Capital Technical Rescue and Safety Consultants, LLC

Student Manual

Rope Rescue Operations

ITRA Rope Rescue Level 1 Responder

ITRA Rope Rescue Level 2 Technician

22 Mill St., Unit 2, Albany, NY 12204 **T** 518-930-4500 **F** 518-207-9018 info@capitaltechrescue.com www.capitaltechrescue.com

v2025.7.29

Disclaimer

This manual is intended as a supplement for students who are enrolled or have taken our Rope Rescue courses. The information within is not all encompassing and should never be used without proper instruction from Capital Technical Rescue and Safety Consultants, LLC instructors.

In most instances we do not get into the specific operation, use, limitations, warnings or dangers of pieces of equipment. Even when we do, you should always consult with the latest version of the manual directly from the manufacturer of the product and contact Capital Technical Rescue and Safety Consultants, LLC to receive the proper hands-on training of that device.

Most of the illustrations in this manual have been created by Capital Technical Rescue and Safety Consultants, LLC utilizing the vRigger software package. Illustrations and diagrams are not to scale. See www.vrigger.com for more details on their software.

For additional information or questions please contact us at info@capitaltechrescue.com or by phone at 518-930-4500.

The latest version of this manual may always be obtained at:

www.capitaltechrescue.com/ropeops-student-manual.pdf

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Pre-Course Information

What to Expect

What to Bring

- PPE
  - Helmet with chinstrap
  - Class III Rescue Harness
  - Long pants / long sleeves or jumpsuits for certain evolutions
  - Good shoes / safety shoes / boots
  - Eye Protection
  - Gloves: Leather / mechanic style
  - Knee pads (optional - rescue classes only)
- Personal Items (optional)
  - Refillable water bottle
  - Snacks / Lunch
- Notify Us
  - Any medical problems
  - Any allergies – food, bees etc.
  - Any concerns you may have
- Winter Training – Dress for the elements
  - Our facility only
    - All training is conducted indoors and away from the elements
    - Be prepared to be working in ~ 50°- 60° temperatures

What is provided

- Additional PPE (pre-arrange)
- Coffee
- Water Bottle Fill Station
- Lunch – check with your organizer

Class at our Training Facility

Address

22 Mill Street, Unit 2
Albany, NY 12204

Directions

Directions via Google Maps: https://goo.gl/maps/r2BDuJtPeRR2

Parking

Do not block the gates at the end of the road.

Parking is limited and we try to be good neighbors to a few businesses, so please do not block the dumpster or the loading dock as it is actively used throughout the day.

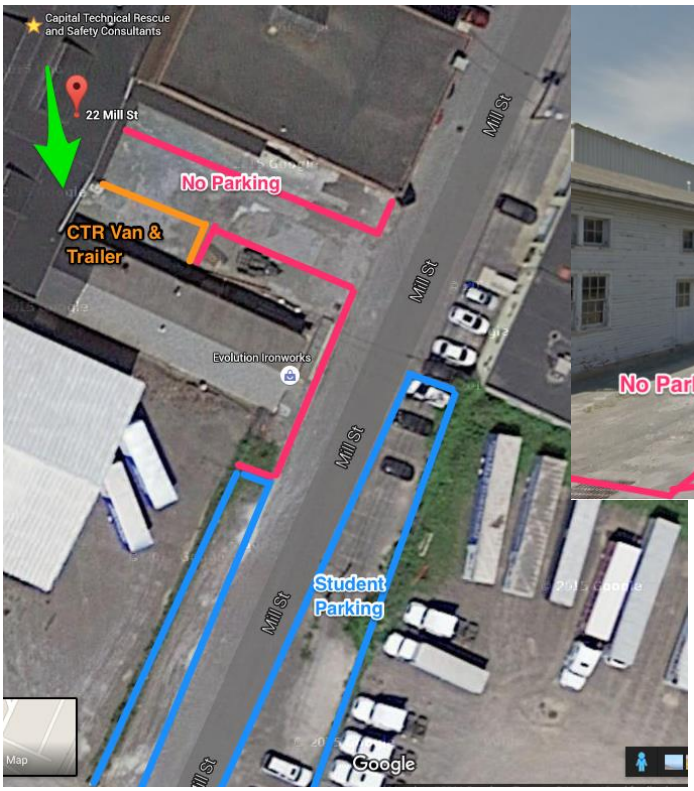

Photo Credit: Google Earth

Photo Credit: Google Earth

Facility Rules

- Tobacco / Vape Free
  - Our facility is 100% Tobacco Free
  - This includes use of smokeless tobacco

Pre-Course Study Material

- Read the Introduction, Standards and Rope Rescue Equipment Sections
- Begin learning the knots, bends and hitches from the Equipment Section. Each knot has its own information and link to videos.

NFPA Rope Operations Course – 32 & 40 hour classes

- Prior to Day 1:
  - Rope Rescue Equipment
    - Rope / cordage construction features
    - Knots / Bends / Hitches
  - Rope Rescue Hardware
- Prior to Day 2:
  - Rope Rescue Techniques
    - Rope commands and communications
    - Anchoring
    - Raising and lowering systems
- Prior to Day 3:
  - Mechanical Advantage Systems
  - Pick Offs
  - System (Team) Based (both suspended and clinging)
- Prior to Day 4:
  - Litters in Raising and Lowering Systems
  - System Failures / Complications

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Introduction

Rope rescue is an ever evolving and changing technical rescue discipline. With its roots deep in the recreational climbing and caving worlds, it has evolved over the years to work and rescue specific equipment and techniques. Many changes have come from various standards organizations throughout the world and have driven various equipment manufacturers to produce amazing gear that continues to get lighter, stronger, and safer to use.

The very basic principles of rope rescue have not changed much, and we still look to always achieve two points of connection in every system we use. This means from the anchor to the load there are always two independent systems, regardless of the equipment and techniques utilized in between.

Environments that teams operate in for rope rescue vary greatly, from back country rescue to urban skyscrapers these basic principles still apply. Rope rescue techniques also find their way into almost every discipline of technical rescue, including trench, confined space, swiftwater, animal, building collapse and more.

This course is designed to address the needs of most teams to perform rescues at the operations level, but also to just start to introduce you into some commonly used technician level skills, depending on the environment you typically work in. We will take you from being able to respond to simple car over an embankment rescue, all the way through to dealing with window washers hanging on their fall protection on a high-rise building.

Regardless of where you work and the territory you respond to, this course is in introduction into rope rescue and begins your lifelong journey and commitment into becoming a well-rounded technical rescuer. You must realize that like all technical rescue skills, these are perishable, and you must train and practice regularly to be effective and efficient. The recommended training and continuing education sections of this manual will help guide you throughout the course of your journey. Please remember that once you have begun the journey with us, we are always here to help you with any questions or problems you may have. Do not hesitate to send us an email or give us a call whenever you need.

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CTR Background

Capital Technical Rescue and Safety Consultants, LLC (CTR) was formed in 2006 to serve the needs of emergency response personnel whose job duties specifically task them with performing a variety of technical rescue disciplines. These responders have come from a variety of agency types including federal and municipal public sector emergency services as well as private industry emergency response teams and fire brigades.

The primary staff of CTR has been working and teaching together for over 10 years, prior to the formation of the company. Their backgrounds vary from volunteer to career firefighters and fire officers, emergency medical technicians to paramedics, and emergency responses from the smallest local incident to natural disasters and terrorist attacks that have had a global impact.

Previous and current CTR contracts have included teaching technical rescue courses from 6 to over 350 students, with scheduled completion ranging from a single day to over the course of several months. This flexibility has allowed our clients to minimize overtime expenses and ensure that production or response is negligibly impacted. This is also true for our industrial clients and has led us to be one of the most experienced groups of standby rescuers.

Capital Technical Rescue and Safety Consultants, LLC is a proud Petzl Technical Partner (PTP).

