Mechanical Advantage Systems

Ropes and rope equipment are widely used to hoist or lower tools, applainaces, or people; to permit safe reset.

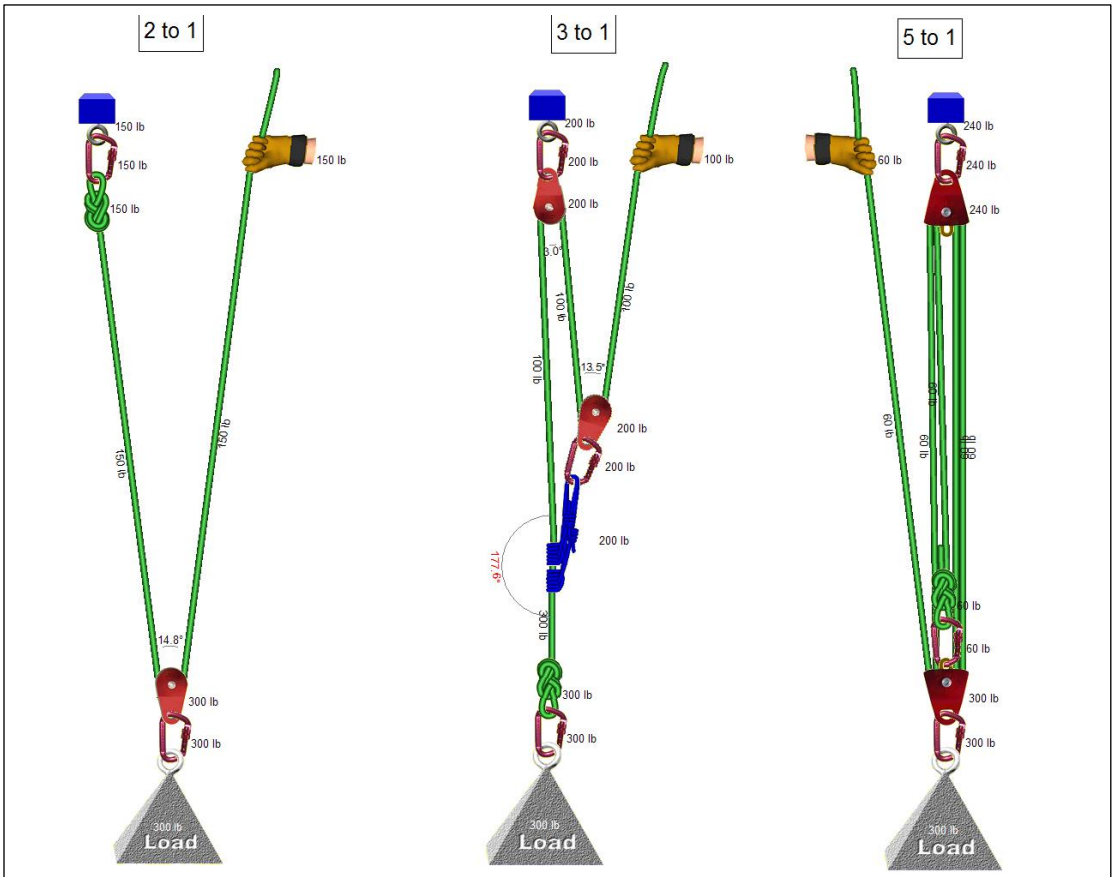
Many rescue situations require raising a victim from an accident site. To do this requires knowledge of pulley systems so the rescue can be accomplished more safely and easily. By using pulley systems, the rescue team can spread the weight of the load over distance.

Rules for Determining Mechanical Advantage

There are three basic rules for determining the theoretical mechanical advantage of a simple pulley system.

1. If the rope is tied off to the load, and the first pulley the rope goes through is attached to the anchor, the advantage will be odd (1:1, 3:1, 5:1, etc.).
2. If the rope is tied off to the anchor, and the first pulley is attached to the load, the mechanical advantage will be even (2:1, 4:1, 6:1, etc.).
3. If the last pulley in a system is attached to the anchor, it adds no mechanical advantage. It acts only as a change-of-direction pulley.

To determine mechanical advantage, keep rules one through three in mind. Simply count the number of lines between the anchor and the load. Do not count the line if it comes off a change-of-direction pulley.



