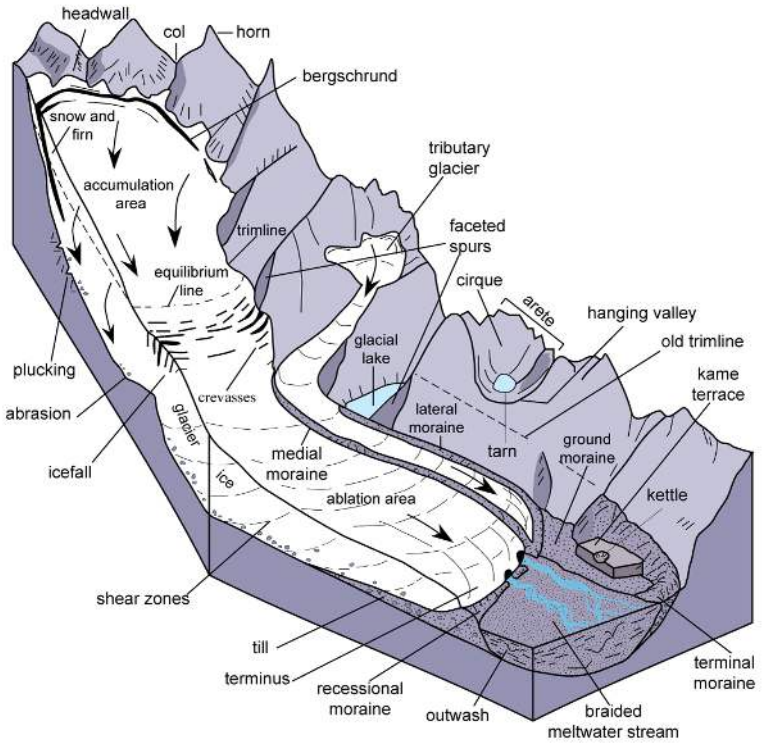
Glacier Ski and Splitboard Touring Course

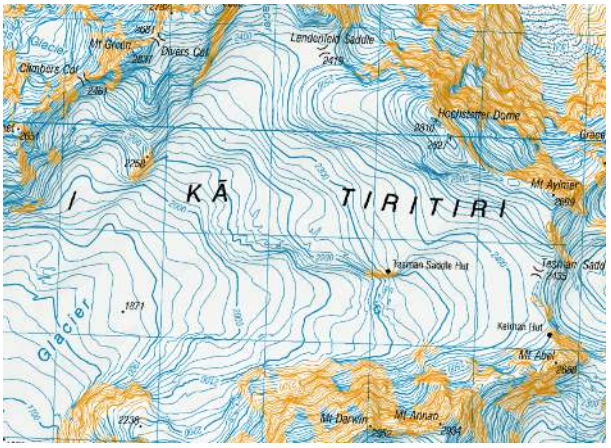
Late winter and spring is the prime time for ski touring on NZs high glaciers. Seasonal snow depths are high and crevasses are generally well bridged with supportive snow. Good route finding can generally avoid the worst areas of crevasses. There is however always the risk of falling into a hidden crevasse resulting in potentially the most challenging and foreseen technical rescue situation that is likely to be encountered in the mountains. It is therefore standard practice for all the members of a team to be familiar with self and companion rescue.

Glacier travel on skis

Identifying crevasse hazards



Glaciers flow down the landscape like a slow-moving river. Crevasses will form in the top 50m of a glacier where the ice is brittle, particularly in areas of tension or friction or where ice is flowing at different speeds. This includes over convexities, over any steep terrain, or towards the edge of the glacier.



Areas of likely crevassing can be identified by analysing the terrain using Topomaps and satellite images. Steep terrain and irregular contour spacing and shape indicated crevassing. Good planning and route finding on snow-covered glaciers will reduce exposure to falling in a crevasse.

Crevasses may be indicated by visible cracks or slumps in the surface of the snow. These clues may however be masked by fresh snow, blowing 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 temperatures[1] commonly encountered mid-winter, will be weak. Older snow has consolidated through a number of melt-freeze cycles (more typical of the warmer spring season) and will be stronger when frozen but may be weakened during the warmth of the day.

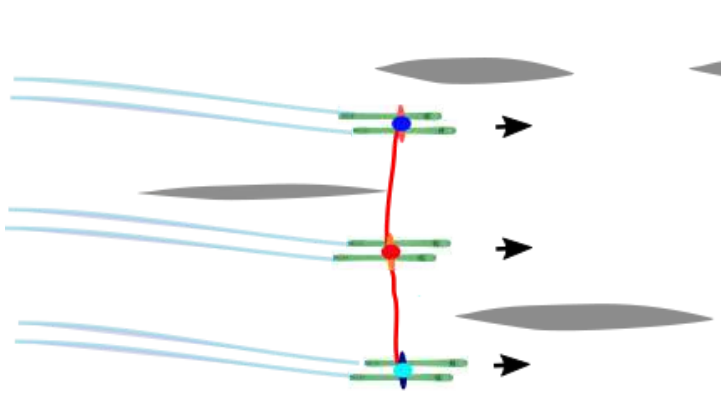
[1] Snowpack metamorphosis also has implications on avalanche problem formation.