What is a Petzl Technical Partner (PTP)?
A PTP is a recognized expert company or individual in a vertical environment that demonstrates a thorough understanding of their respective industry, contributes to the development of best practices, and meaningfully integrates Petzl into their systems and curriculum. In return for this promotional support, Petzl endeavors to share our information, our products, our time, and our resources to ensure mutual success and sustainable growth.

Who is a Petzl Technical Partner?

Trainers & Training Organizations
Industry Leaders & Influencers
Consultants & Field Experts

PTP Mission Statement:
The Petzl Technical Partner (PTP) Program's mission is to develop a diverse network of training company partners and recognized leaders who can help Petzl promote our products and solutions to a wide variety of industries and end-users. Whereas Petzl is an expert in our products and services, we believe that front line, subject-matter experts are the best bridge to the industries we ultimately serve.
As a Petzl Technical Partner, we are part of a network of subject matter experts. There are technical partners located in 5 continents and in over 18 countries.

CTR serves clients from a variety of industries. These include:

Food Service
- Ingredient Facilities
- Food processing and packaging

Paper Mills
- Fine Papers
- Recycled Paper
- Tissue Paper

Nuclear Facilities
- Nuclear research
- Nuclear training facilities

Chemical Plants
- Silicones
- Formaldehyde
- Methanol
- Pharmaceutical research and development
- Pharmaceutical production
- Biotechnology research and development, production

Industrial Plants
- Nanotechnology production
- Nanotechnology research and development
- Packaging production
- Personal Protective Equipment manufacturing
- Armament Production

Mining Operations
Cement Plants
Research Facilities
Environmental Services
Power Generation – Hydroelectric, Coal
Fire Academies
Municipal Services
Airports
Construction

CTR has a warehouse full of rescue equipment, including multiple rescue boats. Depending on the needs of the client and our hazard surveys will depend on what equipment is required. Typical CTR Confined Space Rescue Equipment list:

Atmospheric Monitors, RAE Systems	Ventilation Fan (for actual emergencies only)
Rescue Rope, variety of lengths	Supplied Air Systems (SAR) and SCBA
Mechanical Advantage Rope Systems	Pulley systems
Anchor straps	Rope winch system
Tripods, bipods and monopods	Fall arrest rescue equipment
Patient packaging gear, SKED, SPEC PAK	Intrinsically safe radios and lighting
Edge protection	Reference material, iPads, onsite phone
Ascenders & Descenders	Additional hardware and software as needed

In addition to the rescue equipment, we have our own indoor training facility for rope and confined space rescue. Our props are utilized in clients' courses as well as in testing out new and prototype equipment and techniques as well as keeping our staff up to date.

The confined space rescue simulator has multiple levels, opening types, dimensions and space configurations. These include both vertical and horizontal access points, vessels with bottom openings, top openings and more. The simulator is also located in doors and allows us to train throughout the year, regardless of weather conditions.
We are also located just minutes away from the Hudson River and the Corning Preserve boat launch. This allows us to get out on the water and train, test new equipment and get it all back in service quickly.

There are also various other training props, including cell towers, firefighter survival, and lock out tag out in house. Our warehouse area stages equipment we utilize for HAZ-MAT, trench and collapse rescue courses, as well as rigging equipment for heavy duty operations.

As this space continues to evolve, we imagine many more possibilities. These include the capability to evaluate client's issue on site and re-create it in house, so we can practice performing a potentially difficult rescue within a safe area.

You can learn more about our site at the following links:
https://www.capitaltechrescue.com/post/indoor-training-facility

https://www.firehouse.com/rescue/article/12146756/technical-rescue-training-facility-profile-capital-technical-rescue-safety

Standards

National Fire Protection Association (NFPA)

1006 - Standard for Technical Rescue Personnel Professional Qualifications

This standard identifies the minimum job performance requirements (JPRs) for fire service and other emergency response personnel who perform technical rescue operations. We utilize this standard to ensure that our training programs provide you with the knowledge and skills to meet current national standards. This standard applies directly to you, the individual rescuer.

1670 - Standard on Operations and Training for Technical Search and Rescue Incidents

This standard identifies and establishes levels of functional capability for efficiently and effectively conducting operations at technical search and rescue incidents while minimizing threats to rescuers. It is intended to help the authority having jurisdiction (AHJ) assess a technical search and rescue hazard within the response area, identify the level of operational capability, and establish operational criteria. This is known as an "organizational" standard and specifies what your organization should do and know for technical rescue incidents.

1983 - Standard on Life Safety Rope and Equipment for Emergency Services

This standard specifies requirements for life safety rope and associated equipment used to support emergency services personnel and civilians during rescue, firefighting, or other emergency operations, or during training. It is imperative to understand that this is not a "use" standard. This standard is known as a "manufacturers standard" as it defines how equipment should be made, tested, labeled and documented. Within NFPA 1983 come the terms "General Use" and "Technical Use" which relate to ratings of the specific equipment.

1858 - Standard on Selection, Care, and Maintenance of Life Safety Rope and Equipment for Emergency Services

NFPA 1858 is written for organizations that evaluate the risks faced by emergency responders and their particular needs for life safety rope and equipment. It is also written for users of life safety rope and equipment to enable them to inspect, maintain, and care for the life safety rope and equipment they use during rescue and training operations that is compliant with NFPA 1983, *Standard on Life Safety Rope and Equipment for Emergency Services*.

NFPA 1858 applies to life safety rope, escape rope, fire escape rope, fire escape webbing, escape webbing, throwlines, moderate elongation laid lifesaving rope, life safety harnesses, belts, auxiliary equipment, litters, and victim extrication devices certified as compliant with NFPA 1983.

2500 - Standards for Operations and Training for Technical Search and Rescue Incidents and Life Safety Rope and Equipment for Emergency Services

This standard is a combination of NFPA 1670, 1983 and 1858, and was first released in 2022.

International Technical Rescue Association (ITRA)

About ITRA

The International Technical Rescue Association is a non-profit trade association, established by technical rescue practitioners for technical rescue practitioners. We exist to provide global recognition of technical rescue practitioners including instructors. We have developed a global syllabus to compliment national standards, allowing local flexibility with global recognition.

ITRA currently has approved and deployed curricula for the following rescue disciplines:

- Rope
- Swiftwater
- Boat
- Confined Space

CTR encourages students to take our ITRA courses and to become active members of ITRA.

As a member of ITRA you become part of a collaborative and supportive worldwide trade association that can provide instruction and assessment against global certifications across a range of disciplines and levels. It demonstrates that you are committed to excellence and high standards set by our Code of Conduct, providing external credibility and accountability.

Membership also provides opportunities to be involved in a range of association projects, from governance on the Board, to serving on committees and working groups.
We also envision numerous national and international opportunities from exchanges and conferences becoming part of the future too.

ITRA is now governed by a Board of Directors who were elected by the ITRA membership and who serve three-year terms. Previously, an interim Steering Committee was established to stand up the association and provided initial governance.

CTR has ITRA certified instructors, which means that they have been assessed in both skill and knowledge and have actually performed each of those skill sets to the ITRA standards. These are not just course attendance certificates and ITRA instructors and students can be verified for their current qualifications in the ITRA directory.

To find out more about ITRA or to become a member check out the ITRA Website

PURPOSE: WHY ITRA?

- To promote international best practices and standards for technical rescue.
- To improve the global portability and recognition of professional rescue qualifications.
- To provide local flexibility in delivering technical rescue training curriculum.

VISION, MISSION & VALUES

VISION : Our Hope

- A collaborative and professional global technical rescue industry.

MISSION : What we do

A. Recognize and document locally delivered training according to global best practice.
B. Provide Independent competency-based assessment for instructor and technical rescuers.
C. Maintain a global central database of training records for members.
D. Share safety related lessons learned from technical rescue activities to prevent harm.