Mechanical Advantage

Components

Components needed to build a pulley system are:

- Rescue rope
  - Most pulley systems can be built with 75' or 150' lengths of rope
- Rescue pulleys
- Prusiks
  - Hauling prusiks, to grab the rope and pull it into motion
  - Ratchet prusiks, to stop the rope from moving and allow the system to be reset
- Anchor point or system

Types of Mechanical Advantage Systems

Simple: A simple system has all its pulleys attached to either the anchor or the load. One end of the rope is tied to the anchor or the load and the rope is reeved through the pulleys.

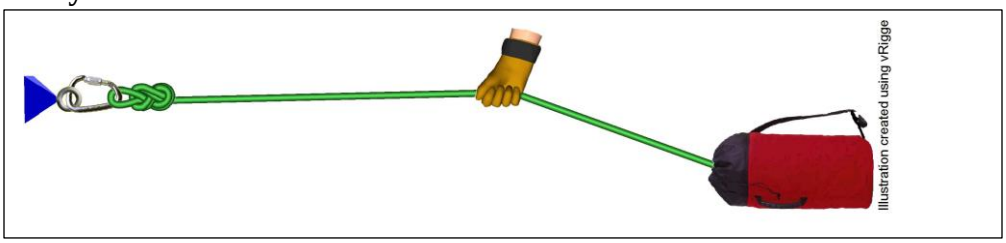
Compound: A compound system is one simple system pulling on another simple system.

Complex: A complex system is any system that is a combination of simple and compound systems.

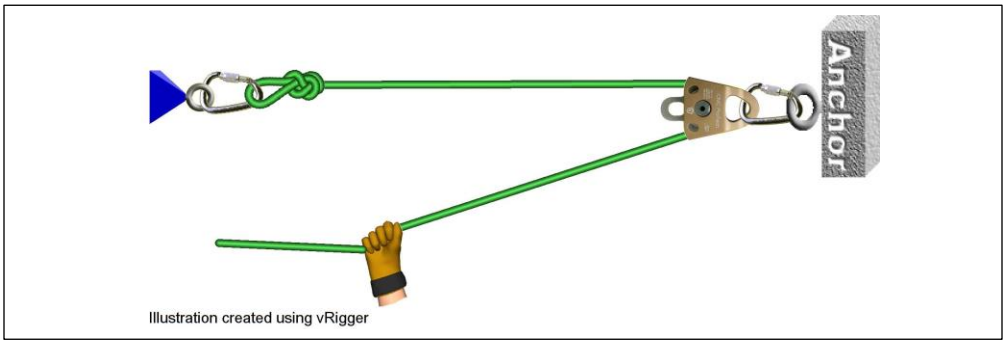
1:1 Systems

A 1:1 mechanical advantage means that a 100-pound load that needs to move 10' will take 100 pounds of force and 10' of rope to move 10'.

Simple 1:1 System



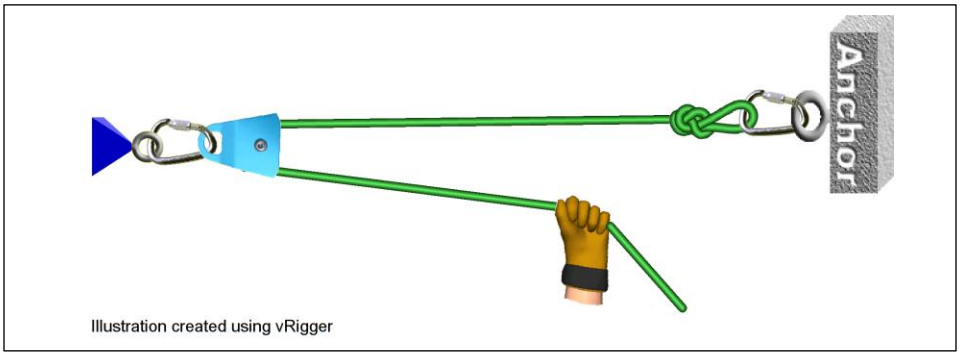
Simple 1:1 System with a Change of Direction



2:1 Systems

A 2:1 mechanical advantage means it will take 50 pounds of force to move the object, but it will take 20' of rope to move the 100 pound object 10'.

