a shock load on the other protection pieces of the anchor system.



**Angle** - The angle created at the focal point when equalising multiple pieces of protection points into an anchor system is of paramount importance because of the Magnification of Vectors. This always needs to be considered, especially if the pieces are separated.



### *Magnification of vectors (Petzl)*

#### Anchor system configurations

Anchor systems can be built using slings or whilst pitching, the climbing rope. Using slings is preferred and used with a direct belay as it keeps the rope and other members of the climbing party out of the system.

#### Fixed anchor systems

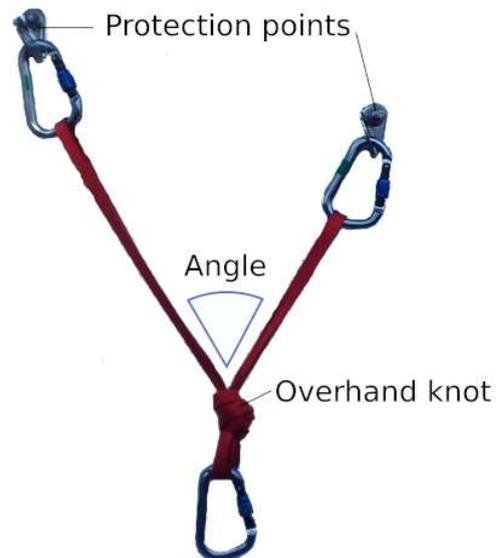
On long multi-pitch or alpine routes, using quick and reliable protection and a simple anchor system that are quick to assemble and disassemble will maximise efficiency.

### Overhand

The simplest anchor system is the Overhand. A sling is clipped through 2 (or more) anchor points and an overhand knot on a bight is tied at a point in line with the direction of pull and equalised on each of the anchor points.

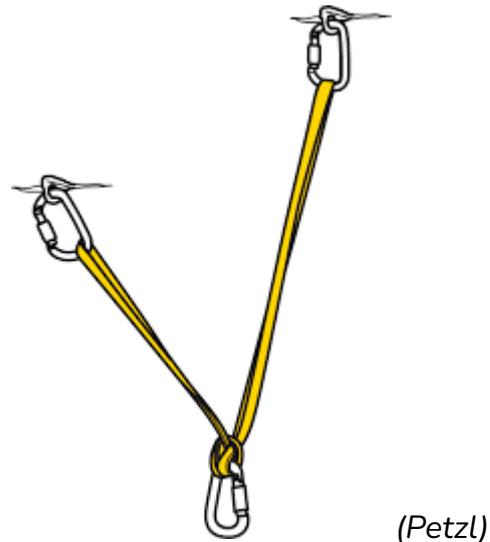
This provides 3 separate attachment points which can be used to keep the anchor organised and separated. These are the Shelf that captures both loops above the overhand knot, and each individual loop below the overhand knot.

This configuration does require anchor points that are relatively close together using a long sling to ensure the angle between the strands is within the acceptable range.



### Sliding X Girth Hitch

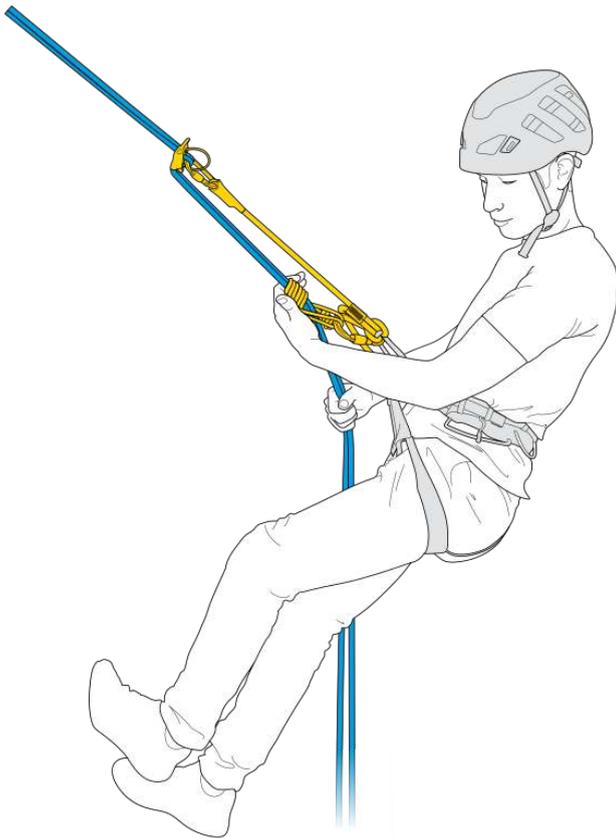
The Sliding X Girth Hitch offers greater redundancy over a standard Girth Hitch anchor and is an efficient use of sling for more widely spaced anchor points. Of particular advantage in alpine climbing is that no knots need to be untied with cold or gloved hands which speeds up the process. This requires an additional Master Carabiner (abseil ring or bears paw) in the system that should remain closed with all other elements of the anchor and belay system clipped to it.



