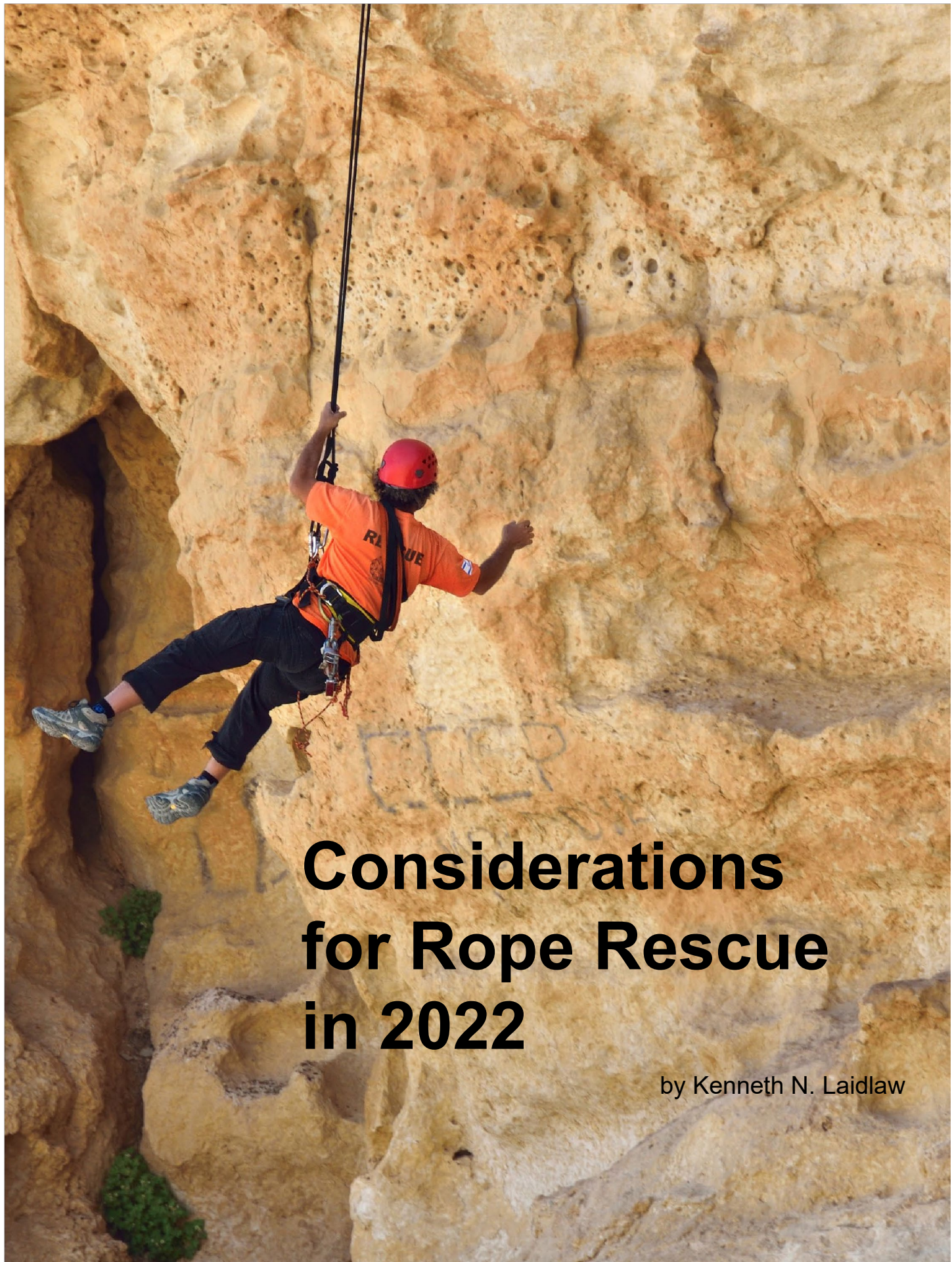




Considerations for Rope Rescue in 2022

by Kenneth N. Laidlaw

CONSIDERATIONS FOR ROPE RESCUE in 2022

August 2022

by

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CERTIFICATIONS: Management, Documentation, Communications, First Responder, Rope Access, Confined Space, Cave Rescue, Mines, Man-Tracking, Hazardous Materials, Dive Operations, Law Enforcement, Fire Fighting.

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Abstract:

Rope rescue presents special challenges, especially in remote areas. With new equipment constantly appearing on the market and techniques continuously being refined, the craft is a very dynamic experience. This presentation will expose new students to safe, basic, fundamentals. Advanced students will increase their knowledge of proper techniques. All experiences are based on current testing and review the techniques of application used by different groups, from cave explorers to mountain rescue personnel. NFPA and OSHA considerations will be addressed. Both hard and soft techniques for attaching to the rope are discussed. At the end of the presentation, a reader should be able to make safe decisions based on their own needs and budget restraints. They will also know the best references for additional information.

WARNING:

Rope rescue is a very dynamic experience and what may be considered safe today, may be determined inappropriate tomorrow. Check the date in the upper right corner of your edition, if you have an earlier version of this paper, destroy it.

Notes:

An effort has been made to use the historically correct terms and systems international measurements for components to accommodate both North American and European interests. The equipment specifications in this paper describe cordage sizes and hardware that is commonly used in rescue situations from caves to mountains. Basic definitions for knots, bends, and hitches come from Clifford W. Ashley. There is a knot glossary comparing the traditional name and other local names on page 54. All equipment must, however, be used in accordance with the manufacturer's recommendations.

Fire Service Considerations:

The fire service community may think this presentation does not apply to them as the equipment does not meet the standards outlined in NFPA 1983. This presentation specifically deals with **special rescue operations**. A quote from NFPA 1983 'NFPA 1983...shall not apply to rope and equipment used for special rescue operations.' NFPA defines **special operations** in NFPA 1670 as '...incidents...that require specific and advanced technical training... and equipment.' NFPA 1006 expands the definition of **special rescue operations** to include '...rope rescue...confined space...'.

Ropes:

Static kernmantle rope should be used. Kernmantle design consists of a central core or kern of parallel fibers that support the load. This core is covered with a woven sheath or mantle. Static is a type of rope that typically stretches only 3% to 5% when a one KILONEWTON force is experienced.

A NEWTON is a unit of force—mass or amount of matter times acceleration or change in speed over time is equal to about .2248 of pound force. A KILONEWTON would be about equal to the mass of a 100-kilogram (220.4 pound) person times acceleration 9.81 m/s² (32.16 ft/s²).

Remote area rescue traditionally uses an 11 mm. (7/16 in.) size. Several versions of static kernmantle rope are often available and a stiffer type, with a more abrasion resistant sheath, used by cavers, may be applicable. A more flexible sheath version might be easier to use for working components. All versions are usually manufactured with a breaking strength greater than 26.7 kN (6,000 lbf.) Avoid getting grease and pitch on the ropes. Discourage people from walking on the ropes. Regularly wash dirt and grit off the rope. Store rope in bags, in a dry area, out of sunlight. The larger rope manufacturers make excellent products. Unless you must have designer colors, buy rope that has more white strands and it will usually be cheaper.

Traditionally, the rope of choice is PMI® Hudson Classic Professional EZ-Bend™. It is 100% nylon, 11 mm., low stretch, about 1.8%, and rated at 28.5 kN (6,407 lbf.)

A newer rope made by Sterling® is becoming popular. HTP™ is 100% polyester, 7/16 in., low stretch, about 2.4%, and rated at 30.5 kN (6,856 lbf.)

The newest rope made by Sterling is their H3 Tech 11™, 100% Technora®, 11 mm., low stretch, about 1.1%, and rated at 42.6 kN (9,576 lbf.) but is expensive.

As of December 2020, most of the rope manufacturer's product line offered an 11 mm. (7/16 in.) rated at 40 kN (8,992 lbf.) to meet the NFPA 'G' rating.

Ropes are the lifeline to success for the patient and the rescuer. Never coil a rope, as that will place twists in it, and management in the field will become difficult. If bags are not used, consider a 'butterfly or backpacker's coil'. Rope is doubled. Leave two meters of free ends on the ground. Proceed to lay the doubled rope back and forth across your shoulders with the loops coming to your waist. When you reach the bight, lift everything off your shoulders. Wrap the bight several times around the rope bundle and secure it. The loose ends can now be passed through the bundle and then used as shoulder straps to secure the rope bundle to your back for carrying.

All the 8 mm. cord used should have a minimum breaking strength of 13.3 kN (3,000 lbf.) or 9 mm. 20 kN (4,500 lbf.) and should have an appropriate sheath for the Prusik hitch to stay snug.

Serious testing of equipment and techniques began in 1982 with an independent group of rescue teams in British Columbia, Canada, known as BCCTR. Further testing included Arnor Larson, John Dill, Reed Thorne, Hal Murray, and the Clem's. Many of the test scenarios they conducted using Prusik hitches were being done on 11 mm. PMI E-Z Bend™ with 8 mm. MAMMUT® and EDELRID® accessory cord.

The ratio of the size of the Prusik cord to the main rope is crucial. Generally, two cross sections of the Prusik cord should equal the cross section of the main line. With many products 8 mm. is the accepted size to use on 11 mm. rope. 9 mm. might be a better choice for 12.5 mm. rope. Practice with the accessory cord and rope you plan to use to make sure they are compatible together. Engage Prusik hitches under a load to see how they grip or do they break. 8 mm. MAMMUT® accessory cord was the cord of choice for a long time. However, the brand has been sold and the new manufacturer has changed the braiding process twice in recent years and MAMMUT® is no longer popular. PETZL® has come out with VECTOR™ cord made by Samson Rope®. It has a polyester sheath over a nylon core that work together to provide supple handling, greatly reduced sheath slippage, ability to retain shape, superior abrasion resistance, a diameter of 8.5 mm, and is rated at 17.8 kN (3,835 lbf.) This cord is available throughout North America. It seems to be a current excellent choice.

Another popular Prusik loop choice is a pre-sewn continuous loop made by Sterling® and sold under the name AZ 8 mm. Bound Loop Prusik™ rated at 20 kN (4,496 lbf.) It allows the Prusik to be snubbed up against a carabiner.

Webbing:

Webbing should be 2.54 cm. (1 in.) wide and rated at about 17.8 kN (4,000 lbf.) Mil-Spec 4088, Class 1A. Generally, it is made with a spiral weave on a shuttle loom, like a tube sock. But, as the manufacturing machines, which date from World War II, can no longer be repaired they are being replaced. Newer machines produce a product made on a needle loom. A version made by Blue Water® is woven flat, then folded and sewn with a double lock stitch along the edge. This modern process will not unravel, tests at about 20 kN (4,500 lbf.) and is cheaper to make. Before buying webbing always check the package label for the webbing's rated strength. Some brands of stitched, folded webbing, with a chain stitch, are made just for general use and should not be used in rope rescue.

If you want to make marks on rope or webbing, manufacturers recommend not using a product that contains phenol. If the ink smells like Pine-Sol™ it should not be used. If the ink smells like alcohol it is safe to use. SANFORD'S® Rub-A-Dub™ laundry pen is okay, but SANFORD'S® Sharpie™ marker is NOT. However, in 2001 Parker and McKently of CMC® conducted testing and could not prove that any type of marking would weaken a rope or webbing. In 2002 they determined that urine would weaken rope strength. In 2004 they reported, among other products, that contact with both DEET® and chewing tobacco spit would not weaken rope. In 2002 Jim Kovich, an Ohio firefighter, sewed rope into a rug and had firefighters wipe their feet daily on it for several months. He also had fire equipment repeatedly drive over the rope on the pavement. In both situations the rope tested to original specifications.

FEMA has had fire departments conform to specific webbing lengths and colors: green – 1.5 m. (5 ft.); yellow – 3.5 m. (12 ft.); blue – 4.5 m. (15 ft.); red – 6 m. (20 ft.); black – 7.5 m. (25 ft.). There does not seem to be a practical logic to those specific lengths and colors can be whatever is cheapest. Webbing should have the ends cut on a bias, at 30° to 45° angles, to make knot tying easier. Each end of webbing should have the length marked with a

Sharpie™. On one side mark the length in feet and on the other the length in meters. Now you know the length of each piece of webbing and the color does not matter.

When not in use webbing should be stored in a chain sinnet or 'monkey braid'. The webbing is doubled and starting at the bight end an overhand slip knot is formed, successive slip knots are added until the free ends are reached and they are tucked through the final loop.



webbing stored in chain sinnet

Anchoring:

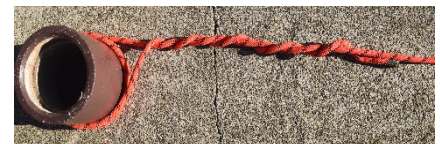
Anchoring with rope:

A good concept to think about, when tying an anchor, is to make it available for other uses. As an example, a user may need to be rescued. Consider placing two loops around an anchor, defined as a round turn. This will hold the rope in position on the anchor. Make a bight in the standing part and with the running end tie a double sheet bend with the end tucked by the running end being redirected through the knot so it exits parallel to the bight. Reed Thorne refers to this as a Blitz Anchor. Look at your exposure or pit and only use enough rope to place a meter or so on the bottom. Now tie loop knot, maybe a lineman loop or 'Alpine Butterfly' and clip that to your Blitz Anchor. The extra rope left is now available for other applications and the Blitz Anchor can be clipped into by a rescuer or others.



Blitz anchor

A more traditionally used anchor takes three wraps around an upright. Again, defined as a round turns. The objective is to have the rope snubbed around the upright absorb the energy of the load with friction so that the running end of the rope will have no tension on it. It is interesting to note that on a smaller diameter upright the rope will exert greater pressure



Tensionless hitch

on the upright's surface. If the surface is exceptionally smooth more than three wraps may be needed. There should be no rope crosses in the turns that might result in the rope rubbing on itself. Leave 1 m. (3 ft.) of running end and wrap it around the standing part. About fourteen crosses. Do not deflect the standing part. Generally, this is called a Tensionless Hitch, but some groups insist on calling this a 'high strength tie off'. The standing part can be used for a single application or in the standing end place a bowline or a Flemish loop. A bowline should have a back-up knot or redirect the running end around, so it passes back through the knot and ends up parallel with the standing part. The Flemish loop or 'figure-of-eight on a bight' has an extra loop and does not require any back-up. Both knots may, however, degrade the strength of the rope by 20% to 30%. These knots can be attached to working components or they may be clipped to a rigging plate at a designated anchor focal point, discussed later. A greater concern than knots weakening the rope is the ability to untie

a knot after it has been loaded. Bowlines have an advantage here. Flemish loops have a disadvantage.

When tying a loop in a rope consider that with 11 mm. PMI E-Z Bend™ the backed-up bowline uses 70 cm. of rope; 12.5 mm. uses 80 cm. The Flemish loop or 'figure-of-eight on a bight' will require a minimum bight of 45 cm. (18 in.) and then uses a total of 90 cm. of rope; 12.5 mm. uses 1 m. Good procedure provides loops only as large as are needed by a device. Knots and bends should be dressed, and tails should only be 8 cm. (3 in.) long. Adding an 'overhand backup knot' for a Flemish loop or 'figure-of-eight on a bight' is unnecessary, as it already has an extra loop, and is defined worldwide as the 'stupid American knot'.

Rope Protection:

If ropes must pass over rough edges, provide padding to prevent abrasion. One of the best appears to be the CMC Ultra-Pro Edge Protector™.



CMC Ultra-Pro edge protector

Alternative Rope Anchor Idea:

In areas without a single defined anchor but with rock outcrops, an anchor can be created. Take 30 m. (100 ft.) or more of 11 mm. (7/16 in.) rope. Divide into four equal parts. Using the side with one bight and two ends, tie a loose Flemish knot or 'figure-of-eight knot' with all four lines. Lay the four lines around an acceptable anchor area. Taking the side with two bights, complete a Flemish bend or 'figure-of-eight-follow-through bend'.



Figure-of-eight bend



alternative anchor with traditional tensioned working rope and un-tensioned belay rope

For back-up, connect all the bights with a carabiner or a piece of cord. Position the bend to the side of further action. You have created four independent anchors. A suggestion is to clip carabiners into one pair for your working components and the other pair for your belay. Make sure the interior angle, where the loads attach, is preferably 60° or less. A smaller system can be tied around another anchor for placing a change of direction pulley, if needed, to take advantage of a good flat working area. A pre-quartered rope with the first Flemish Knot or 'figure-of-eight' can be stored in a rope bag for rapid deployment. This idea is not appropriate where only two anchor points are so positioned that an isosceles triangle is created. This is referred to as the 'death triangle'.

Another rope anchor, using two anchor points, involves a large loop through both anchor points. Focusing towards the target, a bowline with a bight is tied that uses the bight retrace to form a forward facing loop, but the bight's tail, that is 60 cm. (18 ") long is directed into a bight pulled from the center of the bowline's loop and finished off with a double sheet bend (double becket bend). Retrace that rope back through the sheet bend. True knot craft.



Bowline with a retraced bight and a sheet bend

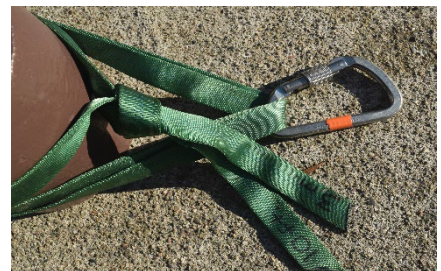
Anchoring with Webbing:

The best choice is to create a round turn type anchor with webbing. This will keep your ropes in better condition. For general use place two loops of webbing around an upright. Tie the ends together with a ring bend or 'overhand follow-through bend' leaving 8 cm. (3 in.) tails. As you start the retrace be sure to pull at least 30 cm. (1 ft.) of webbing through so you will have enough to complete the retrace. Locate the bend on the load or front side of the anchor. In this position the bend will not degrade the strength of the webbing. Pull out a bight to clip a carabiner in. WRAP TWO, PULL ONE. Try to make the interior angle, where the load attaches, 60° to 90° to allow possible additional attachments. BCCTR considers its strength between 24 to 26 kN (5,625 lbf.) Parker and McKently of CMC® tested it at 24.5 to 26.4 kN in 2001. For rescue loads: WRAP THREE, PULL TWO for a strength BCCTR considers about 36 to 40 kN (8,550 lbf.) at 30 degrees. Parker and McKently of CMC® tested it at 35 to 43 kN in 2001. A properly tied ring bend or 'overhand follow-through bend' in webbing does not need to have back-up knots as there is no documented evidence of a properly tied ring bend failing.



Wrap Three, Pull Two

Testing in 2016 led by Kirk Mauthner and his British Columbia group considered using the 'flat overhand bend' for 'wrap-three-pull-two' anchors. Their testing showed an average failure at 34 kN (7,480 lbf.), at the carabiner. They recommend leaving 15 cm. (6 in.) tails. This is a much faster



flat overhand bend

way to join the ends of the webbing for a WRAP THREE, PULL TWO style anchors.

Anchor Focal Point:

After a patient or the load has been located, the rigger should look for a location that is relatively flat and generally free of obstructions to deploy the raising and lowering equipment. If change of direction pulleys is needed, they should be positioned. The required distance for the working components should be allowed for and an anchor focal point established. Anchor leads, probably two or three, that will share the load should then be provided to this spot and connected to the back side of a rigging plate. This concept, defined as a “load sharing anchor”, is the center of all forces, and has leads of fixed lengths. The front of a rigging plate can also be tied off to a suitable anchor to keep it off the ground. Each anchor lead can be hard tied or can utilize a ‘pretension back tie’ which is a lashing involving an improvised three to one haul system (3:1) discussed later, using carabiners. Have someone vector each of the lines progressively to allow an increased pretension. It is good practice to also use pre-tensioned back ties or tie backs also on any anchor points. When using back ties for your anchors interlace your webbing connections and use the three ropes over the entire distance to reduce any possible elongation.

Connections Using a Soft Interface:

Whenever a knot is formed in a bight at the end of a rope, we accept that the strength of the rope is reduced by 20 to 30 percent. The use of the round turn at the anchor end eliminates using a knot in many applications, however, sometimes a knot at the connection point cannot be avoided. By using a soft interface, with the knot, the full strength of the rope can probably be reached again. After the chosen knot has been tied, take a loop made from about 1.35 m. of 8 mm. cord and tie a three wrap Prusik hitch around the standing line. Attach the other end of the loop to your anchor. Tighten the Prusik hitch so a droop of slack is in the standing line. The characteristic of a Prusik hitch is that it may start to slip when a force of around 5.3 kN



soft interface at end of rope



soft interface joining ropes

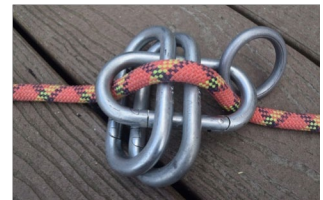
(1,200 lb.) to 7 kN (1,600 lb.) is reached. At that point, the strength of the knot comes into play. Between them, the full strength of the rope will probably be restored. Also, the droop in the rope, created by the soft interface, will act as a 'poor man's' dynamometer, and may visually indicate when a force of around 5 kN to 7 kN has been experienced. These soft interfaces can be placed wherever high forces might be expected.

Consideration:

The concept of a "load distributing anchor" or often incorrectly called a "self-equalizing anchor" attracts a lot of interest, but there are so many variables connected with its use that it might be inappropriate for general use. Keith Schafer did a study that demonstrated with more than a 30 cm. (1 ft.) shift of a 200 kg. (441 lb.) rescue load there was an extremely high probability that there would be a catastrophic failure because of the readjustment. This style of anchor can be made suitable if the webbing is gathered at the anchor focal point and seized with a piece of cord or tie all the legs together with an overhand knot. If the overhand knot method is used be sure to place a wooden toggle or a carabineer through the knot so it will be possible to untie it.

Lowering a Load with a Brake Bar Rack:

A brake bar rack, invented by John Cole, a cave explorer, is a descending device that directs the rope straight through the device and allows the amount of friction to be ADJUSTED when under tension. Its original design evolved from early carabiner rappels which allowed the rope to pass over one or more carabiners placed across another carabiner.



carabiner rappel

In the 1960's the Holubar Company® in Colorado began selling aluminum brake bars that could be slid on a non-locking carabiner gate and clipped over the spine. However, brake bars across a carabiner gate, the weakest point, proved disastrous when later tested with larger loads.



carabiner brake bar rappel

Cole simply formed a steel frame to accommodate several of these brake bars. The common commercial design brake bar rack has a welded eye on one leg and a nut on the other leg. These devices have become extremely popular in rope rescue. Though these welded eye versions are rated by manufacturers at around 44.44 kN (10,000 lbf.), during informal testing by Kim Aufhauser, of West Valley College, with an applied force generated by six persons pulling a 3:1 mechanical advantage it has been discovered that the regular first bar tilts, the rack frame begins to deform, and other bars will bind. With a force of 26.22 kN (5,900 lbf.) Bruce Parker, of CMC®, reported that a standard SMC® folded stainless-steel bar began to collapse. Some rack versions have a wrapped eye, as did John Cole's original rack had, but Butch Feldhaus, of NCRC, reports they tend to unwrap with a 5.33 kN (1,200 lbf.) force. A



John Cole's original rack

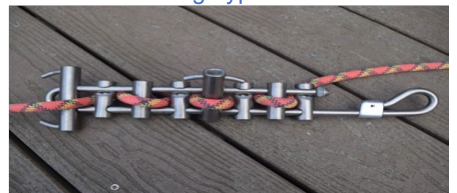
knowledgeable welder, familiar with racks, can retrofit the wraps and weld an eye. Avoid placing unintended forces on a brake bar rack.

Bruce Smith, author of On Rope, considers it important how the bars are arranged on the rack. With standard bars, the first bar has about 90° of contact with the rope. The second through the fifth bar each have about 180° of contact. The sixth bar's contact varies. The first three bars will generally take most of the load and absorb the most energy. Bar four less, bar five still less, and bar six the least. The user also takes a small amount of the load. As an enhancement, an oversized stainless-steel bar can be placed in the second bar position. This large bar will increase the rope contact area but may develop more heat. This bar should be hollow to help dissipate the heat. Avoid using an oversized aluminum bar in the second bar position, as it may absorb too much heat. Nylon will start to melt, glaze, or become tacky at about 122°C [250°F.] and a liquid at about 248°C [480°F]. During a 70 m. (230 ft.) rappel, with a descent rate of one meter per second, Bruce Smith has measured an aluminum bar at 150°C [300°F], but the heat dissipated quickly. Other testing has been done to analyze the temperatures of each stainless-steel bar during 244 m. (800 ft.) descents. Some results indicate a 204°C [400°F] peak during the five-minute descent and a 127°C [260°F] peak in a nine-minute descent. Always pass the rope directly OVER the first bar when you attach the rack. With the traditional racks, orient the short leg away from you or on the bottom to allow the rope to be passed back and forth when bars are added or subtracted. Bars should pivot on the long leg so when they are not being used, they can be stored in the 'well'.