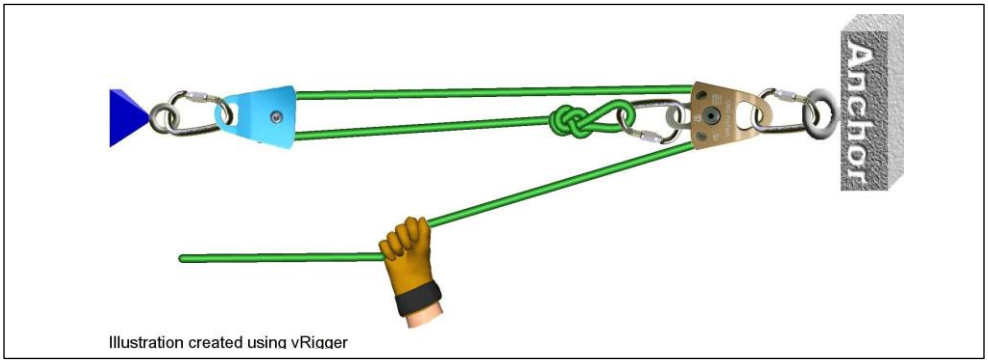
Simple 2:1 Mechanical Advantage System



Simple 2:1 Mechanical Advantage with a Change of Direction

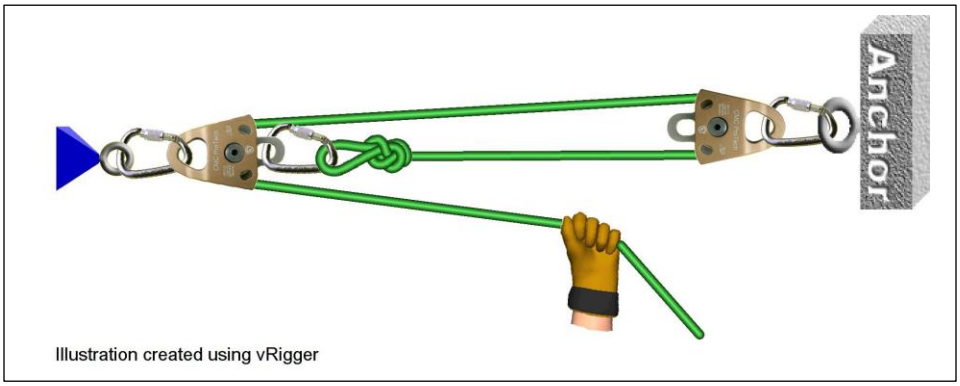
This system is used to create lifting capability from anchor points located above the rescue team. It is designed to pull down, toward the load. The rope is attached to the anchor, run through a pulley that is attached to the load, and back up to a change of direction pulley attached to the anchor.

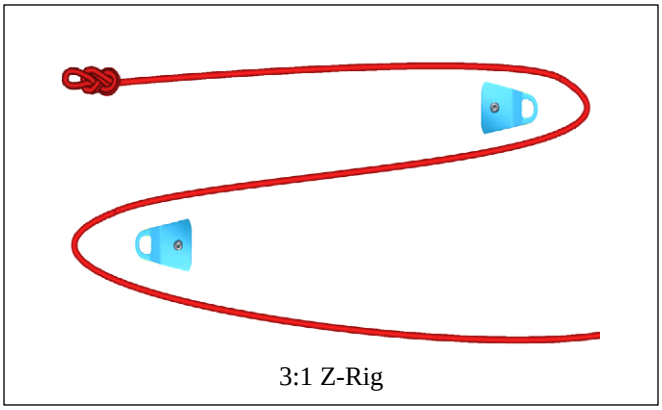
The actual mechanical advantage is less than 2:1 because of friction in the pulleys, rope abrasion, etc. The mechanical advantage referred to in any system is the theoretical mechanical advantage, and you should always assume that the actual mechanical advantage attained is going to be less in field situations.