VALUES : How we do it

Accountability:

1. Training and assessment systems developed by industry for industry.
2. A non-profit entity that is driven by and accountable to its membership.
3. Instructors and Practitioners maintain their currency through robust re-certification process.
4. Members acting professional and accountable under a Code of Conduct.

Transparency:

1. Meaningful and genuine consultation with members on our work.
2. Active use of social media to engage and keep members informed.
3. Annual disclosure of our activities and finances to our members.
4. Public register of qualified practitioners, instructors and assessors.

Working together:

1. To share knowledge, skills, and experiences across all disciplines of technical rescue.
2. Establish an international reporting system to highlight safety concerns within the industry.
3. To review and enhance rescue and rescue related training and assessment standards.
4. To foster collaborative interaction and professional development within the industry.
5. Membership adds value to individuals and organizations.

Legal Status

The International Technical Rescue Association is a non-profit corporation, registered in the state of Pennsylvania, USA.

Rope Rescue Equipment

NFPA 1983 Overview

As mentioned earlier, this is a manufacturing standard and not a use standard, however understanding what the certifications of NFPA 1983 mean helps guide us in the purchasing of quality products.

- NFPA G Rating - General Rating - Minimum breaking strength of 9,000 lbs
- NFPA T Rating - Technical Rating - Minimum breaking strength of 6,000 lbs
- Most hardware is good as long as it passes inspection, which should also include function tests where applicable.
- Most software is good for up to 10 years from the date of manufacture.
- NFPA 1983 also addresses:
    - Labeling on equipment
    - Record keeping and requirements

Definitions

kN – Kilonewton – The Newton is a measure of force
1 kN = 1000 Newtons
1 kN = 224.8 lbf (pounds of force)

Often, we consider 1 kN to equal the weight of 1 average person. Certainly, that can fluctuate, but in simple terms when considering how much weight or force a rope or piece of equipment can handle, if it is rated at 10 kN (2,224 lbf), that is approximately the weight of 10 people.

MBS – Minimum Breaking Strength

Carrier Count - This refers to the number of different yarns that are braided around the core of the rope to form the sheath.

Hand - The "hand" of the rope is a reference to how soft or supple the rope is. Typically, a supple rope will be considered to have a soft hand, versus a stiff rope that has a hard hand.

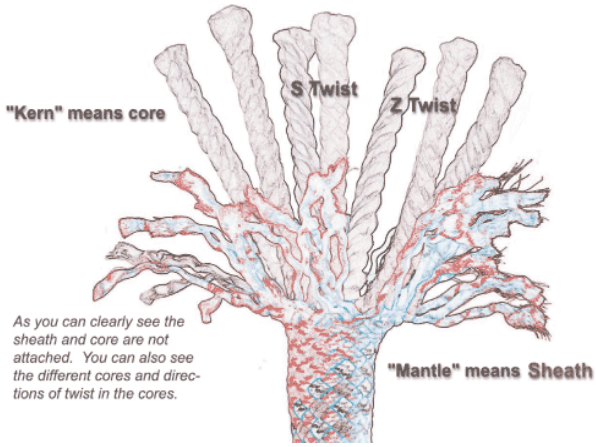


Photo Credit: NRS.com article - Know the Ropes

Kernmantle – The construction style of the rope where the "Kern" is the core, while the "Mantle" is the sheath. The core typically supports the major portion of the load, while the sheath primarily protects the core and supports a portion of the load.

Static Kernmantle Rope – A life safety rope with a maximum elongation of 6% at 10% of its minimum breaking strength. It is the primary type of rope used in technical rescue due to its low elongation, making it efficient for use in lowering and raising systems.

Dynamic Kernmantle Rope – A life safety rope with an elongation greater than 25% at 10% of the minimum breaking strength. These ropes are typically used by climbers since they help absorb the shock of a fall with their high elongation. Technical rescue teams specially trained in lead climbing, tower rescue and rescue from other structures may choose a dynamic rope over a static because they anticipate the potential of a fall.[1]

Rope / cordage construction & features

Suppleness vs. durability
The softer the hand of a rope the easier it is to knot typically. A stiff rope that has a hard hand, will be more difficult to work with and tie knots. Think about how difficult it would be to tie a knot in cable versus a softer rope. Typically, the more supple the rope the less durable it maybe. A stiffer rope will be more like cable and therefore will be more durable. Manufacturers all try to balance this with different techniques in making the ropes including coatings, treatments, fiber tensions, directions of the twists and more.

Each bobbin is a yarn that is being braided around the core of the rope to form a sheath.

High carrier count vs. low carrier count
Ropes with a higher carrier count will typically have a softer hand, while a lower carrier count will have a harder hand. Carrier counts in Static Kernmantle ropes typically range from 16 - 48 carriers. This means that there could be anywhere from 16 to 48 different yarns braided around the core of the rope to make the sheath. This will also affect how smooth or flat the surface of the rope is. The last video link below has the most in-depth explanation of all the factors of how ropes are made.

[1] Cordage Institute, Terminology for Fiber Rope

The 2 main construction characteristics that effect the performance characteristics are the number of carriers in the sheath and how much twist is in the bundles that make up the sheath and the core.

A rope with a high carrier count will have a thinner sheath and larger core, lending itself to a less durable rope with low stretch. The opposite being true of a low carrier count rope with a thicker sheath, more durability with a thinner core and more stretch. This primarily the result of a larger portion of the mass of the rope running straight in a high carrier count rope, transferring the energy in a straight line through the mass of the rope.

With a low carrier count rope there is more mass running at angles to the transfer of energy and those fibers need to straighten and bind on other fibers before holding the load, leading to more elongation.

Twisting the bundles that make up the sheath and the core adds structure, a firmness, to the body of the rope. Less twisting will typically result in a very low stretch rope, but it will feel "mushy" and tend to flatten over edges and through devices.

The amount twisting of these fibers also imparts some stretch to the rope. Adding a lot of twists to these bundles is how a dynamic rope functions as the materials are the same as the fibers used in static ropes.

Common Materials

- Nylon
  - Loses strength in water.
  - More stretch compared to polyester and aramid fibers
- Polyester
  - Unaffected by water
  - Low stretch
- Aramid (i.e. Technora)
  - Unaffected by water
  - Low Stretch
  - High Abrasion/Heat resistance
  - High strength fibers
    - 3 times stronger than nylon / polyester
  - Low resistance to shock

Videos:

How Ropes are Made
By: BlueWater Ropes

How Climbing Ropes are Made
New England Ropes

How is Climbing Rope Made?
By: Sterling Ropes

How Climbing Ropes are Made: Inside / Out
By: WeighMyRack - @Edelrid Ropes

Common Diameters / Sizes & Uses

- 10.5 - 11.5mm (7/16”) Static Kernmantle Rope
  - May be NFPA T rated at 20kN - some are G rated depending on construction
  - Primarily used in industry, technical rescue teams and gaining popularity within the fire service
- 12.5mm (1/2") Static Kernmantle Rope - NFPA G rated at 40 kN - common rope diameter used in fire service.
- 6mm technora cord - used for tiebacks - rated for 21kN
- 8mm prusik cords - used as rope grabs, mini-haul systems, accessory cord, sewn cord used as anchors
  - Rated at 15 kN as a single part
  - Cords tied into a prusik loop with a double fisherman’s have a theoretical rating of up to 50% less than 15 kN
  - Sewn cords in a bound prusik loop rated at 20 kN
- 1” Tubular Webbing - rated at approximately 19kN [2]
- 1” Flat Webbing - rated at approximately 26kN[3]

The practice of tying prusiks should be eliminated completely. Sewn bound loop prusiks offer a level of safety that far exceeds the cost savings of making your own.

Rated sewn terminations can be used as anchor straps with a degree of certainty that un-accounted for tied prusiks cannot.

