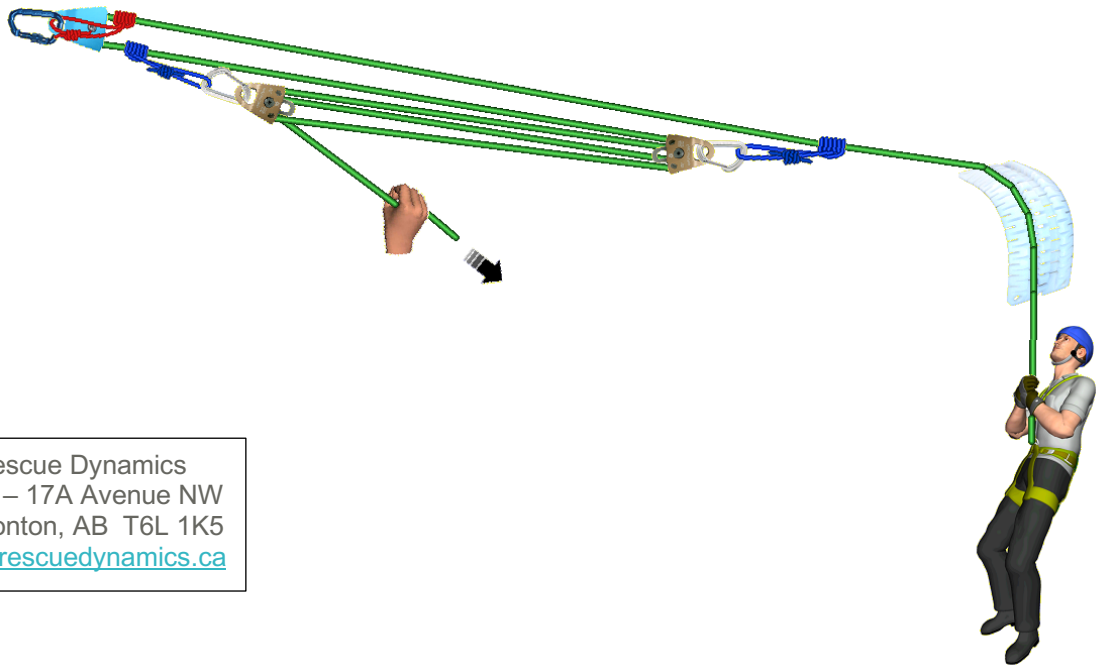
Eight Simple Systems…



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An Overview Of Eight Pulley Systems For Use In Small Team Companion Mountain Rescue (and they're not all simple!)

Preamble

First of all, you shouldn't take the title of this article literally since the article will actually look at pulley systems in three different classes; simple, compound and complex. Second, this is only a basic treatment of some pulley systems that may, in certain circumstances, be useful to a small or very small team (i.e. one or two people) conducting a companion mountain rescue on rock, snow or ice.