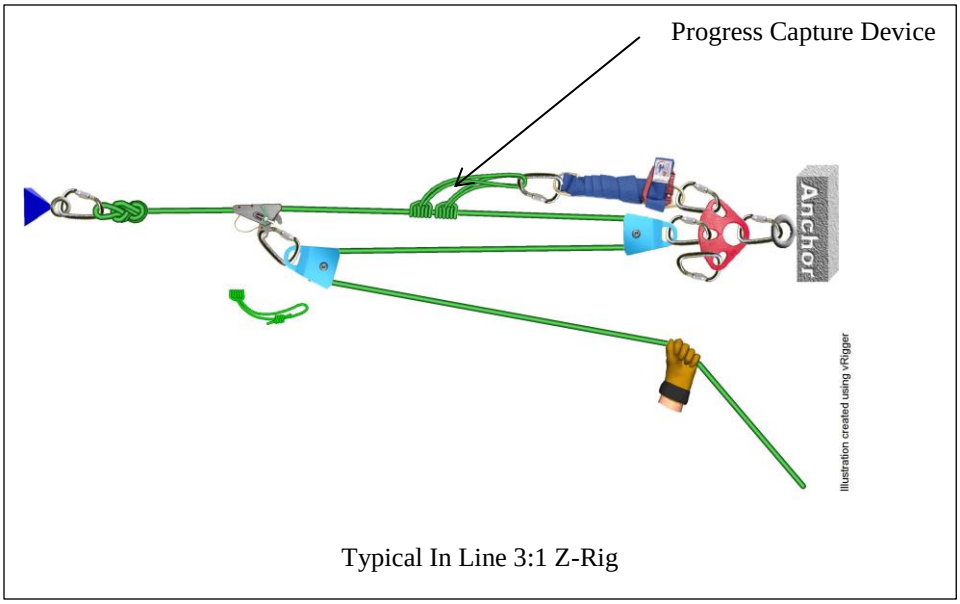
Simple 3:1 Mechanical Advantage System

It is designed to be used horizontally rather than vertically. By attaching the rope to the load, then running it through a pulley that is attached to the anchor, then back to a pulley attached to the load, the mechanical advantage becomes 3:1. The pull will be away from the load. This system lends itself to being attached to another rescue line with a hauling prusik. By hauling on the pig rig, the load attached to the other line is raised with a 3:1 mechanical advantage.





3:1 Z-Rig



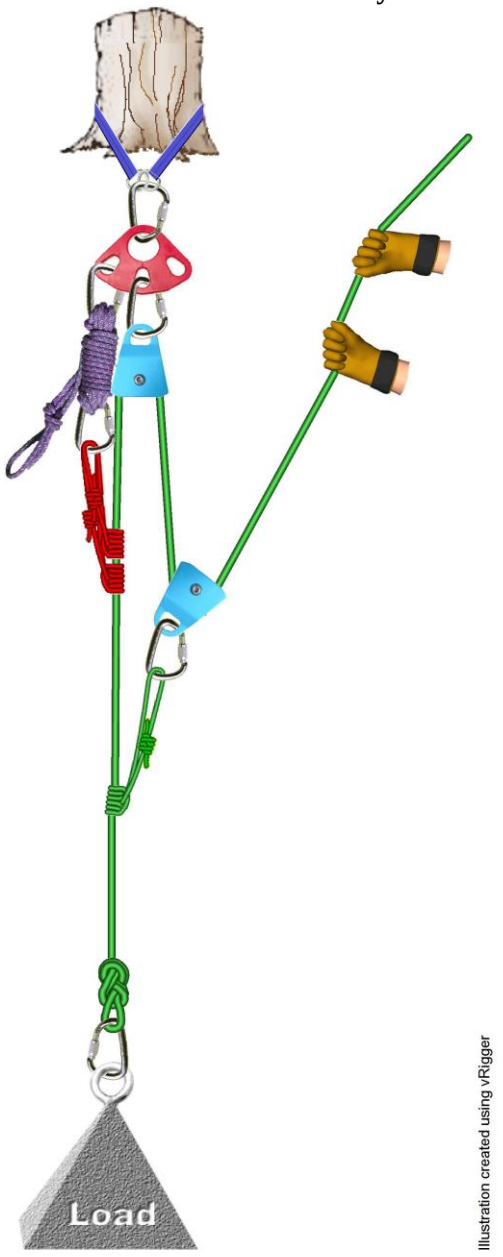
Typical In Line 3:1 Z-Rig

IN-LINE 3:1 Z-RIG SYSTEM

The Z-rig system, also known as "Z pulley system", is quite universal in the Rope Rescue community. It is easily constructed from standard rescue gear typically carried by field teams. This system provides sufficient mechanical advantage to suffice rescue requirements if the load is kept to a minimum and sufficient haulers for the load are available.

A typical example of a 3-to-1 raising system using the proper equipment is shown in Figure 1-2. For field applications where minimum gear is available, carabineers can replace pulleys and the anchor plate can be eliminated.