Roped travel on skis

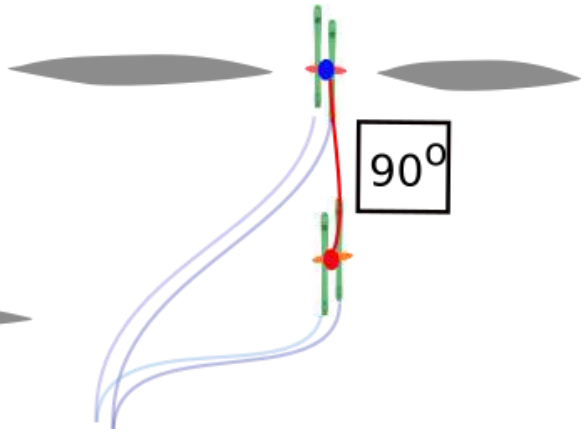
Roped glacier travel on skis should be a consideration in unfamiliar terrain or when visibility is poor. In downhill mode this is very difficult to manage so being roped up is most likely used when touring uphill.

As the slope angle increases, consideration must be given to the avalanche and slide hazards relative to any crevasse hazard. More so than on foot, ski tourers will have to zigzag which introduces issues with slack forming in the rope, and coming out from perpendicular with the crevassing.

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



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 avoid pendulum falls that can be difficult to arrest. With skis parallel to crevasses however can increase the risk of punching through hidden snowbridges.

Crossing crevasses

When travelling near visible crevasses, determining the characteristics and shape of the shape of the crevasses will assist with route finding. Bell-shaped crevasses get wider as they get deeper and should be given a wide berth. Narrow parallel or constricting crevasses can often be stepped over.

When crossing visible or potentially hidden 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. This may require different team members to take different lines.

On approaching the edge of a crevasse or any suspect areas the leader can probe using their feet, ice axe or ski pole whilst the other team members are braced. Whenever in doubt. Put in a snow anchor and belay across.

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 usual practice for glacier ski tourers to carry 30-60 m of dynamic or lightweight 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, the distance between them in the area and the 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 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

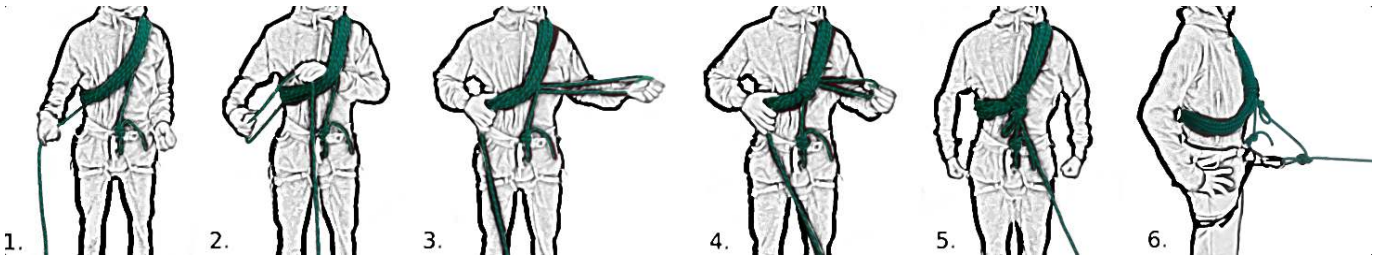
With a spacing of 8-12m between rope team members, the 30+m rope needs to be shortened. There are a number of methods for carrying the excess rope including stuffing it in a stuff sack and putting it in a backpack if it is already not too full or using Kiwi coils. Carrying excess rope in Kiwis coils 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.

Kiwi coils

To tie Kiwi coils:

1. Find the middle of the rope and measure out the required distance between team members. Remember to account for the extra length required for tying brake knots. Tie into the end of the rope. This is especially important if it is anticipated that the rope may be lengthened for pitching during the course of the day. From the knot, run the rope over your shoulder and start coiling the rope around your opposite hand, held statically at waist level (for example rope initially runs over the left shoulder so coils are taken around the right hand). Keeping your hand static at your belly button level will create uniform length and neat coils;
2. Pass your hand behind the coils and grab the loop of rope.
3. Pull back through a long loop of rope. Hold the coiled end of this loop using the waist hand to ensure the strand of rope does not ride up;
4. Wrap the long loop around the coils a few times, this keeps the coils neat and secure;
5. With the remaining loop, tie an overhand knot around the rope coming from your figure-8 knot and the live rope (the rope connecting you to your partner);
6. An isolation knot is required to provide a low tie-off and ensure any loading comes directly onto the harness. A bright knot makes it easier to escape the system for companion crevasse rescue if the live rope is loaded. Whilst pitching or moving together, a clove hitch can also be used as it is easily adjustable, providing it is regularly checked to avoid it loosening during movement.