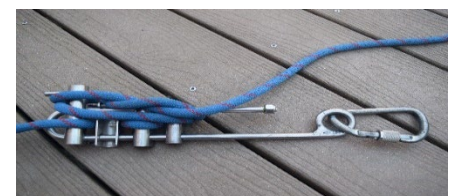
Another rack improvement is to replace the first bar with a snug fitting, extended stainless steel bar, referred to as a hyper-bar. Sam (Larry) Howell, from Colorado, is credited with this idea. The bar extends about one inch past the short leg and has a vertical steel pin in the end. This allows the rack to be tied off with ease and offers a leverage point, if needed, to move the bars closer together, to more efficiently increase the friction created by the regular bars. If this technique is used, bar six should be a round type rather than a folded type with edges. To save money, a round aluminum bar may be used here since bar six experiences the least friction. Howell also manufactured a rack that not only had the hyper-bar but also included another extended bar in the middle of the rack. When this bar was pulled against the rope it acted as a brake and slowed down one's descent. Pure aluminum brake bars may generally create more friction; but wear excessively, are hotter to the touch, and transfer aluminum oxide to equipment and clothing. Bars with titanium over aluminum have been experimented with, but in practical use it was discovered that the bars wore out quickly on excessively dirty ropes. Heavier gauge titanium is prohibitively expensive in the United States. Current practice in the cave rescue community favors using only stainless-steel bars. To tie off a rack with a hyper-bar: With the running end of rope over the hyper-bar pass it under all the bars and bring a bight of rope back



using hyper bar



Howell's other rack version



rack tie-off



modified rack tie-off

up towards the hyper bar pin. Put at least a full twist or more in the bight so the ropes cross and hook the bight over the vertical pin. Remove any slack. Sometimes a safety officer may require a modified rack tie-off that can be observed from a distance. In this case, pass the rope over the top of the rack and pull it down. Bring the rope under the bottom bar and forming a bight of rope, bring it above the rack and tie two snug half hitches with the bight around the standing part. This tie off will be visible from a great distance.

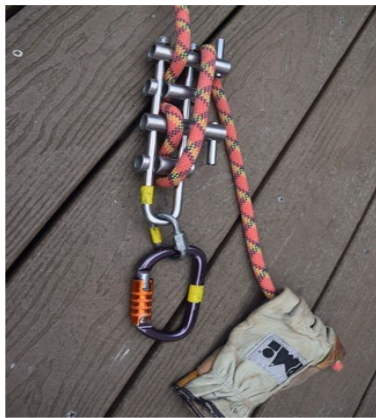
An improved rack design is now available that may be more appropriate for rescue forces. It is U-shaped with nuts on both ends and is anchored from the bend in the frame. A current version with heavy gauge stainless steel bars is manufactured by BMS® in West Virginia and is comparably priced to the traditional racks. In testing that the manufacturer had done by LTI, Inc. of Dublin, PA, the nuts did not fail until 97 kN (22,000 lb.) of force was applied. In further testing with an 11 mm. rope in its proper function, but tied off, the second, round stainless-steel bar started to deform when it experienced 27.5 kN (6,200 lb.) of force. In the same sequence of tests, an NFPA approved rack with standard aluminum bars had the third bar shatter when it experienced 17.7 kN (4,000 lb.) of force. It may take more skill to operate this U-shaped style of rack, as three brake bars are fixed to the frame. This U-shaped rack is the standard width of SMC® rack frames and comes with a hyper-bar that extends from both sides of the frame. For increased efficiency, as an accessory, an oversized steel bar could be placed in the second position. To place this rack on a rope, rotate the three moveable bars away from the frame. Push a bight of rope through the frame and engage a bar. Check that this bar is orientated to lock correctly. Push a bight through the frame for the other two moveable bars and engage them. Remember to engage ALL available bars and pass the rope over the hyper-bar before starting to use a rack. Check again that the rope is threaded properly over the bars. With all bars engaged and the rope over the hyper-bar, the rack can be tied off by taking a bight of the running end of rope and push it through the frame. Placing a full twist in this bight, hook it over a pin on the hyper-bar and remove any slack.



U-shaped rack



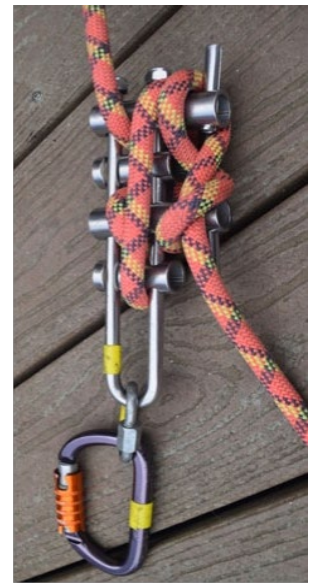
U-shaped rack tied off



descending with MICRO-Rack

A smaller version of the U-shaped rack, MICRO-RACK™ manufactured by BMS has only four bars. The first bar is a fixed hyper-bar with the pin pointing up, second bar is moveable, third bar is a fixed hyper-bar with the pin pointing down, and fourth bar is moveable. This arrangement for the bars can be attributed to an idea from Rick Lipke. The rope weaves through the bars and passes over the top hyper-bar when in use. The frame strength exceeds 62 kN (14,000 lbf) and the second bar will start

to collapse around 23 kN (5,200 lbf.) To tie off the rack, pass the running end of rope under the bottom hyper-bar, place a full twist or more in the bight, and hook it over the top pin and remove any slack. This rack is immensely popular with cave explorers and with adequate experience will also handle rescue loads. In all operations always have the rack set up and off to the side in case a change of direction is required in any exercise.



tied off MICRO-Rack

Two rack safeties are often used. The best one connects a 6 mm. or 7 mm. Prusik to the rope as it enters the rack. The other, uses an 8 mm. Prusik attached to a Load Release Hitch and connects to the rope as it leaves the rack. Both methods will pass the whistle test discussed later.

Figure-of-eight descending devices are still used but cannot be adjusted under tension, tend to twist the rope, will cause problems in the internal rope construction, must be unclipped to attach, are difficult for many to control a rescue load of 200 kg. (441 lb.) once it starts to move. They are not a good choice for use in rope rescue.

Belaying a Load:

A basic philosophy is that the belay line is only used for the belay function, and it is not used in shifting the load during a working operation.

During World War II, for airborne operations, testing by the US Army determined that the human body is usually damaged when it experiences a force of about 12 kN (2,700 lbf). It might be concluded that all techniques and devices must allow a dissipation of force before 12 kN is experienced or injury can occur. OSHA revised the force issue to 8 kN per person. Dr. Maurice Amphoux recommended 6 kN force. BCCTR decided on 15 kN for an entire load, consisting of 6 kN for patient, 6 kN for barrow boy or attendant, and 3 kN for gear.

The BCCTR proposed that for a belay device to be acceptable, it must arrest a 200 kg. (441 lb.) load free falling 100 cm. (3 ft. 3 in.) on an initial rope length of 300 cm. (9 ft. 9 in.). The resulting Mass Arresting Force must be less than 15 kN (3,375 lbf.) and that the stopping distance must be less than 100 cm. (3 ft. 3 in.). Afterwards, any releasing hitch or other device must be easily undone and used to lower the mass under the control of one person.

ASTM has now adopted a similar belay test standard, but theirs does not include a stopping distance. That decision is left to the user.

The mountain rescue community considers 80 kg. (176 lb. or 13 stone) as a one person climbing load; 200 kg. (441 lb. or 32 stone) as a two-person rescue load; and 280 kg. (617 lb. or 44 stone) as a three-person large rescue load or NFPA two-person load.

Mezzo Barcaiolo (MB) Hitch Belay:

A popular belay involves the use of a Mezzo Barcaiolo [bar-ca-io-lo] hitch ('mezzo' meaning 'half' and 'barcaiolo' meaning 'boatman' hitch) or MB hitch on a Halbmastwurf-Sicherung or HMS carabiner. A background story by Carlo Zanantoni, of the Italian Alpine Club Safety Commission, is that the technique was developed by Mario Bisaccia, Franco Garda, and Pietro Gilardoni. The Britons will refer to it as an Italian Hitch. The Americans will call it Mnter's Hitch, referring to a Swiss guide named Werner Mnter who demonstrated the MB hitch during his visit to mountaineering circles in the United States in the 1970's. This hitch is also referred to as a carabiner hitch, HMS hitch, and snap break. Referring to it as an MB hitch would best reflect its origin. When applied correctly it can provide friction in both directions. For some applications, involving equipment only, or a single person load on a steep incline it will be an excellent choice. However, informal tests have repeatedly shown that many persons cannot control a 200 kg. load using a MB hitch once the load starts to move. In 1.50 seconds, a normal reaction time that includes the thinking time, plus movement time, plus response time, an object will travel approximately 11 m. (36 ft.) in free fall, less with friction.

Effects of Gravity

The distance that a free-falling object has fallen from a position of rest is dependent upon the time of the fall:

$$\text{Distance} = 0.5 \times \text{gravity (9.8 m)} \times \text{time (seconds)}^2$$

Falling Time in Seconds	Displacement in meters	Displacement in feet
0	0	0
1	4.9	16
2	19.6	64
3	44.1	143
4	78.4	255
5	122.5	388

Further testing by Kirk and Katie Mauthner has shown that there is a wide range of gripping abilities among the general population, ranging from 46 N. (10 lb.) to 426 N. (96 lb.) in their inferred statistical population range. The average person probably has a gripping ability, of

about 209 N. (47 lb.) with one hand. The angle of the rope in and out of the MB hitch, edge padding, presence of a shock absorber, and the length of the rope all may increase the effectiveness of this belay. It is best applied with a 0° angle on the ropes and the load rope dragging over a padded edge surface.

In conclusion, it is unlikely that an average person can hold a rescue load with an MB hitch once it starts moving and be able to tie the hitch off. A version of the MB hitch (super MB) places an additional bight around the standing part on the rope and passes it through the carabiner a second time to create a super MB hitch which might be more appropriate for heavier loads. This hitch may require an extra-large steel carabiner to allow it to change direction.

Another idea to make the MB hitch very safe is to use a tied off Prusik hitch on the control side rope. Without modifications, the fact that an MB hitch belay works is conditional on the belayer holding on to and controlling the rope. **BELAY EXPERIENCE IS ESSENTIAL.**

A variety of other techniques and devices are often also described as belays. Some may be satisfactory for their intended use for a single person load of 80 kg. (176 lb.) in rock climbing. But in rope rescue, they are also conditional at best. A proper belay should pass the “BTCCR critical point test”, that asks, ‘Is there any one point in the system, that were it to fail, it would lead to catastrophic failure?’ For maximum safety, the belay device should also engage without attention. The “BTCCR hold up [or] whistle test” is for objective hazard and asks, ‘What happens to the patient, attendant, and other rescuers if everyone were to let go?’ At the sound of a whistle have everyone let go of the rope and hold up his or her hands. If the belay holds, it should be safe to proceed. Despite its popularity, a standard MB hitch, without the Prusik safety, fails this test.

Tandem Prusik Belay:

Tandem Prusik hitches may be the safest and most inexpensive technique to use, however, their use may require the most training and aptitude. This hitch or ‘double strap’ comes from seamen’s traditional techniques of ‘strapping a rope’. Dr. Karl Prusik introduced this hitch to the mountaineering community, and it is usually described with his name. In Sweden however, the name given to this hitch, translates to English as “triple Lark’s foot”. Use two pieces of 8 mm. cord, 1.35 m. (53 in.) and 1.65 m. (65 in.) long, the accepted North American standard lengths. Joining the ends with a Grapevine Bend or ‘double overhand bend’ creates each loop. Tie three wrap Prusik hitches with each loop around your belay line. Tie them neatly with the hitches’ bridges matching and bends offset to a side. When both are snug and positioned, the hitches will be about 10 cm. (4 in.) apart. Generally, when engaged, Prusik hitches were thought to slip slightly before other parts of the system were stressed. The compatibility of cordage to rope may be a real issue as with some matches the loop breaks before the hitch slips. It was first thought that the Prusik hitches worked in tandem, but it appears that one Prusik hitch takes most of the load. As it grips, it bends or tilts the line being engaged, at an angle. The second Prusik hitch is then unable to bend the rope and therefore is not effective in gripping. Close observation of how Prusik hitches work is warranted.

The BCCTR and other groups have repeatedly tested tandem Prusik hitches, and they have been found to be an exceptionally reliable belay with a proper technique. Current knowledge shows that the 10 cm. offset between the hitches is not critical but makes them easier to work with, provides better photos, and allows them to sustain higher falls. Two wrap Prusik hitches, used by climbers, do not have enough dynamic capability, and tend to heat up too much with rescue size loads. The rope entry issue into Prusik hitches remains a concern. So properly dressed, snug hitches, with good technique is a major issue. Users must be very attentive and keep the hitches snug but free running. A properly tied Prusik hitch will make a noise and vibrate as the rope is pulled through it. The BCCTR speculate that the first Prusik takes between 7.0 kN and 9.5 kN of force (90%). The second Prusik only increases that force to 10.5 kN (10%). Users should experiment with their chosen cordage to try to determine when their particular Prusik hitch will slip or if the loop will break.

On a lowering, the correct technique for the belayer is to grasp the front Prusik hitch, closest to the load, with one gloved hand. Pull out any slack in the anchor rope and have the hitches in line with the load. Rotate the gloved hand 90° so the Prusik hitch is orientated vertically. Grasp the belay rope with the other gloved hand. With an upward motion pull out some belay rope. Move your hands next to each other creating about a 30 cm. (12 in.) bight of slack. Keith Schafter's study concluded that a 30 cm. shift in a rescue load would probably not have an adverse effect. As the load takes this slack the gloved hand rotates, feels the load, and allows the belay line to slide. When the bight is gone the gloved hand pulls up and out another bight of slack. Listen for the noise the rope makes and feel the friction as it passes through the Prusik hitches. The gloved hand is held at 90° and holds the front Prusik steady so it will not tighten and keeps any slack out of the anchor rope.



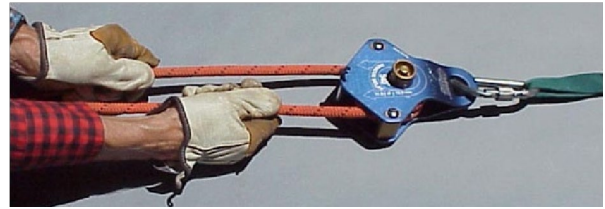
belay hand position sequence

During a haul, the back Prusik is held by one gloved hand and the belay rope pulled up through both hitches to prevent any droop of slack. If you have two sets of loops available, you will be able to safely pass a bend. It is best to use a 'manly' method and pull the rope through the Prusiks. However, on a long haul the belayer may need help bringing up the rope. In that case the 'wimpy' method may be used to pull the belay rope up through a pulley. You might think that a Prusik Minding Pulley would be the best choice. In 2007 Reed Thorne reported having a failure with a 200 kg. load being tended by a tandem Prusik belay, using new Sterling cordage Prusiks on new Sterling rope, and with a Prusik Minding Pulley. This concern had been discussed a lot in the late 1980's and John Dill considered this in his paper Are You Really On Belay? Thorne's recommendation now is to use the 'manly' method to bring the belay rope in. If a pulley must be used, use a round pulley which will force the tandem Prusiks up on the pulley's side. In that position the rope will exit the pulley in a 90° orientation increasing the potential they will grip in an emergency.

Holding the tandem Prusik hitches at 90° allows them to effectively grip the rope. If a shock load were to be experienced the Prusik hitches just rotate 90° and lock. Your hands will move with the hitches. Whether your thumbs are in or out does not appear to be an issue.

Other Rescue Belay Devices:

Now available from Traverse Rescue® in British Columbia is the **540° RESCUE BELAY™**, a pulley like device, which allows a line to be belayed in either direction. It automatically engages when shock loaded and has a release lever to slowly release it. It also requires skill, as back pressure is required, to keep the unit from locking unexpectedly. Two sizes are offered. A small unit (green) fits 11 mm. rope and less. A large unit (blue) fits 12.5 mm. rope and greater. Weighs 666 grams (1 lb. 7 1/2 oz.) and costs about \$382.00 USD. Passes BCCTR drop test and is considered the best belay device.



belaying with 540 RESCUE BELAY™

The **MPD™** or **MULTI-PURPOSE-DEVICE** is sold by CMC®. It can function as a pulley, descent control device, progress capture device, and a rescue belay. It comes in two models for 11 mm. (7/16 in.) grey or 13 mm. (1/2 in.) red. It weighs 1.2 kg. (2 lbs. 10 oz.). Its use requires considerable practice but, it can replace some equipment required for most operations. How friction is properly controlled is a major issue. The T-handle is not designed for friction control. Using the MPD in a belay mode is exceedingly difficult. The user's manual should be thoroughly read, and the unit practiced with regularly. Weighs 914 grams (1 lb. 2 oz.) costs about \$ 799.00 USD.



using an MPD

The **Petzl Gri-Gri™** has a working load rating of 80 kg. (180 lbs.) Some testing of the Petzl Gri-Gri™ using rescue loads was started in the United Kingdom. Then, in Canada in 2000, 200 kg. (441 lb.) was dropped, by the author, on a Gri-Gri™ to the BCCTR standard. The extension exceeded the limit standard by 2 cm., but the load was caught and could be released under control with one hand. One side plate was slightly sprung. More investigation could be warranted. Weighs 225 grams (8 oz.) and costs about \$ 129.95 USD. Other versions of the Petzl Gri-Gri are the Model 2 and 3, both of which operate similar to the original but are smaller and lighter 173 grams (6 oz.) For all these versions, if you pull the control handle all the way down you will be out of control.



Petzl Gri-Gri

The **Petzl Gri-Gri +™** is the latest variation. It has a control handle, that if pulled down in a panic, the device will grab the rope and stop you. It also has a locking dial which adjusts the resistance of the device's cam spring. In the lead climber mode, it operates like the original. In the top roping mode, the cam has increased sensitivity and grabs the rope quicker. The Petzl Gri-Gri +™ also accepts a wide variety of rope sizes from 8.5 mm. to 11 mm. Otherwise it belays like the original



Petzl Gri-Gri +™

Petzl Gri-Gri™, but makes it easier to use as a descent device. It weighs 209 grams (7 oz.) and costs \$129.00USD.

The **Petzl Rig™** has a working load rating of 80 kg. (180 lbs.) and is for experienced users in work positioning. It locks when you let go of the handle, but does not lock if in a panic you pull the handle down. It does pass the BCCTR drop test. Weighs 400 grams (14 oz.) and costs \$219.95 USD



Petzl Rig

The **Petzl I'D™** is similar to a Rig™ but has more safety features. It will lock if you let go of the handle. It will also lock if you pull the handle down in a panic. Testing with 200 kg. (441 lb.) load dropped 1 m. on 1 m. of rope, showed a force of 6.3 kN. and had a slippage of 38 cm. (15 in.). Weighs 539 grams (1 lb. 3 oz.) and costs \$299.95 USD.



Petzl I'D

The **Harkin (CMC) Clutch™** is similar to the MPD™ but, seems to be more user friendly and has become the author's choice. Testing with a 200 kg. (441 lb.) load dropped 1 m. on 3 m. of Petzl EZ Bend™ showed a force of 9.25 kN and had a slippage of 22 cm. (8.6 in.) Weighs 836 grams (1 lb. 13 ½ oz.) and costs \$649.00USD.



Harkin (CMC) Clutch

The **Petzl Maestro™** has been tested with a 250 kg, (550 lb.) load dropped 1 m. on 1 m. of semi-static rope showed a force of 9.4 kN and had a slippage of 1 cm. The author is unfamiliar with it. Weighs 1100 grams (2 lb. 7 oz.) and costs \$549.95USD.

When attached to an anchor carabiner most of these devices will be orientated horizontally. In some applications it might be better to have the device orient vertically. This can be accomplished by using a 'helical-shaped' carabiner. An example is the Kong Ovalone DNA™ carabiner. Weighs 227 grams (8 oz.), and costs \$36.95USD.

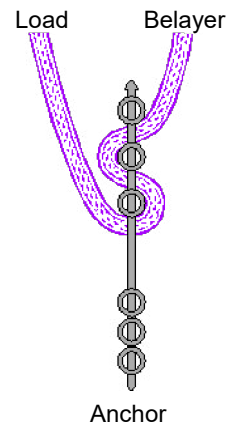


Kong Ovalone carabiner

During the year 2000 Carroll Bassett of BMS® in West Virginia began investigating the use of closed frame racks as belay devices. He discovered that if a rack is rigged upside down a load would tend to squeeze the bars together, generating friction in proportion to the load applied. A test model, close to the BCCTR standard but with a 136 kg. (300 lb.) load was set up using 11 mm.



NANO-BELAY with UNLOADER



(7/16 in.) PMI E-Z Bend™ and three tubular stainless-steel bars on a closed frame. The results showed a rope slip average of 50 cm. (20 in.) and an average anchor force of 8.2 kN (1,845 lbf.) calculated by a high-speed digital force measuring system. Another test was tried using four bars and the result was a ROPE FAILURE. Only use three bars. To configure a rack as a belay device, anchor the bend side. Pass the rope from the load over the third bar up from the nuts, a half turn around the second bar, and a quarter turn across the first bar. The belayer holds this end. In raising, the belayer pulls in the rope. In lowering the belayer must hold the third bar up to allow the rope to pass. When a shock load occurs, the third bar is pulled from the belayer's grip. The loaded rope now pulls the bars together creating friction and arresting the load. Belayers had problems holding the third bar up. In spring 2001 the NANO-BE-LAY™ and NANO-UNLOAD-ER™ were introduced. Open eyes allow the belay to be attached anywhere on a line. The third bar was extended and cut to make holding it easier. The Unloader uses a lever device to gradually free the locked off bar. Costs about \$ 200.00 USD.

When one or both traditional tandem Prusik hitches lock and cannot be released because they are under tension, consider a load release hitch.

Load Release Hitch:

To overcome the problem of a belayer allowing the hitches to lock at the wrong time, place a Load Release Hitch above the tandem Prusik hitches so they can be released. This hitch, developed by Arnor Larson, exceeded the BCCTR testing model. The hitch also acted, it was thought, as a shock absorber, increasing the safety factor of the unit. This may be just a myth with 200 kg loads on modern ropes. Also, if this hitch did function as a shock absorber, you would increase the distance the load would travel causing increased forces.

In December 1999 Kirk and Katie Mauthner published a comparative analysis of the eleven most popular release devices. The original British Columbia – Load Release Hitch continues to be acceptable but has been over-shadowed by the Radium Release Hitch 3:1, which was developed during the study, while enjoying a soak in the Radium Hot Springs, and is now recommended for use by the Mauthner's. Start with 10 m. (33 ft.) of 8 mm. low stretch cord and two locking, 25 kN rated at a minimum, carabiners. Lite steel 40 kN carabiners might be the best choice. Tie a poacher's hitch or 'double overhand slip noose' on the load-side carabiner on its spine side. Run the cord up through the anchor carabiner, back down through the load carabiner, and up to the anchor carabiner again. Allow about 12 cm. (5 in.) between the carabiners. Tie an MB hitch on the anchor carabiner on its gate side. Ensure that the MB hitch is in the release position with the in-feed cord towards the gate side of the carabiner. Secure the Radium Release Hitch by using a bight of the in-feed cord to tie a half hitch around the long axis just below the MB hitch. Then back that up with another half hitch with the bight, again around the long axis, but do NOT capture the running end of the in-feed cord. If you do capture the running end any pull on the in-feed cord will tend to untie the half hitch. The excess cord can be placed in a Chain Sinnet or 'monkey braid', but the best choice is to use a small stuff sack (3 in. by 3 in. by 8 in.) to store the cord in. A loop can be placed in the other end so it can be clipped to a secure anchor if desired.



releasing a Radium 3:1 hitch

NEVER use a Load Release Hitch until you have determined where the load is being shifted to and you have estimated the distance necessary to accomplish this. This distance may be roughly estimated. If only 31 m. (100 ft.) of rope is in use, with 2 kN of force applied, a two-person load, and the rope stretches about 5%, it will require about 1.5 m. (5 ft.) of distance to remove the rope stretch and about another 1.2 m. (4 ft.) of distance to transfer the load to another rope. This is a total of about 2.7 m. (9 ft.), and this is close to the limit for the Radium Release Hitch 3:1. If one cannot determine a distance, do not untie the load release hitch.

A compact alternative with 5 m. of 2.54 cm. tubular webbing is to use a Mariner's hitch. The Mariner's hitch does not use an MB hitch, but after the midpoint bend, wraps the webbing through both carabiners several times. The excess is secured with a half hitch and is tucked away. This version could be dangerous as it does not seem to offer the control the rope version does as you attempt to loosen it.

Remember, the use of tandem Prusik hitches requires skill and careful attention. **A BELAYER SHOULD BE YOUR MOST EXPERIENCED PERSON.** After using a Load Release Hitch always retie it, so it will be ready for its next application.

Because of distance limitations and difficulty in tying, some trainers do not teach load releasing hitches, but rely on a jigger or other techniques to resolve jammed Prusiks.

It makes common sense to use a belay whenever possible, and usually it can become a matter of habit. However, if the rope distance is more than 90 m. it is probably not advised to use a belay as the ropes can tangle.

Raising a Load:

Ideal Mechanical Advantage Concepts:

1:1 - Without any mechanical advantage: A direct pull is called the “Armstrong Technique”.