Basic In-Line 3:1 Haul System



Anchor, Anchor Strap, Carabineers, Rigging Plate, LRH, Prusiks, Prusik Minding Pulleys

A 3:1 Z-RIG with a COD

A 3:1 Z-Rig requires two anchor points, one to anchor the mechanical advantage system and the other for the change of the direction in the system.

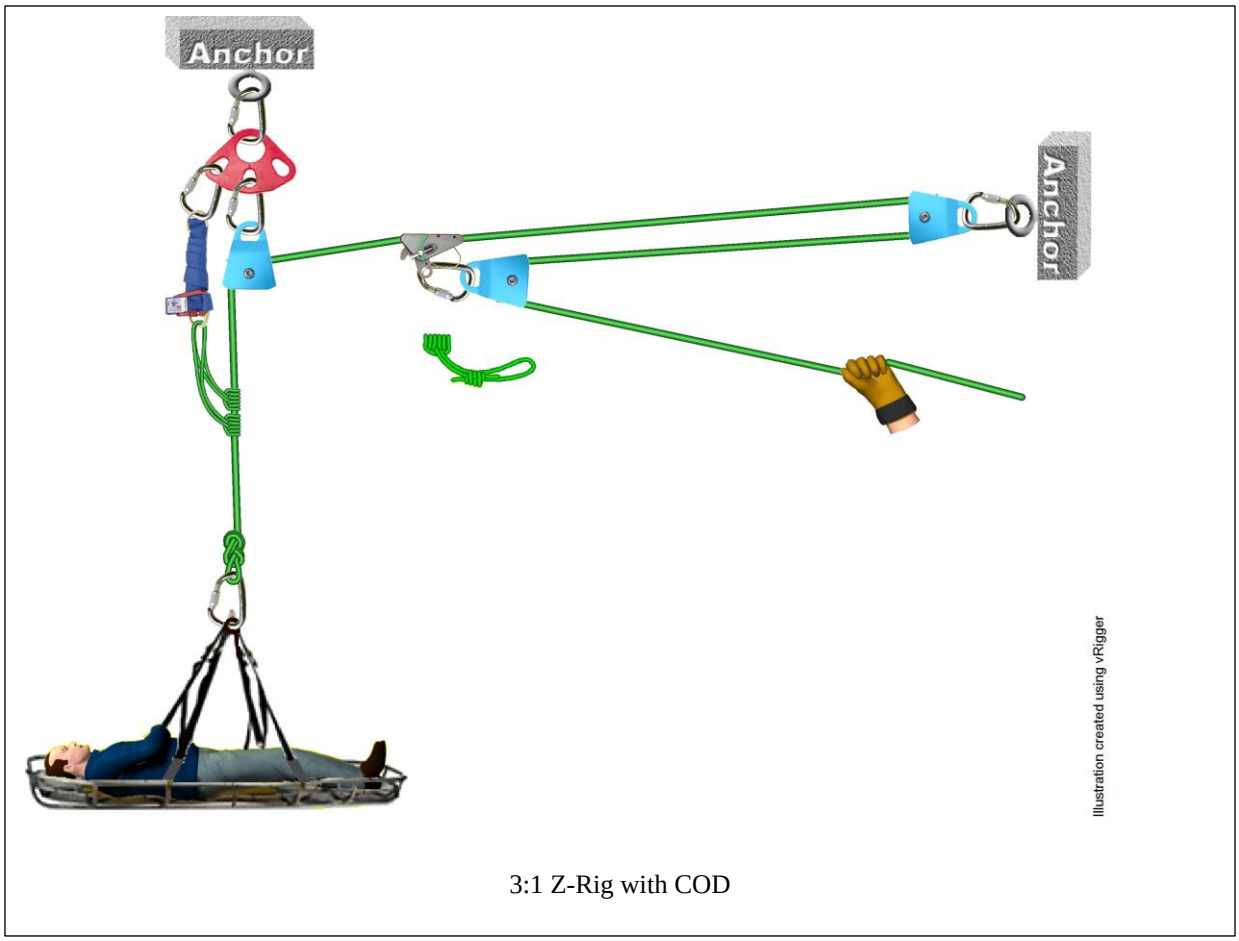
Necessary Components:

Anchor Point

Load Capturing Device

GIBBS Ascender or Prusiks

2 – Prusik Minding Pulleys or



3:1 Z-Rig with COD

The operation of the Z-rig requires three positions although a hauler may perform double duty.