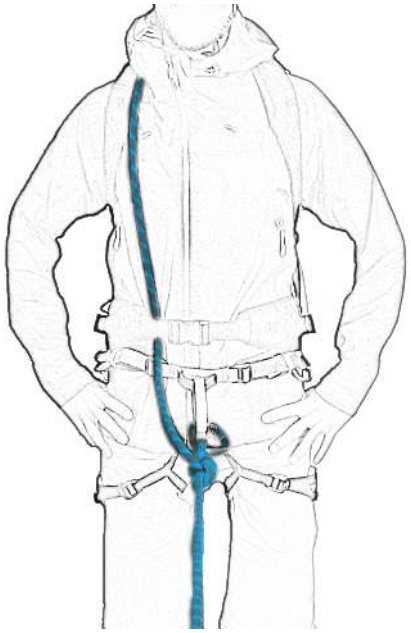
Kiwi coils

Pre-rigging

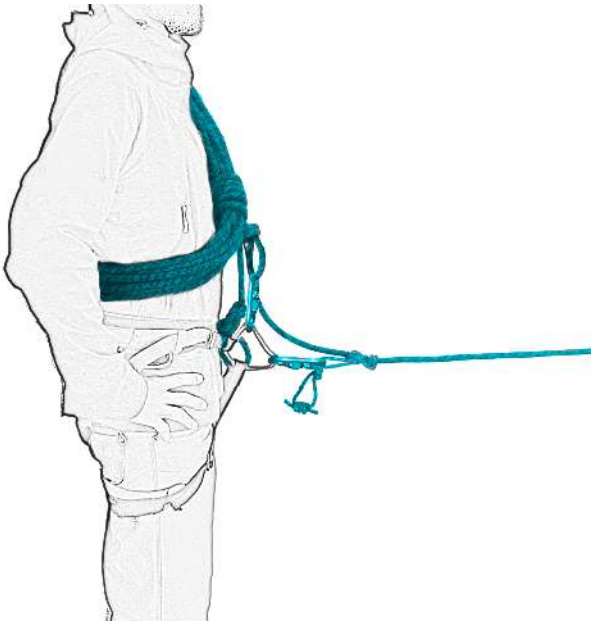
Pre-rigging is the method of putting prusiks around the rope between members of a rope team so that they can be quickly and easily used for crevasse rescue if required. This is an added step but means that it is easier and quicker to react to any crevasse emergency.

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.



Clipping into rope with a bight knot and rope in pack



Rope stored as mountaineering coils with pre-rigged prusik

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

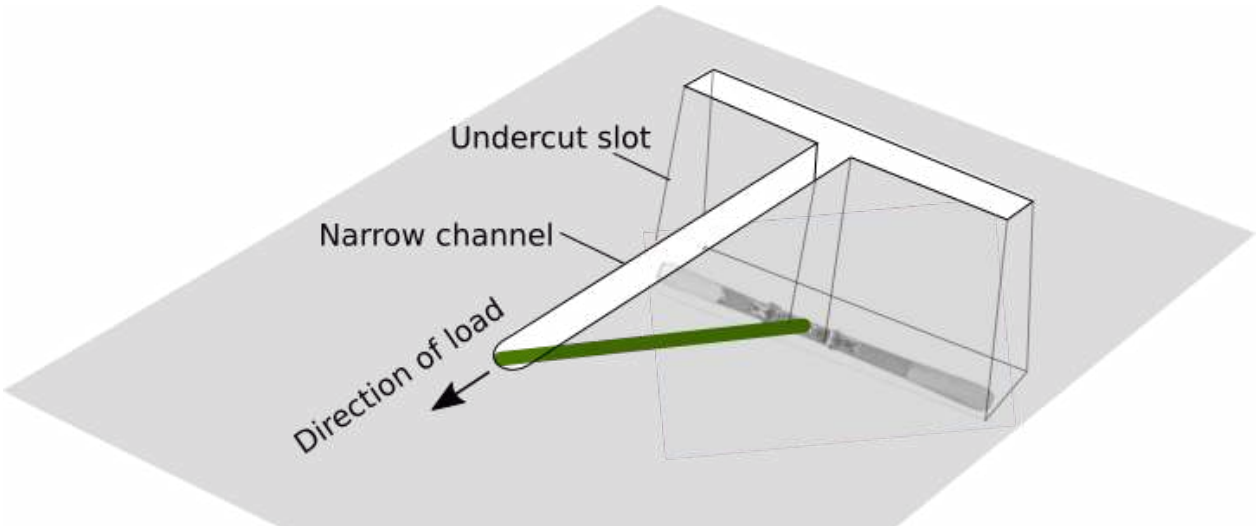
For any crevasse fall where the victim is injured and unable to extract themselves, the team members on the surface will have to execute a companion rescue.