## Abseiling

Abseiling (also known as rappelling) is a fundamental technique required for climbing and mountaineering. Whether abseiling on a single or doubled rope, the principles remain the same. For pitched climbs that require steep abseiling often two 50 or 60 metre ropes are usually carried so that full pitches can be abseiled.

### Abseiling systems



(Petzl)

An extended abseil system is most commonly used with the abseil device extended above the belay loop with a short, knotted sling or a Personal Anchor System (PAS) and the backup prusik attached to the harness belay loop. Although dedicated PAS are commonly used for sport climbing, for mountaineering an extended abseil is only used during the descent and for weight efficiency can easily be improvised from a 120cm sling when required.

A backup is often used when abseiling in case of inadvertently letting go of the dead rope. A backup is also useful when having to clean a route, manage rope or to construct multi-pitch anchors whilst hanging on the abseil rope. A French prusik can be placed around the rope and attached to the belay loop of the harness. French prusiks are preferable in this situation as they are releasable when loaded. It is important that the abseil device is extended sufficiently so that the backup prusik cannot interfere with the device which could result in it failing to lock.

A prusik backup can be avoided if there is someone at the bottom able to hold the rope. If this backup belayer is ready to pull down hard on the rope, the abseil device will lock. This is known as a Fireman's belay.

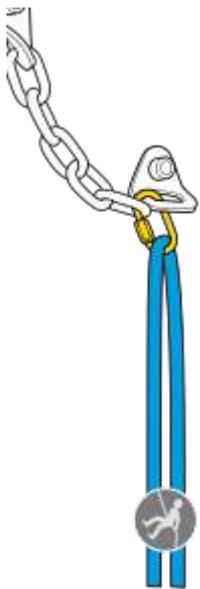
On all abseils where the rope doesn't reach the ground, individual knots should be tied in each end of the rope. Alternatively the first abseiler can stay tied into the end of one of the ropes, providing the ropes are secured at the abseil anchor.

Before committing to an abseil:



1. Ensure that the anchors are secure and attached correctly, you are likely already attached to the anchors so this would have been done already;
2. Check that your harness is on correctly and the buckle(s) are doubled back on non-self-locking harnesses;
3. Check your belay device is threaded correctly and the carabiner attaching your belay device to your harness is locked (squeeze the gate to test it);
4. Check that the end(s) of the rope are touching the ground or have a knot tied in it/them;
5. If you are using one, check your abseiling backup is working correctly (see below);
6. If you are using a *Personal Anchor System* (PAS) to attach to the anchor, all your weight should be on the abseil device and rope with the personal safety is slack as a check before unclipping it from the anchor.

### Retrievable abseils



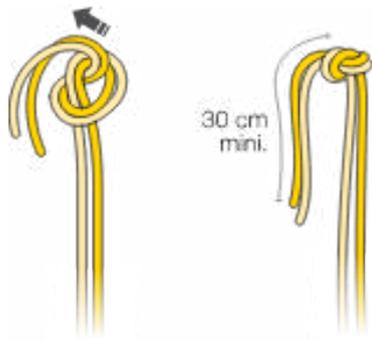
(Petzl)

Most of the time when multi-pitch abseiling in the mountains a Retrievable abseil system is required. This allows the rope to be pulled down after use in order to continue onwards with the descent. This is done by threading the rope or ropes through an anchor that is left behind and then abseiling on two strands of rope. When the bottom of the pitch is reached, one strand can be pulled to retrieve the rope(s). If using a single rope only half its length can be descended at a time.

Once a retrievable abseil is set up, the ends of the rope can be lapped and thrown down. It is common for the rope to get caught on ledges so the first person down should backup their abseil system leaving their hands free to manage the rope if need be so as to never allow the ends of the rope to get snagged above them.

On steeper faces and in windy conditions it is to lap the rope over a sling attached to the side of the harness in 'saddle bags' for the first abseiler to carry down.





(Petzl)

Two ropes are often carried on longer steeper and more technical routes to enable full rope length pitches to be descended. There are a number of options to join two ropes but the simplest for tow ropes of the same diameter is using an overhand knot. The knot must be neatly dressed with at least 30 cm of tail for each rope as in extreme cases it is possible for this knot to roll and undo itself. A major advantage of this knot is that it has a flat surface that rolls well over edges. The ropes must be of similar diameter or very near to it. If not, then use a double fisherman's knot.