1:1 with PCD

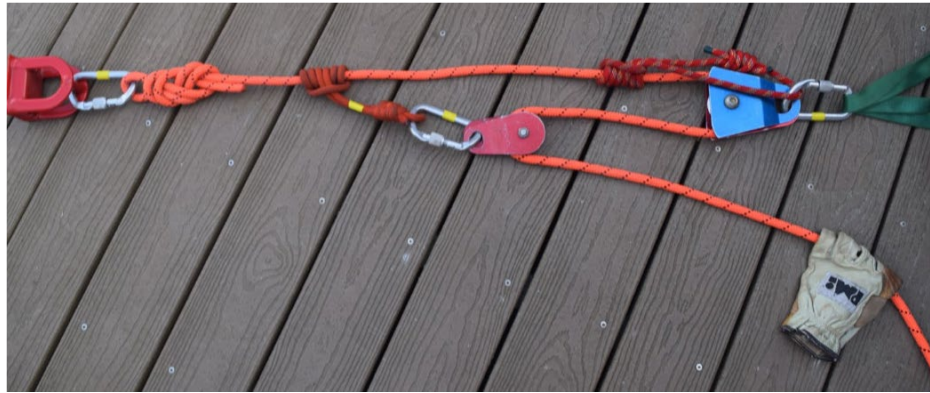
2:1 - Mechanical advantage: In order to have a 2:1 advantage, a pulley is attached at the load side, and it travels with the load towards the anchor. Watch for possible abrasion on the rope on the non-moving side. Watch that the traveling loop does not snag on something.



2:1 with PCD

Two of these systems compounded together provide a 4:1 mechanical advantage.

3:1 - Mechanical advantage: In order to have a 3:1 advantage there must be two pulleys. The first pulley, when following the load rope away from the load is attached to the anchor. The load rope is directed back to the load and the second pulley is attached to the load side and travels with the load towards the anchor system.



3:1 with PCD

The most common systems are either 2:1, 3:1, or combinations of the two. Compound systems must be multiplied together, NOT ADDED. Additional pulleys that are added, usually just change directions of the haul for convenience. To get the greatest mechanical advantage with the smallest number of pulleys compound several 2:1 systems. For safety and to demonstrate proper technique a haul person should stand in one place and just pull hand over hand. In this mode each haul person will pull about 22 kg. (50 lb.) If difficulty is being experienced by a haul team increase the mechanical advantage.

Many sources agree that, as a rule of thumb, the size of a pulley should be four times the diameter of the rope for about .85 efficiency. With modern kernmantle rope this may no longer be true. Traditionally, for 11 mm. (7/16 in.) rope use a pulley with a 2 in. tread. Beware, some pulleys sold as 2 in., are turned out of 2 in. stock and the tread is closer to 1 ½ in. Manufacturers claim ball bearing pulleys have an efficiency of .95, Oilite bronze bearing pulleys .85, and a common carabiner .60. Oilite bronze bearing pulleys are an excellent choice in poor conditions as they can be cleaned and lubricated when they get dirty. Place the best pulleys you have closest to the haul position or in the moving pulley positions for greatest efficiency. It is good practice to always apply your pull at 0° to your other lines.

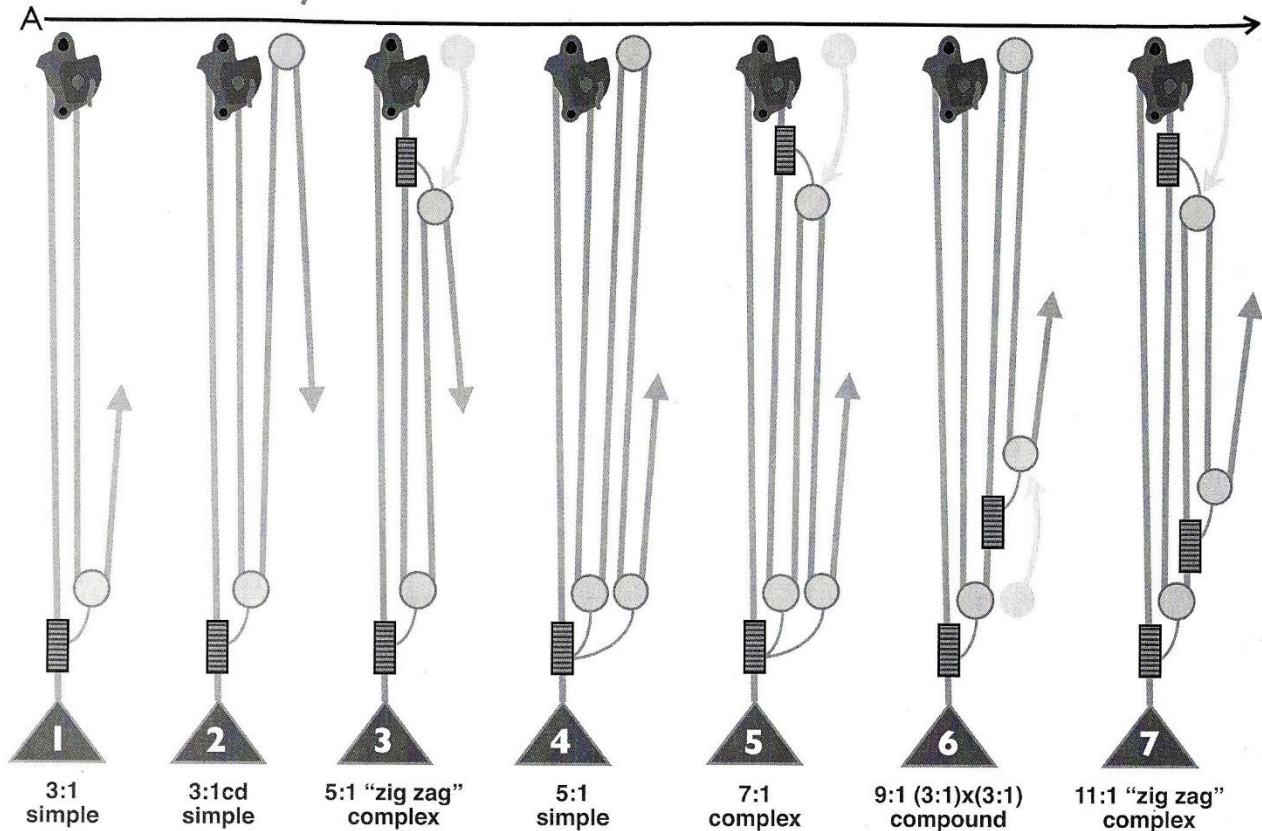
If it is necessary to prove the amount of mechanical advantage being applied, the most graphic way is to measure the distance of the pull in relation to the distance the load moves. If you pull three meters and the load moves one meter, the mechanical advantage will be about 3:1.

Another way to calculate mechanical advantage is referred to as the “T” method. For a 3:1 system, starting at the haul side, slide your hand down to the first moving pulley. As your hand follows the rope around this moving pulley say, “One tug in and one tug out” noting that where the pulley is attached has ‘two tugs’. Your hand follows the rope up and around a stationary pulley and say, “One tug in and one tug out”. Continue sliding your hand down towards the load and where it intersects your attachment with ‘two tugs’ say, “One tug plus two tugs equal three tugs” or 3:1.

Mechanical advantage systems are either simple, with all moving pulleys moving at the same speed as the load; compound, with moving pulleys usually moving at different speeds; or complex usually with pulleys moving in different directions. It is often easiest and safest to use available personnel and pull the load up without using any mechanical advantage or the least mechanical advantage needed.

Reed Thorne of Ropes That Rescue™ developed a mechanical advantage progression:

Arizona Progression of Seven - 2013



Attaching to the Main Line:

Various techniques are presented.

Traditional Prusik hitch:

Traditionally, a single three wrap Prusik hitch, was used for the haul system. Experiment with your cordage and use the smallest loop possible to accommodate the three wrap Prusik hitch. The Prusik hitch was chosen because of the characteristic that it will probably slip when experiencing a force between 7 kN and 9.5 kN (1,575 lbf. and 2,125 lbf.). During a haul sequence, if it does slip, STOP the raising



traditional Prusik hitch

operation, and determine what the problem is. Have a couple units available, as this loop may start to glaze during the resets after continuous use. Over the years the Prusik hitch has always been tied where the bend is offset on the attachment loop

Bend-on-the-Bridge Prusik hitch:

I once heard about the 'quick release Prusik' where the bend is positioned over the wraps in the 'bridge' position. Knowledgeable people, however, were satisfied with the traditional tie and all its available testing. There were no testing results available for the 'quick release' version. Warwick Marlin and Dagmar Muhlbaner of Emergency Care Services in South Africa have now completed a study that compares the traditional Prusik hitch and the 'bend-on-the-bridge' Prusik hitch. Their results showed the traditional Prusiks had an average failure at 11.08 kN (2,497 lbf.) and the 'bend on the bridge' Prusik an average failure at 11.22 kN. (2,524 lbf.). The average slippage was much greater for the 'bend-on-the-bridge' Prusik at 18.6 cm. (7 in.) compared to 5.46 cm. (2 in.) for the traditional Prusik.



bend-on-the-bridge Prusik hitch

The slippage with the 'bend-on-the-bridge' Prusik was more consistent and occurred sooner so would make it a good choice as a 'load limiter' in a haul system. This version must be carefully dressed, however.

Blue-Water VT Prusik™:

Currently the Blue-Water VT Prusik™ is becoming popular. It was developed by Rich Carlson of the American Canyoneering Academy and is a variation of a magnus hitch used to strap a rope. It is constructed using a heat resistant Technora™ aramid sheath over a nylon core with sewn eyes at each end. The diameter is 8 mm., and the length is 80 cm. (31 in.). Pulled end to end the MBS is 16 kN (4,400 lbf.) The instructions show its use configuration three ways: Valdotaire Tresse, Distel, and Schwabisch. The Schwabisch, tied as an asymmetric Prusik, is the most popular. A lot of current testing is being done with it and it can accommodate various diameters of rope when configured in what is being called by Rigging for Rescue® 'max over one'. As many wraps as possible are made on the load side of the hitch and one wrap is made on the haul side. Passes BCCTR drop test. Costs about \$22.00 USD.



max over one on 11 mm. rope



max over one on 8 mm. cord

Rescucender™:

An alternative is to use a Rescucender™ in place of the hitch. In informal tests by a six-person haul team on a 3:1 mechanical advantage, the Rescucender™ generally slipped about 10 cm. (4 in.) as the team about reached their pulling limit. The Rescucender™ success varies, however, with different brands of rope. A new first generation Rescucender™ has also been known to cause failures.



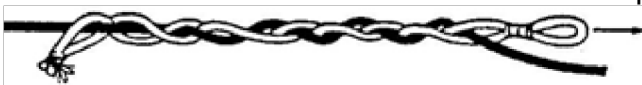
Rescucender™

New early model Rescucenders™ should have ± 100 m. of rope run through the device to smooth out any possible burrs near the wear pin. Newer versions of the Rescucender™ do not have a wear pin. The Rescucender™ should also be connected by a soft link using 55 cm. (18 in.) of 8 mm. or 75 cm. of 9 mm. cord to eliminate potential binding on a rope when a haul system is applied. Costs about \$90.00 USD.

Gibbs® ascenders are not a good choice for use in rope rescue. Six persons pulling at a 3:1 mechanical advantage can regularly cause the sheath and then the core of a rope to fail. John Dill reported that in 50 cm. (20 in.) drop tests, with a rescue load, the rope was cut often. Both ascenders come with warnings that they are designed for one person loads and are pull tested to 4.44 kN (1,000 lbf.) ONLY. They should NEVER be used in a dynamic belay situation. In practice however, for specific applications, the Rescucender™ tends to slip, on most ropes, reducing the tension, while the Gibbs® tends to destroy the rope. The variety of newer versions of Gibbs® ascenders need more testing results. With repeated applications most still cut the rope.

Cross-Lashed Strap:

If it is necessary to make an attachment to a mainline, loaded or not, use a cross-lashed strap or 'dog-n-tails', common in the maritime industry. Using about 1.80 m. (70 in.) of 8 mm. or 9 mm. of accessory cord, find the midpoint and create a loop and seize it with whipping cord. This is laid against the rope you wish to attach to. The tails are laced back and forth, over and under the rope. Usually, the traditional fourteen crosses will result. The ends can be whipped together with a small piece of cord. When this hitch is collapsed it can be positioned where it is needed. When located pull the tails smoothly away from the loop. Even under tension it can be moved down a rope.



cross-lashed strap

A cross lashed strap or 'dog and tails', is not a good choice for a haul device as it will not slip when positioned. For a hauling application it would be safer to use a hitch that may slip. In a drop test the author observed a cross lashed strap catch a 200 kg. load using the BCCTR drop standard. A longer version of a cross lashed strap can be used to pass knots through a descent device.

Capture the Distance the Load is Hauled:

A variety of terms, 'safety', 'ratchet', etcetera, are used to describe this action in rope rescue but 'Progress Capture Device' has been found to be easiest way to translate this concept into foreign languages.

There seems to be a practical difference of where a progress capture device is located. Mountain rescue trained personnel place it back at the anchor. Cave rescue people historically placed the progress capture device in front of all activities, usually at the edge of a drop. Placing the unit closer to the edge may allow that person to provide communication between the litter attendant and the haul team. The progress capture device uses a single three wrap Prusik hitch, 1.35 m. attached to the anchor. A second 1.35 m. Prusik loop should be available in case a bend must be passed. An alternative is to use a Rescucender™, with a soft link, in place of the hitch. Gibbs® ascenders are not a good choice for use in rope rescue. Gibbs® ascenders have consistently demonstrated that under a shock load they will destroy the rope. When the command SET is given, the progress capture device attendant must pull all the slack out of the line as the device is set, otherwise the load will settle, and progress will be lost. If an attendant is not available using a Prusik Minding Pulley can automatically tend the capture hitch. For optimum efficiency, the length of the Prusik loop can be shortened to custom fit the type of the pulley and rope you use. Experiment with the cordage you use so the Prusik hitch is a thumb width away from the pulley sides. If you change ropes, the relationships may also change. In the progress capture mode, place the pulley on the carabiner first to have it closest to the carabiner spine, then the Prusik loop. In this application the pulley is seeing all the forces, and the hitch just holds the load during the reset.

The Commands:

The basic commands as agreed on by the rope rescue community:

"HAUL" or "HAUL SLOW" - 2 whistles - Team begins hauling.

"SET" - Team stops and the progress capture device is pulled taut and set.

"SLACK" - Signals the haul team to reset the haul system for a new bight.

"STOP" - 1 whistle - Movement stops and tension is held until any problem is resolved.

"DOWN" - 3 whistles - Lower the load.

Usually a "leader" wants to give all these commands, but it may be safer for the person performing the function to shout the next command when their device is set on the rope and their fingers are clear. Commands should use as few words as possible so there is little chance of confusion or misunderstanding.

On the following page is an example of more formal format for leading a rope rescue operation as recommended by Reed Thorne of 'Ropes That Rescue'™

CONTROL OFFICER CHECKLIST

LOW DIRECTIONAL

NOTE: TSO has passed control to the CONTROL OFFICER

 **SINGLE, LONG WHISTLE BLAST**
"OPERATIONS ARE ABOUT TO BEGIN – ALL PERSONNEL TAKE YOUR POSITIONS – QUIET PLEASE"

"SAFETY, ALL SYSTEMS CHECKED?"

"Systems checked – ready for operation"

"MAIN LINE?"

"MAIN LINE, ready!"

"BELAY LINE?"

"BELAY, ready!"

"ATTENDANT?"

"ATTENDANT, ready!"

"EDGE?"

"EDGE, ready!"

AFTER ALL STATIONS ARE READY

"BELAY ON??"

"On belay!"

**"MAINLINE – TAKE UP SLACK—LOAD & LOCK—
—ADVISE WHEN READY"**

"MAIN LINE loaded and locked!"

"MAIN LINE—HOW MANY BARS?" (if lowering)

"MAIN LINE, (reply number of bars)"

"ATTENDANT—MOVE INTO THE HAZARD ZONE"

"ATTENDANT in position"

"ATTENDANT—LOAD THE SYSTEM—ADVISE WHEN READY"

"System loaded!"

"ATTENDANT—READY FOR DOWN?"

"ATTENDANT ready!"

 **THREE SHORT WHISTLE BLASTS**

"MAIN LINE—DOWN ROPE?"

"MAIN LINE—down rope!"

 **SINGLE WHISTLE BLAST "STOP!"**

"MAIN LINE stop!"

"MAIN LINE—RIG FOR RAISE—ADVISE WHEN READY!"

"MAIN LINE rigged for raise!"

 **TWO SHORT WHISTLE BLASTS**

"MAIN LINE—UP ROPE!"

"MAIN LINE up rope!"

 **SINGLE LONG WHISTLE BLAST**

"STOP—ALL STOP!"

"MAIN LINE all stop!"

HIGH DIRECTIONAL

NOTE: TSO has passed control to the CONTROL OFFICER

 **SINGLE, LONG WHISTLE BLAST**
"OPERATIONS ARE STARTING—ALL PERSONNEL TAKE YOUR POSITIONS—QUIET PLEASE"

"SAFETY, ALL SYSTEMS CHECKED?"

"Systems checked—ready for operation"

"MAIN LINE READY—ONE BAR?"

"MAIN LINE, ready—ONE BAR!"

"BELAY LINE?"

"BELAY, ready!"

"ATTENDANT?"

"ATTENDANT, ready!"

"EDGE?"

"EDGE, ready!"

"VECTOR TEAM?" (if needed)

"VECTOR TEAM, ready!"

AFTER ALL STATIONS ARE READY

"BELAY ON??"

"ON BELAY!"

"ATTENDANT—MOVE INTO THE HAZARD ZONE"

"ATTENDANT in position" (yoke as close as possible to HD)

**"MAINLINE—TAKE UP SLACK—LOAD & LOCK—
—ADVISE WHEN READY"**

"MAIN LINE loaded and locked!"

"MAIN LINE—HOW MANY BARS?" (if lowering)

"MAIN LINE, (reply number of bars)"

"VECTOR TEAM—VECTOR UP"

"VECTOR TEAM vectoring up!"

"ATTENDANT—TEST THE WATERS—IN POSITION"

"ATTENDANT in position"

"ATTENDANT—READY FOR DOWN?"

"ATTENDANT ready!"

"VECTOR TEAM—VECTOR DOWN"

"VECTOR TEAM vectoring down!"

 **THREE SHORT WHISTLE BLASTS**

"MAIN LINE—DOWN ROPE?"

"MAIN LINE—down rope!"

 **SINGLE WHISTLE BLAST "STOP!"**

"MAIN LINE stop!"

"MAIN LINE—RIG FOR RAISE—ADVISE WHEN READY!"

"MAIN LINE rigged for raise!" (After ready only)

 **TWO SHORT WHISTLE BLASTS**

"MAIN LINE—UP ROPE!"

"MAIN LINE up rope!"

 **SINGLE LONG WHISTLE BLAST**

"STOP—ALL STOP!"

"MAIN LINE all stop!"

Use of a Jigger or 'A Set-of-Fours':

Locked off Prusik hitches, knot passing, litter attendant or barrow boy positioning, adjustment of litter orientation, and other unforeseen problems in rope rescue can be reduced or accomplished by having a pre-assembled jigger available on site. It might be quicker to use a jigger; than untie, release, and retie a Load Releasing Hitch.

Basic Jigger:

A very practical compact unit can be constructed using 10 m. of 8 mm. cord. In the 4:1 or 5:1 mode 2.14 m. (84 in.) can be collapsed to 25 cm. (10 in.). In the 9:1 mode 2.2 m. (87 in.) will collapse to 1.65 m. (65 in.).



jigger in 4:1/5:1 mode



jigger in 9:1 mode

To assemble a jigger, place a poacher's hitch or double overhand noose' on a 5 mm. Maillon Rapide™ rated at 450 kg. at the load end of 10 m. of 8 mm. cord. Attach this link to a pear shaped or HMS carabiner. Run the cord to the anchor end and around a small double Prusik Minding Pulley rated at least 22 kN. Where the cord enters this pulley place a Prusik hitch formed with a 90 cm. loop of 6 mm. cord to act as a Progress Capture Device. Run the cord back to the load end and around a small single pulley rated at least 22 kN. Now place a floating 80 cm., 6 mm. Prusik loop here, for the 9:1 conversion, and continue the cord back to the anchor point and around the double pulley again. Cord returns to the load side and goes through another small single pulley rated at least 22 kN which is attached by another 5 mm. Maillon Rapide™ to the pear shaped or HMS carabiner on the load side. A 110 cm., 8 mm. Prusik loop is available in load carabiner for applications. Another carabiner is attached to the double pulley at the anchor end, and it also has available a 110 cm., 8 mm. Prusik loop. The hauling end of the cord is finished off with a Blood Knot or 'double overhand stopper knot'. To convert the jigger to 9:1 in one move, disconnect the quick link with its pulley and connect it to the floating 80 cm, 6 mm Prusik loop. The jigger should be stored in a bag in a collapsed form to prevent crossed ropes or twists in the rope from developing. The list price of the parts for this jigger and a bag to keep it in will be about \$200.00. This compact unit will allow jammed Prusik hitches to be released quickly and loads shifted. It can also be used for adjustments in litter orientation by a single litter attendant or barrow boy.

AZTEK™ Kit:

Reed Thorne of 'Ropes that Rescue Ltd®' recommends the use of the AZTEK™ kit as personal gear on one's harness. It is a version of a jigger and excellent instructions on how to construct one using various kinds of pulleys can be found at the 'Ropes that Rescue' website. As you are following all the directions slip a two-foot piece of webbing over the cord just below the auto-lock anchor device. This allows the anchor to be used on something larger than would fit in anchor device. The webbing keeps your cord from chaffing on anchors like steel beams. Tie your cord to the auto-lock device with a poacher's hitch or 'double overhand noose'. The AZTEK™ kit has a documented one hundred and twenty-five applications. The basic unit costs about \$440.00 USD. The photo shows other equipment that may be used with the AZTEK™ Kit: a set of 6mm. Purcell Prusiks, gloves, webbing for a chest safety, two auto lock carabiners, two VT Prusiks™, and one small pulley with a carabiner for the 9:1 conversion.



AZTEK™ kit with accessories

Attendant Jigger:

The attendant or barrow boy can also use another jigger to position oneself anywhere around the litter and this may be easier than using personal climbing equipment. The attendant's jigger is a 3:1 with a change of direction. Using 8 m. (26 ft.) of 8 mm. cord attach to a 5 mm. Maillon Rapide™ quick link rated at 450 kg. with a poacher's hitch or 'double overhand noose'. The quick link is attached to a carabiner for the attendant. The cord goes through a small double pulley rated at 22 kN. And back down to a single Prusik Minding Pulley rated at least 22 kN. Where the cord enters this pulley place a Prusik hitch formed with a 90 cm. loop of 6 mm. cord to act as a Progress Capture Device. The cord returns to the double pulley at the anchor end and passes through it to provide a change of direction for the user to pull down. Store in a bag. The parts list for about \$150.00 USD.



attendant's 3:1 jigger

Heavy Duty Jigger:

To assemble a heavy-duty jigger use about 12 m. (39 ft.) or more of 11 mm. (7/16 in.) rope, one twin Prusik Minding Pulley with a becket hole, two single pulleys, four Prusik loops, three carabiners and one oval screw link. It is assembled in the same procedure first described above. It offers the flexibility as a simple 4:1, reversed to a simple 5:1, or converted with one move to a compound 9:1 that will collapse to accommodate one meter of load travel. Anchored conveniently and using a



heavy duty jigger

Prusik hitch or a Rescucender™ to grab a rope a variety of tasks can be performed quickly. This larger version works well as a bolt-on haul system or for adjusting tension on a guiding line.

Litters:

In the United States the two most frequently seen litters are, the older chicken wire 'Stokes's type' basket and a Ferno-Washington® plastic model.

Some Stokes litters have a leg divider. To improve a patient's comfort a person skillful in welding can remove this divider and use the pieces to replace any damaged bottom cross pieces. Another improvement is to add a section of electrical conduit that conforms to the shape of the bottom to improve strength and provide a skid. With a small propane torch the soldered chicken wire can be modified and soldered to a new central wire. The US Coast Guard has recommended wrapping a piece of 2.54 cm. (1 in.) tubular webbing around the top rail to increase security if the rail collapses.

The acceptable Ferno-Washington® litters are orange in color, Model 71™. Some look-alike units may still be in service that are red colored, Model 70™. The plastic in the Model 70™ is affected by sunlight and they have been known to abruptly fail. The Model 70™ should no longer be used in rope rescue. The newer Ferno-Washington® litter comes with a 5 m. (16 ft.) piece of rope laced around its perimeter. This rope should be replaced by a piece of 8 mm cord that has a 'figure-of-eight knot' at each section along the inside of the litter. The presence of the knot makes it easier to pass a piece of webbing under it. To accommodate the 20 required knots, add 3 m. (10 ft.) to the original 5 m., use 9 m. (29 ft.) to be safe. It is good practice to keep all litters covered and away from weather and the sun.

The SKED® litter has proven to be an excellent choice for use in caves and other confined space situations. It is especially important to always use the SKED Oregon Spine Splint™ to keep the SKED® from putting unnecessary pressure on the patient's shoulders. Easy to follow instructions accompany each SKED®.

Traverse Rescue® litters are manufactured in Mississauga, Ontario, Canada. The company is part of the Ferno Group®. Cascade Rescue® litters are manufactured in Sandpoint, Idaho. Both these companies offer a variety of styles of litters; one piece, two pieces, stainless steel, titanium, et cetera.

Litter Attachments:

The Arizona Litter Spider™ designed by Reed Thorne is one of the best thought out and most compact ideas currently available. The components can be purchased commercially, or they can also be assembled from 7 mm. cord. 7 mm. cord is rated at 10.7 kN (2,405 lbf.) so doubled in a Prusik loop the strength would be 21.4 kN (4,793 lbf.)