Sewn anchor slings should be used wherever possible for the same reasons.

[2] CMC Rescue
[3] CMC Rescue

Knots / Bends / Hitches

These knots, bends and hitches are the common ones we utilize in rope, water and confined space rescue. There are many ways to tie each of these, and it is always good to know several ways to tie each.

A knot has many definitions, but for our purposes it is an intentional complication in rope, cordage or webbing which has a practical application. A bend is a type of knot that ties 2 ropes ends together, while a hitch is a knot which secures a rope, cord or webbing to another object.

A bight is a fold in a piece of rope so that the two parts lay alongside each other. This is often used to form a loop, as when we tie the "figure 8 on a bight". We make this bight, or loop sized appropriately for the task. We refer to the size of the loop or bight, as the "gain" of the knot. The gain is the overall size of the knot. The larger the gain, the larger the loop. In confined space rescue we often try to tie our knots so the gain of the knot is small enough to just clip in two carabiners. This allows us to maximize our lifting height, because if we had a knot with a large gain, and our overhead clearance was low, we could potentially not be able to get a rescuer or victim out of that space.

The working end of the rope refers to the "short" end, the part doing the knotting or the work, or the part under load. It is also referred to by some as the "running end".

The standing end of the rope is the long part of the rope, or the part not knotted, or the "free" end of the rope.

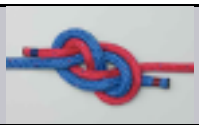
The bitter end refers to the tail end of the standing end of the rope.

Typically, regardless of the knot, bend or hitch we de-rate the breaking strength of the rope a minimum of 30% but more often de-rate it at 50%. This is because there is such a variation in the materials used in rope construction, strength loss of various knots, and condition of the rope itself – new versus used. De-rating the rope at 50% ensures that we have considered all of these factors.

Anything we tie must be easily identifiable by everyone involved. Clean and well-dressed knots, bends and hitches help us quickly inspected our system and ensure we are ready to proceed. Unless noted in the table below, we do not use "safety" knots when tying the majority of these. Instead, we follow a few rules:

- Tails in rope should be 6" or length of hand
- Tails in webbing should be 4" or width of hand
- Knots should be well dressed, set and easily identifiable

Scan the QR codes below with your camera app, or just tap on the QR Code on your mobile device and it will bring you to a video on how to tie that knot.

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
		Stopper knot, used in the terminal end of a rope
Figure 8	Figure 8 Stopper, Flemish Knot	
		Creates a loop to anchor the end of a rope. Loop typically should only be large enough to accommodate 2 carabiners. Tail should be the length of your hand, if it is longer you can tie it off.
Figure 8 on a bight		
		Creates a loop in the end of a rope going through a ring, carabiner, harness, object, anchor point etc. Tail should be the length of your hand, if it is longer you can tie it off.
Figure 8 Follow Through		
		Joins two ropes together Tails should be the length of your hand, if it is longer you can tie it off.
Figure 8 Bend	Flemish Bend	
		Creates a loop / attachment point in the middle of a rope. Can also isolate a damaged section of rope.
Butterfly	Alpine Butterfly	
		Join two ropes together. Binding knot, often used in the terminal end of patient packaging devices. It is imperative that a safety knot is tied on either side of the knot, right up against it.

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
Square Knot	Reef Knot	
		Stopper knot, typically used up against another knot, such as the square knot.
Overhand Knot		
		Stopper knot, used in the terminal end of a rope. It is also the basis for several other knots and is used as a safety in conjunction with other knots.
Double Overhand Stopper		
		Used to place limbs as wristlets, must be backed up to ensure locking action. This knot can cause potential trauma and only should be used when other methods are not available/practical.
Handcuff Knot	Texas/California Love Knot, Hobble Knot	
		Joins two ropes of similar size together, often used to create Prusik loops.
Double Fisherman's Bend	Grapevine Bend	
		Typically a temporary holding hitch, easily adjustable. This hitch does slip and should be backed up.
Clove Hitch - Rope End		
		Two opposite hitches are created and dropped over an object to create this hitch. Typically a temporary holding hitch, easily adjustable. This hitch does slip and should be backed up.
Clove Hitch - Half Hitches	Drop Over Clove	

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
		Anchor around a post or tree for a static rope, can be used for rappelling or a static safety line. No strength degradation of rope. Post diameter should be at least 8 times the diameter of the rope, typically at least 3 full turns around the post. Can be secured with a carabiner or a figure 8 follow through.
Tensionless Hitch		
		Can be used to tie off descenders. Attention must be paid to the tail strand to be pulled on is away from the device.
Slip Knot	Slipped Overhand Knot	
		Triple wrapped loop of cord for system loads, this creates friction on a rope and can be used as a rope grab. Double wrapped are only suitable for a single person load such as ascending, and should never be used in systems.
Prusik Knot	Triple Sliding Hitch, Prusik Hitch	
		Utility knot creating a loop in rope or webbing, either in the end or the middle. No life loads in rescue.
Overhand Knot on a Bight		
		Forms a bight in the end of the rope that will cinch down the bight. This is useful when you need a carabiner to be loaded upon the spine to keep it from easily side loading the gate or to the becket of a double pulley when using it at the dead end of a mechanical advantage system.

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
Poachers Knot / Double Overhand Knot	Strangle Snare	Triple wrap is known as a Scaffold Knot
		Used with webbing or rope to attach a sling or loop around a bar, ring, or other attachment point. This hitch significantly weakens slings. If using to join two slings together, it maybe better to use a carabiner.
Girth Hitch		
		Attaches two ends of webbing together by rethreading one end through an overhand tied in the other side. Tails should be at least the width of your hand.
Water Knot	Ring Bend, Tape Knot, Overhand Follow Through	
		Allows for controlled descent with minimal hardware
Munter Hitch	Italian Hitch	
		Load releasing hitch, using 33' (10 meters) of 8mm static cord
Radium Release Hitch		

Rescue Knots / Bends / Hitches and their uses		
Photo / Name	**QR / Alternate Names**	**Uses**
Photo / Video Credits: AnimatedKnots.com, REI.com, CMC.com		

Rope Rescue Hardware

Descent Control Devices

Descent control devices (DCDs) or descenders are the basis of many of our systems for both lowering and raising systems. Traditionally people have thought of simple descenders only for things such as rappelling, however over the past 25+ years more modern devices have been brought to the market and allow for many more features. These legacy type of descenders are still in use by many teams, however they don't have some the inherent safety and efficiency the modern devices offer us.

- Legacy DCDs
    - Features
        - Pros
            - Works mostly with any diameter of ropes
            - Friction based / little to no moving parts
        - Cons
            - Lighter / Cheaper
            - Used for lowering / rappelling only
            - Must be tied off to go hands free
            - Require the rope to be removed when changing over to an ascending or raising system
            - No built-in progress capture
    - Examples
        - Figure 8 with Ears (Rescue 8)
        - Brake Bar Rack
        - SCARAB

- Modern DCDs

These are the only descent control devices we utilize in our classes unless there is a specific reason / application to use a legacy device. These devices are generally known to be safer and more efficient than legacy devices.

- Features
    - Pros
        - Auto-locking devices - operator can let go and the device automatically stops any descent

- Automatic progress capture - acts like a ratchet - and allows you to take tension off your hauling or ascending system to rest or reset without any rope sliding back through the device
- No need to remove the rope from the device during a change over to a raising system
- Some have integrated pulleys and beckets to incorporate as part of a mechanical advantage system
- Additional safety features depending on device
- Some can operate as a belay device or a "twin tensioned" device

▪ Cons

- Heavier
- Only compatible with specific diameter of ropes
- More Expensive

o Examples

			
Petzl ID'L	Petzl Maestro L	CMC / Harken Clutch	CMC MPD

Photo Credit: Petzl & CMC Stock Photos

Backup / Safety Devices

Backup devices are an option to utilize as opposed to a traditional belay or twin tensioned system that utilizes a descent control device on the second line attached to the rescuer. These devices work in a similar fashion to seat belts. The devices move freely on the rope, without the need for the rescuer to tend to them, and in the event of a shock or sudden movement the device locks up on the rope and stops the rescuer.