To remember which strand of the rope to pull, the personal safety can be clipped around it. It is also important to remember to take the knots out before retrieving the ropes as they can get stuck at the anchor.

On lower angle broken ground it is best to keep abseils short to make the rope easier to manage. Many established abseil descents in NZ mountains are setup for 30m abseils.

Carrying a lightweight tagline (a thin 50m or 60m long 5.5mm diameter spectra chord or similar) allows full rope lengths to be abseiled without carrying a full second rope. The abseil is set up on the full rope and the tagline is used to pull and retrieve the rope.

## Crevasse rescue

Ski tourers will usually discover a hidden crevasse by punching a ski/foot through into the hole but remaining on the surface. In poor visibility, there is more chance of falling in an open crevasse which is why roping up should be considered.

### **Companion rescue**

For any crevasse fall where the victim is injured and unable to extract themselves, the team members on the surface will have to execute a companion rescue.

#### Self-extraction

The victim of a roped crevasse fall may end up dangling in space or land on a snowbridge. If uninjured and once the team members on the surface have secured themselves, the victim may be able to climb out with a belay from above, get lowered down to a snow bridge and climb out on belay or extract themselves by ascending the rope using prusiks (that may or may not have been pre-rigged). If the victim of an unroped fall also lands uninjured on a shallow snow bridge, ascending a rope that is secured and sent down to them may also be the easiest option:

1. The weight of a heavy pack will be uncomfortable so take it off and clip it to the live rope coming from your harness. The pack will dangle beneath you putting tension on the rope,



making sliding prusiks up the rope easier and creating a basic pulley system to pull the pack out once you get to the surface;

2. As you ascend the rope, pull up the loop of rope forming between your harness and the prusiks and attach it to the carabiner on your belay loop with a clove hitch. This acts as a backup so if the prusiks were to slip, you would not end up all the way down to where you started. Using a clove hitch means that every few metres you can bring up the slack without untying the hitch;
3. If there are brake knots in the rope, these will have to be passed. Bight knots can be clipped into if required;
4. When you get just below the lip of the crevasse you are likely to find that the rope has cut into the lip and further upward movement is going to involve clearing the snow away. If you are lucky enough to have a good partner, they may have finished building an anchor system, prepared the lip and be secured at the crevasse edge to assist.