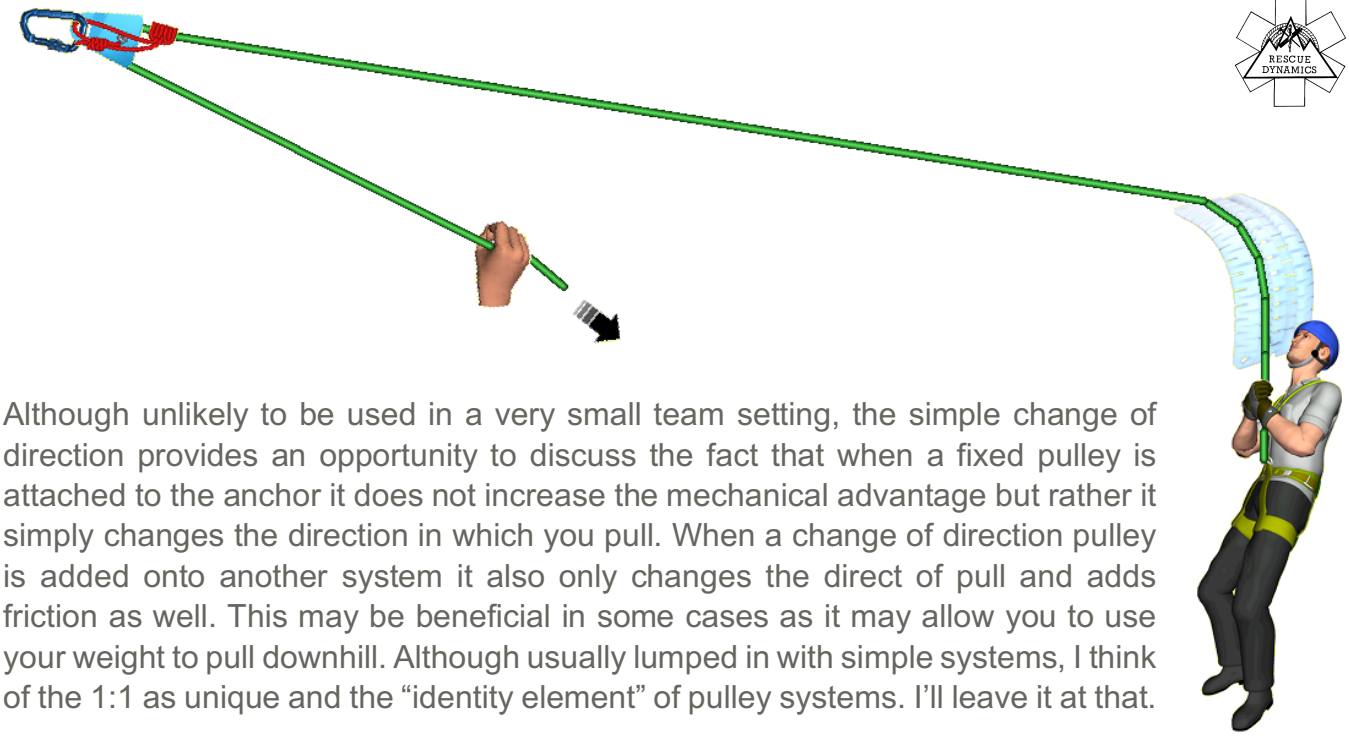
Third, please don't write me to say that I got the *ideal mechanical advantage* (IMA) of one of the systems wrong. Investigate the t-system or look up the method by which ideal mechanical advantage of pulley systems is calculated before doing so. I can assure you that *all* of the quoted IMAs in this article are correct… (The title illustration is actually a complex system. For fun, you can test your knowledge of the t-system by figuring out its IMA.)

None of the systems shown require more than three pulleys (or carabiners used as an inefficient equivalent). For consistency, all systems are shown with a prusik minding pulley as a progress capture. For a treatment of pulley systems for use in larger teams and organized rescue consult the article, "*Pulley Systems In Organized Rescue: A Logical Progression?*"

The Role of Edge Friction

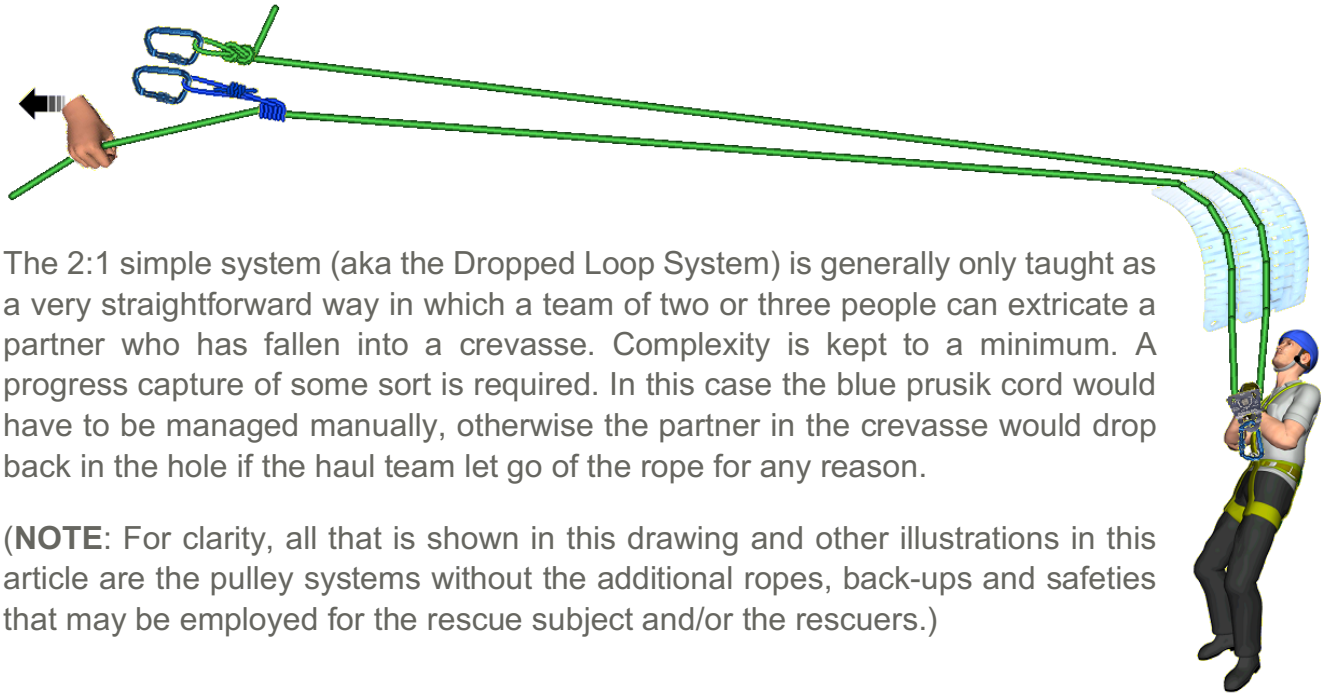
Before beginning, it is important to emphasize that friction of the rope going over a rock, snow or ice edge can easily defeat a single person trying to raise a large partner. Do everything you can to mitigate the friction of the rope running over a rough edge!