Arizona Litter Spider™

Two independent head end units (yellow) use commercially sewn 175 cm. (68 in.) loops or the loops can be made with 4 m. (155 in.) of 7 mm. cord joined with a grapevine bend or 'double overhand bend' to form the loops. These loops are each tied as a Purcell Prusik, described later. Two independent foot end units (green) use commercially sewn 87 cm. (34 in.) loops or the loops can be made with 223 cm. (87 in.) of 7 mm. cord joined with a grapevine bend or 'double overhand bend' to form the loops.

Each unit is attached to the litter with a ring hitch or 'girth hitch'. The double cord part of the head units attaches to a 9 mm. or 10 mm. Delta® link at a collection point. The loops on the foot units attach to an AZTEK™ or jigger. The other end of the AZTEK™ or jigger attaches to the Delta® at the collection point. The AZTEK™ or jigger can be used to change the orientation of the litter from horizontal to vertical.



Arizona Litter Spider™ in use

For low angle applications the head unit becomes a litter bridle. The foot units become two barrow boy or bearer tie ins. Add two more of the shorter units at the head end for to forward barrow boys or bearers. Other spider attachments for high angle vertical rescue with a horizontal litter orientation can be purchased commercially. But a traditional one can also be easily constructed. At the mid-point of 3 m. (10 ft.) of 9 mm. of cord a Flemish loop or 'figure-of-eight-on-a-bight' is tied. On each standing part a three wrap Prusik is tied using one meter of 6 mm. cord. The doubled 6 mm. ends are joined to the 9 mm. end with a grapevine bend or 'double overhand bend'. Construct another unit. Each pair of adjustable legs of the spider hang from carabiners on a rigging plate and attach to the litter rail with extra-large carabiners. Despite what Ferno-Washington® now recommends, these carabiners should be orientated so the gate is on the inside, to prevent an accidental opening from contact with the rock face. The carabiner gate locking screw should rotate down so with any vibration gravity will keep the carabiner locked. The main and belay lines are connected to a rigging plate by interlocking long tail bowlines. The carabiners on the spider legs also attach to the rigging plate. Other holes in the rigging plate will accommodate the attendant's jigger and the jigger for changing litter orientation. The use of interlocking bowlines allows for lengthening or changing ropes independent of one another. A 2 m. main line tail is for the litter and a 3 m. belay line tail is for the attendant. The reason the belay end needs to go to the attendant is in the guiding line application the belay is disconnected when a talus slope is reached, and the patient will not be concerned about their safety being disconnected.



traditional spider



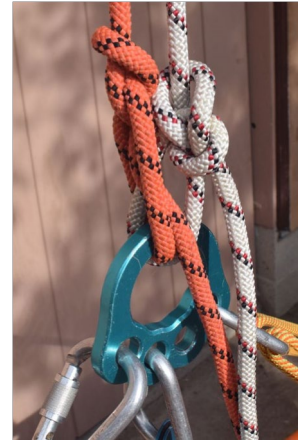
Interlocking yoke knot on rigging plate with spider and jigger attached

There is also a bridle attachment for low angle incline rescue, or vertical orientation of a litter. The bridle is tied to the head end and uses 3.5 m. (11.5 ft.) of 11 mm. (7/16 in.) rope. Half of a grapevine bend or 'double overhand bend' is tied in one end. A clove hitch is placed around the litter rail. The rope passes around the front of the litter. Another clove hitch is tied around the opposite side rail. The ends are joined completing the grapevine bend or 'double overhand bend', which is located outside the litter. The ropes are aligned and a lineman loop or an 'Alpine

butterfly' is tied in the bight. The grapevine bend or 'double overhand bend' at the midpoint, on the front of the litter, will provide an attachment point to grab or to connect a carabiner to in close quarters.

Attaching Litters to a System:

The main and belay ropes are connected to the designated load by what some call a yoke knot. It will be under significant strain from the loads placed on them. A lineman's loop or 'alpine butterfly' and Flemish loops or 'figure-of-eight loops' will work but may be exceedingly difficult to untie after being loaded. A doubled long-tail bowline or interlocked long-tail bowlines are the best choices as they are easy to tie, are compact, and easier to untie. Often a rigging plate or a four-inch ring are used but it is also possible to connect the litter and the attendant directly into the bowline's loops. If you do connect them, directly make sure the bowlines are the outside variety. Richard Delaney of RopeLab® in Australia tested this application and discovered that when forces are applied horizontally to the loop, an inside bowline began to slip at 3 kN. And the outside bowline did not start to slip until about 20 kN. These bowlines do not need to be backed up as their tails continue to attach as safeties for the attendant and the litter.



Interlocking long-tailed bowlines

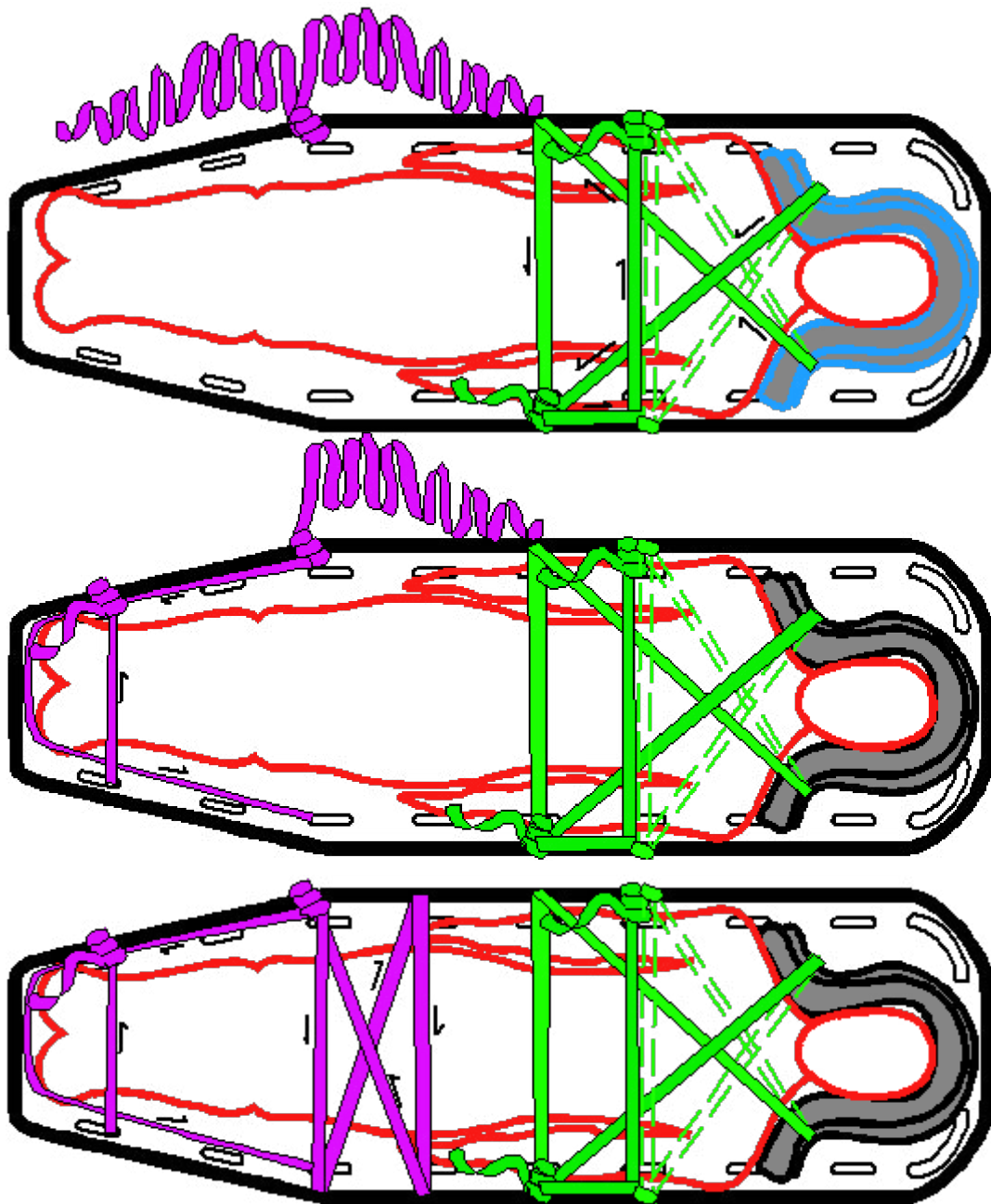
Packaging a patient in a Litter:

There are commercially available units for this but sometimes using webbing is the best. The following procedure, developed by National Cave Rescue Commission medical advisors, might be the best for the most extreme conditions found in a cave, mine, or other high hazard area; but can be modified, as needed, for other situations.

Using the available litter, prepare it with two attached pieces of 9 m. (30 ft.) webbing. Place the midpoint of the first piece of webbing centered between the third connection points down from the head. Secure this webbing on each side with an overhand knot. Tails pointing out the head end of the litter form an 'X' under the mid-back area. Use the second piece of webbing and tie an overhand knot at the mid-point on either side of the litter at the third rigging point up from the bottom. Leave the tails available. If local conditions require it. Place a vapor barrier down first. A 3 m. (9 ft.) by 4 m. (12 ft.) piece of plastic tarp will work and is laid in a rectangular position in the litter. Next lay down one or more blankets, as a thermal barrier, also in a rectangular fashion.

Position the patient in the litter. Roll up another blanket and place at the top of the head. The roll ends come down along the head and turn out at the shoulders. Now wrap the patient in the thermal barriers and then the vapor barrier.

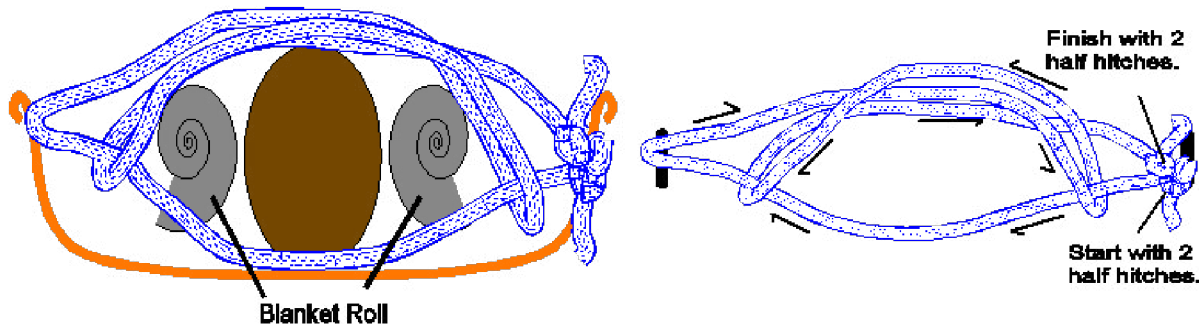
With the webbing coming out under the shoulders pass them over the blanket roll, cross at mid-torso, and passes through the fourth connection point down from the head. One of these two ends then goes directly across body and is secured on other side with two half hitches or a common lashing. The other end should be redirected up the side of the litter, pass through a higher up connection spot and then cross the body to be secured with two half hitches or a common lashing.



litter lashing sequence diagrams

Locating one of the tails from the second piece of webbing, pass it under both feet and up to the third connection point (opposite the other knee). Pull it snug under the instep of the feet, or single foot if one leg is injured and secure with a half hitch. Feed the webbing back down to a connection point opposite the ankle and loop it through the litter, under the ankles, through the other side of the litter and back over the ankles. Pull snug and secure with two half hitches or a common lashing. With the other tail, from the second piece of webbing, lace it across above the knee area, back across the thigh area, across the waist area, and back across the thigh area forming a boxed "X". Secure with two half hitches or a common lashing. Using a third piece of webbing about 3 m. (10 ft.) long, secure the head, which has been padded with the blanket roll. Tie two half hitches to the first connection point. Pass the webbing under the head and through the connection point on the opposite side. The webbing

then goes over the forehead, around the webbing under the head, back over the forehead, under the webbing again under the head, and back over the forehead a third time. Finish with two half hitches at the origin connection point. A helmet affects spinal neutrality or airway and is no longer appropriate to use. However, protect the eyes from debris, maybe a bandana.



Let the patient determine whether their arms are secured. Padding in various places, as behind the knees, under neck, may also be appropriate.

Under less hazardous conditions, other straps might be more appropriate. Avoid using buckles with a button release or a pull release. Best choices for buckles are the interlocking types with versions offered by Cascade and Traverse.

The test for a properly secured patient is to stand the litter on each end. If the patient slips down more than an inch in either position, the packaging was inappropriate.

Multi-purpose litter attendant bridle:

This bridle's primary use is an attachment for litter attendants or barrow boys who support a litter during a steel slope haul. The bridle connects to the head of the litter attachment point and a leg goes down each side of the litter. The litter attendants are attached to it with 7 mm. Prusik hitches allowing them to position themselves. The ends are clipped to the lowest person on each side as a back-up. Normally a litter is carried by three persons. One on each side at the load's mid-point and one at the foot end who guides the operation. If the load is exceptionally heavy two persons can be on each side. Each attendant is attached to the litter rail with another Prusik loop that uses a ring hitch or Lark's foot. The other end clips to their harness. By leaning back, the harness holds the load, and the hands are not needed.

A secondary function of this bridle is to attach to each side of the litter with carabiners to bring the litter over the edge of a cliff edge in a vertical orientation during the 'pike and pivot' maneuver.

The bridle can be made with 6 m. (19.5 ft.) of 9 mm. (5/16 in.) cord. At the mid-point tie a bowline on a bight. The ends have small, retraced bowlines.



multi-purpose litter attendant bridle

The Prusik loops are made with 1 m. (39 in.) of 7 mm. cord and

the hitches are tied with the three wraps over two wraps hitch where the three wraps point towards the anchor.

Harness Considerations:

Rescue professionals need to consider which harness, from a variety offered, will best meet their individual needs. The tasks being performed while in a harness will determine which harness type you want to consider. Generally, there are three styles of harnesses that are probably used in rope rescue. Each deserves some discussion and examples are mentioned so the reader may research their specifications. For each style there is a reference to a product from both a European and an American manufacturer. These are not endorsements but reference points for the three styles discussed.

A common style of harness used in rope rescue is probably going to be worn by a person with a rock climbing or climbing wall background. It has a waist belt that is worn above the hip bones and is usually fastened with a buckle. It has leg loops that fit around the thighs. A sewn double loop joins the leg loops and the waist belt and serves as the attachment point. This attachment point is at the waist and often above the navel. It will probably keep the user upright and will not allow the user to invert. This might be a disadvantage. Another disadvantage of this style of harness is the tendency of the user to have the waist belt too tight and as one hangs in it there is a compression of the body's organs and an increased upward pressure from them on the diaphragm making it difficult to take a deep breath. Generally, this would not be an issue as the primary design of these harnesses is to be used by a lead climber probably accessing a patient. Two examples of this style of harness are the Petzl Mercury C31™ and the Wild Country® Helix™.



Petzl Mercury C31™



Wild Country® Helix™

A second style of harness, probably worn by a litter attendant, may have some other requirements. The attendant must have a wide range of movement to guide the litter and meet the needs of the patient. As an attendant initially approaches a patient it might be advisable to stop above the subject and invert to assess the mental condition before coming within the patient's reach. Cave explorers also often require inverting. Their harnesses traditionally have a much lower attachment point. The harness consists again of thigh loops and another larger loop around the pelvic girdle which has two small end loops that are joined using a semicircular steel screw link. This screw link becomes the attachment point. Two examples of this style of harness are the Petzl Super Avanti Harness C12™ and the Pigeon Mountain Industries® Viper Caving™ harness. Both harnesses work well with the frog climbing system and give the user the ability to rotate in any direction. A disadvantage is that the user could invert when not expecting to. Another advantage is compactness and reasonable cost.



Petzl Super Avanti Harness C12™



Pigeon Mountain Industries Viper Caving™

The last style of harness is a full body type that is commonly found in an industrial setting where work positioning is the primary focus. Generally, these harnesses have leg loops. The waist belt tightens down from each side across the pelvis taking pressure off the abdomen. The attachment point is often a square steel link positioned below the navel. Shoulder straps complete the full body style. There will be dorsal D ring to meet United States OSHA requirements and a sternum area D ring allowed internationally. Two examples of this style of harness are the Petzl Navaho Complete C71™ and the Yates® Ropeworks Rope Access Harness™. Both can have a Petzl Croll™ attached to use for a frog climbing system. A disadvantage of these harnesses is probably cost and weight.



Petzl Navaho Complete C71™



Yates Ropeworks Rope Access Harness™

These are some of the options available and they have their advantages and disadvantages. Practice with your harness and be able to put it on in less than five minutes. Start with the thigh loops snug. Hang in it for periods of time. If a waist belt is present, is it pressing in on your soft body parts? Realize that when you keep moving your legs around, you keep the blood flowing. Try picking an unconscious person off, of a rope. If you do not have that skill, consider rigging the working rope from a tied off descending device. Then, in case of an emergency a less skilled person could loosen the rope in the device and lower the injured party to the ground. When working on rope it is a best practice to always rig two ropes as OSHA requires. One to climb on and the other for a traveling belay device, i.e., Petzl ASAP™.

Work restraint systems and their travel restrictions are not a focus of this discussion. However, we need to consider what will happen if a person falls using either of the first two groups of described harnesses. When the attachment point reaches the end of the rope it stops but usually the head and the feet continue to travel with some resultant bone and tissue damage. The shock will probably render the user unable to help oneself. The result will be suspension trauma, also known as Harness Hang Syndrome—HHS. The medical term is called compartmental syndrome, where the blood does not circulate properly and tends to pool in the extremities. This can be a very, serious medical situation and the hanging person needs to be removed quickly but there must be consideration of the pooling complications. Paul Seddon in 2002 wrote a lengthy document on this subject: www.hse.gov.uk/research/crr_hrm/2002/crr02451.

OSHA has a presentation at:

www.osha.gov, Suspension Trauma/Orthostatic Intolerance.

The most recent study, about suspension trauma has been completed by Dr. Roger Mortimer, M.D. His scholarly presentation can be viewed at:

[http://wemjournal.org/article/S1080-6032\(10\)00320-0/](http://wemjournal.org/article/S1080-6032(10)00320-0/) full text.

This presentation should clarify the best way to mitigate the blood that is pooled in the extremities when you get the patient on the ground.

Harness Made from Webbing:

Always have climbing gear available. Using a 6 m. (20 ft.) piece of webbing tie one of a variety of known harness styles on yourself. For a superior style that will not adjust and constrict, use a mountaineer or Star-Bird style seat harness popularized by Arnor Larson. Using a 4.5 m. (14.5 ft.) piece of webbing for an average sized person, place an overhand knot at the mid-point and form a 20 to 25 cm. (9 in. to 10 in.) loop around the thigh using an overhand follow-through bend. About 20 cm. (8 in.) down the shorter tail form another 20 to 25 cm. loop around the other thigh with another overhand follow through bend. This allows a 20 cm. (9 in.) gap between the loops. With the loops over the thighs, the tails wrap around the waist once and are tied with a snug overhand follow-through bend. A second overhand follow-through bend is tied to create an equipment loop. The remaining tails will be used later. For the chest, use a 3.5 m. (11 ft.) piece of webbing and tie an overhand knot at the mid-point. Wrap one tail snugly around the chest and finish off with a ring bend or 'overhand follow-through bend'. With the other tail, pass it over a shoulder, under the webbing across the back, and back across the opposite shoulder. Complete a ring bend or 'overhand follow-through bend' with both tails. With the longer tail from the waist component, pass it under the chest component and join it to the shorter tail with a ring bend or 'overhand follow-through bend'.



Star-Bird harness

Harness Belay Catch Modification:

There is a simple idea for waist only style harnesses, which are not a full body harness, to establish a belay catch point around the sternum which will allow the user to be caught in an upright position where the connection can be easily reached. It was discussed earlier in the Star-Bird harness discussion. But to tie a simpler version take a 360 cm. (12 ft.) piece of 2.54 cm. (1 in.) tubular webbing. Attach one end with a Poacher's Hitch or 'double overhand noose' to a ring. The SMC Rigging Ring™ rated at 32 kN (7,100 lbf) is one choice. Cost about \$4.90USD. Place this ring on your sternum and pass the webbing around your chest and back through the ring, securing it with a half hitch. Take the webbing, throw over one shoulder, pass under the around the chest part, bring back over the other shoulder. Pass the webbing through the ring and secure with a half hitch. Continue the webbing down to your existing harness, pull snug, and tie off with multiple half hitches.



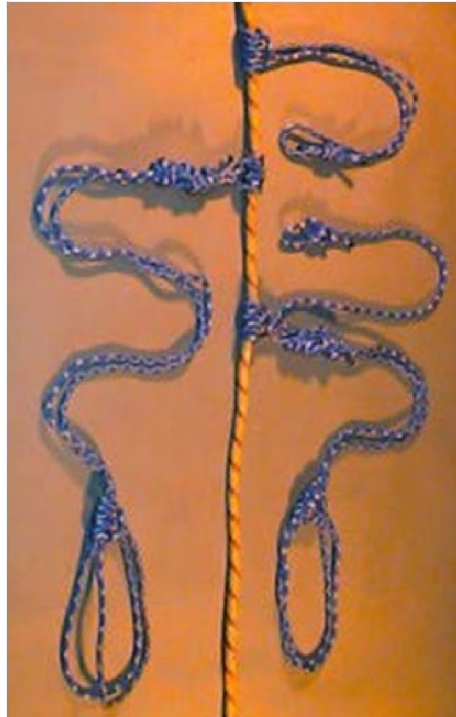
putting on the quick harness belay catch

Pass your belay behind the ring at your sternum and connect it to your harness. In a fall the impact will catch you in an upright position. You may be slapped in the face, but you will be able to recover from the incident. Whether or not you use a belay in the United States may depend on your legal status. If you are involved in recreation or serving as a volunteer for rope rescue you are not required to have an independent belay. If you are a paid worker, you are required to be attached to two ropes by OSHA. OSHA, however, says the connection should be in the dorsal area. But this will make self-recovery difficult in the real world.

It makes common sense to use a belay whenever possible, and usually it can become a matter of habit. However, if the rope distance is more than 90 m. it is probably not a good idea as the two ropes will twist together.