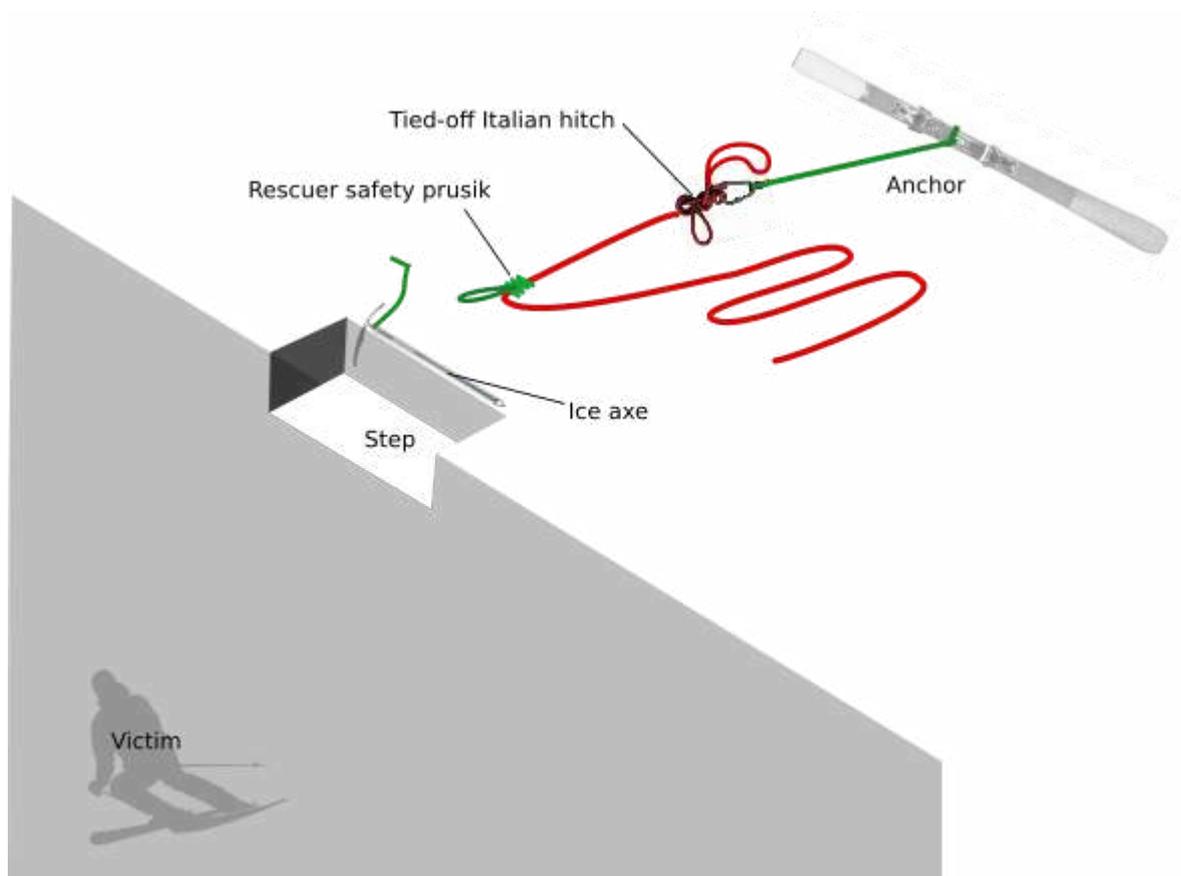
### Preparing the lip

Whenever approaching the edge, the rescuer should be attached to the anchor and protected from falling into the crevasse. Place a prusik around the anchor rope, extended if required using a personal anchor system, and keep it tight as the edge is approached. Once at the edge, the rescuer will be able to re-establish communication with their partner and assess the situation.

If the victim is incapacitated and requires being hauled up, it is vital to prepare the crevasse lip for the rescue rope before it is tensioned. This is done by building an inset step into the crevasse edge with feet or an ice axe (or snow shovel if available). Warn the victim before doing this so they can be prepared for the snow and ice that will likely be knocked down on top of them. If it is a roped crevasse fall, the rescuer will also need to take note of where the buried rope is cut into the snow to avoid digging through it. Take the time to do this well as it will make getting the victim out of the crevasse a lot easier.

Once dug, the ice axe can be placed lengthwise along the top edge of the step to run the rope over. This avoids the rope cutting further into the snow and also helps to reduce friction when hauling. It is a good idea to clip the leash of the ice axe into the live rope to avoid it being dislodged and losing it into the crevasse.





### *Preparing the lip*

### Hauling

In the unlikely event that the victim is incapacitated to the extent that they can't clip themselves into the rescue rope that is sent down to them, the rescuer will have to first abseil down, attach the victim and then climb or prusik out - a time consuming and complicated procedure.

Even if roped up, the live rope will likely have cut into the soft snow at the lip of the crevasse so will not be able to be used for rescue and it is usual to haul on an untensioned rescue rope.

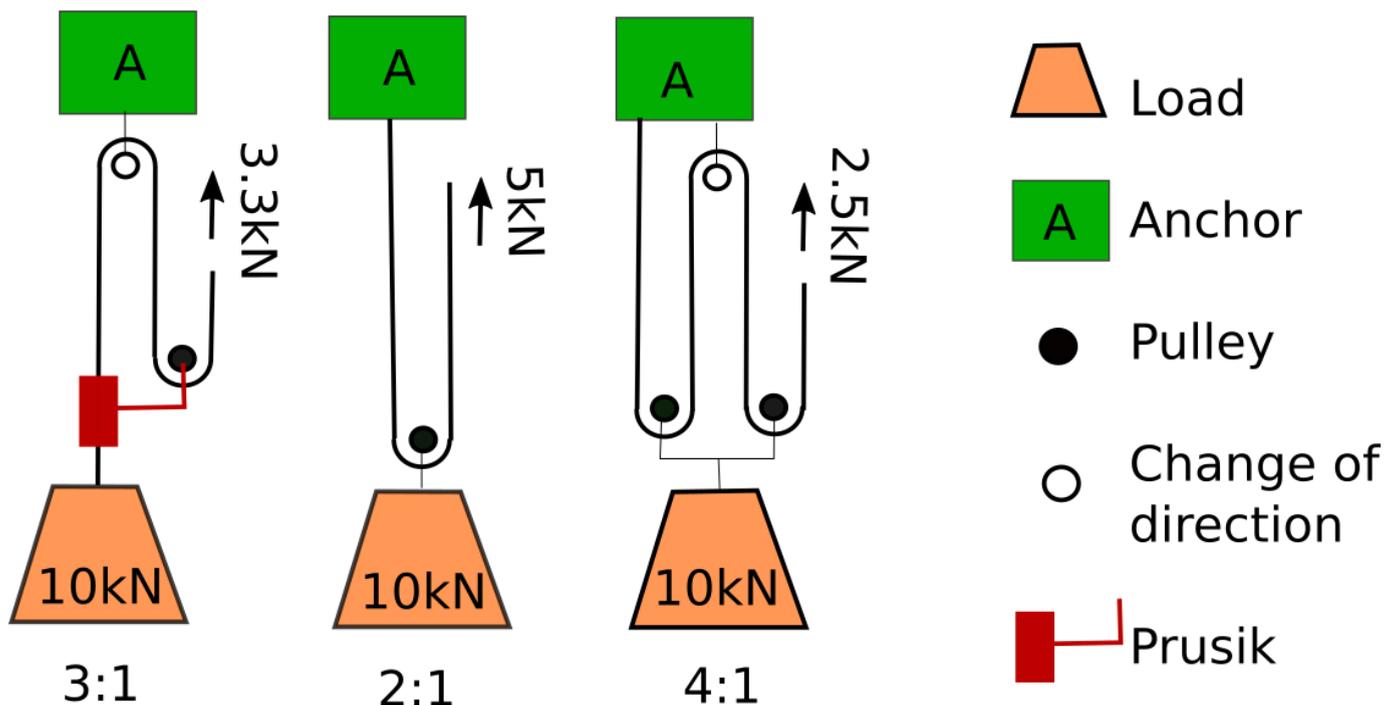
Hauling is hard work, no matter what system the rescuer has created. For best results keep the pull close to parallel with the snow surface and use stronger leg muscles rather than arms. A seated rowing position works well. Another option is to attach the rescue rope to a carabiner on the belay loop using a clove hitch that can be adjusted and relatively easy to release after being loaded), face away from the crevasse and 'climb' along the surface using legs to pull the rescue rope.