Most backup devices on the market are specific to rope diameter, with the exception of the Petzl ASAP and ASAP Lock. The Petzl ASAP series works with both 11mm and 12.5 mm rope, and when coupled with the proper shock absorbing lanyard, is rated for two person loads.

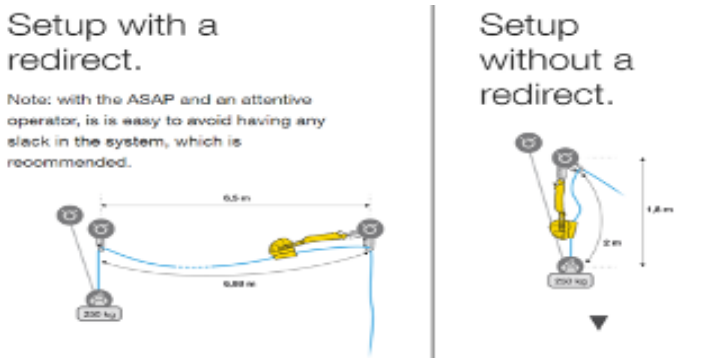
Video:
HOW TO Belay with Petzl ASAP / ASAP Lock
By: Petzl

			
Petzl ASAP installed correctly on rope	Petzl ASAP Lock	Petzl ASAP'Sorber Axess 2 person lanyard for use with ASAPs	Kong BackUp (11mm only)

Photo Credit: Petzl and Kong stock photos

The Petzl ASAP series can be used as a personal device (attached to the rescuer), or at the anchor as part of a system, given that there is a second carabiner at the anchor to help keep the rope oriented and feeding into the ASAP properly, and that there is at least 10' from the anchor to the edge / change of direction. It is important to place appropriate back tension on the tail end of the rope to ensure that excess slack does not develop in the belay line. Too much back tension may cause the ASAP to not engage should a main line failure occur.

Video:
HOW TO Use ASAP / ASAP Lock on a Vertical Lifeline
By: Petzl



From Petzl Tech Tip web page

Rope grabs

Rope grabs are devices that do just that, grab onto the rope. We utilize them most often to help create hauling and ascending systems. There are many types of rope grabs, including both hardware and software based.

Software Rope Grabs

Prusik Cord - Traditionally we used 8mm cord for 12.5mm rope that we tied into a loop with a Double Fisherman's Bend and created a prusik hitch. These tied prusik loops were often tied incorrectly or at different lengths based upon who tied them. Additionally, they were not truly rated and did not allow for easy inspection. We have instead moved towards sewn prusik loops, which are manufactured and rated.

- Pros
  - Inexpensive
  - Lightweight
- Cons
  - More expensive
  - Lightweight
  - Tend to slip on wet / muddy ropes

Hardware Rope Grabs

- Styles / Features
  - Smooth cam
    - "Smooth" in that the teeth are not sharp, and are less aggressive
  - Toothed cam
    - Teeth are sharp / more aggressive
  - Captive / non-captive devices
    - Captive - rope is fully enclosed in the rope grab and can't come out
    - Non-Captive - rope is not fully enclosed in the rope grab
- Pros
  - Rated device
  - Typically, fast to install and remove from rope
- Cons
  - Can damage rope if shock loaded

- Heavier
- More Expensive

			
Petzl Rescuecender Smooth Cam, Captive	CMC Ascender Smooth Cam, Captive	CT Handled Ascender Tooth Cam, non-captive, captive with carabiner	Petzl Croll Tooth Cam, Non-Captive
Photo Credit: Petzl, CMC, CT stock photos			
			
CMC Capto 11mm & 12.5mm versions Integrated Pulley & Rope Grab	CT Roll N Lock Rope Grab or Pulley	CT Cric Integrated pulley and rope grab. 8mm – 12mm only	Harken Ninja MultiAscend Dual Cam 9mm – 13mm
Photo Credit: CMC, CT, Harken stock photos			

Anchor straps

There are a variety of rescue rated anchor straps on the market, and many teams still elect to tie their own with 1" tubular webbing. A rated anchor strap can be fixed, or variable in length and may or may not have metal hardware as connection points on the ends of the straps. Fixed anchor straps typically come in a variety of lengths, while variable straps usually only have one option for the range of lengths they will handle. Metal hardware on the ends of anchor straps may be identical on each end, which will not allow a choker

configuration, or may be designed with one end of the strap having a larger metal “eye” that allows you to pass the other end of the strap through the eye, creating a choker.

Anchor straps are typically used and rated in 3 configurations

Choker
- Typically, the weakest configuration
- Cinches to anchor / object

Vertical
- Inline / standard strength
- Not often used in rescue

Basket
- Strongest configuration

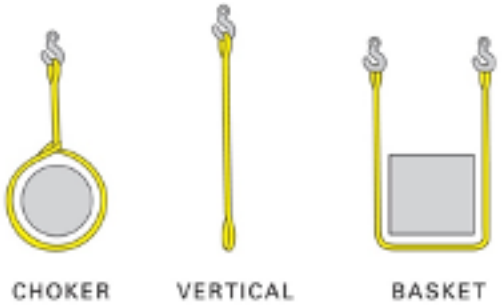


Photo Credit: Doleco-USA

			
CMC ProSeries Anchor Strap	Bluewater Rhino Sling	PMI Vari-Rigger	Petzl Wire Strop

Photo Credit: CMC, Bluewater Ropes, PMI, Petzl stock photos

Carabiners

One of the most important components of our systems is the carabiner. This allows us to connect two or more pieces of gear together. There are more options for carabiners than any other component in our systems and choosing and purchasing a compatible one is very important.

Carabiners are made either of Aluminum or Steel, with aluminum traditionally being NFPA T rated with steel holding a NFPA G rating. This however, has also evolved and there are now many lightweight aluminum and lightweight steel carabiners that are NFPA G rated.

Anatomy:

Photo Credit: Fusion Climb

The shape of a carabiner is also important, especially when it comes to device compatibility. The most common are the 4 below.

			
Oval	D	Off set D	Pear

Photo Credit: RockExotica and OmegaPacific stock photos

There are a variety of types of gates and locking mechanisms for those gates on the market. In the rescue world we typically use one of the following styles below. It is

important to note that the 3 carabiners below are all made by KONG and are all the same style and model of carabiner, but with three different locking mechanisms.

Screwgate

Twist Lock

Triple Lock

Photo Credit: Kong stock photos

Nose

Most modern carabiners manufactures have changed the "nose" of the carabiner to a Key Lock style to keep the carabiner from snagging on various other items it comes into contact with. Previous designs included open hooks on either the nose of the carabiner or the top of the gate.

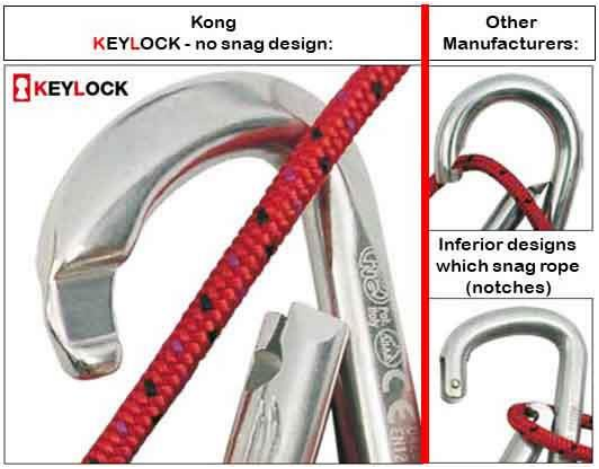


Photo Credit: Kong

Captive eye

Carabiners may also have a permanent or temporary "captive eye". This ensures the carabiner doesn't get side loaded but may also be utilized on systems where you don't want the user to be able to easily remove the carabiner from that component of the system. Pre-rigged 4:1s are an example of where these maybe used.