1:1 Change of Direction



Although unlikely to be used in a very small team setting, the simple change of direction provides an opportunity to discuss the fact that when a fixed pulley is attached to the anchor it does not increase the mechanical advantage but rather it simply changes the direction in which you pull. When a change of direction pulley is added onto another system it also only changes the direct of pull and adds friction as well. This may be beneficial in some cases as it may allow you to use your weight to pull downhill. Although usually lumped in with simple systems, I think of the 1:1 as unique and the "identity element" of pulley systems. I'll leave it at that.

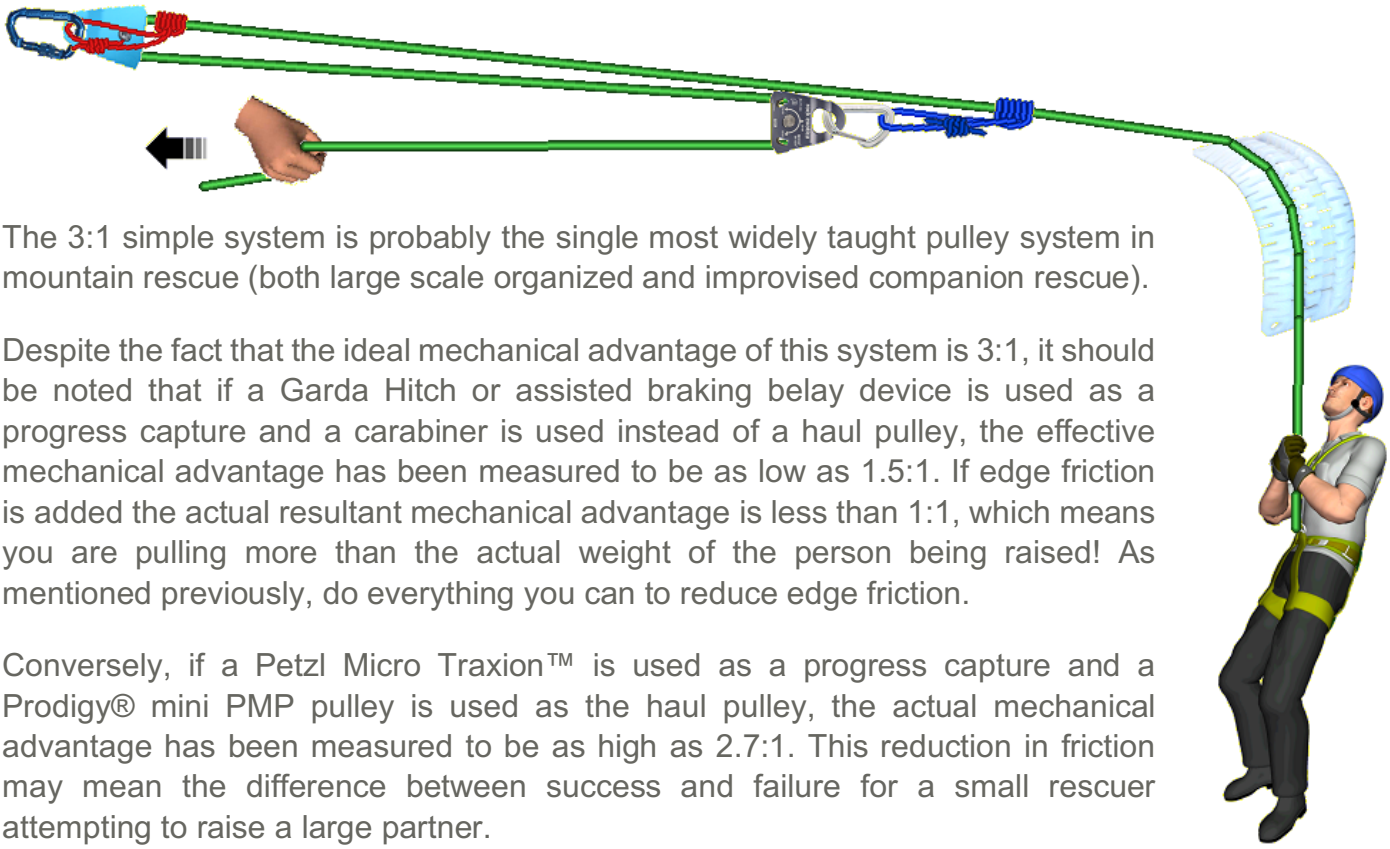
2:1 Simple System- *aka Dropped Loop system…*