## Pulley systems

The aim with pulley systems is to use mechanical advantage to multiply the force of the pulling. The force required to pull decreases it but increases the amount of rope that has to be pulled through the system.

This is the theoretical value and in reality, the effect of stretch and friction reduces the effective advantage significantly. Friction is introduced at any point where the rope is running through a carabiner along the surface of the snow. Friction can be avoided by making sure the strands of rope are running neatly, using pulleys on carabiners if they are available and excavating snow from under all the moving parts of the system. If pulley devices are available, they should be used in priority on any moving pulleys (those moving towards the anchor). If only one pulley device is available, this should be placed as close as possible to the hauling end of the rope so its benefit will be multiplied through the system to the load.

Pulley systems can be simple or compound. Simple systems use one continuous flow of rope.



*Mechanical advantage of simple pulley systems*

Mechanical advantage of simple pulley systems can be determined by:

- Measuring the distance the load moves relative to the rope being pulled through the pulley system.
- Counting the strands of rope in the pulley
- If the rope is fixed at the load end then the advantage of the pulley system will be odd (eg 1:3,5...). If the rope is fixed at the anchor end, the advantage will be even (eg 1:2,4,6..).
- Pulleys moving towards the anchor add advantage. If the rope runs through a carabiner or pulley and it doesn't move, it is referred to as a change of direction.

### Progress capture

All pulley systems work best with a form of progress capture. This is a system that takes the load as progress is made, which means that the rescuer can take a break and the weight of the victim is taken directly on the anchor. Using an efficient progress capture will make the hauling easier and quicker.

For all pulley systems, it is useful to create a focal point with a bight knot for the progress capture about 3.5 metres away from the crevasse edge on the anchor rope. This provides an efficient space for hauling. If a brake knot on the live rope is in a suitable position, these can also be used.

There are a number of different options for progress capture;

- **Progress Capture Device** - These small devices (eg Petzl Micro Traxion<sup>®</sup>) are the most efficient autoblock and highly recommended. A Petzl Tibloc<sup>®</sup> is a mechanical prusik that can be used for ascending a rope and can be used as an efficient and simple progress capture.
- **Prusik** - This is a simple but effective autoblock. It is important to use a french prusik so that it can be bumped under load. Using a Prusik Minding Pulley (PMP) instead of the belay device reduces friction.
- **Plaquette** - Using a guide plate (eg Petzl Reverso<sup>®</sup> or Black Diamond ATC<sup>®</sup> Guide) as a progress capture introduces a lot of friction into the system and should only be used for smaller diameter ropes.