Snow anchors

In most situations, an anchor will need to be built, initially so that the rescuer can safely approach the edge of the crevasse to assess the situation. During the winter and spring seasons, ski tourers are likely to encounter soft snow on the surface of the glacier. In mid winter and immediately after fresh snowfall, it may be dry snow. Later in the spring season, particularly after rain or a number of melt-freeze cycles , the snow will likely be wet.

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.

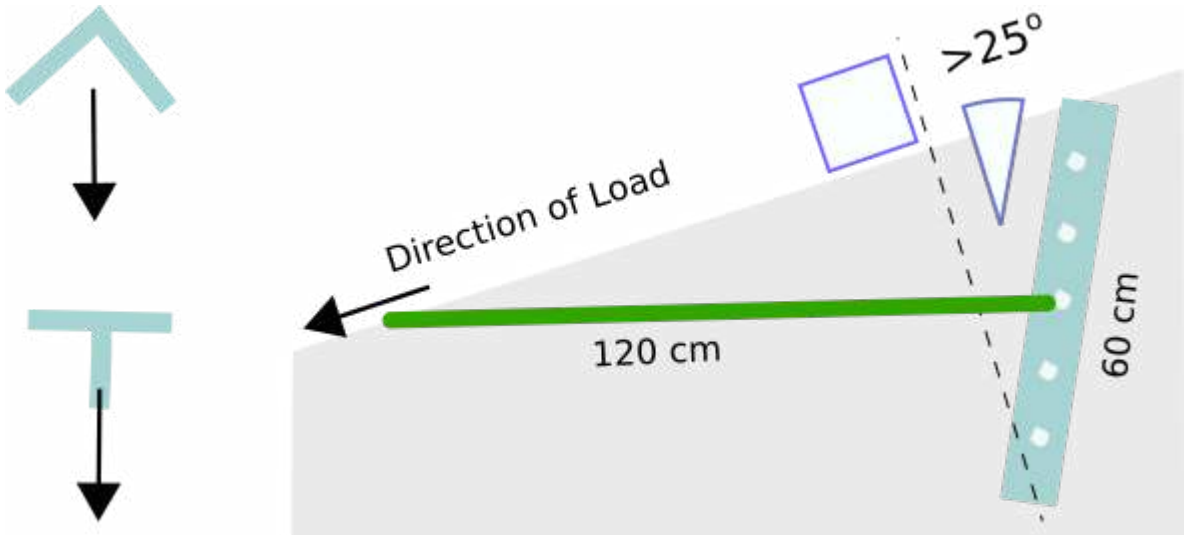
If wet snow can be formed into a snowball, it can be made stronger through compacting with hands. Otherwise, or if the snow is dry, it is best not to disturb the snow in front of the anchor. Unless the snow is compatible, the snow in front of the T-slot should not be disturbed. Backfilling the slot does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

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° 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.

Self-extraction

The victim of a roped crevasse fall may end up dangling in space or land on a snow bridge. 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;

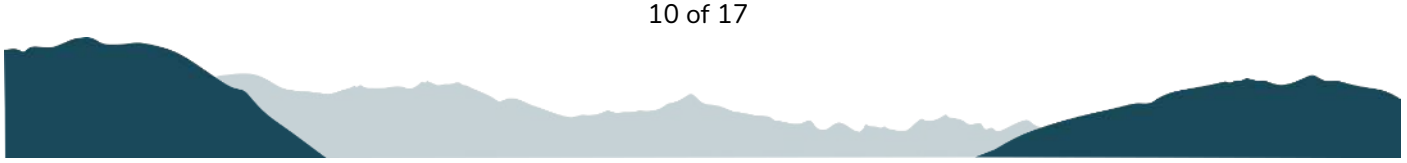
3. If there are brake knots in the rope, these will have to be passed. Bight knots can be clipped into if required;