The 2:1 simple system (aka the Dropped Loop System) is generally only taught as a very straightforward way in which a team of two or three people can extricate a partner who has fallen into a crevasse. Complexity is kept to a minimum. A progress capture of some sort is required. In this case the blue prusik cord would have to be managed manually, otherwise the partner in the crevasse would drop back in the hole if the haul team let go of the rope for any reason.

(**NOTE**: For clarity, all that is shown in this drawing and other illustrations in this article are the pulley systems without the additional ropes, back-ups and safeties that may be employed for the rescue subject and/or the rescuers.)

The Ubiquitous 3:1 Simple System – *aka Z-pulley system…*



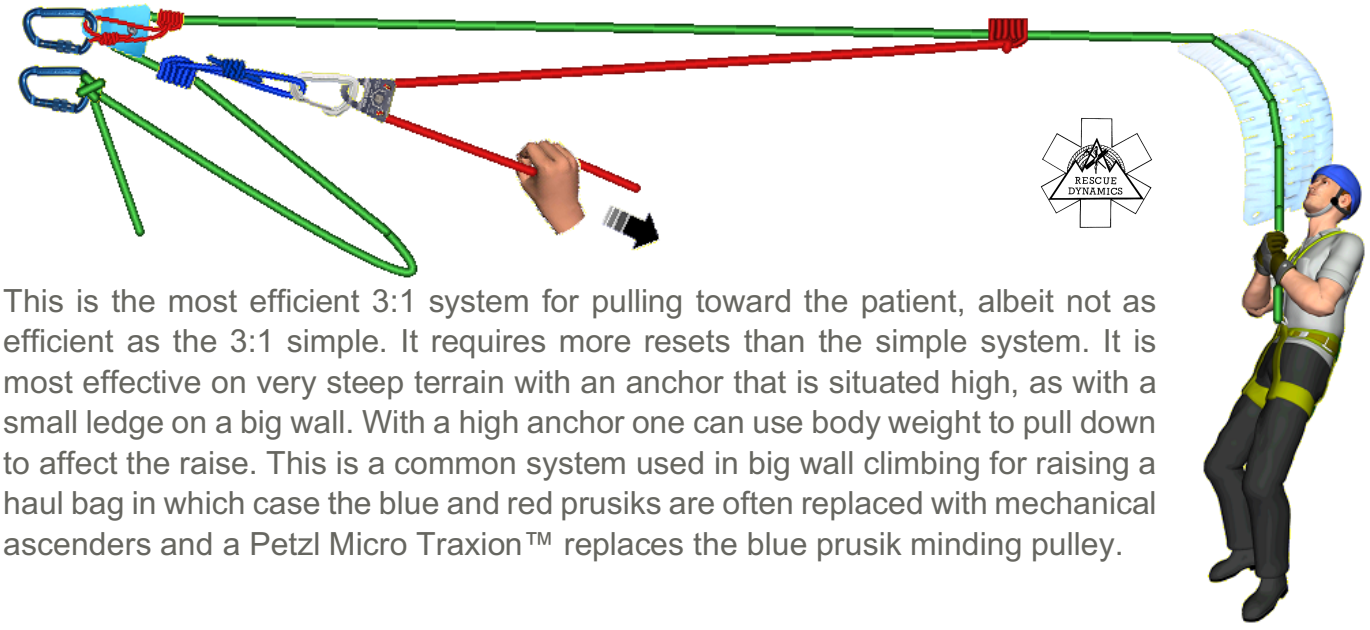
The 3:1 simple system is probably the single most widely taught pulley system in mountain rescue (both large scale organized and improvised companion rescue).