### Simple pulley systems

#### Assisted hoist

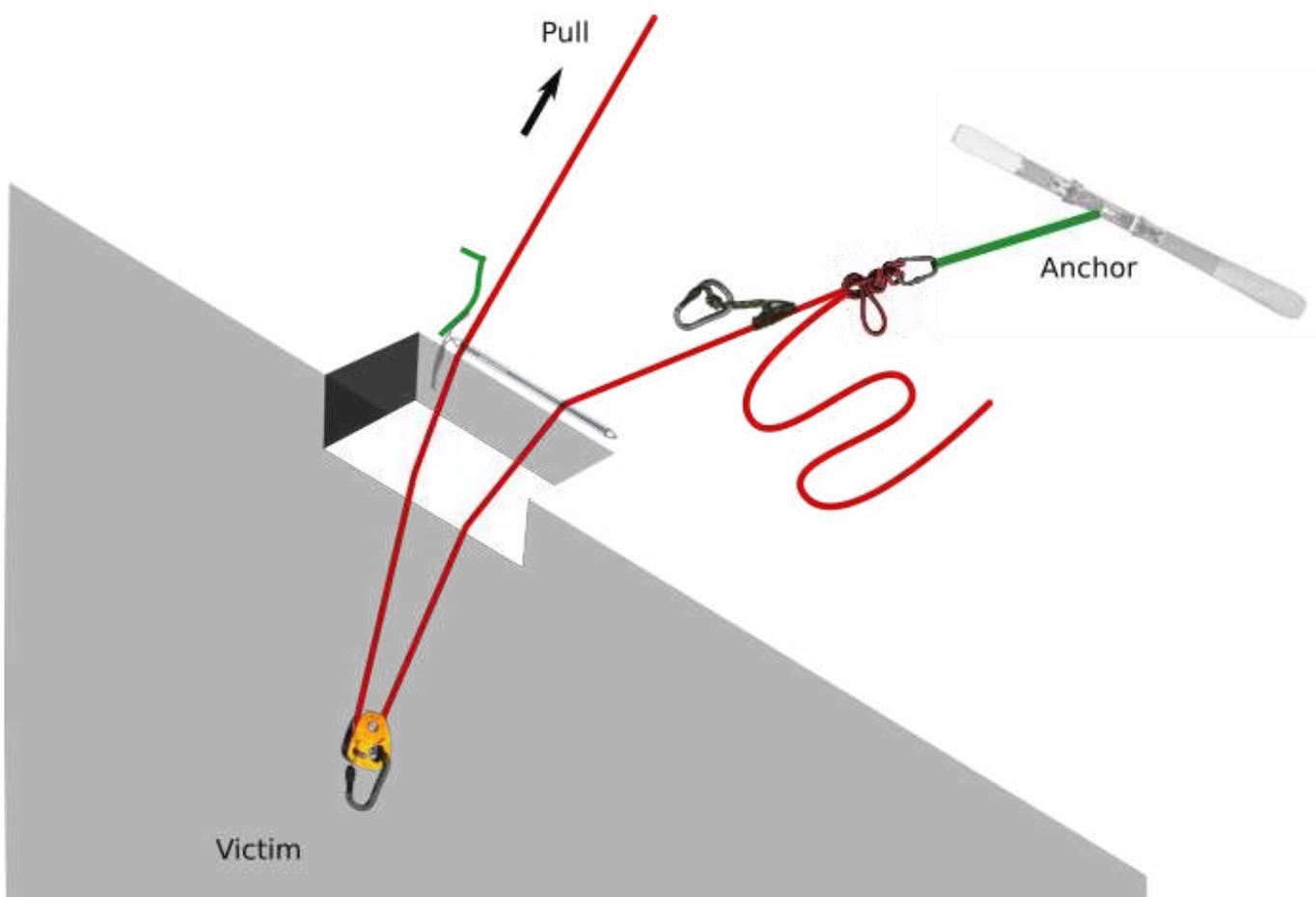
The simplest pulley system is an assisted hoist (also known as a drop loop). It has a 2:1 mechanical advantage so works best when the victim is able to help or there are a few people on



the surface to pull. If the victim is incapacitated and/or there is only one rescuer, a more complicated hauling system with more mechanical advantage will probably be needed.