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

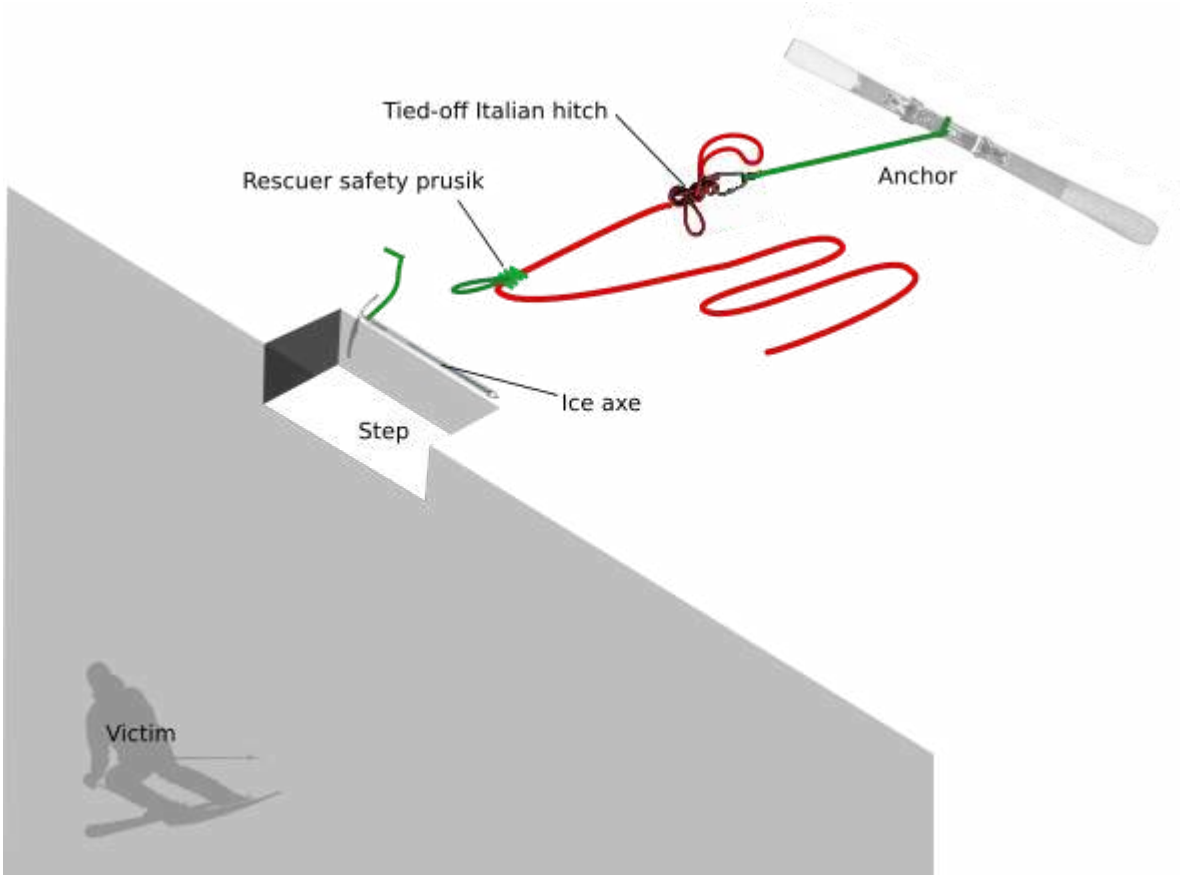
Whenever approaching the edge, the rescuer should be attached to the anchor and protected from falling into the crevasse. Place a prusik around the anchor rope, extended if required using a personal anchor system, and keep it tight as the edge is approached. Once at the edge, the rescuer will be able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

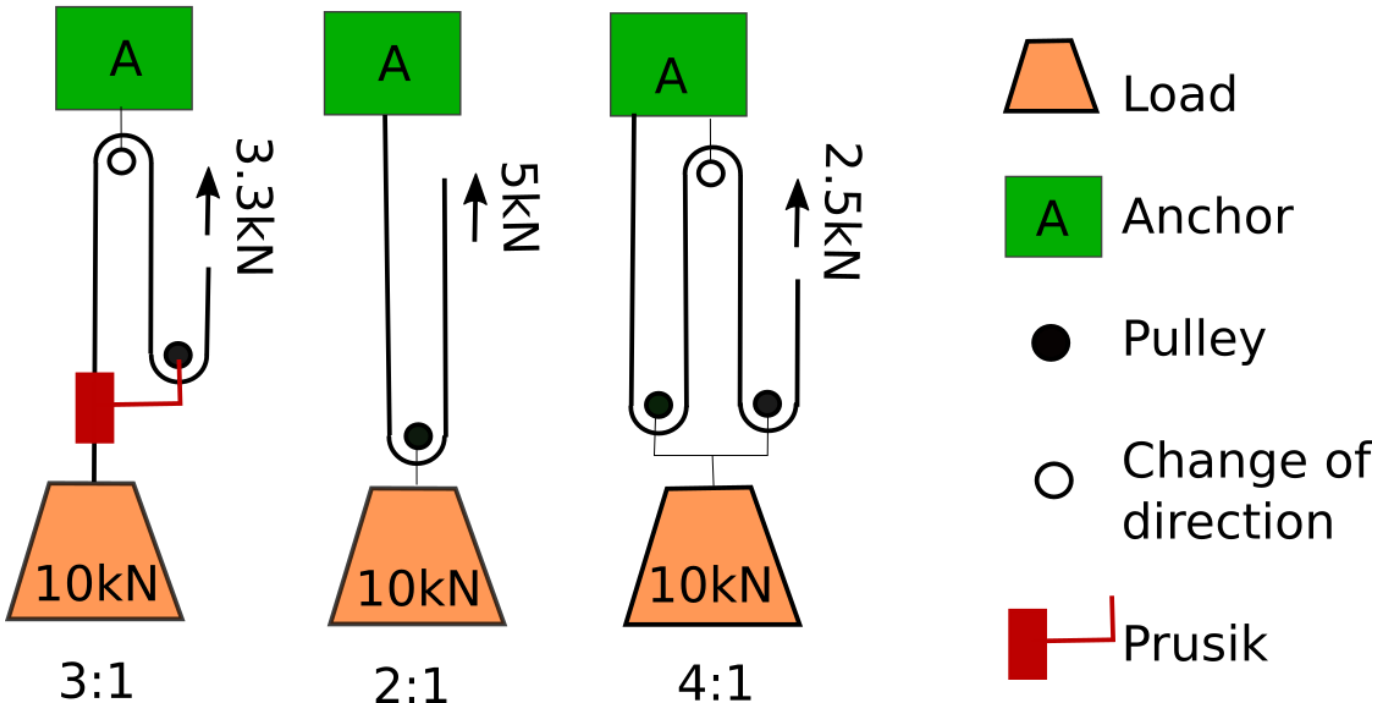
the belay loop using a clove hitch that can be adjusted and relatively easy to release after being loaded), face away from the crevasse and 'climb' along the surface using legs to pull the rescue rope.