Despite the fact that the ideal mechanical advantage of this system is 3:1, it should be noted that if a Garda Hitch or assisted braking belay device is used as a progress capture and a carabiner is used instead of a haul pulley, the effective mechanical advantage has been measured to be as low as 1.5:1. If edge friction is added the actual resultant mechanical advantage is less than 1:1, which means you are pulling more than the actual weight of the person being raised! As mentioned previously, do everything you can to reduce edge friction.

Conversely, if a Petzl Micro Traxion™ is used as a progress capture and a Prodigy® mini PMP pulley is used as the haul pulley, the actual mechanical advantage has been measured to be as high as 2.7:1. This reduction in friction may mean the difference between success and failure for a small rescuer attempting to raise a large partner.

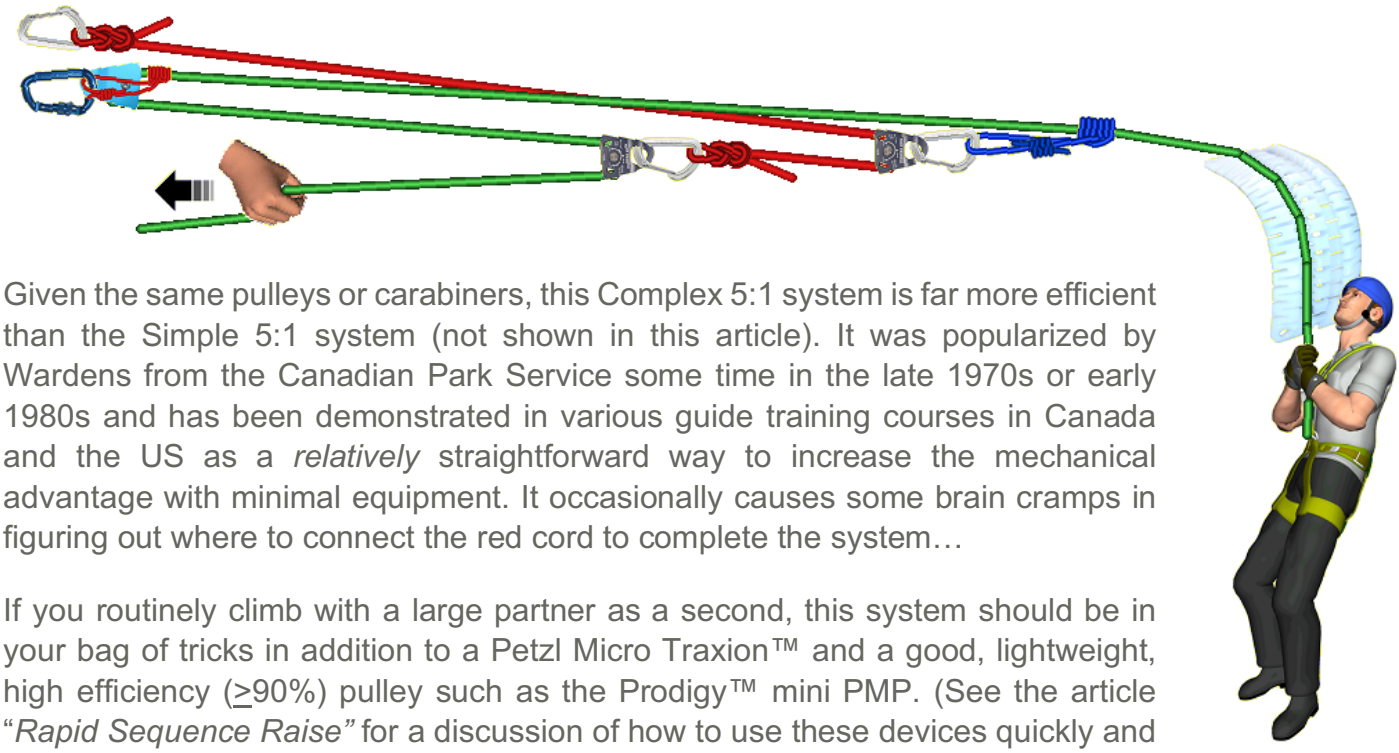
Opinion: Many have taken to calling this a “Z-pulley system or Z-drag”. Several systems exist where the rope takes a Z shaped path but only one is actually a 3:1 simple system. It may be more correct to refer to this system purely as the *3:1 Simple System*, since it is a unique identifier.