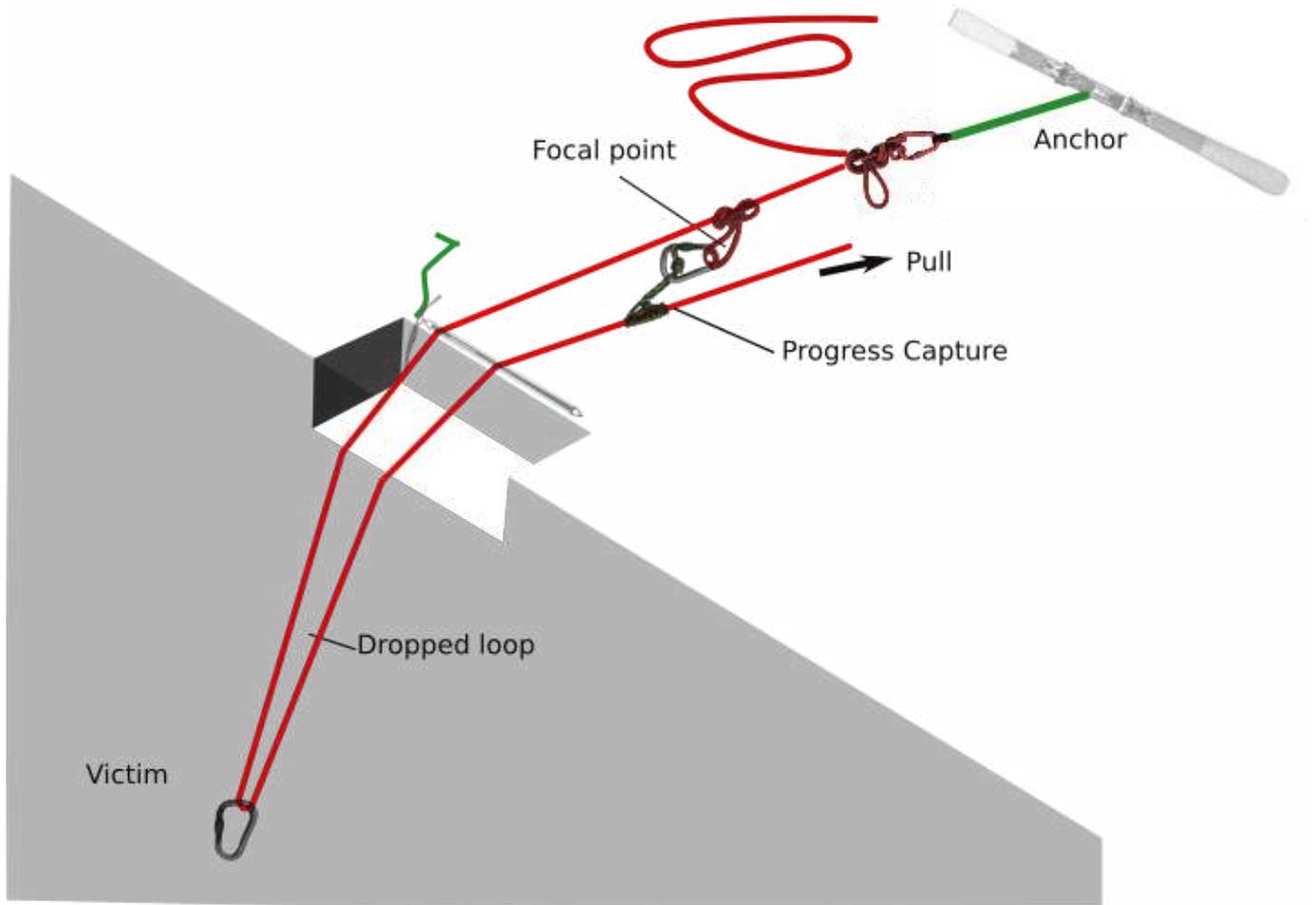
To build an assisted hoist:

1. Drop a loop of rope down to the victim with a screwgate carabiner freely attached that the victim can clip to their harness. If the rescuer or the victim has a pulley, this is the best place to use it;
2. Take the slack out of the drop loop by pulling up on the rescue rope and add a progress capture to the rescue rope. This can be a simple prusik or more efficient device;
3. The victim can assist by pulling on the anchor rope. This is the strand of rope that is moving towards them as they travel upwards. The rescuer will pull on the rescue rope whilst making sure that the slack rope travels through the progress capture.
4. If the rescue rope can be attached to a micro traxion on the victim's harness, the victim can assist and with one rescuer, the assisted direct pull is the most efficient technique. The rescuer is secured at the lip of the crevasse and pulls up on the rescue rope. This technique minimises the length of tensioned rope in the system and avoids any friction of rope running over the edge.