Pulley systems

The aim of 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 it's 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.



The mechanical advantage of simple pulley systems

The 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.

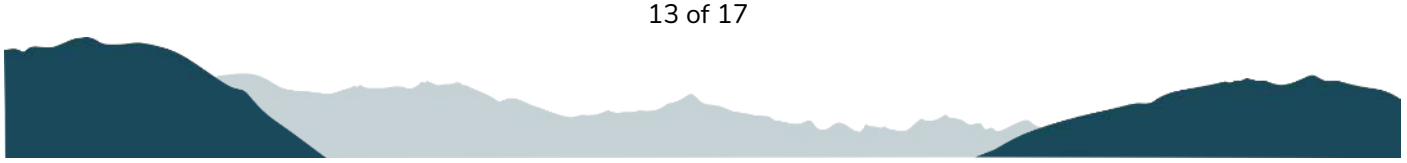
There are a number of different options for progress capture;

- **Progress Capture Device -** These small devices (eg Petzl Micro Traxion®) are the most efficient autoblock and are highly recommended. A Petzl Tibloc® 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® or Black Diamond ATC® 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

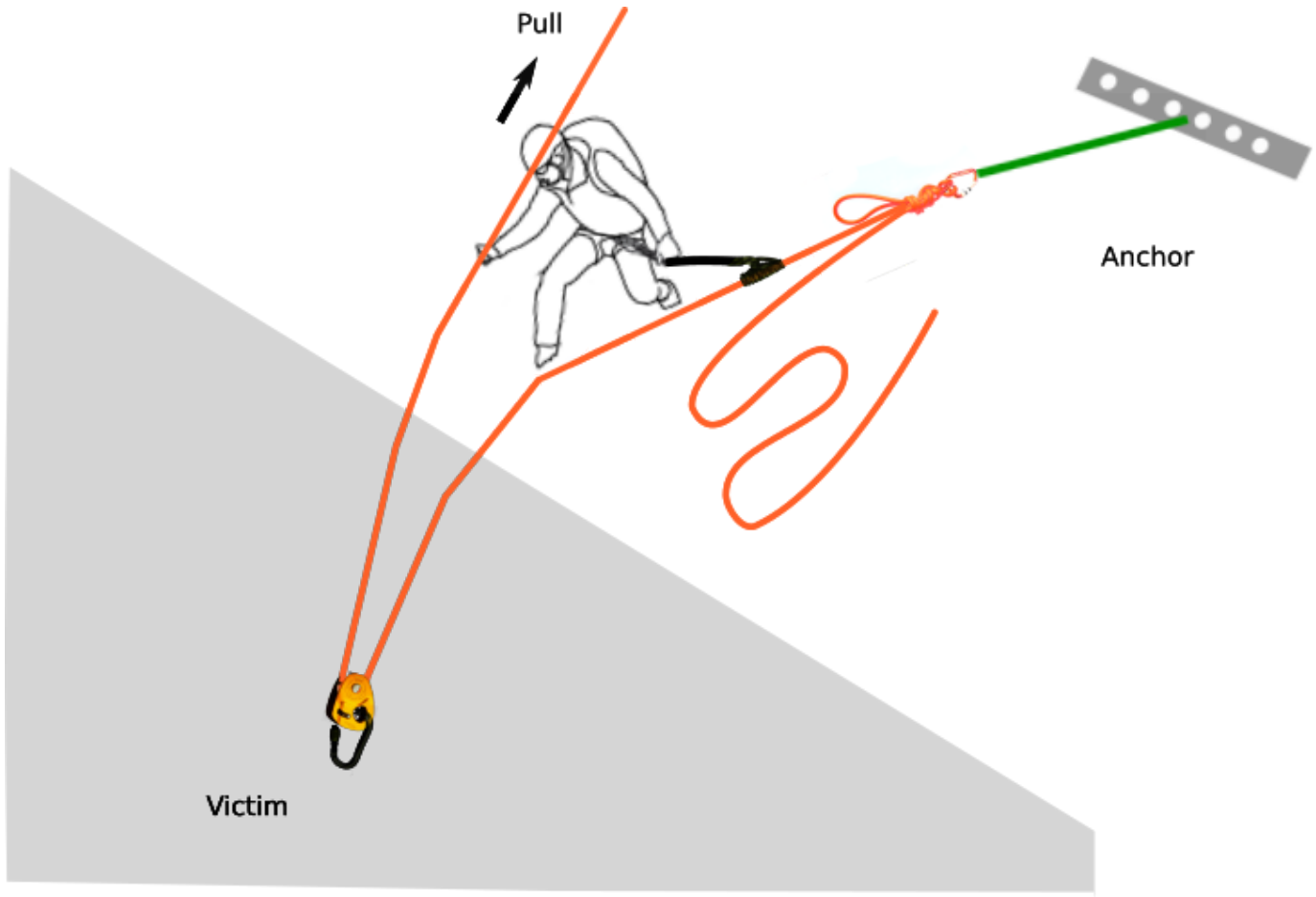
The simplest pulley system is an assisted hoist (also known as a drop loop). It has a 2:1 mechanical advantage so works best when the victim is able to help or there are a few people on