Photo Credit: Rock Exotica stock photos

Snap Hooks

We may also utilize snap hooks in some of our systems, which have both a captive eye and typically a double or triple lock mechanism to open up the snap hook.

Photo Credit: Kong

Labeling & Inspection

Carabiners must be labeled and rated for their appropriate certifications and strengths. The numbers will be marked on the spine of the carabiner and are now rated in 3 strength categories:

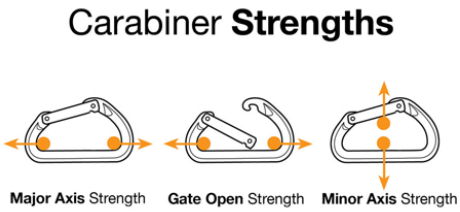


Photo Credit: Black Diamond

Inspection of the carabiner is fairly simple, examine it for any obvious damage, dirt or debris and ensure that it functions correctly by opening and closing it several times. If the carabiner does not close properly or auto lock if it is supposed to then it should be removed from service.

Harnesses

Modern rope and confined space rescue harnesses have a lot of features, with many brands available. For all industrial rescue teams and almost all fire service agencies we recommend utilizing a NFPA Class III rescue harness. There are several key features to consider when selecting a harness for team members.

The harness is considered Personal Protective Equipment (PPE) and as such what fits and works well for one team member may not work for another. Various body types, sizes and gender all play a role in harness selection. While most team members will fit in standard sizes, there are those rescuers who are outside of the standard small and large sizes. For these members a custom personal harness maybe necessary and are available from several manufacturers.

Harness Components and Considerations:

- Ventral Connection
  - Main connection at waist for descent control devices or main line attachment
- Sternal Connection
  - Back up device / belay connection point at the chest.
  - This is the preferred connection point for fall arrest systems to help prevent suspension trauma
- Dorsal Connection
  - Between the shoulder blades, traditionally used for backup / belay connections
  - Current OSHA requirements dictate to use this connection in fall arrest systems; however, the sternal connection is still our preferred connection point based upon industry research. In Europe, some manufacturers have eliminated the dorsal connection completely.
- Work Positioning Rings
  - Extra D-Rings on either side of the hips, that are used in conjunction with a work positioning strap or device to allow a rescuer to stand securely and still have their hands free to perform work. Think of a climber on a utility pole. There still must be some type of fall protection in place. This is especially useful on ladders and structural steel such as cellular and water towers.
  - You must always use both rings together, never attach to just one ring!
- Gear Loops

Photo Credit: Petzl Stock Photos

- Gear loops are intended only to hang additional gear from and are not weight or load bearing

- Padding
  - Most padding is removable and is a user preference for comfort
- Shock load indicator
  - Most modern rescue harnesses with dorsal connection points will also have a shock load indicator below the dorsal connection and is usually evident by the webbing between the chest and waist harness being folded over and stitched together. When activated a red label / flag comes out indicating the harness has seen an impact or shock load.
- Labels
  - All harnesses should have labels indicating the standards it meets, the sizes, date of manufacture as well as the ratings for the various connection points.
  - An inspection log is also included in the label.
- Inspection
  - Look for signs of excessive wear, tearing, discoloration in webbing and stitching, check hardware for any gouges and deformities. If any doubt, remove from service. Follow the manufacturers guidelines.

Photo Credit: Petzl

Photo Credit: Petzl

- Adjusting the harness
  - Tighten waist of the harness so the two straps are even with each other. You should just be able to slip in 2 fingers between the webbing and your body.
  - Adjust the chest harness so that you can reach over your shoulders and touch the dorsal connection ring. That should be positioned between your shoulder blades.

- If you are going to be suspended by the harness for any length of time, tighten the chest so you can just slip in two fingers.

Manufacturer Resources

Petzl Harness Inspection Procedure

Petzl Inspection Form

Petzl - Tips for Protecting Equipment - Harnesses

Petzl AVAO Harness Technical Notice

AZTEKs / Set of Fours / Mini-Haul

These terms are utilized interchangeably to refer to a small, pre-rigged mechanical advantage system made from small diameter rope, pulleys, and a progress capture device. Typically, these are 8mm cord, two double pulleys and prusiks, but may also incorporate a cam-based capture device, smaller cord and even triple pulleys to increase the overall potential mechanical advantage. The cord varies in length and allows for a system to extend out anywhere from 3' up to just over 10', by utilizing 30' - 50' of cord.

Photo Credit: Sterling Stock Photo

An AZTEK is the Arizona Technicians Edge Kit, which is a product name and distributed by several companies and configured with various options. A "Set of Fours" (SOFs) is also referring to the same idea as the AZTEK in that we are using rope that is weaved into two double pulleys, giving the appearance of four ropes. The AZTEK kit has over 100 documented variety of uses in rope rescue, most of which also apply to other companies "Set of Fours" or any mini-haul system, regardless of the actual mechanical advantage of the system.

			
Sterling Elite AZTEK Kit	SMC Advance Pulleys	Bluewater Ropes Mini-Haul	PMI Mini-Haul

Photo Credit: Sterling, SMC, Bluewater Ropes and PMI stock photos

		
Petzl JAG System	ISC MiniHaul 6:1 / 7:1	Harken Wingman
Photo Credit: Petzl, ISC, and Harken stock photos		

The AZTEK and various Set of Four (SOF) kits we carry have some great uses, but we also must recognize some of the limitations we encounter when utilizing the AZTEK.

The configuration of these kits typically includes either 40’ or 50’ of 8mm cord.

This allows for up to about 8' - 12’ maximum useful lifting height as we must take into account the rope around pulleys, the sewn termination and enough haul line left to be able to grip to begin a haul when fully extended.

Common Uses and Limitations of AZTEKs / Set of Fours

Primary Use	Limitations	Alternative Equipment / Considerations
Personal Travel Restraint	Must be setup, equipped and utilized properly, NOT fall protection, can fail	Grillon / work positioning lanyard
Short M:A System	Less than 10' - 12' of overall haul. Must account for anchor height, depth of confined space and clearance. Can be difficult to haul a rescue load vertically gripping 8mm cord by hand. (consider using ascenders on harness). Should only be used when other options not available, space truly dictates a small system.	Build a drop loop 5:1 system with shorter rope, build a 4:1 Maestro haul system with pull cord and length of 11mm or 12.5mm rope
Piggyback M:A System	Need to ensure progress capture by tending the rope through the progress capture device, could cause too much M:A if piggybacked onto another M:A System. Can be difficult to haul a rescue load gripping 8mm cord by hand. (consider using ascenders on harness)	Staggered 9:1 (3:1 built on a 3:1)
Adjustable Litter Bridle	Extra rope all over, consider using shorter ones, overkill if not needed, and utilizing a valuable piece of gear	Manufactured bridle, grillon / work positioning lanyards
Litter Attendant	Can be overkill, and utilizing valuable piece of gear	Petzl ID, Grillon, any descender
Adjustable / Vectored Anchors	Can be overkill, and utilizing valuable piece of gear	Petzl ID, GriGri, Grillon, TieBack Cords
Change of direction / deflections and line vectoring	Can be overkill, and utilizing valuable piece of gear	Petzl ID, GriGri, Grillon, TieBack Cords
Adjustable belay height	Can be overkill, and utilizing valuable piece of gear	Grillon / work positioning lanyard
System Knot Passing	Training and ensuring that you account for the length you will need to accommodate the knot passing	This is one of the best places for this gear. Other M:A systems can be utilized though.
Pick Off System	Heavy and can be overkill.	Grillon / work positioning lanyard / Counterbalance foot loop
Tie Back	Can be overkill, and utilizing valuable piece of gear, anchors must be close, but very fast to setup.	Petzl ID, GriGri, Grillon, TieBack Cords

Videos from Rock Exotica

AZTEK uses:
https://youtu.be/mY2EyXczDhU
Note that it shown as a replacement for a standard 4:1 system, due to the overall length limitations, especially with an overhead anchor and a confined space with additional depth.