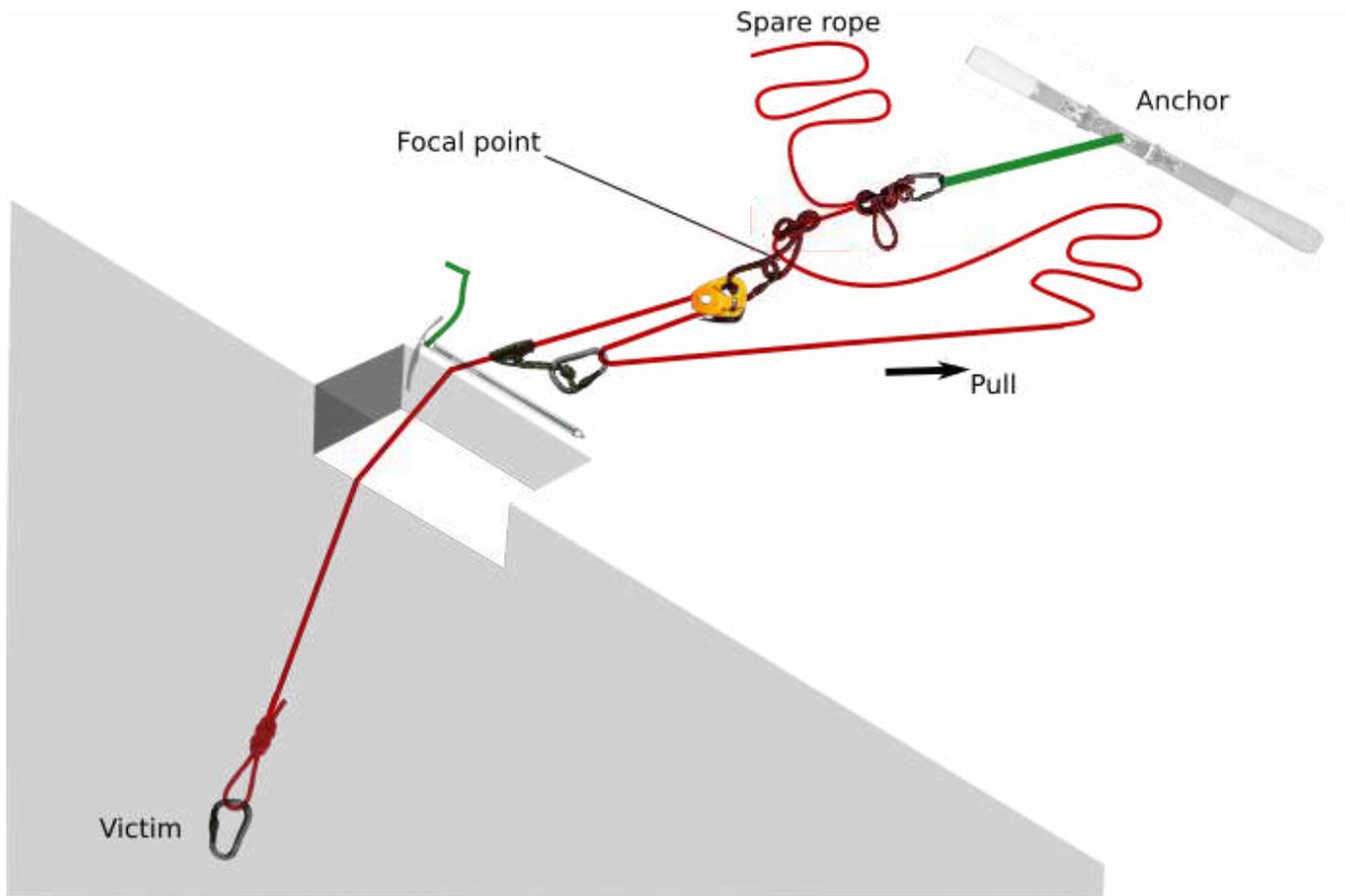
*Assisted (drop loop) hoist (2:1) Direct Pull*

- With more than one rescuer a simple progress capture prusik can be placed on the rescue rope and allows for multiple rescuers to pull on the rescue rope away from the edge.

*Assisted (drop loop) hoist (2:1)***Unassisted hoist**

If the victim is unable to assist, more mechanical advantage is needed. An unassisted hoist (also known as a Z haul) has a mechanical advantage of 3:1 so will require more effort on the surface to haul out the victim. This is constructed in a similar way to the assisted hoist but instead of dropping a loop down to the victim, the rescuer sends the end of the rope for the victim to clip into and all the moving elements of the hauling system are created on the surface.





### *Unassisted hoist (Z haul) (3:1)*

It is also possible to construct an unassisted hoist directly onto the live rope without dropping an end of the rope down to the victim. This may not work efficiently if there are brake knots in the rope and especially if they have dug deep into the snow.

### **Compound pulley systems**

For a simple pulley system, increasing the theoretical mechanical advantage beyond 4 or 5:1 tends not to increase the practical advantage due to increasing friction and inefficiencies of the equipment.

If simple systems are not working, then a bigger mechanical advantage can be achieved by combining two simple systems into a compound system.