- Hauler: No skills required and the more the better, so non-SAR personnel and bystanders can be put to use if it is safe. A hauler either pulls hand-over-hand or grabs the rope and walks with the rope. Haulers should haul as close to in line with the anchor and load axis to minimize pulling against the system. Each throw of a haul should be smooth and even. The haulers should not jerk the rope as in "one-two-three pull." This is to prevent shock loading the system and to give the subject and litter tenders an easier ride up over rough terrain.
- Haul Prusik Re-setter: This person resets the haul Prusik forward toward the load as far as safely possible.
- Tandem Prusik Minder: This position should always be filled unless there is a bare minimum of rescuers available to haul. This rescuer will monitor the tandem "ratchet" Prusiks to ensure they are in their forward position as much as possible, and lock-off the Prusiks at the end of a haul cycle. The tandem Prusiks should always be locked-off when the system is stopped for any reason.

Z-Rig Operation

The haul cycle is as follows:

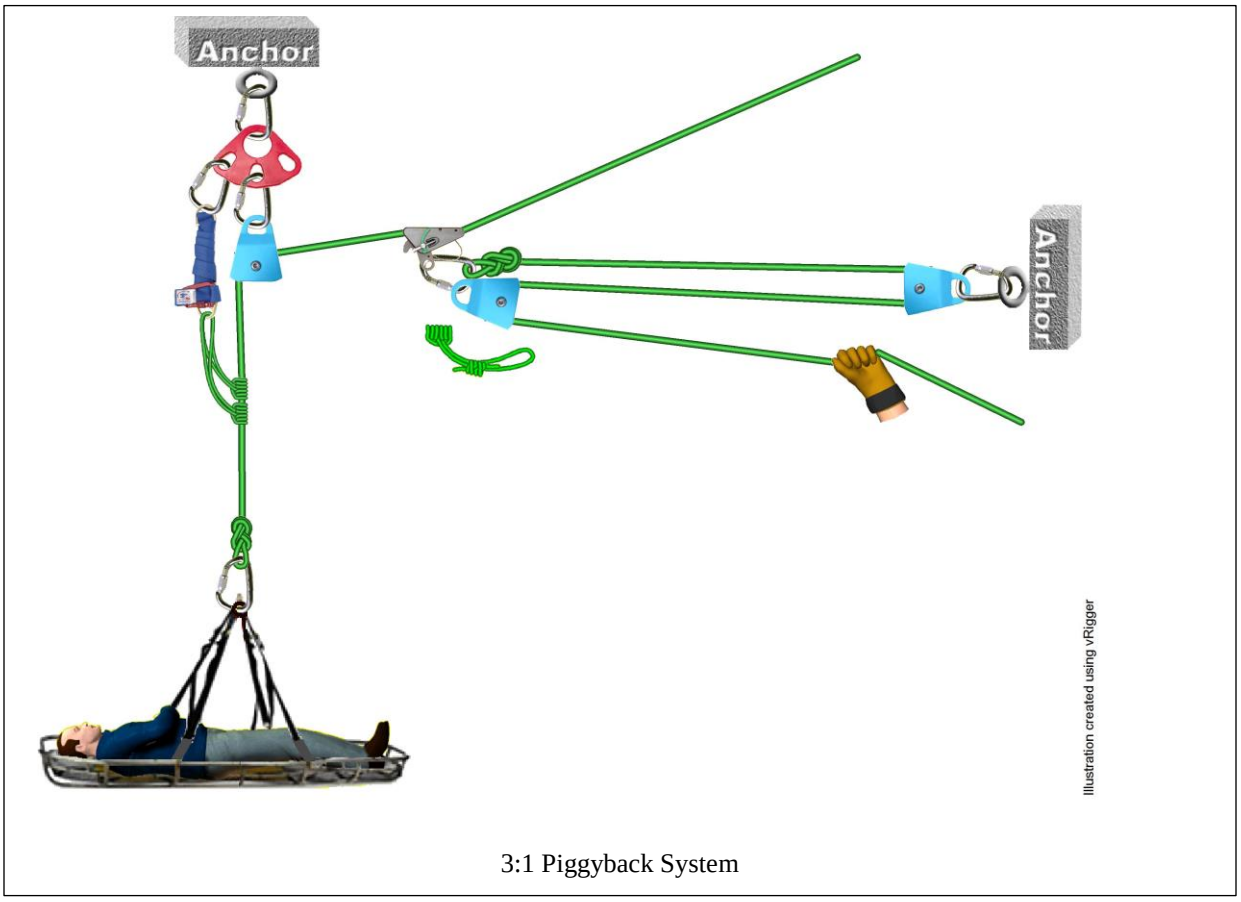
1. The haul Prusik should be as far forward as possible at the start.
2. Once all systems are ready, the Operations Leader will give the "haul" command.
3. The haulers will haul smoothly on the haul line.
4. The Prusik minder will monitor the tandem Prusiks.
5. When the haul Prusik approaches the ratchet Prusiks, The Prusik minder will give the "stop, lock-off" command.
6. The Prusik minder will force the tandem Prusiks forward to lock-off the system. This will minimize the distance the load will lower when the haulers release tension.
7. Once the tandem Prusiks are locked off, the haulers can release tension on the haul line.
8. The haul Prusik re-setter will position the haul Prusik as far forward as safely possible. The longer the throw, the fewer the number of hauling cycles needed during the raising process.
9. The haul cycle is repeated until the load is at the top.