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:

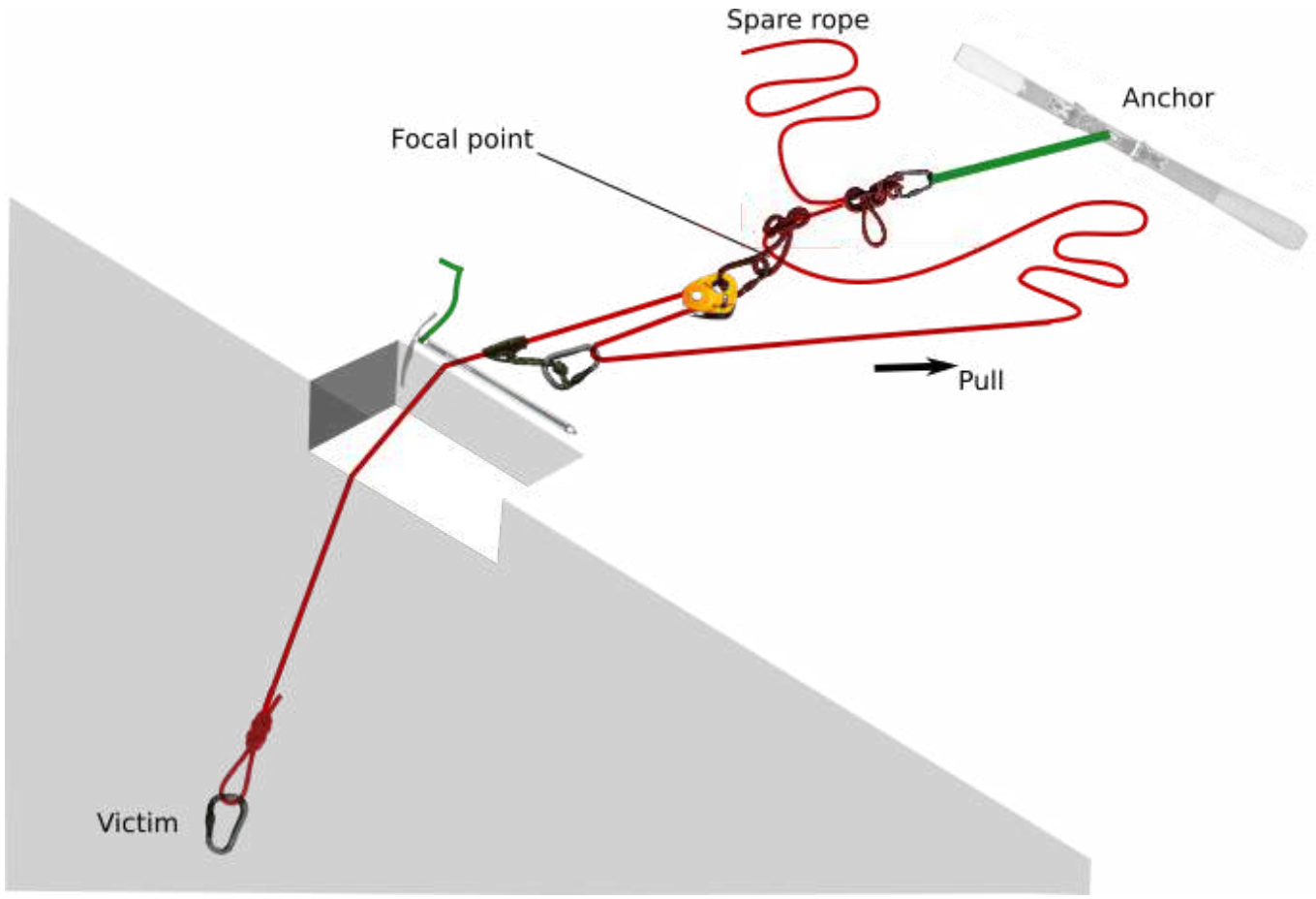
1. Drop a loop of rope down to the victim with a screwgate carabiner freely attached that the victim can clip to their harness. If the rescuer or the victim has a pulley, this is the best place to use it;
2. Take the slack out of the drop loop by pulling up on the rescue rope and adding a progress capture to the rescue rope. This can be a simple prusik or a 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

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, especially if they have dug deep into the snow.