3:1 Complex System – *aka Spanish Burton or Pig Rig…*



This is the most efficient 3:1 system for pulling toward the patient, albeit not as efficient as the 3:1 simple. It requires more resets than the simple system. It is most effective on very steep terrain with an anchor that is situated high, as with a small ledge on a big wall. With a high anchor one can use body weight to pull down to affect the raise. This is a common system used in big wall climbing for raising a haul bag in which case the blue and red prusiks are often replaced with mechanical ascenders and a Petzl Micro Traxion™ replaces the blue prusik minding pulley.

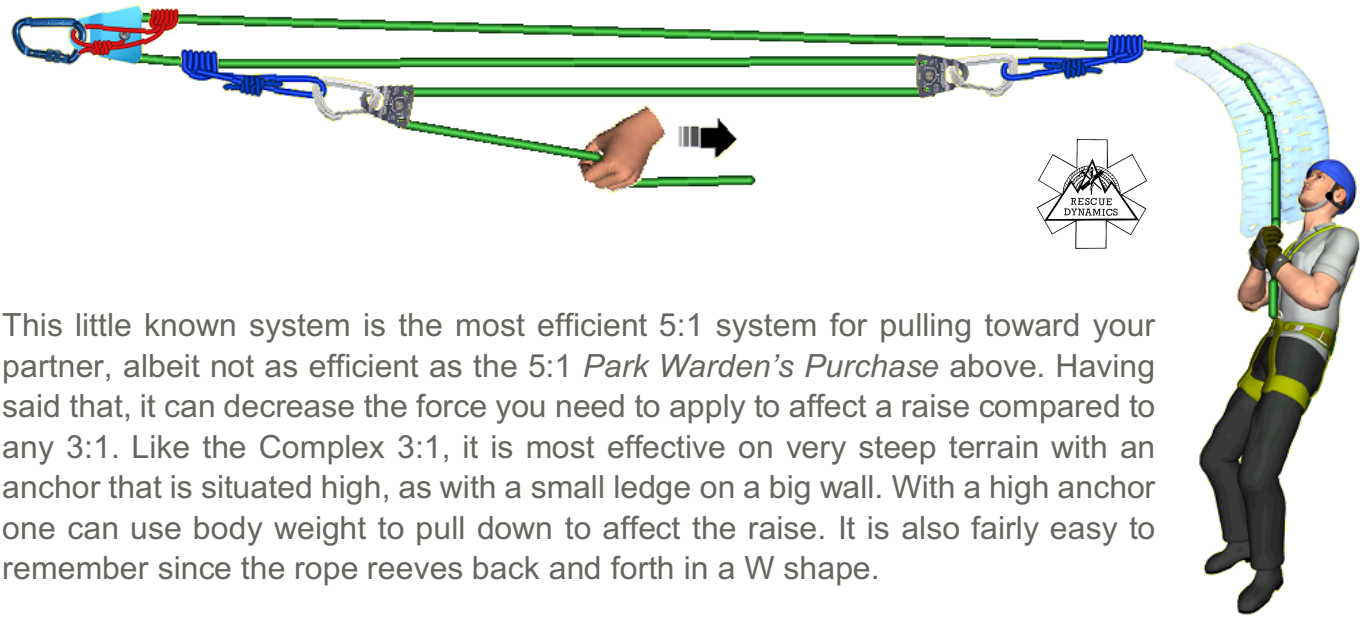
5:1 Complex System – *aka Park Warden's Purchase…*



Given the same pulleys or carabiners, this Complex 5:1 system is far more efficient than the Simple 5:1 system (not shown in this article). It was popularized by Wardens from the Canadian Park Service some time in the late 1970s or early 1980s and has been demonstrated in various guide training courses in Canada and the US as a *relatively* straightforward way to increase the mechanical advantage with minimal equipment. It occasionally causes some brain cramps in figuring out where to connect the red cord to complete the system…