Making your own Purcell Prusik Set:

A set of three Purcell Prusiks made from 6 mm. cords is a compact climbing system. Two are tied the same. For an average height person, each uses 5 m. (16 ft.) of 6 mm. rope. With each piece form bights in each end of the cord. Choose one end and tie a blood knot or 'double overhand knot' around the two ropes. Pull out a 4 cm. (17 in.) bight on one side. On the longer bight form a three over-two wrap Prusik hitch around your fist and pass all the rope through the hitch wraps. Return to the 40 cm. bight and tie a figure eight knot in the three ropes. For the longer Purcell Prusik unit keep adjusting the figure-of-eight knot until the top of the small loop reaches the nipple line when the Prusik hitch loops are secured over the boot. On the medium unit keep adjusting the figure-of-eight knot until the top of the small loop reaches the crotch when the Prusik hitch loops are secured over the boot. When both are adjusted, finish off the units with a second blood knot or 'double overhand knot' securing the bend. The medium unit should have about a one-meter tail. This is a modification to the original Purcell Prusiks but later evaluations of the climbing system by Arnor Larson demonstrated the advantage in having two contact points to the waist. This will allow the climber to recover from a

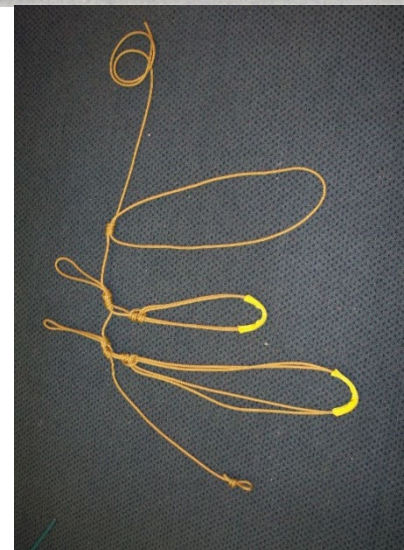
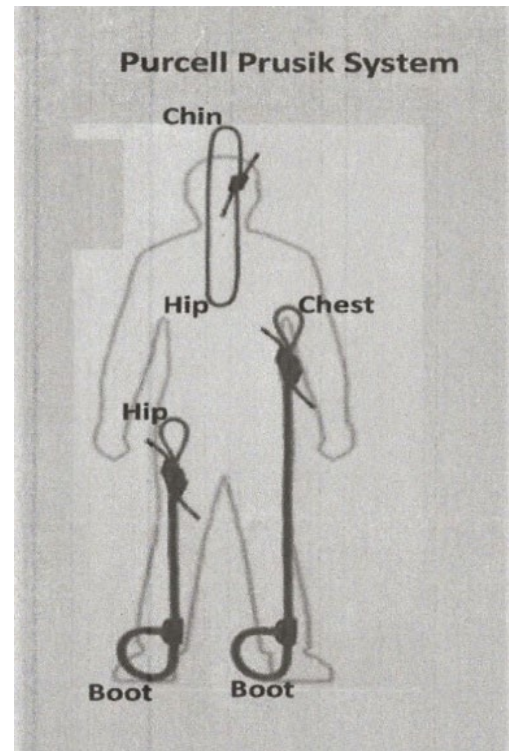
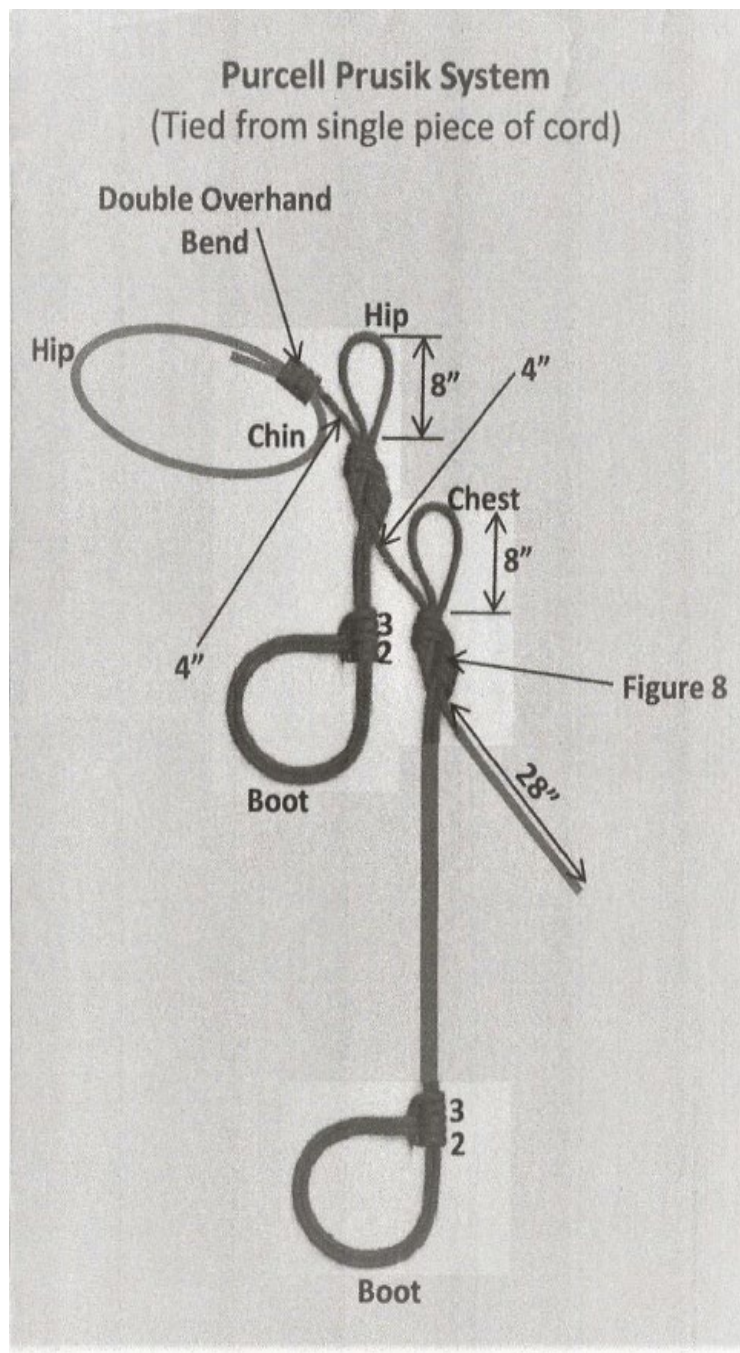


Purcell Prusik set



failure of the short loop. Place an interwoven Yosemite version bowline in the end, which can be attached to your harness. The third Purcell Prusik is made from 1.9 m. (6 ft.) and a simple loop is formed with a grapevine bend or 'double overhand bend' and passes through the Star-Bird harness connection at the waist. The loop length should be from the navel to the top of the head. The sequence for attaching to the rope to climb: short loop, long loop, and medium loop – SLM.

Arnor Larson conducted rope rescue classes in British Columbia for many years. One of his student challenges, at the classes, was to tie a personal set of Purcell Prusiks from one continuous piece of 6 mm. cord 10 m. (33 ft.) long. Below are some diagrams of the process that were passed out at a recent SAREX Conference in California. When you start, place a 6 mm. quick link on the end of the cord secured by a poacher's hitch or double overhand noose. Then, leaving a 71 cm. (28 in.) tail start your ties. Both of the figure-of-eights will have a third cord passed through them. The Prusik hitches on the double cord Purcells for each foot are asymmetrical three wraps over two wraps which can be tied over your hand.



Purcell Prusik set tied

Before you tie these Prusik hitches pass the double cord through a six inch piece of different colored webbing to form a sturrip for each foot. When completed, separate the units by cutting at the two four inch gaps.

Artificial High Directional Devices:

Available units are the Arachnipod™ sold by Rescue TECH1®, the Larkin Rescue Frame™ sold by Rescue TECH1®, the Arizona Vortex™ sold by CMC and the TerrAdaptor™ sold by PMI®. All are in the \$4,000.00 USD range and vary in weight from 23 kg (60 lbs.) to 39 kg (87 lbs.)

Currently the Arizona Vortex™ and the TerrAdaptor™ are the most common in the United States. The TerrAdaptor is a little heavier than the Arizona Vortex™ by 6.7 kg (15 lbs.). but it is one foot taller. The TerrAdaptor™ may be more versatile and configuration settings can be documented for future use. The Arizona Vortex™ is usually described as less complicated which might be an advantage if infrequently used. Reed Thorne of Ropes that Rescue® offers an excellent seven-day class on the use of the Arizona Vortex™.

Generally, if your device is to be used to remove a load vertically out of a confined space use it at full height. If the goal is to simply reduce friction at a cliff edge consider using the device as low as possible, maybe closer to four or five feet of height. This greatly reduces a danger of capsizing your high directional device.

Personal Skills:

A minimum standard for individuals working in the vertical world should include:

- Climbing gear can be put on in less than five minutes.
- On 5 m. (15 ft.) of rope climb past a knot, change to descend mode, and descend past a knot in less than 8 minutes.
- Climb 100 m. (300 ft.) in less than 30 minutes.

Personal Equipment:

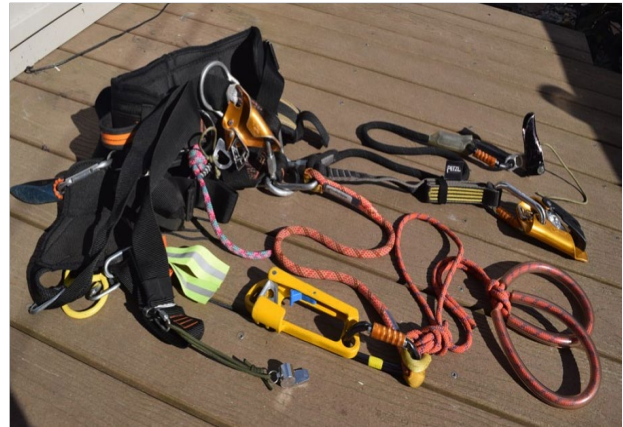
What to carry on your harness is generally decided by what your function is going to be. A basic reference might be a mountain guide who may have to access remote areas and provide protection for a client. The harness might contain a descent device, two pulleys, two hanks of cord (6 m. of 7 mm. cord and 10 m. of 8 mm. cord), two Prusik loops, some carabiners, and the knowledge to build whatever is needed. A cave explorer might add a climbing system for vertical caves and substitute 6 m. (20 ft.) of webbing for one hank of rope. A rope access technician will modify the ascending and descending equipment choices, by adding back-up systems, and a two-foot sewn anchor loop.

A typical rope access technician will wear a full body style harness. At the waist area will be attached three lanyards with fixed lengths connected to a 10 mm square steel screw link:

- One 20 cm. Petzl ASAP'SORBER™ with a Petzl ASAP™ for general use as an OSHA required back-up on a safety line.
- One 100 cm. lanyard with a Petzl Shunt™ for passing obstructions and extra length advisable when passing re-belay stations. The Petzl Shunt™ must only be used for a single person load.
- One 60 cm. lanyard with an ascender of choice connected to a foot stirrup. The author prefers a Jumar™ ascender for compactness and a homemade foot stirrup made from

cord that uses a double loop knot, so the overall length is constant whether using one foot or both feet in the loops.

- Also, at the waist, a Petzl I'd™ is connected by a carabiner to the half-moon sewed into the harness and is used for descending. An extra 7 mm. quick link should be available to isolate a patient during a pick-off maneuver.
- A second half-moon carabiner like a Petzl Omni™ is secured to the harness as an attachment point for a Purcell Prusik's quick link used for fall prevention.



Rope access harness with attachments

Other equipment is stored on the harness loops. Each is attached with auto-lock carabiners. Auto-locks are recommended in rope access work as when attached they are locked, and one does not have to worry about screwing down a carabiner lock and spending the time to do so.

- A Petzl Gri-Gri™ which has several potential uses but a primary use might be for rigging a main working line so a lower skilled person could release and lower an injured worker to the ground.
- Sewn anchor loop two feet long to be used as a quick choker or basket anchor. It can also be doubled to connect to a patient during a pick-off.
- A mini double PMP pulley either Petzl™ or CMC™ with a 115 cm. by 7 mm. Prusik loop (described later) that could be used as a progress capture or ratchet in a constructed haul system.



Other equipment carried on harness

- A mini single PMP pulley either Petzl™ or SMC™ with a 105 cm. by 7 mm. Prusik loop (described later) that may be used as a haul Prusik in a constructed haul system.
- Hank of 10 m. (33 ft.) of 8 mm. cord that might be used to build an independent haul system load release hitch, multi-point anchor, act as a hand line, assemble a jigger, et cetera.
- Hank of 7 m. (23 ft.) of 7 mm. cord for similar purposes.
- AZTEK™ Kit could be used to replace the two pulleys and the hanks of cord.

Most groups and even NASAR's SAR Technician program recommend carrying two Prusik loops but no recommendation is given to size or possible uses. Since groups use rope varying in size from 12.5 mm. (1/2 in.) to 8 mm. (3/8 in.) the deciding on the right size Prusik loop is a challenge. For single person loads, however, a 7 mm. Prusik works well. 105 cm. (41 in.) of 7 mm. cord is the minimum length required to tie a three wrap Prusik on 12.5 mm. (1/2 in.) rope. 115 cm. (45 in.) of 7 mm. cord is the minimum length required to tie a three wrap Prusik on 12.5 mm. (1/2 in.) rope that will fit below a common mini PMP pulley. Using the more common 11 mm. (7/16 in.) rope there will be a more cord to play with. When properly dressed, these Prusiks will grip on 8 mm. (3/8 in.) rope. If all team or trip members carry a pulley and a Prusik set a variety of situations can be overcome.

Air Force Para-rescueman team equipment:

- 60 m. (200 ft.) 9.5 mm. Technora™ rope
- 8 m. (26 ft.) 2.54 cm (1 in.) webbing
- 2 Metolius slings
- 2 120 cm. (4 ft.) Dynex™ 10 mm. runners
- 1 1.53 m. (5 ft.) 6.8 mm. TVAC Prusik
- 1 1.85 m. (6 ft.) 6.8 mm. TVAC Prusik
- 1 rope guard sleeve
- 3 single mini pulleys
- 4 Petzl William (HMS)™ carabiners
- 1 rigging plate
- 1 Kong Gi-Gi™
- 1 Petzl Pro-Traxion™
- 1 Petzl Micro-cender

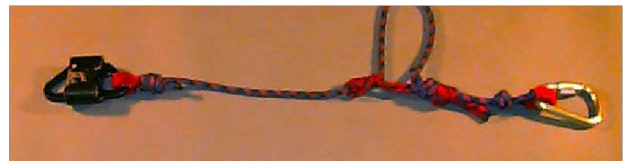
CBP BORSTAR team equipment:

- 90 m. (300 ft.) 90.5 mm. canyon tech rope
- AZTEK Kit™ complete
- 1 long webbing loop
- 1 short webbing loop
- 1 VT Prusik
- 10 m. (33 ft.) power cord
- 1 edge protection
- 6 carabiners
- 1 tri-link
- 4 single pulleys
- 1 single omni-pulley
- 1 double omni-pulley
- 1 Delta V™ (rescue ATC)
- 1 Conterra SCARAB™
- 1 Petzl Gri-Gri™

Each agent carries personal climbing gear

Quick Attachment Safety (QAS):

Recommended as a tether or a Quick Attachment Safety (QAS), as the cave rescue community call it. When working near an edge, be attached with this tether, as fall prevention. When climbing, have the tether available. An adjustable unit, using a personal ascender of your choice and a locking carabiner, can be assembled. It can be made using 2.1 m. (7 ft.) of 8 mm. cord and 1.1 m. (43 in.) of 6 mm. cord. Attach one end to your ascender with a poacher's hitch or 'double overhand slip noose'. At the other end form a bight fitted around a nylon rope thimble. Tie a poacher's hitch or 'double overhand noose' but leave a tail. With a bight from the 6 mm. cord tie a three on two wrap Prusik hitch around longer 8 mm. cord. This will allow length adjustment of the unit. Connect the loose ends of the 6 mm. cord by a grapevine bend or 'double overhand bend' to the tail of the 8 mm. cord.



Quick Attachment Safety

High Angle vs. Low Angle:

The difference between low angle and high angle rescue is probably related to risks from exposure and whether to use one or two ropes. Often the same techniques can be applied in both realms. Usually, the definition is related to the vertical angle in degrees. A review of the literature has found a wide variety of opinions and it might prove helpful to review them. The Bozeman Fire Department considers high angle is over 45°. Fire Rescue/EMS Journal defines low angle as 15° to 67.5° and high angle as 67.5° to 90°. Michael Dunn of Emergency Response Training uses three categories, low angle 15° to 35°, steep angle 35° to 60°, high angle 60° and above. Raven Rescue of Canada considers 0 to 15° as flat terrain, 15° to 29° low angle, 30° to 50° steep angle, and 50° and above high angle. Canadian Rope Access Specialists expand on the concept defining low angle as up to 35° where most of one's weight is on one's feet, steep angle is 35° to 65° one's weight is shared between the feet and a rope system, high angle is 65° or higher where all the weight is on a rope system. Rick Lipke in his Technical Rescue Riggers Guide lists flat as up to 15°, low angle as 15° to 30°, maybe consider using a second rope, steep angle 30° to 50° with two ropes and probably the highest risk, and high angle 50° and above, using two ropes. The California State Fire Training materials are moot on a definition and only mentions 'the low angle rescue environment'.

A conclusion, to bring all these opinions into perspective, is probably best not to worry about the degrees of angle. If the rescuer's weight is supported by their feet, the operation is low angle. If most of the rescuer's weight is supported by a harness the operation is high angle. If the consideration is whether to use two ropes, first consider the risk potential i.e., is there a cliff or rushing water below. Then evaluate these three variables: Consider the available footing, i.e., is it stable or slippery; consider the operator's skill level, i.e., is one comfortable performing the task; and consider the personal fitness of the operator, i.e., can one function on the available terrain. These factors should determine whether you use one or two ropes if you are a volunteer or involved in recreation. If you are paid employee OSHA says you need two ropes.

Safety factor:

The safety factor is described as a ratio between the breaking strength and the force you intend to put on it. The American Society of Civil Engineering has a live load principle of breaking strength that uses a force factor of 1.7:1. These principles are practiced by both IRATA and SPRAT, which are certifying groups for people who professionally, actively work on ropes worldwide. A realistic guideline for rope rescue teams has been to try to have around a 7:1 safety factor. If the rope is 11 mm with minimum rating of 26 kN, then the forces should not exceed 3.7 kN. Through experimentation, the BCCTR developed the twelve people pulling idea, as a safe limit of the force to apply for a system when tensioning a high line. On 11 mm rope, rated at about 30 kN, then the twelve people pulling idea was a safe limit to apply for tensioning a high line with a rescue load at mid span. Remember, a pulling person is defined as someone just pulling hand over hand, and this effort, in a group setting, approximates only 222 N (50 lbs.) of force for each person. For 12.5 mm. rope maybe eighteen people pulling is appropriate. If any mechanical advantage is in a system, you will need to adjust the number of pullers you use.

Rope Rescue System – Dedicated Main, Dedicated Belay (DMDB):

This rope rescue system has been used for more than thirty years and has been popular with a variety of disciplines who use ropes. The basic idea is that one rope does all the work, and the second rope is not under tension but is there in case of a failure of the working rope. The main working rope will use one of the lowering and raising techniques described earlier. The second rope is rigged to provide one of the belay techniques described earlier to catch the load should the main line fail. Below are some pictures of the Dedicated Main, Dedicated Belay (DMDB) system and showing it in a lowering and a raising configuration:



Dedicated Main, Dedicated Belay (DMDB) system's equipment



DMDB lowering



DMDB raising

DMDB equipment list:

BELAY Unit:

61 m.	PMI Sport rope E-Z Bend, 11 mm. orange w/ black tracer	228.70
30 ft.	2.5 cm. PMI tubular webbing @ \$0.42 ft.	13.86
10 m.	cord, accessory 8 mm. @ \$1.60	16.00
2 each	SMC Lite Alloy steel locking carabiner @ \$36.00	72.00
1 set	tandem Prusik set, 8 mm (1.35 m/1.65 m)	4.94
1 each	Petzl Am'D aluminum locking carabiner	15.95
1 each	rope bag, nylon (orange)	30.00
1 each	cord bag, nylon for LRH storage	6.00
	Sub-total	<u>\$387.45</u>

WORKING Unit:

61 m.	PMI Sport rope E-Z Bend, 11 mm. white w/ black tracer	\$185.80
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30 ft.	2.5 cm. PMI tubular webbing, @ \$0.42 ft.	13.86
10 m.	cord, accessory 8 mm. @ \$1.60	16.00
4 each	Petzl Am'D aluminum locking carabiners @ \$15.95	63.80
1 each	Petzl William aluminum locking carabiner @ \$17.95	17.95
1 each	CMI pulley, single, Prusik minding, bushing, 2 in. aluminum	53.90
1 each	CMI pulley, single, bushing 2 in. aluminum	33.30
1 each	rack frame, SMC six bar size	37.25
1 each	hyper-bar, BMS	19.00
2 each	brake bars, SS w/o groove @ \$10.40	20.80
2 each	brake bars, SS w/ groove @ \$10.40	20.80
1 each	brake bar, round aluminum	7.00
1 set	Prusik loops, 8 mm. (1.35 m. and 1.15 m.)	4.00
1 each	rope bag, nylon (blue)	30.00
1 each	cord bag, nylon for LRH storage	6.00
Sub-total:		\$529.46

Total cost: \$916.91

Two Tensioned Rope Systems:

When this paper was originally written, it was to reflect the basic rope system that relied on one working loaded rope and a second unloaded belay rope. Two tensioned rope systems, popular throughout Great Britain, Canada, Australia, and New Zealand, are essentially a refinement of the well-established load and belay two rope system. It offers advantages in operating efficiency, while reducing some of the hazards that occur in the separate load and belay rope system and consists of two working main lines each with similar equipment. Both stations are designed to be always failsafe in the event of operator error or incapacitation. Each station can lower the load, provide a tensioned belay, or be converted into a raise system as all the required equipment is in place. This system uses two ropes and will meet the OSHA standard.

With this increased popularity of two tensioned rope systems, four common, but different techniques of lowering a litter have evolved:

1. Two ropes, two descent control devices, going to one attachment on litter.
2. Two ropes, two descent control devices, going to two attachments on litter.
3. Two ropes, both in one descent control device, going to one attachment on litter.
4. Two ropes, both in one descent control device, going to two attachments on litter.

The specific technique a team might use is probably dictated by which method they saw demonstrated first. When different teams want to work together however, interoperability concerns will arise.

Kirk Mauthner, a consultant for Emergency Management British Columbia has noted some of the advantages to using two tensioned rope systems:

- The rigging and devices for managing each rope can be identical. This reduces training and operating complexity as there are not different systems to learn for operating mainlines and belay lines. As a result, human factor risks are reduced.
- Communication is improved because, except on edge transitions, each operator is doing similar activities with their respective devices.

- Having tension on both ropes makes the descent or ascent smoother because any sudden movement on one rope is absorbed by the other rope.
- Peak force and stopping distance are significantly reduced compared with un-tensioned backup systems.
- Friction is reduced in the system which makes it easier to raise the load with both ropes and reduces forces on the haul systems.
- If required, it is fast and simple to shift tension between ropes, for example, when passing knots or if ropes need to be repositioned away from terrain hazards such as sharp edges or cracks. Though normally sharing the load, each rope has the capacity to raise or lower the full load independently, or function as an unloaded belay.
- Conversion from lower to raise under load is much simplified, as one rope holds the load while the haul system is set up on the other, the progress capture device, and change of direction pulley are already in place. The haul Prusik and traveling pulley are nearby.
- Maximum arrest force and, more importantly, stopping distance are substantially reduced compared to DMDB systems.
- Greater survivability to sharp edge exposure.



two tensioned rope system



two tensioned rope system lowering with Scrabe and rack



two tensioned rope system raising

Dual Capability Two Tensioned Rope System (DCTTRS):

In 2016 the Canadian Government sponsored a group of thirteen skilled rope rescue persons, led by Kirk Mauthner, of Basecamp Innovations®, with a financial grant for thirty days to embark on an evidence-based approach to overhaul and modernize Canadian rope rescue practices, techniques, and produce a training delivery model. The results would establish a common protocol for Canadian Parks, Canadian Military SAR TECH's, RCMP, and local SAR groups. Rather than relying on the traditional 10:1 Static System Safety Factor, which has many shortcomings, their results would focus on adopting force limiting principles to control forces and cap these forces to a value that humans can stand. They would also determine strength requirements for individual components.

We know through measuring that our working loads average between 1 and 4 kN. We also know that the human body cannot handle forces greater than 12 kN. Therefore, our force limiting on all components must be within a range of 6 to 12 kN. All these forces can easily be determined using the established 'belay competence test'. This committee further determined that all components should have a minimum breaking strength that would conform to the American Society of Civil Engineering live load principle of using a force factor of 1.7. Therefore, with a maximum allowable peak force of 12 kN. the minimum component breaking strength of 20 kN. would insure a strength margin in the rigging. This safety concept is utilized in varying degrees by rope access associations such as SPRAT and IRATA.

Human factors, a primary concern, would also be addressed. As an example, testing by Mike Gibbs, of 'Rigging for Rescue®', in 2015 and by Billy Masterson in 2011, showed that MPD's™ may not self-actuate when a line failure occurred if there was no tailing or back pressure on the feed line. The same has been found true with the 540 Belay device. We know that the human brain automatically responds to an external crisis by letting go to get away from a perceived issue. To overcome this situation a rope system would need to have a manual override on any self-braking feature a descent control device may have. With this feature, the rope system would also pass the recommended 'whistle test'.

The result of the project was to adopt what is now described as a 'Dual Capability Two Tensioned Rope System' (DCTTRS), whereby each system is simultaneously capable and competent as both a main line function as well as a back-up function to the other line. The idea is that each line can take on the full load at any time without requiring a friction change on its descent control device system. A summary of the benefits of the Dual Capability Two Tensioned Rope System (DCTTRS) over the Dedicated Main Dedicated Belay (DMDDB) are:

- Better for sharp edge exposure as rope is under less tension.
- Maximum arrest force and stopping distance is reduced.
- Rigging and managing each rope is identical reducing training time.
- Communication is improved as each operator is doing similar tasks.
- Lowering and raising are smoother.
- Rope drag, causing rock fall is greatly reduced.
- Less effort is required to raise loads.
- Generally, passing knots, changing direction, repositioning ropes is easier.

Dual Capability Two Tensioned Rope System set-up:

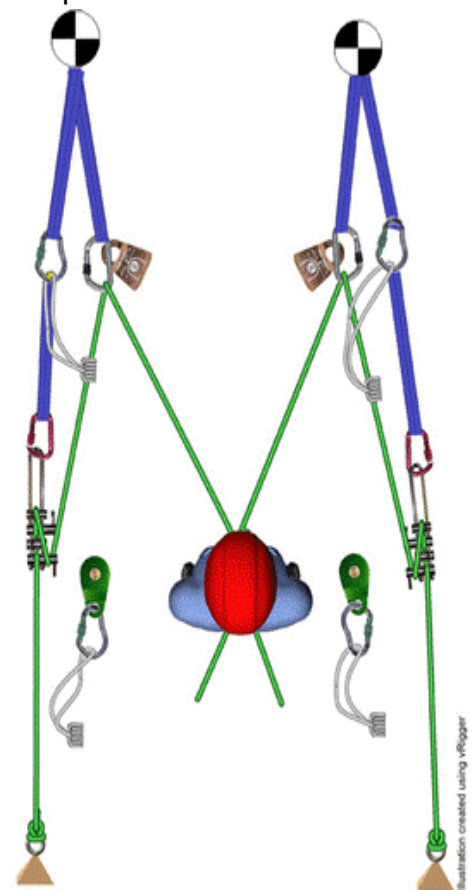
Each line in the system is set up using similar functions with the chosen descent control device extended from the anchor on a 60 cm. (2 ft.) sewn sling. A three wrap, 8 mm. kernmantle cord Prusik positioned behind, or on the anchor side, of the DCD is attached to the carabiner holding the sewn sling. The controlled rope would then pass through a second carabiner, preferably steel, attached to the anchor, continue through the Prusik, and into the chosen DCD. This second carabiner provides a minimal rope tailing of ≤ 0.1 kN. and provides a location to place a pulley when converting to a haul.