It is not necessary to coordinate "reset" & "haul" commands with tenders or over the radio unless there will be an unexpected delay. The ratchet effect is well known and expected by the tender. This minimizes unnecessary radio traffic and allows the system to flow more efficiently.

3:1 Piggyback System

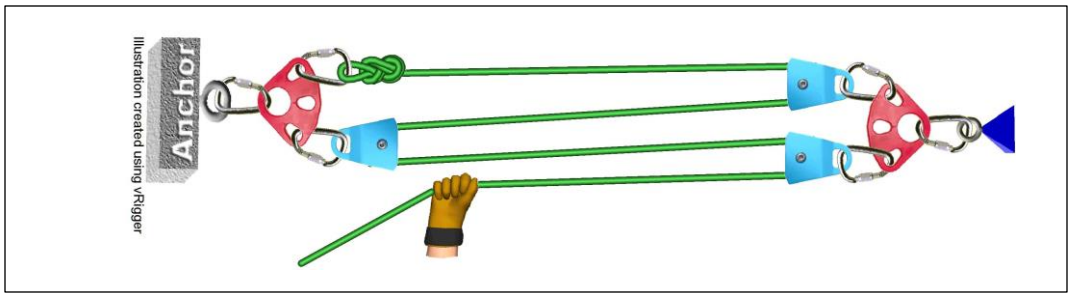
This system is used primarily when the first rope (Main Line) was used to lower the rescuer to the victim. A second 3:1 Mechanical Advantage System rope would then be connected by either a Prusik or Descender rope grab device to the Main Line and used to haul.

The 3:1 Piggyback System additionally requires two anchor points, six carabineers, three pulleys, a load releasing hitch or strap, and tandem prusiks used as a Progress Capture Device.

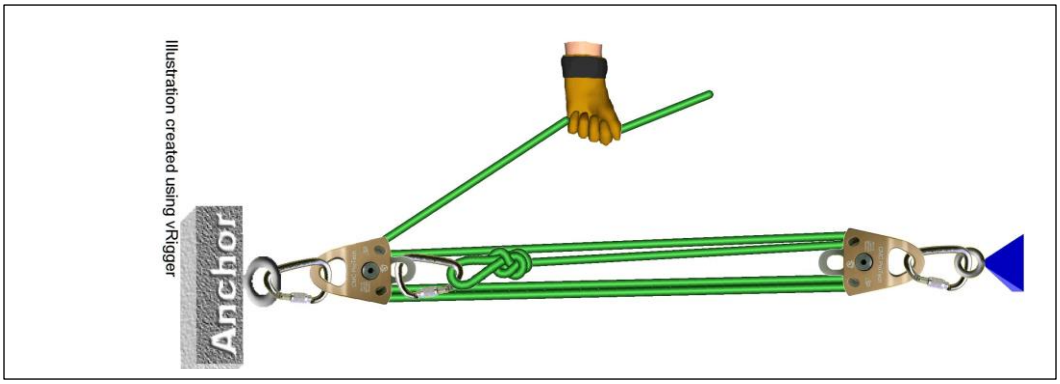


3:1 Piggyback System

Simple 4:1 Mechanical Advantage using Single Pulleys



Simple 4:1 Mechanical Advantage using Double Pulleys with a Change of Direction



Simple 5:1 Mechanical Advantage using Double Pulleys with a Change of Direction