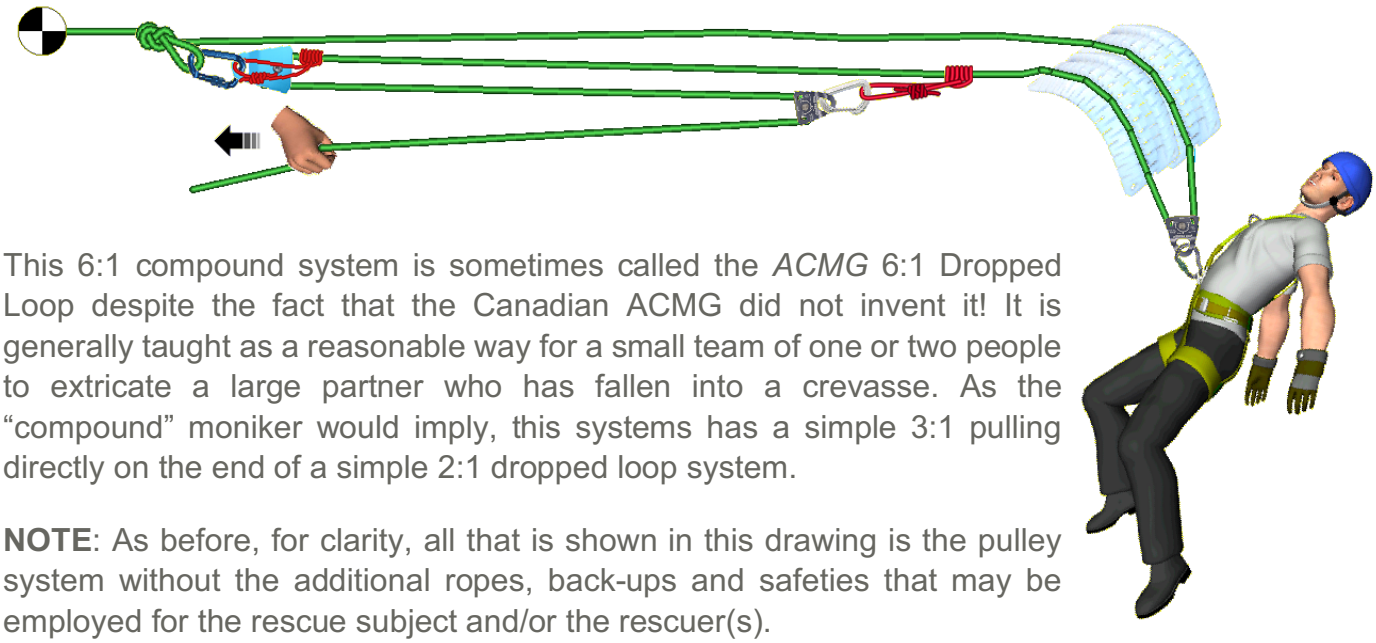
If you routinely climb with a large partner as a second, this system should be in your bag of tricks in addition to a Petzl Micro Traxion™ and a good, lightweight, high efficiency (≥90%) pulley such as the Prodigy™ mini PMP. (See the article "*Rapid Sequence Raise"* for a discussion of how to use these devices quickly and efficiently.)

5:1 Complex System – *aka Complex W…*



This little known system is the most efficient 5:1 system for pulling toward your partner, albeit not as efficient as the 5:1 *Park Warden's Purchase* above. Having said that, it can decrease the force you need to apply to affect a raise compared to any 3:1. Like the Complex 3:1, it is most effective on very steep terrain with an anchor that is situated high, as with a small ledge on a big wall. With a high anchor one can use body weight to pull down to affect the raise. It is also fairly easy to remember since the rope reeves back and forth in a W shape.

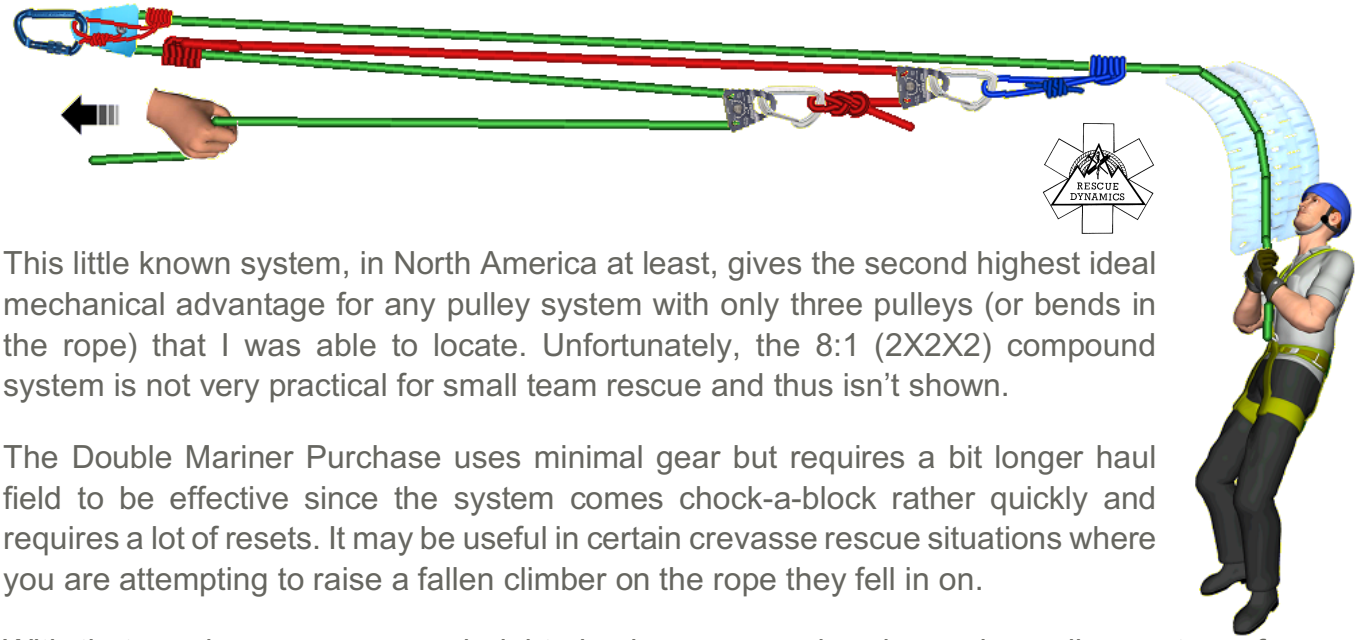
6:1 Compound System – aka *6:1 Dropped Loop…*