On a lowering, a small amount of back pressure is provided by the anchor carabiner, and the Prusik must be manually overridden by an operator before the rope enters the DCD of choice.

There is a remote chance that if one of the rope systems fails and all the load suddenly comes onto the remaining system it could cause a 'jolt'. Testing has shown that a 'jolt' of this type will generate less than a 3 kN. maximum force. The operator may not take the correct action of letting go, so the Prusik can function. To reduce this chance of human error, a separate person has been assigned to 'tail' both ropes and feed them to the respective operators. This person, tailing the ropes, becomes another set of eyes to actively monitor the actions of the DCD operators. The rope tailing is now increased to about 0.5 kN. They would also make it easier to maintain an appropriate feed rate to allow more equal tension in each system.

Two techniques have evolved for the operator to manipulate the Prusik. If the load is light a technique like the hand motion for a tandem Prusik belay may be used to feed the rope into the DCD. If the load is significant, the separate person 'tailing' the ropes would feed the rope through the anchor carabiner and the operator would keep knocking back the Prusik with a scissor motion using two fingers. If a Prusik does get locked up, simply route the running end of the rope through a carabiner that can be connected at the DCD and create an improvised 3:1. A short pull will break the stuck Prusik free. When it is time to change over to a raise, one system stops and holds tension. The other system allows enough line to pass through the DCD to create enough slack for its removal from the rope. A Prusik Minding Pulley is placed in the anchor carabiner and the rope installed in it. The attached Prusik now acts as a Progress Capturing Device. A haul Prusik is attached below the DCD with a pulley to construct a three to one haul system. Once the haul system on one rope is tensioned, the changeover process is completed on the second rope.

For an edge transition, both ropes should be under tension. If a high directional is used, both ropes should be elevated, but after the edge transition is completed, one rope may be lowered.



DCTTRS diagram

If a high directional is not available, then the litter may be taken over the edge in a vertical orientation. Once free of the edge, the litter can then be orientated horizontally. Another recommendation, to overcome the human factor, is to discuss what the plan is in common language, if you do not want to follow a formal command system. Then, always do one or more dry runs for the edge transition before committing to the actual evolution. Everyone will now be aware of the current situation and will not be relying on previous trainings.

When first working with a DCTTRS System it might be best to have identical equipment on each rope. As experience develops an operator may substitute any DCD, they are more comfortable with. Or more pulleys can be added to provide a smoother raise. One of the ropes can have a constructed five to one haul system by placing a double pulley in the haul position and moving the original haul pulley to piggy-back on the anchor pulley. These modifications do not change the basic functions but will accommodate an individual operator's skills.

DCTTRS Equipment list:

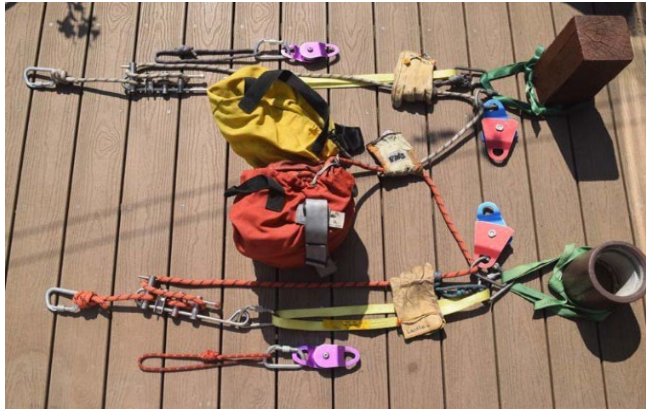
First Unit:

61 m.	PMI Sport rope, 11 mm., white w/ black tracer	\$185.80
30 ft.	2.5 cm. PMI tubular webbing, @ \$0.42 ft.	13.86
3 each	Petzl Am'D aluminum locking carabiner @ \$15.95	53.85
1 only	SMC Lite Alloy steel locking carabiner	36.00
1 only	60 cm. Yates rigging strap, 24 kN	12.00
1 only	BMS Micro rack with dual hyper bars	93.88
2 each	1.35 m. Petzl 8 mm. Vector cord, @ \$2.61 m. = \$3.54	7.08
1 only	CMI pulley, single, Prusik minding, bushing, 2 in. aluminum	53.90
1 only	CMI pulley, single, bushing, 2 in. aluminum	<u>33.30</u>
	Sub-total	\$489.67

Second Unit:

61 m.	PMI Sport rope, 11 mm., orange w/ black tracer	\$228.70
30 ft.	2.5 cm. PMI tubular webbing @ \$0.42 ft.	13.85
3 each	Petzl Am'D aluminum locking carabiner @ \$15.95	53.85
1 only	60 cm. Yates rigging strap, 24 kN	12.00
1 only	BMS Micro rack with dual hyper bars	93.88
2 each	1.35 m. Petzl 8 mm. Vector cord, @ \$2.61 m. = \$3.54	7.08
1 only	CMI pulley, single, Prusik minding, bushing, 2 in., aluminum	53.90
1 only	CMI pulley, single, bushing, 2 in., aluminum	<u>33.30</u>
	Sub-total:	\$532.56

Grand-total: \$1,022.23



DCTTRS lowering



DCTTRS raising

The final document will have units for three training levels: Awareness, Technician 1, and Technician 2. A 'beta' version of the workbooks became available in May of 2017.

If your team has been using standard six bar rappel racks with a hyper-bar, these racks can be reused for the DCTTR system by simply removing two bars.

Following are pictures of a DCTTRS application that uses alternative items. The functions remain the same, but the tools may vary, due to equipment availability or the operator's skill level.



DCTTRS raising with a 3:1 and a 5:1 system



DTTRS lowering with a rack and a Scarab™

TSO Checklist and Worksheet:

The following page is a document that allows one to document a chosen rope rescue system. Drawing out what you have created is one of the best ways to learn about each rope rescue

technique. This document is provided by Reed Thorne of 'Ropes That Rescue™'.

T S O CHECKLIST & WORKSHEET

1

Position	Name	TSO check?
Safety:		[]
Blitz/EMS:		[]
Staging:		[]
Main 1:		[]
Main/Belay 2:		[]
Attendant 1:		[]
Attendant 2:		[]
Edge:		[]
Frames:		[]
Offset:		[]
		[]
CONTROL:		[]

Pulley/Raising System used:

SYMBOLS

Other Symbols

POINT ANCHORS

A	Anchor (generic)
AM	Marginal
AB	Bombproof
As	System anchor
AF	Focused
AFF	Focused-Floating

LINEAR ANCHORS

ABT	Back tie
Ao	Front tie (opposition)
PR	Ratchet prusik
PH	Haul prusik
PG	Ganging prusik
PB	Prusik bypass
HD	High Directional Frame
H	Hauler
Hs	Hauler (manned ratchet)
PMP	Prusik-minding-pulley
TPB	Tandem Prusik Belay

2

Draw Schematic

3

Main Line 1:
Main/Belay 2:

READY TO BEGIN OPERATIONS?

☐ CHECKLIST COMPLETE?
☐ ONE LONG WHISTLE BLAST
☐ "CONTROL, YOU'RE IN CHARGE!"

Outside Training:

Training in the subject of rope rescue and/or working at height may be difficult to define as there is an extreme range of skills involved. Most instructors and training company employees have learned their rope rescue material by rote, a fixed mechanical way of doing something by memory only, without understanding or thought.

This offers an opportunity to look at the experiences and expectations of a variety of groups who are involved in rope rescue or working at height.

Workers at height, operate under OSHA, ANSI, and MSHA, use 5/8 and 3/4 in. ropes, no knots are allowed, only all steel connectors, a component safety factor greater than 5,000 lbf. – No training level apparent as rope skills are ancillary to the worker's hired focus.

Fire Department personnel, operate under NFPA and IFSA, use 1/2 in. or 12.5 mm. rope, use the figure-of-eight family of knots, all steel carabiners, a component safety factor 15:1, and ratings at 40 kN. (9,000 lbf.) – Training level probably at a FEMA Awareness level.

Mountain Rescue Association teams, National Cave Rescue Commission personnel, Fire Department Special Operations units, commercial rope access technicians, operate under IRATA and SPRAT, use 5/16 in. or 11 mm. rope, add the bowline family of knots, use aluminum carabiners, a component safety factor 10:1 and component ratings at 25 kN. (5,600 lbf.) – Training level is probably at a FEMA Operations level.

Serious students of rope rescue involved in innovation, testing, and teaching, operate under the laws of physics, use critical thinking, use 3/8 in. or 9 mm. and smaller rope, use a wide variety of knot craft, use aluminum carabiners, a safety factor 7:1 or less, and component ratings at 20 kN. – Training level probably at a FEMA Technician level.

For those who are serious about rope rescue, the author will endorse courses taught by Reed Thorne of 'Ropes That Rescue, Ltd™' at www.ropesthatrescue.com or courses taught by Kirk Mauthner of 'Basecamp Innovations™' at www.kirkmauthner.ca.

Another training venue is the International Technical Rescue Symposium, annually held in early November. It is co-sponsored by Mountain Rescue Association, National Cave Rescue Commission, National Association for Search and Rescue, Society of Professional Rope Access Technicians, and is jointly presented by California Mountain Company® and Pigeon Mountain Industries®.

Thoughts in Review:

- You should always train at a higher level than you will have to perform.
- Your goal is to get the maximum potential with the minimum of manpower and equipment.
- A general concept is to use two ropes of different colors to avoid confusion and keep them in the best condition, trying not to tie them directly to an anchor. Store the ropes in different color bags.

- Consider using soft methods of attaching to the main line.
- Appropriate equipment should be available to pass a bend.
- If using a traditional belay line, it should not be used when the load must be shifted. Use other techniques or a jigger.
- Avoid any situations where a load has a potential of shifting more than 30 cm. (1 ft.).
- If you need to make a mid-line connection use a cross-lashed strap or 'dog-n-tails' rather than an in-line knot.
- Carabiners should be chosen with consideration. Besides locking, the gate design should assure that it will catch when the long axis is stretched. Consider carabiners with the key lock design. Consider auto-lock carabiners. On loaded working ropes and anchor ropes make sure the carabiners are placed with the gates up, for safety checks and to add things, but locks are orientated to screw downslope to keep the lock engaged if vibration occurs. With unloaded ropes, as belays, also keep the gates up. This will accommodate any potential shock load when the carabiner spine hits the rock face. Again, only hand tighten the lock.
- A main issue with knots, may not be the loss of strength to a rope, but can you untie the knot after it has been loaded. Flemish Knots or 'figure-of-eight family of knots' are not the best choice.
- Interior angles on components should be less than 90°.

• Considering a 100 kg load:

...at 0 degrees each leg has a 50 kg load...at 30 degrees each leg has a 52 kg load
 ...at 45 degrees each leg has a 54 kg load...at 60 degrees each leg has a 58 kg load
 ...at 90 degrees each leg has a 71 kg load...at 120 degrees each leg has a 100 kg load
 ...with an interior angle of 150 degrees each leg has a 193 kg load

Acknowledgements:

I would like to thank the following individuals for their help over the years in gathering the information presented. Their patience was also appreciated: Arnor Larson, Kirk and Katie Mauthner, Steve Hudson, Bruce Smith, John Dill, Reed Thorne, Bill Cuddington, Carroll Bassett, Jon Olson, William Lane, Kim Aufhauser, Bruce Parker, John McKently, DJ Walker, Gary Storrick, David Lamont, Dale Stewart, Qiuyi Chen, John Carnes, the illustrator, and Jeff Stevens, the Internet advisor.

Publications:

These publications offer more information about rope rescue:

- Technical Rescue Riggers Guide, Second Edition, by Rick Lipke, Conterra Inc.,
- The Ashley Book of Knots, by Clifford W. Ashley, Doubleday, 1944
- On Rope, New Revised Edition, by Bruce Smith and Allen Padgett, National Speleological Society, 1996
- Are You REALLY On Belay? by John T. Dill, NASAR RESPONSE®, 1990
- Release-Devices: A Comparative Analysis, by Katie and Kirk Mauthner, 1999

- The Load Distributing Anchor System, by Keith Schafer, NASAR RESPONSE, 1991
- Gripping Ability on Rope in Motion, by Katie and Kirk Mauthner, 1994
- Everything you ever wanted to know about vertical equipment go to Dr. Gary Storrick's website: www.verticalmuseum.com/index.php
- Look for Rope Rescue Myths exposed at: <http://www.onrope1.com/myth9.com>

Vendor:

The author currently has most of the items discussed in this presentation available for sale or can obtain them at a good price. Feel free to contact him and request a price quote. Another vendor is AHS Rescue, 3244 East Thomas Road, Phoenix, Arizona 85018, (602) 944-7723. If you want to place an order for equipment with them, be sure to ask for the 'RESCUE' pricing as a reward for reading this paper.

About the Author:

Kenneth N. Laidlaw has been a practitioner of Search and Rescue skills with twelve different types of organizations over the last fifty years. His background includes:

Red Cross Emergency Medical First Responder,
American Red Cross Disaster Responder, Logistics
National Association of Search and Rescue SAR-Technician Evaluator,
National Association of Search and Rescue FUNSAR Instructor qualification,
National Association of Search and Rescue Tracking Instructor qualification,
National Cave Rescue Commission Instructor qualification,
Society of Professional Rope Access Technician qualification,
Joel Hardin Sign-cutter Tracking certification,
S-131 Wildland Firefighter qualification,
Hazardous Materials Operations qualification,
Confined Space Operations certification,
Mine Safety and Health Administration certification,
Mountain Rescue Association qualification,
Public Safety diver and tender qualification,
Forklift operator qualification,
Amateur radio General license N6GFE,
California Rescue Dog Association Mission Ready Support Person, qualification
Alameda County Sheriff's Search and Rescue member,
Humane Society of United States Disaster Emergency Responder,
North Valley Animal Disaster Group Emergency Responder,
United States Fish and Wildlife refuge volunteer,
Technical skills consultant for the Fire Department for the East Bay Regional Park District,
Contract Seasonal Police Officer with the East Bay Regional Park District for 25 years,
United States Marine Corps Reserve, MOS 1833, Armored Amphibian Tractors for 5 years
Variety of job assignments with the Berkeley Unified School District for 30 years.
2020 Recipient of National Speleological Society's Steve Hudson Cave Rescue Award.

Knot Glossary:

Historic Name	Local Name	Application
Blood knot	double overhand stopper knot	rope or cord termination
Bowline w/ retrace	Yosemite bowline	end of line loop
Bowline on a bight		anchors needing fixed loops
Bowline, Portuguese	bowline on a coil with only two loops	anchors needing two adjustable loops
Clove hitch		midline attachments on pickets and pod legs
Common lashing	trucker's hitch or wrangler's hitch	anchors and litters
Constrictor hitch		end of line attachments on pickets and pod legs
Double sheet bend with a retrace	double becket bend	anchors and joining ropes
Flat overhand bend	European Death Knot	joining webbing
Flemish bend	figure-of-eight follow through bend	joining ropes or cords
Flemish loop	figure-of-eight on a bight	end of line loop
Grapevine bend	double overhand bend	joining ropes or cords
Lineman's loop	Alpine butterfly	midline loop
Mezzo Barcaiolo hitch (MB)	Münter's or Italian hitch	providing friction
Poacher's Hitch	double overhand noose	attaching devices
Ring bend	overhand follow through bend or water 'knot'	joining webbing
Ring hitch	girth hitch or Lark's foot	litters
Tensionless hitch	high strength tie-off	anchor
'Mule' a hitch or a device	'dog' a hitch or device	securing in place

Tying a 'mule' or 'dog':

Technique: Grasp a bight in the running rope end near the hitch or device. Pass it under the standing part, then over and down through the newly formed bight forming a 'slippery half-hitch'. Snug it down on the device. Lengthen the bight and continue around and form at least two more half hitches with the bight and snug each of them down on the device. This is a British version.

The American version starts with a half-twist loop, passed behind the standing part. Then, form a bight, which passes over the standing part, is pushed through the loop, and pulled snug. Then lengthen the bight and tie an overhand knot with it; but to tighten an overhand knot you must pull it away from the device, thus loosening your securing 'mule' or 'dog'.

Inside Training Options:

If you are interested in developing your personal rope rescue skill's you should participate in a regular training regime. In the author's experience, with a variety of organizations, a rope rescue training sequence always starts with a knot class. Participants find this class very frustrating and usually chose not to continue. The next year the cycle repeats, and participants find the same frustrations. A recommendation is to not teach a knot class. At the first class, guide students to set up a system and make it work. Participants will now see how knot craft plays an important part and they will seek out learning the required knots, bends, and hitches on their own from the many online sources available and will be very motivated to do so.

Following are training program recommendations for both the DMDB and the DCTTRS systems. First for each system is a list of the skills necessary for that system, which you can consider as a 'task book'. Once these skills have been validated by a third party you can be considered at an awareness level. These skills can be self-taught, with some in person coaching and access to the internet.

To be considered at an operational level you must be able to put all these individual skills together, efficiently build a working system with all its components, within an acceptable established time limit. This operational test should be required at least every two years. During each two-year period you should regularly drill to keep your skills.

ROPE RESCUE AWARENESS SKILLS for DMDB SYSTEMFor operating **D**edicated **M**ain and **D**edicated **B**elay systems

Name: _____

No.	Item	Date	Signed Off By
1	Flemish loop (figure-of-eight on a bight) on 11 mm		
2	Ring bend (water knot) w/ 10 cm. (4 in.) tails		
3	Improvised harness with webbing		
4	Bowline w/ retrace (Yosemite finish)		
5	Blood knot (double overhand stopper knot)		
6	Grapevine bend (double overhand bend)		
7	Flat overhand bend with 12 cm. (6 in.) tails		
8	Poacher's hitch (double overhand noose)		
9	Three wrap Prusik hitch (8 mm. cord on 11 mm. rope)		
10	Clove hitch w/ 8 or 9 mm.		
11	Constrictor hitch w/ 8 or 9 mm.		
12	Double sheet bend w/ end tucked or retraced on 11 mm		
13	MB (Münter's) hitch on 11 mm		
14	Lineman's loop (Alpine butterfly) on 11 mm		
15	Radium 3:1 hitch w/ 8 mm		
16	Construct a wrap 3 / pull 2 anchor system		
17	Demonstrate a 1:1 w/ Progress Capture Device		
18	Demonstrate a 2:1 w/ PCD (bolt on to a separate rope)		
19	Demonstrate a 3:1 w/ PCD		
20	Demonstrate a lower: with rack		
21	Demonstrate a lower: with scarab		
22	Demonstrate an MB (Münter's hitch) belay		
23	Demonstrate a tandem Prusik belay		
24	Attach litter bridal		
25	Attach litter spider		
26	Package a patient in a litter		

ROPE RESCUE OPERATIONAL TEST for DMDB SYSTEM:**Name:** _____ **Signed Off By:** _____

Assemble from assorted equipment a rope rescue system that has a **Dedicated Main** line and a **Dedicated Belay** line in less than 30 minutes. You may lay out all the equipment you will need before your time begins. This test must be performed every two years to remain operational.

RULES OF ENGAGEMENT:

No.	Item	Estimated Time 14 ½ min.	☒
1	Both separate anchors will be the 'wrap three, pull two' style with webbing.	2 min.	
2	Belay line will have a Tandem Prusik belay with steel carabiners and a 3:1 Radium load release hitch.	1 ½ min.	
3	Main line will have a brake bar rack or Scarab, and a 3:1 Radium load release hitch extended to not allow a pulley with its progress capture device to interfere with the rack.	3 ½ min.	
4	A haul Prusik, with its pulley, ready to use, will be attached to the main line.	1 min.	
5	The load focal point, which could be a rigging plate, or a 4" steel ring, will be attached to the main and belay lines by interlocking knots.	2 min.	
6	The load focal point will also contain a litter spider and a jigger for an attendant.	1 min.	
7	The tail to the belay line will be attached to a litter using a tied bridle.	3 min.	
8	The tail of the main line will be attached to the bottom of the attendant's jigger by a knot with a loop.	1 min.	
9	The litter spider will be attached to a litter with carabiners in the correct orientation.	1/2 min.	

ROPE RESCUE AWARENESS SKILLS (DCTTRS) SYSTEM:For operating **Dual Capability Two Tensioned Rope Systems**:**Name:** _____

No.	Item	Date	Signed Off By
1	Flemish loop (figure-of-eight on a bight) on 11 mm		
2	Ring bend (water knot) w/ 10 cm. (4 in.) tails		
3	Improvised harness with webbing		
4	Bowline w/ retrace (Yosemite finish)		
5	Blood knot (double overhand stopper knot)		
6	Grapevine bend (double overhand bend)		
7	Flat overhand bend with 15 cm. (6 in.) tails		
8	Poacher's hitch (double overhand noose)		
9	Three wrap Prusik hitch (8 mm. cord on 11 mm. rope)		
10	Clove hitch w/ 8 or 9 mm.		
11	Constrictor hitch w/ 8 or 9 mm.		
12	Double sheet bend w/ end retraced on 11 mm		
13	MB (Münter's) hitch on 11 mm		
14	Lineman's loop (Alpine butterfly) on 11 mm		
15	Construct a wrap 3 / pull 2 anchor system		
16	Construct a Blitz anchor w/ lineman loop & carabiner		
17	Demonstrate a 1:1 w/ Progress Capture Device		
18	Demonstrate a 2:1 w/ PCD (bolt on to a separate rope)		
19	Demonstrate a 3:1 w/ PCD		
20	Demonstrate a lower: with rack		
21	Demonstrate a lower: with scarab		
22	Demonstrate an MB (Münter's hitch) belay		
23	Attach litter bridal		
24	Attach litter spider		
25	Package a patient in a litter		

ROPE RESCUE OPERATIONAL TEST for DCTTRS SYSTEM:

Name: _____ **Signed Off By:** _____

Assemble from assorted equipment a **Dual Capability Two Tensioned Rope System**, in less than 20 minutes. You may lay out all the equipment you will need before your time begins. This test must be performed every two years to remain operational.

RULES OF ENGAGEMENT:

No.	Item	Estimated Time 12 min.	☒
1	Each of two operational anchors will be the 'wrap three, pull two' style with webbing. You may use a bend of your choice including a flat overhand bend in 'frost knot' configuration.	1 min.	
2	Each anchor will have a steel carabiner with an open PMP pulley attached to it. Each anchor will also have an aluminum carabiner with an attached Prusik loop and a 60 cm. strap. On the end of the strap will be an aluminum carabiner containing the descent control device of your choice.	2 min.	
3	Both operational lines of different colors will be installed. They will each pass through the steel carabiner and through a tied triple wrapped Prusik hitch.	2 min.	
4	A haul Prusik, with its aluminum carabiner and open pulley, ready to use, will be attached to the anchor.	1/2 min.	
5	The load focal point, which could be a rigging plate, or a 4" steel ring, will be attached to both operational lines by long tailed interlocking knots.	2 min.	
6	The load focal point will contain a litter spider and a jigger for an attendant.	1/2 min.	
7	The tail to the one line will be attached to a litter using a tied bridle.	3 min.	
8	The tail of the other line will be attached to the bottom of the attendant's jigger by a knot with a loop.	1/2 min.	
9	The litter spider will be attached to a litter with carabiners in the correct orientation.	1/2 min.	

INTERNATIONAL SYSTEM OF UNITS

Recommended for Rope Systems testing and evaluation

<i>for this quantity</i>	<i>to <u>convert</u> from customary unit</i>	<i><u>multiply</u> by</i>	<i>to <u>obtain</u> S I unit</i>
<u>MASS</u>	pound–mass (lbm) (lb. avoirdupois) slug (when pound is used for force)	0.453 592 37 (exact) 14.593 90	kilogram (kg) kilogram (kg)
<u>LENGTH</u>	inch (in.) foot (ft.)	25.4 (exact) .3048 (exact)	millimeters (mm) meters (m)
<u>SPEED</u> (velocity)	feet per second (ft./s)	.3048 (exact)	meter per second (m/s)
<u>ACCELERATION</u>	feet per second squared (ft./s ²)	.3048 (exact)	meter per second squared (m/s ²)
<u>FORCE</u> (tension)	poundal (when pound is used for mass) pound–force (lbf)	.138 255 0 4.448 222 (4.448 221 615 260 5 exact)	newton (N) (kg · m/s ²) newton (N)
<u>STRESS</u> (force/area)	pound–force per square inch (lbf./in. ²)	6.894 757	kilopascals (kPa) (kN/m ²)
<u>ENERGY</u> (work)	foot pound–force (ft. · lbf)	1.355 818	joule (J) (N · m)

NOTE: To retain accuracy in a conversion, multiply the specified quantity by the conversion factor exactly as given above, then round the product to the number of significant digits that will neither sacrifice nor exaggerate the accuracy of the result. To convert the other way, divide by the conversion factor. A FINAL result should contain no more significant digits than the number with the smallest number of significant digits in the multiplication or division unless a $\pm$ degree of accuracy is included.

MG–force (previously called weight)

A mass hanging statically from a rope will cause a force (tension) to exist in the rope which is proportional to the mass *and* the value of gravitational attraction at the location where the mass is suspended. The tension in the rope is the MG–force and is expressed in newtons (N). The standard international value for the acceleration of gravity (*g*) is 9.806 650 m/s² and this is the assumed value often applied when mass is mistakenly equated to force. The actual value of *g* ranges between 9.77 and 9.83 m/s² over the surface of the earth and even more widely above and below the surface. The MG–force is not an intrinsic value of an object but will vary depending on the buoyancy and the local gravity acting on the object.

kilogram–force (kgf) (also kilopond, kp)

A name that causes much confusion since the “force” is often left off and the resulting mass unit (kg) is not appropriate for describing a force. Even when properly used, kgf is confusing since it implies the force exerted when one kilogram is suspended under the influence of gravity which, as we have seen above, can vary. This term is to be avoided. The proper term for force is newton (N).