AZTEK and Mechanical Advantage:
https://youtu.be/9JszpXjcjEg
Again, it should be noted that its use for mechanical advantage is typically as an add on system, and not the primary system (although it may work)

Edge Protection

In either the natural or manmade environments, the edges our ropes run over can cause them to fail. This could be due to sharp edges, abrasive surfaces, hot surfaces and more. The edges also add friction into our system making it more difficult to haul. Ropes should be protected with edge protection wherever it is needed with the proper type of edge protection.

Edge protection should always be tied off to ensure it doesn't fall onto those working below it. The protection maybe made of soft materials such as canvass or firehose, plastic, or even metal rollers.

Edge rollers should be utilized any time moving rope goes over the first severe edge, such as a parapet wall. Canvass pads shouldn't be relied on alone in these situations, even some of the newer, heavier duty ones can't protect the rope or the edge pad itself from damage in these situations. Plastic options maybe OK to protect the rope, but there will be a loss in efficiency.

			
CMC Edge Pad	CMC Ultra-Pro Edge Protector	Petzl ProTec Plus aka Rope Snake	Petzl Roller Coaster

Photo Credit: Petzl & CMC Stock Photos

Fall Arrest System

A fall arrest system is designed to stop a fall that has already begun. Twin lanyards for climbing structures and the Petzl ASAP with shock absorber maybe considered fall arrest systems. Once the fall occurs those devices lock up and / or have shock absorbers that are designed to absorb the energy of the fall to minimize injury. Fall arrest systems are really a last resort since a fall may still be able to occur. Other systems maybe better suited for the application.

Edge / Travel Restraint

Edge restraint, fall restraint / travel restraint, edge restriction, travel restriction are all terms used to describe a single point anchor system that is attached to the harness and keeps the user from reaching the edge of a cliff, roof, or other fall hazard. These can be adjustable work positioning lanyards such as the Petzl Grillon, or as simple as tying a knot in the rope that won't allow you to fall off the edge.

Work positioning systems

A work positioning system is an engineering control that limits the distance of free fall to two feet or less, reducing the risk of injury due to a fall to a lower level. This type of system supports the rescuer on an elevated vertical surface, such as a tower, ladder, bridge, pole, or other structure, and allowing them to work hands free.

It must also be utilized with a personal fall arrest or belay system. This could be a backup device such as a Petzl ASAP, a traditional belay system, or a set of twin or Y fall arrest lanyards.

The system consists of an anchor, a body harness with work positioning rings, and a lanyard specifically designed for positioning.

In the example shown, the rescuer is climbing a tower, wearing a Class III rescue harness with work positioning rings at his hips, and a Petzl Grillon work positioning lanyard. This lanyard is adjustable and allows the rescuer to get in a comfortable and optimal position to accomplish a task. The rescuer can work hands free and concentrate on the tasks,

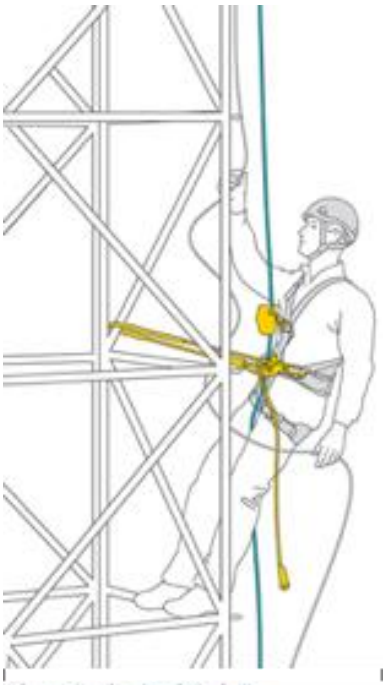


Photo Credit: Petzl Tech Tips

while also maintaining a Petzl ASAP on the blue rope as his fall arrest system.

			
Petzl Grillon	Kong Trimmer	Petzl Connect Adjust	ISC RAD
Photo Credit: Petzl, Kong, and ISC stock photos			

Rope Rescue Techniques

Rope commands and communications

Any set designation of commands can be used as long as they are known to the entire team.

Any member can call "Stop" for any recognized safety issue. Proper sequence to ensure a team is ready for an evolution is important. As an example:

Technical Rescue Officer Asks: "Belay On?"
Belay Operator Responds: "On Belay."

Technical Rescue Officer Asks: "Main line ready?"
Main Line Operator Responds: "Main Line ready."

Technical Rescue Officer States: “Down” or “Up”

When utilizing radios, transmissions should be short and concise. Consideration should be given to operating on a designated channel to prevent cross-chatter and confusion. Radios can be difficult to use in areas of dense building materials, steel and concrete block radio transmissions.

Background noise and reverberations/ echoes can render conventional microphones ineffective; use of bone or throat microphones reduce background noise interference. Hearing protective headsets should be used in high noise environments to ensure communications can be heard as well as preventing distractions and hearing damage for rescuers.

In situations where radios or direct verbal communication cannot be used, a different system must be utilized and may include whistle signals as alternatives. Again, these communication systems should be simple commands and not be too verbose as to cause confusion to rescuers. It is too easy to also chain words together that may have opposite meaning, and the recipient only hears the last part of the command, which may have not been the overall intent. We also want the commands utilized to be applicable across multiple disciplines of rescue. For example, if your team does rope and confined space rescue and interacts with a team that does swiftwater rescue you want to have these simple commands that will work across these disciplines.

Effective communication involves two key parties: the sender, who conveys the message, and the recipient, who receives it. To ensure that the message has been understood correctly, it is important for the recipient to repeat back the information. This practice helps confirm clarity and reduces the risk of misunderstandings.

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These commands are our preferred method of communications in many rescue applications:

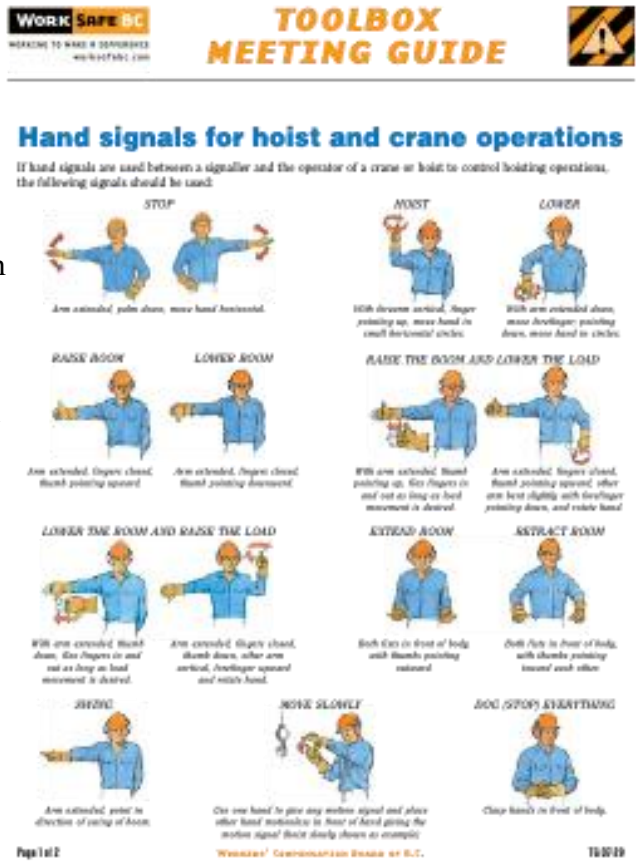
Commands	
STOP	1 Whistle Blast
UP	2 Whistle Blasts
DOWN	3 Whistle blasts
SLOW	SLOW UP / SLOW Down
TENSION	Tension by Hand
SLACK	Make Soft / Slack the line
FLOAT	Lift Up 1 meter (off ground)
AT WILL	Your discretion
RIG FOR	"Rig for raise" - next step
REPEAT COMMAND BACK Ensures they know you heard correctly	

Another method is the OATH System, which has different meaning depending on who initiates the communication. OATH can be used for communication across rope tugs pulls, whistle blasts or light flashes.