This 6:1 compound system is sometimes called the *ACMG* 6:1 Dropped Loop despite the fact that the Canadian ACMG did not invent it! It is generally taught as a reasonable way for a small team of one or two people to extricate a large partner who has fallen into a crevasse. As the "compound" moniker would imply, this systems has a simple 3:1 pulling directly on the end of a simple 2:1 dropped loop system.

NOTE: As before, for clarity, all that is shown in this drawing is the pulley system without the additional ropes, back-ups and safeties that may be employed for the rescue subject and/or the rescuer(s).

7:1 Complex System – *aka Double Mariner Purchase…*



This little known system, in North America at least, gives the second highest ideal mechanical advantage for any pulley system with only three pulleys (or bends in the rope) that I was able to locate. Unfortunately, the 8:1 (2X2X2) compound system is not very practical for small team rescue and thus isn't shown.

The Double Mariner Purchase uses minimal gear but requires a bit longer haul field to be effective since the system comes chock-a-block rather quickly and requires a lot of resets. It may be useful in certain crevasse rescue situations where you are attempting to raise a fallen climber on the rope they fell in on.

With that, we have now covered eight simple, compound and complex pulley systems for use by small teams of one or two people. As always, in order to optimize the actual mechanical advantage with limited pulleys, it is usually best to place your most efficient pulley at the first place where the rope bends when it leaves your hand. Given that we now have a modern full strength 24kN mini prusik minding pulley that weighs only 43 grams (Prodigy™ mini PMP), it is well worth carrying at least one pulley that you know how to use well. Small climbers with large partners may also want to consider the Petzl Micro Traxion™ at only 85 grams. (An iPhone 6s weighs 163 grams…)

About the Author

Cyril Shokoples is an internationally certified Mountain Guide and Past-President of the Association of Canadian Mountain Guides. He has been a member of the Alpine Club of Canada and Edmonton Section since 1975 and became a "Senior Member" in 1979. He received the Silver Rope award in 1988 and the Distinguished Service Award in 2002. In 2005, the Edmonton Section of the ACC awarded Cyril with the George Stefanick Legacy Award (only the second time this award was presented). In 2012 Cyril was inducted as an Honorary (Life) Member of the ACC.

Cyril also received the Distinguished Service Award from the Association of Canadian Mountain Guides in 2003.

Cyril has been teaching mountain leadership for well over a quarter century and he continues to broaden his background and skills into many related areas of safety and rescue education. He trained Emergency Medical Technicians for over a decade and is a life member of the National Association for Search and Rescue (US). He has been training the Canadian military Search and Rescue Technicians in mountain climbing and mountain rescue for over thirty years. He created the Parks Emergency Responder program for National Park Wardens and taught that program across Canada for almost two decades.

Cyril is a PADI Divemaster and Open Water Scuba Instructor. He is also a professional member of the Canadian Avalanche Association, a CSIA Ski Instructor and a licenced Advanced Amateur Radio Operator. He has taught courses and seminars in BC, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, The Yukon, North West Territories and Nunavut.

Cyril's climbing and diving exploits have taken him across North America and Europe to New Zealand, Hawaii and the Caribbean. He currently resides in Alberta, Canada and is the proprietor of the firm Rescue Dynamics, which is involved in climbing, rescue and safety instruction, as well as mountain guiding.

Further information on courses as well as additional copies of the many technical notes he has written can be obtained directly from Rescue Dynamics. http://www.rescuedynamics.ca