PROJECTS: Putting all these ideas together in a bigger operation:

ARIZONA VORTEX ASSEMBLY in a Lazy Leg A-Frame configuration Set-up:

1. Locate the blue head, two outer legs, two inner legs, and assemble them with the inner leg on the bottom, then an outer leg, with blue head on top. Adjust the inner legs so the 'A' frame head is five feet off the ground.
2. Place the appropriate feet, probably the raptor foot, for the terrain, on the inner legs and orientate them to be efficient.
3. Attach orange head to blue head.
4. Connect three outer legs and one inner leg, to create the 'lazy leg'.
5. Connect the inner leg to the orange head with about one foot protruding and put the appropriate foot, raptor or the flat foot, on the end of the outer leg.
6. Connect the three orange strap hobbles to all the feet and tension them snug.
7. Attach a 'set-of-fours' to the blue head with preferably a side loading pulley on its bottom end.
8. Attach another pulley to the blue head.
9. Secure the orange cord to the Vortex head and deploy it as a safety line.
10. Belaying the safety line through an MB Hitch move the Arizona Vortex to the vertical edge.
11. Position the 'A' frame feet so that the resultant focal point of the hanging pulley will be inside the triangle created by the orange hobble and will suspend the main lines just above the ground at the edge.
12. A goal is to have the 'lazy leg' foot force itself into the ground like a plow. If the ground is too hard, drive a picket in the ground next to the foot to prevent the foot from lifting off the ground when under a load.
13. Approximately 10 m. (about 33 ft.) from the vertical edge locate the front your anchor system.
14. During an operation, a litter is slid under the 'A' frame parallel to the lazy leg. One rope is passed through the pulley on the blue head.
15. The other rope passes through the side loading pulley on the 'set-of-fours'.
16. Both main lines can be vectored for tension to allow the litter bearers to slid through the 'A' frame with the litter as they start over the edge.
17. The tensioning vector is slowly released, and the litter bearers start their descent.
18. Appropriate edge protection is provided, if necessary, so the ropes do not make contact with the ground. After the load is over the edge the rope in the 'set-of-fours' pulley is lowered closer to ground level.
19. On an assent the bearers stop when the end of the litter reaches the 'A' frame and the rope in the 'set-of-fours' side loading gate pulley is removed.
20. The operators of the rope through the remaining pulley now move their haul Prusik the rear and prepare to lower their rope out as the other rope continues to pull the load in, thus creating a paradoxical motion until the litter is in a safe zone.



Arizona VORTEX as a lazy leg A-frame

ELEVATED FORWARD FOCUSED FLOATING 'BEACH-HEAD ANCHOR using the AZORB Set-up:

1. Locate three rear anchors within 30° to 45° of the center line.
2. Each anchor will be a wrap three pull two style, and the bend can be a flat overhand bend, or a ring bend (water knot).
3. The pulled webbing will be focused on the AZORB and then seized with 1 m. of cord, or an overhand knot can be tied with a wooden toggle placed in it.
4. If rock pro is used there must be two or three for each anchor and the webbing pulled out, focused, and seized or tied off using a toggle.
5. The leg is assembled, inner leg on bottom, with the appropriate foot, to a height of 125 cm. or 4 feet and positioned so that the target, ground edge, and AZORB all line up.
6. Orange section of AZORB is on top, half-way out of blue section, and is attached by a pin to the leg.
7. Small holes in units are to the rear or anchor side to allow more forward connection points.
8. A front tie, with 7 mm. accessory cord, uses a constrictor hitch around the leg below the AZORB but above the pin.
9. Front tie anchor uses an appropriate device with an HMS style carabiner placed in it. A single strand of cord with a round turn is placed through the HMS style carabiner before it is tensioned and tied off with at least two half-hitches using a bight.
10. Each of the three rear anchors uses a 165 cm., 9 mm. Prusik loop secured to both orange and blue heads with carabiners.
11. The Prusik loop is orientated with a twist in it to form an X.
12. A carabiner is placed in the X.
13. Using 15 m. pieces of 6 mm. Power Cord, rated at 19 kN, tie a small bowline with a retrace safety and attach to each of the carabiners in the X's.
14. Form a circle with the cord and another carabiner, extend the circle out to each focused anchor attachment.
15. Place a round turn on the carabiner at the anchor end and use it to remove any slack in the anchor ties. Each is secured at the anchor end with two or more half-hitches using a bight.
16. All carabiners will be orientated with the gates up and locking collar screwing down to insure it will not vibrate open.
17. Each outside anchor can be tightened using a common lashing or trucker's hitch but be careful to use a knot that can be untied, like a lineman loop (Alpine butterfly).
18. One main line attaches to the orange head and the other main line attaches to the blue head.
19. If it is more efficient to attach change of direction pulleys to the heads, another 165 cm. 9 mm. Prusik loop can be connected, as above, to the heads and an opposing force anchor established for the change of direction anchor.
20. Each component in this application exceeds 20 kN.
21. Inventory: 25 Am'D carabiners, 2 William carabiners.

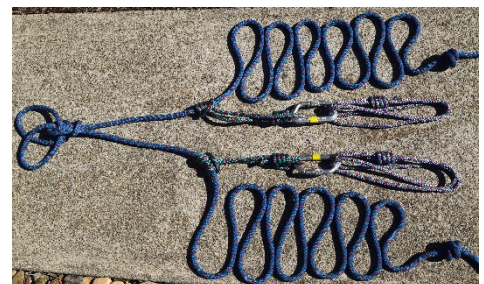


AZORB as an elevated forward focused floating anchor

Para-tech Monopod Set-up:

1. Place trailer hitch unit in the receiver on a truck and position the anchor ring below the strut socket. Make sure the 2 ½" spacer stays with hitch.
2. Place extending end of 8/12 strut in the socket on the trailer hitch unit and tighten its adjustment ring creating a boom.
3. Place monopod head on outer end of 8/12 strut.
4. Attach the bowline on a bight, on the pre-rigged guy rope bridle assembly, to the two upper rings on the monopod head with a carabiner from each loop to a ring.
5. There is an 8 mm. three on two wrap Prusik hitch pre-tied on each bridle leg.
6. Place a long Prusik loop in a basket hitch configuration through the ring bolt on the truck body on each side and connect each basket hitch to each Prusik hitch with a carabiner.
7. Lift boom-strut up and adjust the Prusik hitches so the boom is not resting on the hitch body and is now suspended by the guy rope bridle.
8. Hang a change of direction single pulley with a carabiner to one of the lower rings of the monopod head. To the other ring, hang a 'set-of-fours' with a side-loading pulley.
9. Place two, change of direction single pulleys, with carabiners to a set of Prusik loops in basket hitch configurations placed through the lower anchor ring on the hitch assembly. The loops are different lengths so the pulleys will be offset from each other, avoiding conflicts
10. After putting a load on the boom strut, recheck that the boom strut is not touching the hitch body. If it is, STOP the operation, and tighten the bridle.
11. Obtain both pre-rigged rope kits and reeve each kit's main line through the appropriate change of direction pulleys and leave the rope ends about 30 cm. (1 ft.) above the ground.
12. Back the truck towards the edge of the cliff until the rope ends are right at the break over point of the cliff or where an attendant can see the bottom at the base of the cliff.
13. Position a second vehicle parallel to the cliff edge about 10 m. (33 ft.) on either the left or right side of the monopod truck to serve as the rope system's anchor.
14. Attach the rope system's anchors to this vehicle with the standard protocol.
15. On a lowering, when the litter transitions out of the safe zone, vector the main lines, to keep the litter and the bearers from swinging out of control as they transition themselves over the edge. On raising, at the transition, disconnect the rope from the side-loading pulley and use paradoxical motion to bring litter into the safe zone

[The pre-rigged guy rope bridle uses 9 m. (29 ft.) of 11 mm. (7/16 in.) rope. Tie a bowline on a bight at the rope's mid-point. Place a 3:2 Prusik hitch on each leg. Place a blood (stopper) knot at the end of each leg]



monopod guy rope bridle

Pitch-Tow Rescue Technique:

1. Tie a Blitz anchor.
2. Deploy two ropes and allow each rope to have one meter of slack on the bottom or below the patient.
3. Descend one rope using a device of your choice. [Micro-rack]
4. Use a self-belay of your choice on the other rope. [Shunt]
5. When you reach the patient provide and attach a victim harness or similar device.
6. Provide patient with a self-belay attached to the second rope. [short Purcell or two wrap Prusik]
7. Change over to climbing mode.
8. Place a rope grab of your choice above your foot ascender. [Rescuecender]
9. Attach orange end of AZTEK to this rope grab in 4:1 CD mode.
10. Attach blue end of AZTEK to patient.
11. Provide patient with progress capture device and place it on main rope. [Gri-Gri]
12. As you climb push the rope grab up the rope with your foot ascender and your AZTEK will deploy below you. In practice this will cause excessive drag and it might be easier to deploy the AZTEK to full length and let the patient manage the lines, as well as their progress capture device, and self-belay.
13. After climbing twelve feet, begin raising the patient by pulling on your AZTEK haul line and stepping on a stirrup on a second ascender attached to AZTEK's haul line. [Jumar with sewn stirrup]
14. When the patient reaches your level.
15. Repeat the climbing and hauling process.
16. If patient is useless, attach a Gri-Gri for his belay, and tie end of main line to your harness and pull it up through the Gri-Gri as you raise the patient.

The Seven Minimalist Rescue Archetypes from Ropes That Rescue ©™

These exercises may seem to be doing the same thing. However, they approach the task from seven different perspectives. Each rescue archetype takes into consideration the number of rescuers present, their skill levels, the equipment available, and local scene situation. All should be mastered so that the appropriate technique may be used for the immediate situation. The following diagrams are provided with the specific approval from the author Reed Thorne of Ropes that Rescue.

The 7 Minimalist Rescue Archetypes

Ropes That
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1

#1 of 7MRA

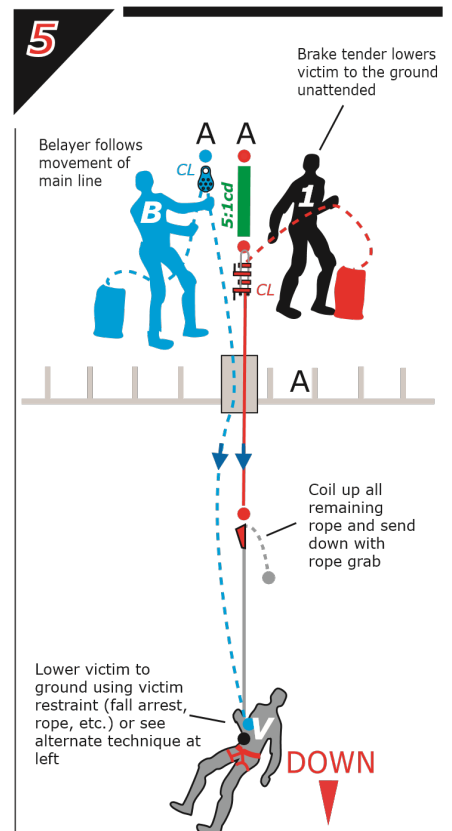
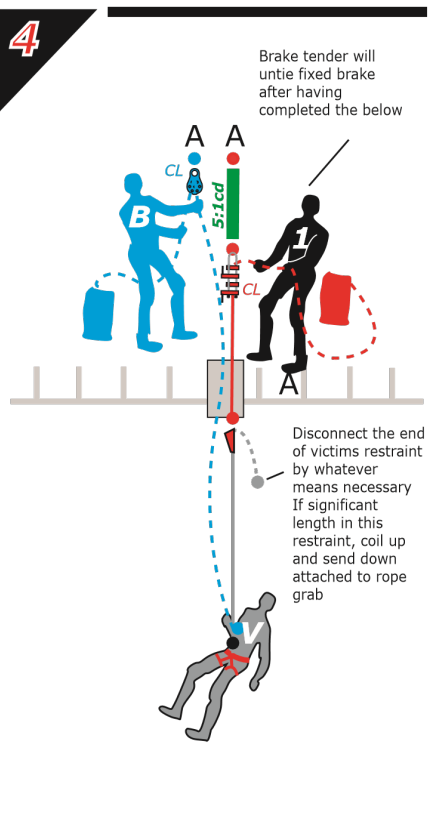
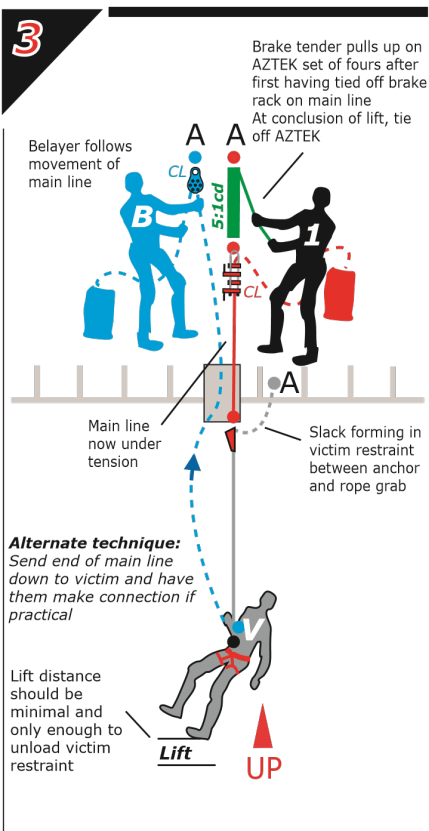
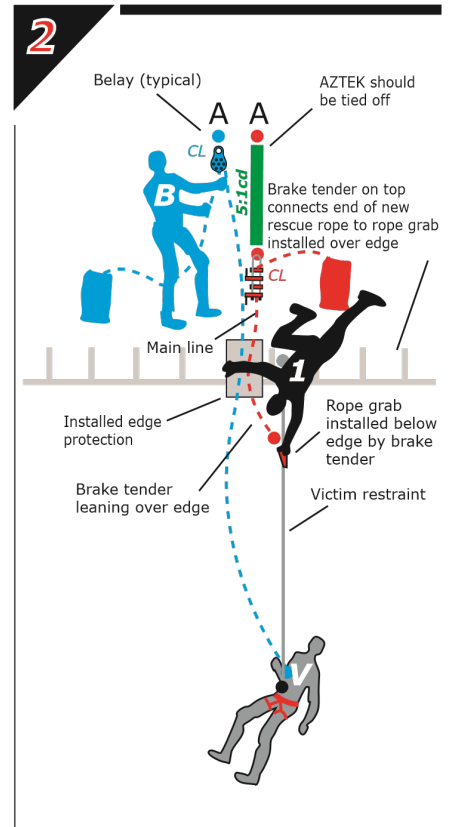
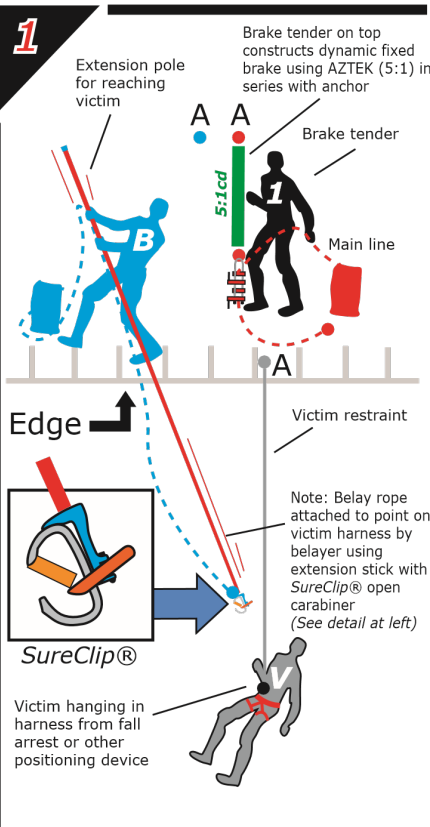
- No Rescuer Over Edge
- Dynamic Fixed Brake
- Victim Hanging in Harness

Ropes That
RESCUE[®] Ltd.
Rigging in the Vertical Realm

© 2006-08 Reed Thorne for Ropes That Rescue Ltd.

Must Have:

2	Rescuers: Belayer (B) Brake (1)
1	Belay device (Climbing Load)
1	Friction devices (Climbing Load)
1	AZTEK set of 4's
2	Rescue ropes which reach the ground: Main & belay
1	Rope grab
1	Edge protection
1	SureClip [®] & extension pole



The 7 Minimalist Rescue Archetypes

Ropes That RESCUE[®]

2

#2 of 7MRA

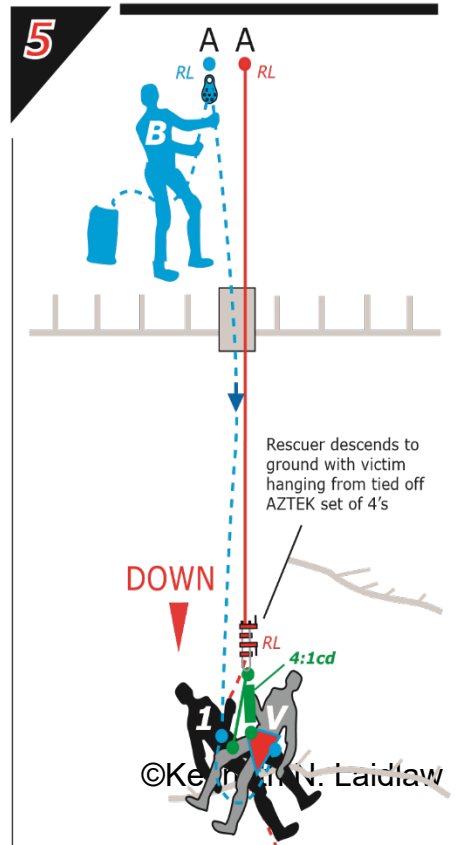
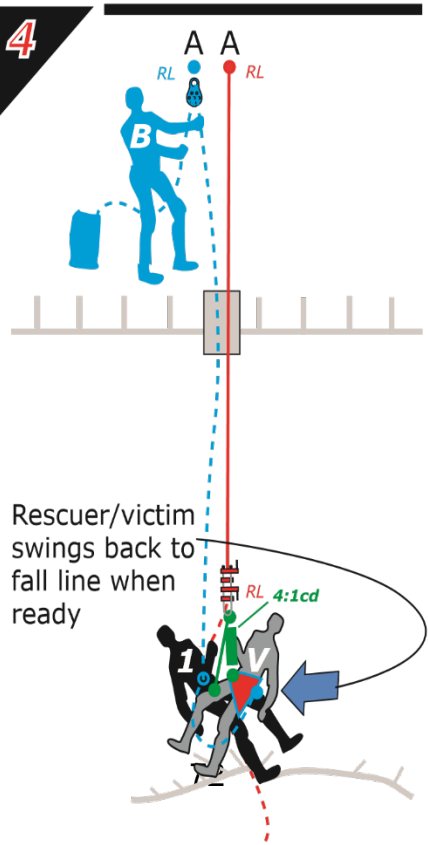
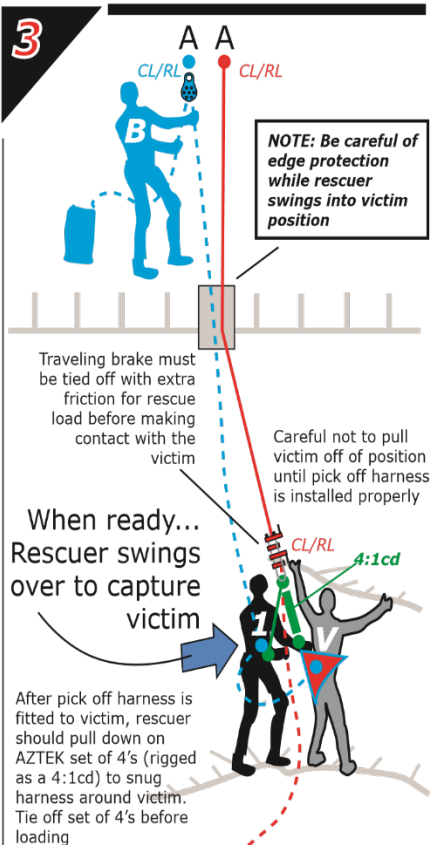
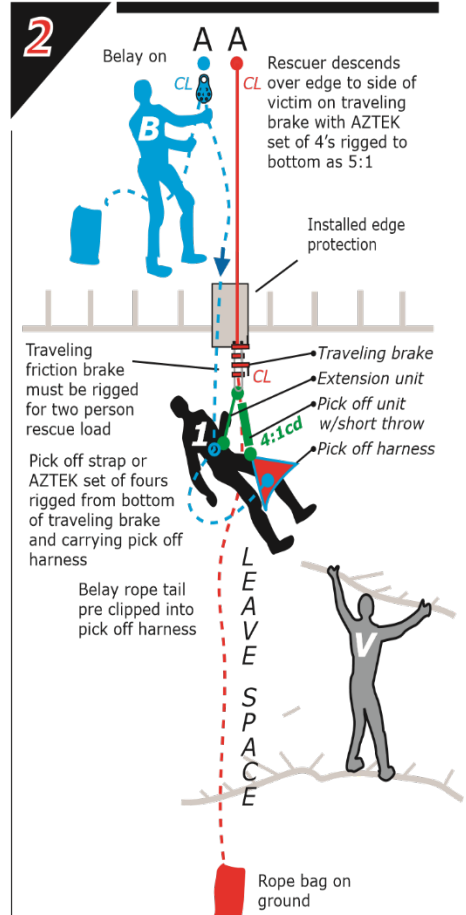
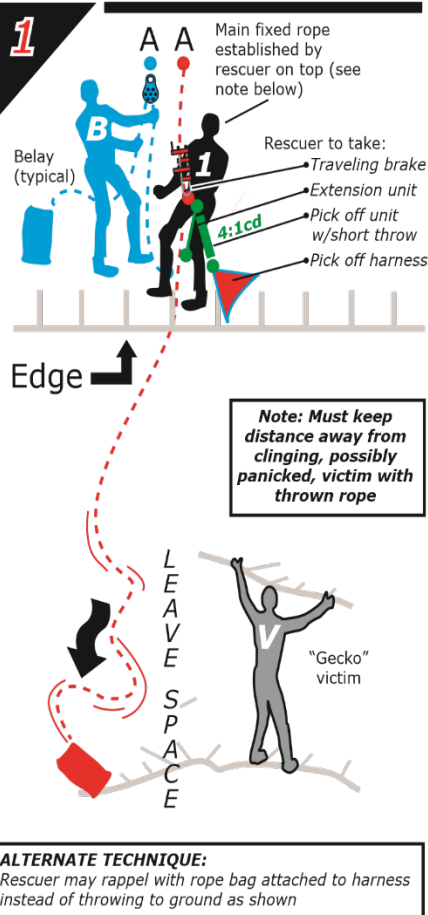
- Solo Rescue
- Clinging "Gecko" Victim—NO Harness
- Rescuer/Victim descend together

Ropes That RESCUE[®]
Rigging in the Vertical Realm

© 2006-08 Reed Thorne for Ropes That Rescue Ltd.