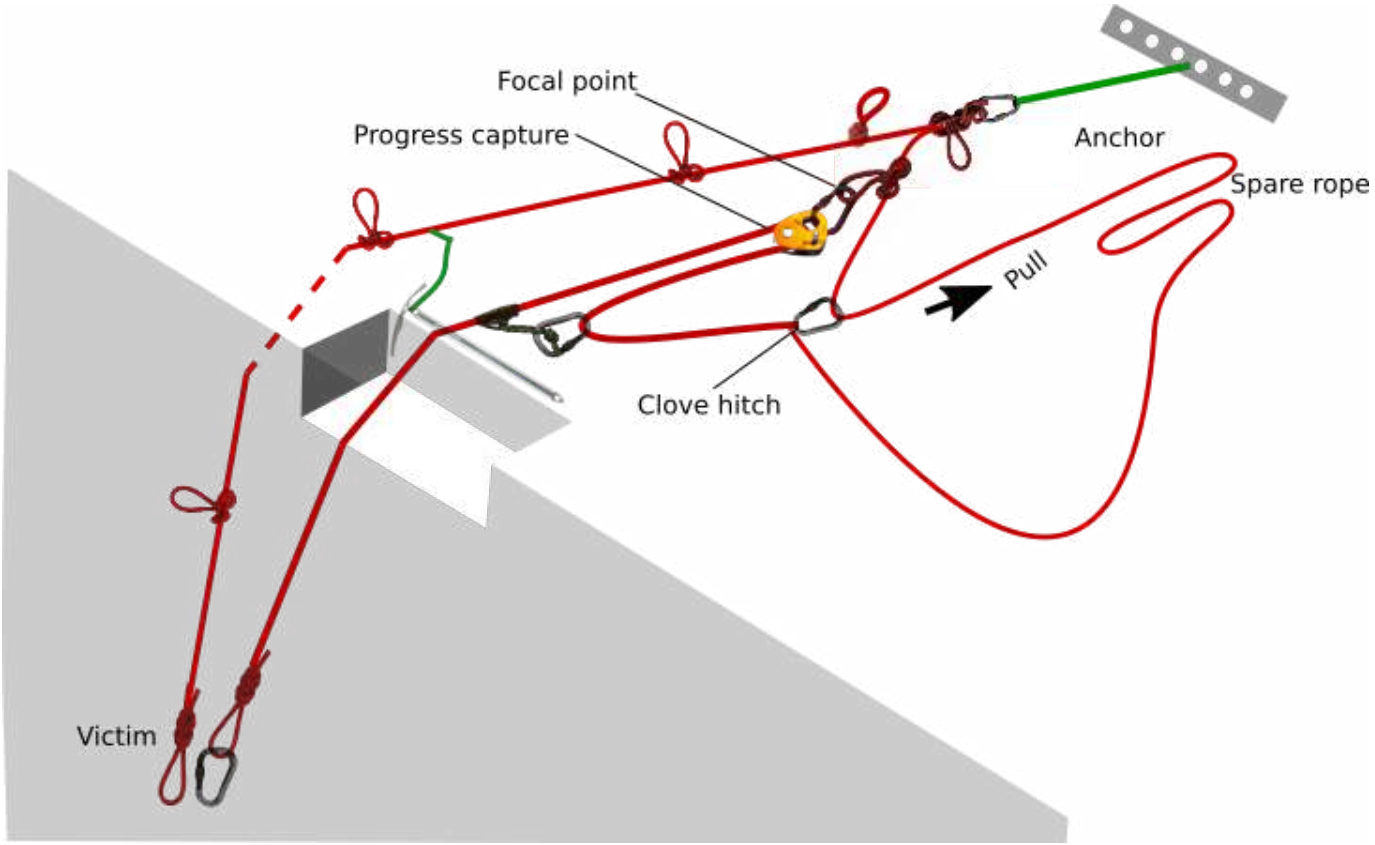
Compound pulley systems

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

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 a simple hauling system is not working then a bigger mechanical advantage may be required. This can be achieved by combining two simple systems into a compound system. The mechanical advantage of a compound pulley system can be determined by multiplying the mechanical advantage of the individual systems together. Compound systems can be

identified by having individual pulleys that travel towards the anchor at different speeds during the haul.



Compound (6:1) - Z haul 3:1 with extra 2:1