Must Have:

- | | |
|---|---|
| 2 | Rescuers: Belayer (B) and Rescuer (1) |
| 1 | Belay device (Rescue Load-200kg) |
| 1 | Friction devices (Rescue Ld-200kg) with extension rigging |
| 1 | Pick off unit/AZTEK set of 4's |
| 2 | Rescue ropes which reach the ground: Main & belay |
| 1 | Pick off harness |
| 1 | Edge protection |



The 7 Minimalist Rescue Archetypes

Ropes That RESCUE[®]

3

#3 of 7MRA

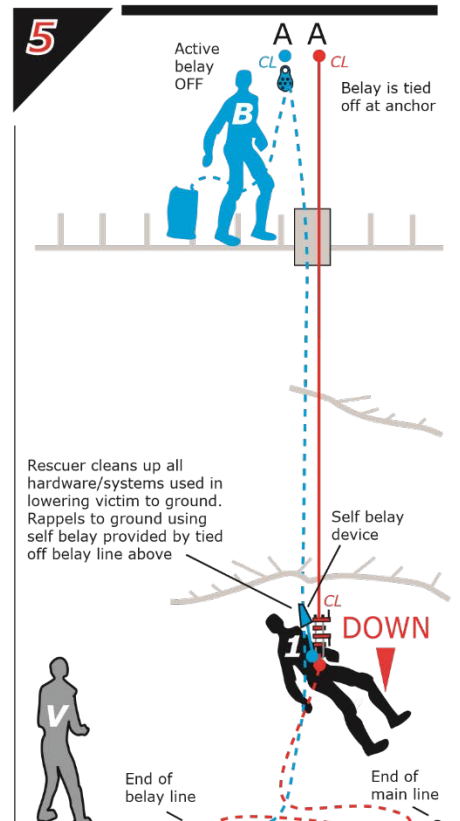
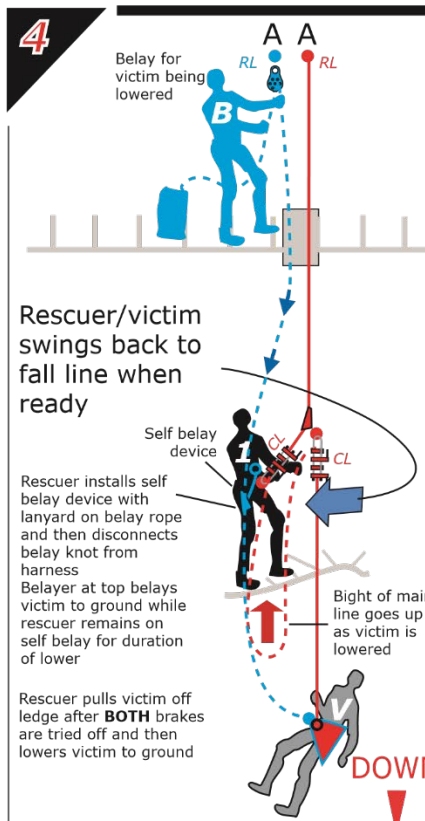
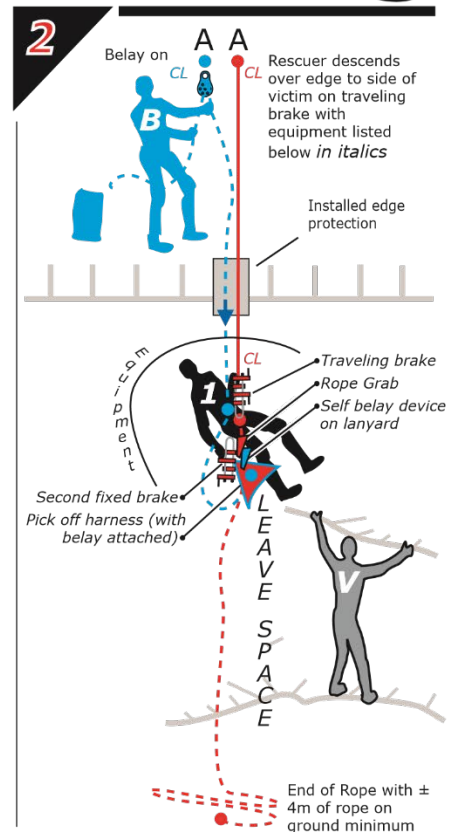
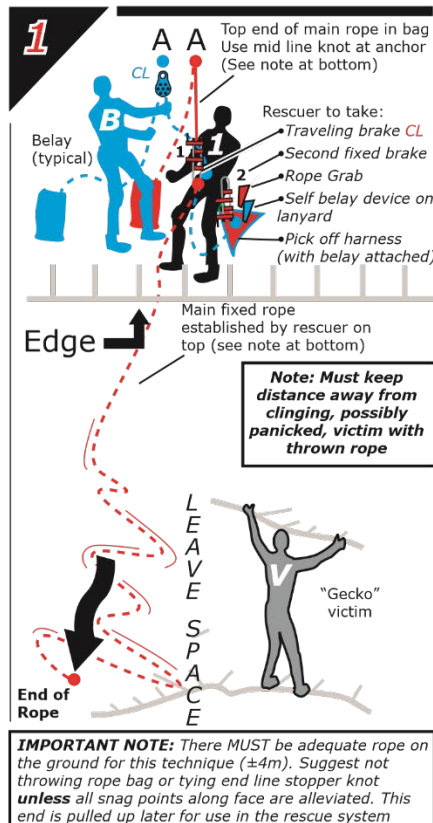
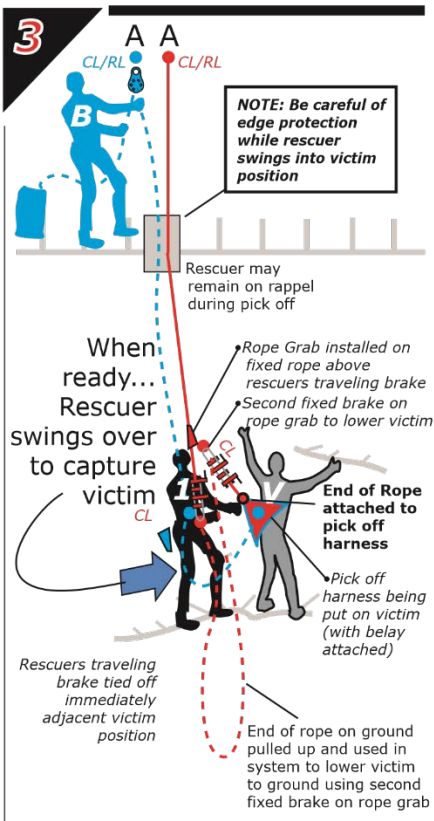
- Solo Rescue
- Clinging "Gecko" Victim—NO Harness
- Mid-Face Lower on Fixed Brake

Ropes That RESCUE[®]
Rigging in the Vertical Realm

© 2006-08 Reed Thorne for Ropes That Rescue Ltd.

Must Have:

2	Rescuers: Belayer (B) and Rescuer (1)
1	Belay device (Rescue Load-200kg)
2	Friction devices (Climbing Ld-100kg)
2	Rescue ropes which reach the ground: Main & belay
1	Pick off harness
1	Rope grab
1	Self belay device w/lanyard
1	Edge protection



The 7 Minimalist Rescue Archetypes

Ropes That RESCUE[®] 4

#4 of 7MRA

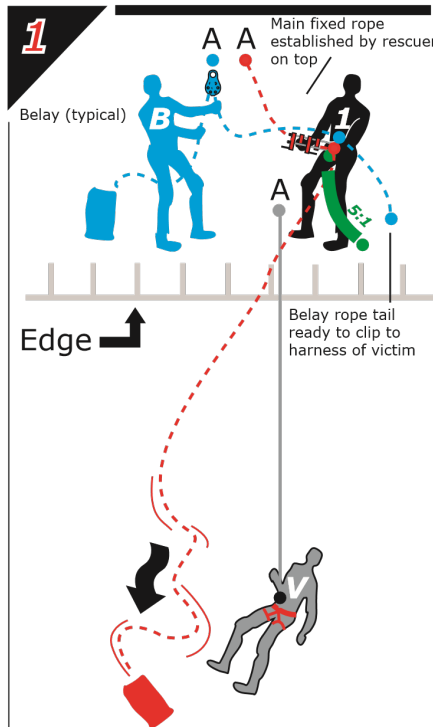
- Solo Rescue
- Traveling Brake
- Mid Face AZTEK Pick
- Victim Hanging in Harness

Ropes That RESCUE[®]
Rigging in the Vertical Realm

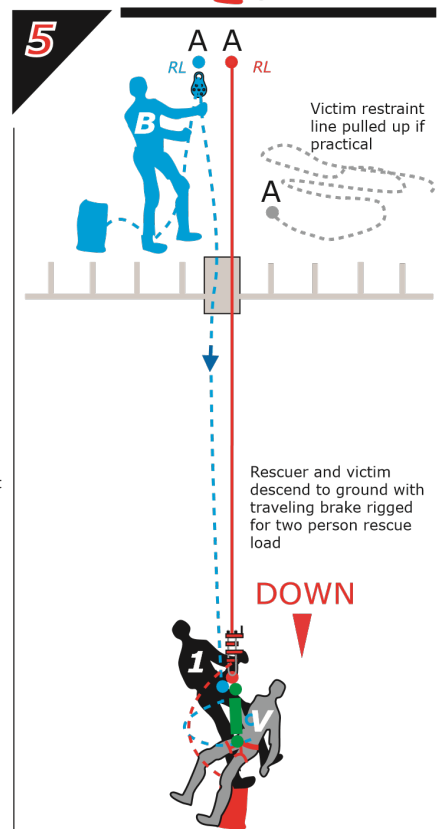
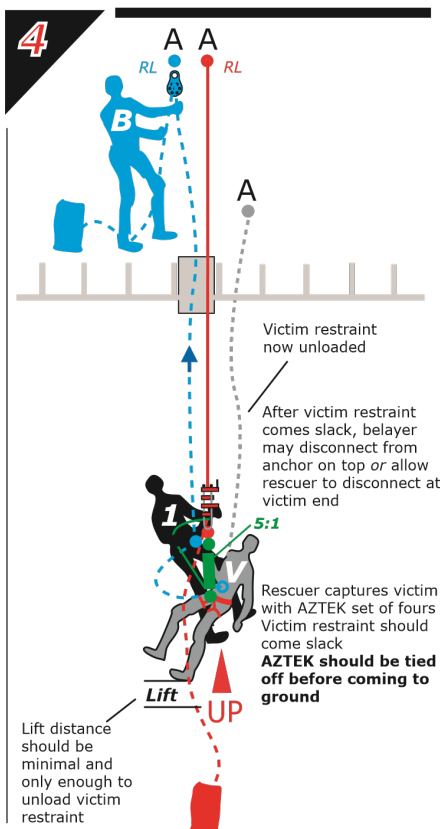
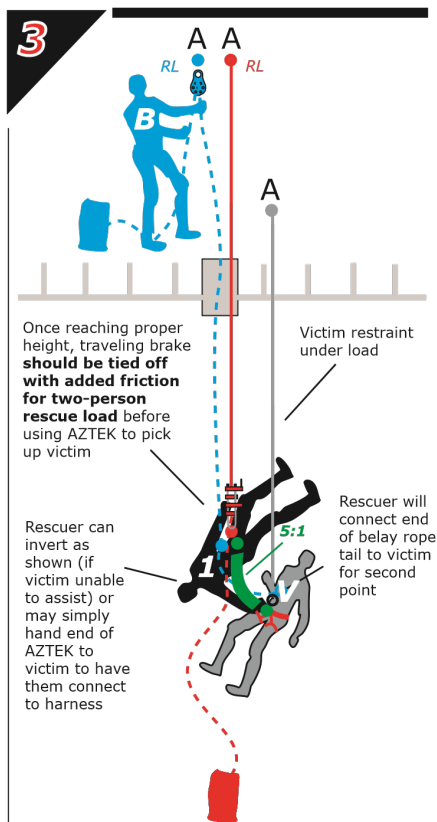
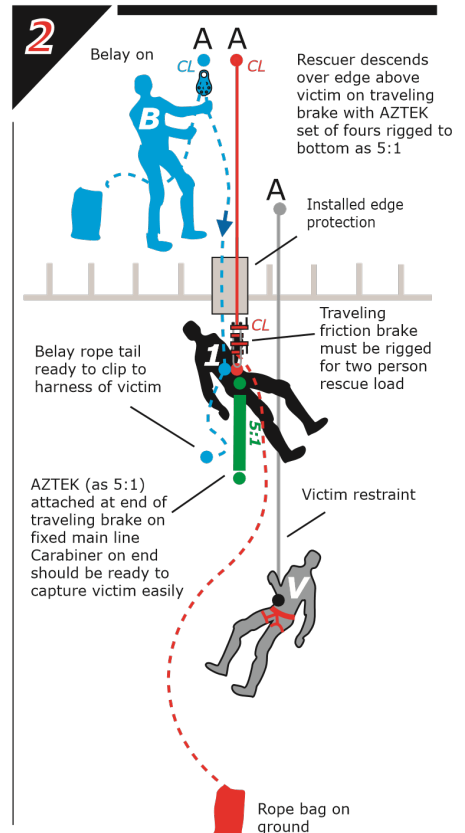
© 2006-08 Reed Thorne for Ropes That Rescue Ltd.

Must Have:

2	Rescuers: Belay (B), Rescuer (1)
1	Belay device (Rescue Load-200kg)
1	Friction device (Rescue Load-200kg)
1	AZTEK set of 4's (36kN)
2	Rescue ropes which reach the ground: Main & belay
1	Edge protection



Alternate technique:
Rescuer may rappel with rope bag attached to harness instead of throwing to ground as shown



The 7 Minimalist Rescue Archetypes

Ropes That RESCUE[®] Ltd.

5

#5 of 7MRA

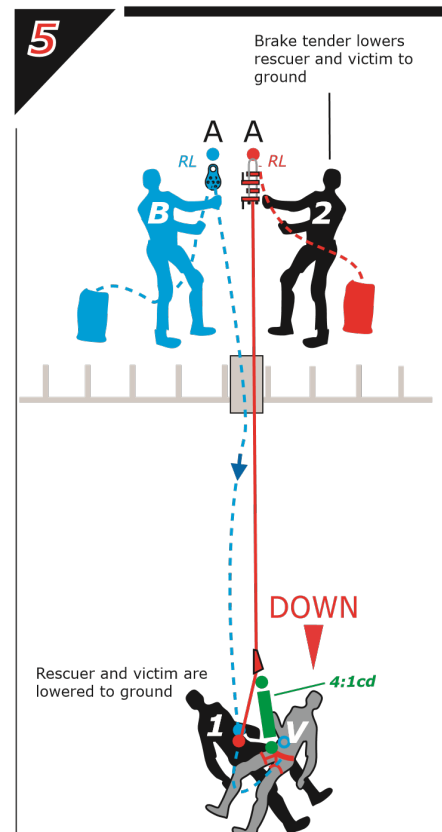
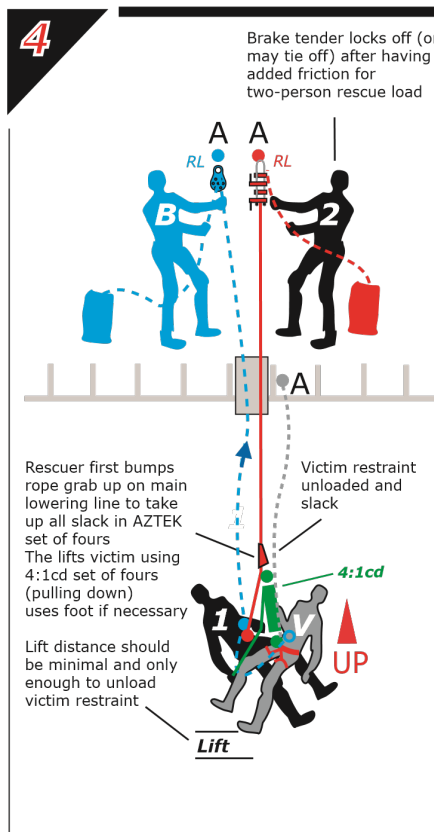
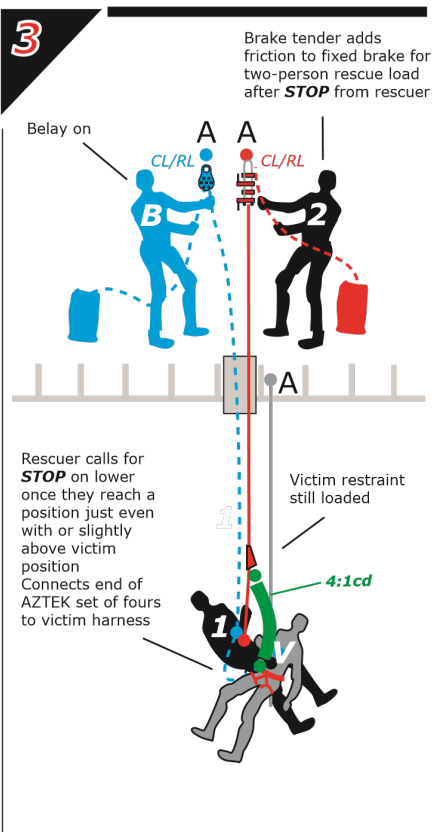
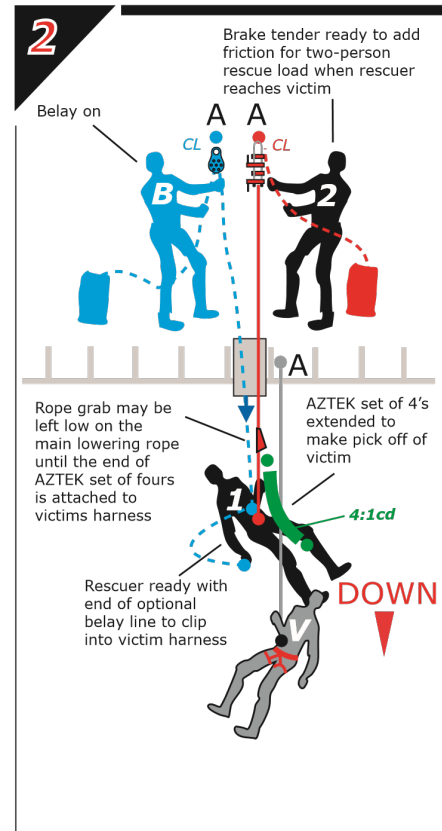
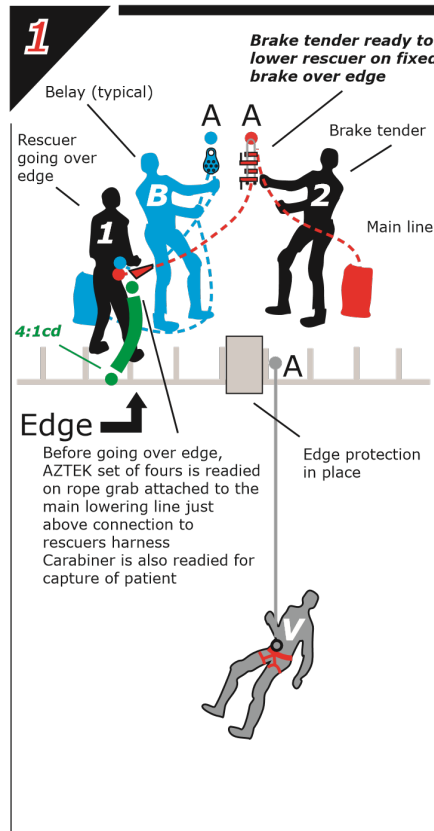
- Semi-Solo Rescue
- Top Fixed Brake
- Mid Face AZTEK Pick
- Victim Hanging in Harness

Ropes That RESCUE[®] Ltd.
Rigging in the Vertical Realm

© 2006-08 Reed Thorne for Ropes That Rescue Ltd.

Must Have:

3	Rescuers: Belay (B), Rescuer (1) and Brake (2)
1	Belay device (Rescue Load-200kg)
1	Friction device (Rescue Load-200kg)
1	AZTEK set of 4's (36kN)
2	Rescue ropes which reach the ground: Main & belay
1	Rope grab
1	Edge protection



The 7 Minimalist Rescue Archetypes

Ropes That RESCUE[®]

6

#6 of 7MRA

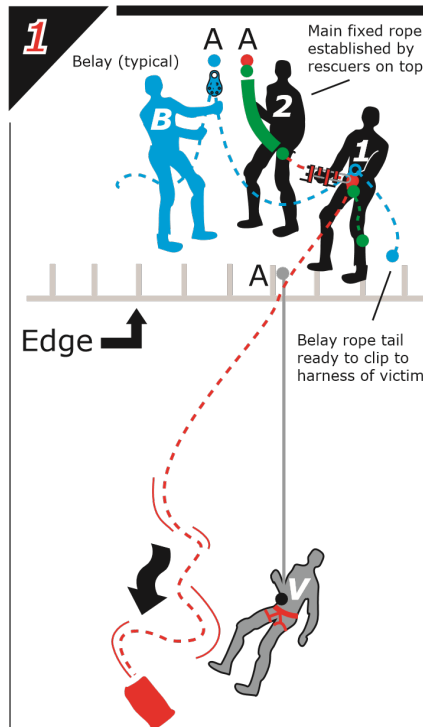
- Semi-Solo Rescue
- Dynamic Traveling Brake
- Victim Hanging in Harness

Ropes That RESCUE[®]
Rigging in the Vertical Realm

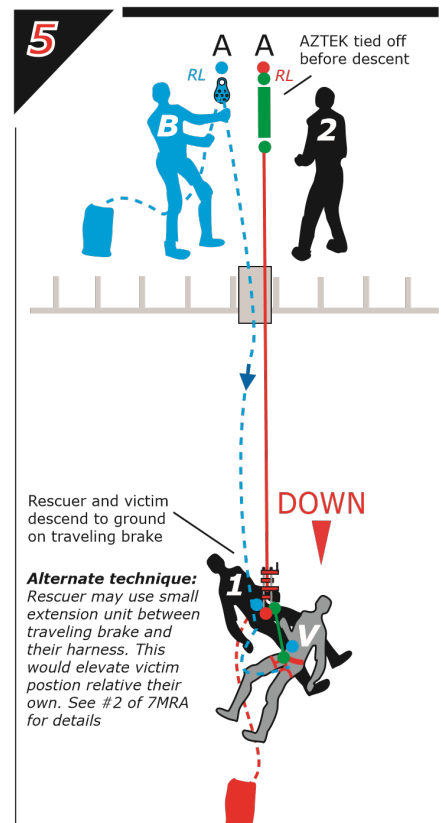
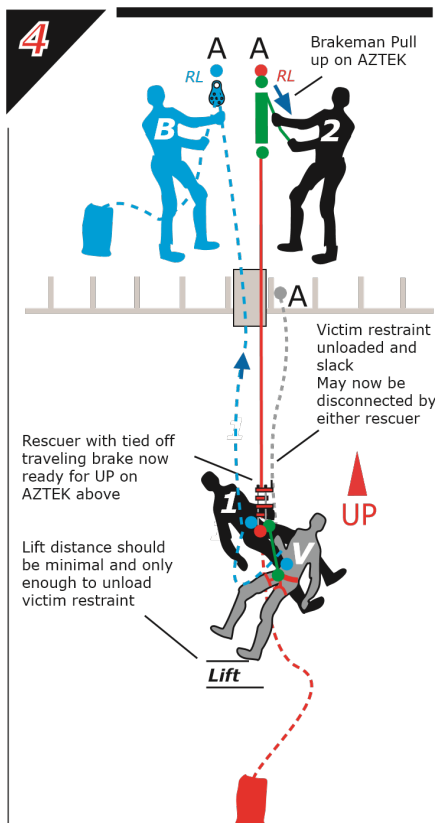
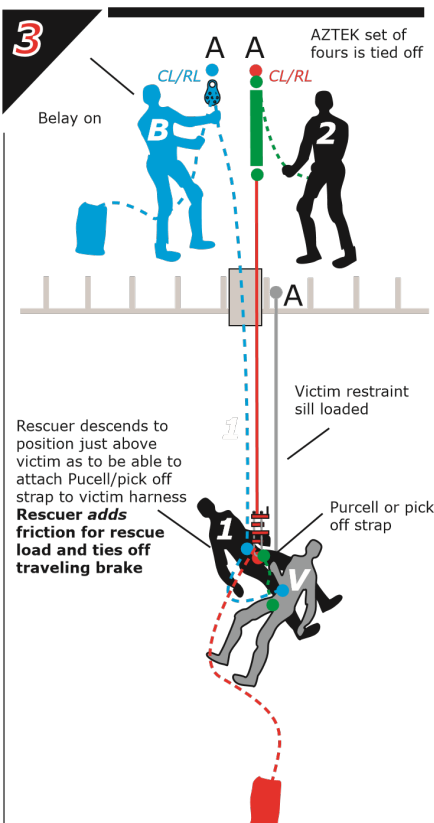
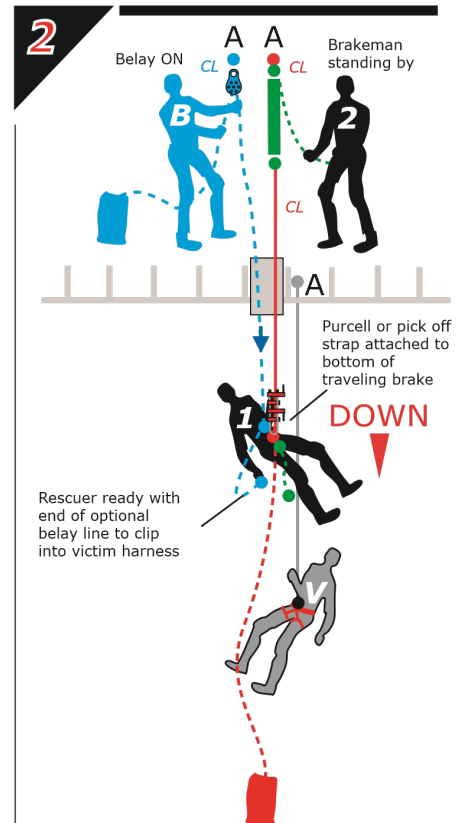
© 2006-08 Reed Thorne for Ropes That Rescue Ltd.

Must Have:

3	Rescuers: Belay (B), Rescuer (1) and Brake (2)
1	Belay device (Rescue Load-200kg)
1	Friction device (Rescue Load-200kg)
1	AZTEK set of 4's (36kN)
2	Rescue ropes which reach the ground: Main & belay
1	Purcell or pick off strap
1	Edge protection



Alternate technique:
Rescuer may rappel with rope bag attached to harness instead of throwing to ground as shown



The 7 Minimalist Rescue Archetypes

Ropes That RESCUE[®] Ltd.

7

#7 of 7MRA

- Semi-Solo Rescue
- Dynamic Fixed Brake
- Victim Hanging in Harness

Ropes That RESCUE[®] Ltd.
Rigging in the Vertical Realm

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Must Have:

3	Rescuers: Belay (B), Rescuer (1) and Brake (2)
1	Belay device (Rescue Load-200kg)
1	Friction device (Rescue Load-200kg)
1	AZTEK set of 4's (36kN)
2	Rescue ropes which reach the ground: Main & belay
1	Rope grab
1	Purcell or pick off strap
1	Edge protection