# OF TUGS	ATTENDANT / Technical Rescue Officer	ENTRANT / Rescuer
1 – **O**k:	All OK? OK / Attention / Stop	All is OK / Attention / Stop
2 – **A**dvance:	Advance / Lower	Give More / Lower
3 – **T**ake up:	Turn Back / Tension / Haul	Backing Out / Tension / Haul
4 – **H**elp:	Get Out	Send Help

Crane operator hand signals can be used when direct line of sight can be maintained and / or in high noise environments.

All operators on the team must be familiar with the signals to remain safe and effective.


WORKSAFEBC

TOOLBOX MEETING GUIDE

Hand signals for hoist and crane operations

If hand signals are used between a signaller and the operator of a crane or hoist to control hoisting operations, the following signals should be used:

STOP

HOIST

LOWER

RAISE BOOM

LOWER BOOM

RAISE THE BOOM AND LOWER THE LOAD

LOWER THE BOOM AND RAISE THE LOAD

EXTEND BOOM

RETRACT BOOM

SWING

MOVE SLOWLY

DOG (STOP) EVERYTHING

Photo Credit: WorkSafeBC

Other terminology maybe utilized. Some teams prefer “Up” and “Down” for rope movements instead of raise and lower. We find that using terms that cannot be confused for something else are best. For example, we have heard rescuers state: “Halt” instead of “Stop” and what the rescuers heard was “Haul”. The result is not what was intended. Therefore, terminology such as raise/lower and up/down are preferred.

Indicating a speed, or performance-based direction is often very helpful as well. “Up Slow”, “Down 2 feet”, “Good Speed”, “Down Faster” etc.

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Two Rope System Overview

In all rope systems when operating in a high angle rescue environment with a live load, we will always utilize two independent and redundant connection points. This two-rope system means that one rope may be the primary support of the rescue system, while the second provides safety / backup. Each of these two systems will have its own anchor point, anchor strap, rope, rope device (descender, backup device, etc) and attachment to the rescue package.

If the need arises to remove one of the attachment points or devices in a system, we must first add another attachment point in to always maintain at least two points of independent attachment. This temporary, third attachment point, could be a fixed lanyard or rope, that will only be installed to clear a problem and does not actually offer any working purpose, other than to serve as a second point of attachment.

This will be a major principle of our operations throughout all of our rope and confined space rescue courses.

Anchoring

Anchoring is the foundation of our systems. For the purposes of this manual and course we will only be focusing on selecting single point anchors. These anchors may be substantial or could be "bombproof". A substantial anchor is one that can withstand any force that could potentially be placed upon it, intentionally or unintentionally.

The term Bombproof anchor is a term that has been used in the fire service to describe an object that is substantial enough to use for both Main and Belay/Safety lines. There is no formal definition of this term in any literature. It is subjective to the technicians doing the rigging.

We will not be discussing marginal anchors at this point, which would require tying multiple anchor points together to create an "anchor system".

Following the guidelines of "an anchor strong enough to hold the Main and/or Belay/Safety lines" will be our guiding principle and ultimate goal for this discussion.

It is important to remember that whenever possible the Belay/Safety lines should be kept independent of portable anchors that are being used to direct the main line of the systems.

Selection

Anchors are typically man-made or natural, and sometimes we combine the two to create our anchor point.

Man-made	Natural
Structural Steel / columns / standpipes	Trees
Vehicles	Large Rocks
Concrete posts / stairwell supports	

Anchors must be examined prior to use for sharp edges, corrosion, deterioration or anything else that could potentially weaken them or damage the anchor system.

When utilizing vehicles, it is important to ensure the parking brake is set, the vehicle is turned off, keys are removed and either LOTO is performed, or the technical rescue officer has control of the keys. Chock wheels if appropriate, and ensure you are anchoring to clean, dry structural parts of the chassis and not just bumpers, suspension systems or areas that are coated with oil and grease. Only use tow hooks that are closed loops and do not have sharp edges.

Anchor Strap Configurations

Anchor straps, whether commercially bought or tied, maintain certain strength profiles depending on the configuration which they are used. All slings will come with a rated "end to end" or "vertical" rating and others will come with ratings for various configurations. As with rope, when we tie knots in webbing, we should de-rate the MBS of the webbing by 50%. When using tied flat or tubular webbing as a sling, we do not de-rate it a second time if used in a choker configuration. If a sling does not have ratings for individual configurations the following approximate strength ratings can be used to determine the strength of a sling:

Straight / Vertical	Listed rating (e.g. 22kN)
Basket	2x rating (e.g. 44kN)
Choker	½ rating (e.g.11kN)

Commercial anchor straps may or may not have hardware, such as D-rings, or sliding adjustments on them. When selecting commercial anchor straps you should consider if you want hardware on them at all, if D-rings should be the same size, or if one D-ring should be larger than the other so you may achieve a choker configuration. Some teams choose not to have hardware on the end of the commercial anchor straps due to weight concerns, while others try to limit the amount of metal that maybe used in the environment that they operate in. For example, in confined spaces where the vessel is lined with glass, metal is often avoided so it will not cause damage to the vessel, which can be a very costly repair or replacement.

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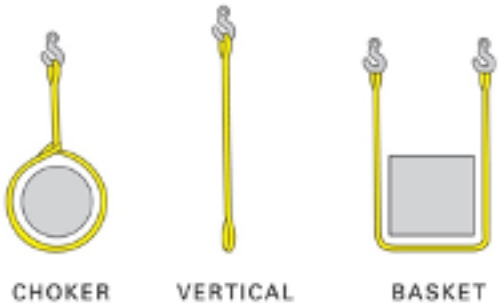


Photo Credit: Doleco-USA

Double 1" webbing baskets

When using 1" tubular webbing we tie it into a loop with a water knot and then place it around the anchor in a basket configuration. This effectively doubles the webbing as there are two parallel parts of webbing on each side of the anchor. Since webbing can be either flat or tubular, and the rating varies greatly based upon construction and manufacturer, we double the webbing basket to get the higher strengths needed to fit into our systems. Many teams will require that you have two of these webbing baskets to satisfy the strength requirements for a single anchor point.

Wrap 3 Pull 2

The wrap 3 pull 2 is considered a high strength anchor, however it can be time consuming to complete. This also uses 1" webbing and even with tubular webbing is rated at 35kN[4], with flat webbing at over 46kN[5]. Refer to the knot section on how to tie a wrap 3 pull 2.

Tensionless Hitch

A tensionless hitch is tied utilizing rope to create a rappel line or an anchor point. Because it is tensionless, it maintains 100% of the strength of the rope. The number of turns around the anchor post or tree should be at least eight times the diameter of the rope. Depending on the surface of the anchor object, more turns could be necessary. A 6" smooth post has less friction than a 6" tree, therefore it may require more wraps based solely upon the composition of the surface. Typically, there is a minimum of 3 - 4 turns around an anchor starting from the base of the anchor, working upwards without the turns crossing over each other.

Sewn Prusiks and Dyneema Slings as anchors

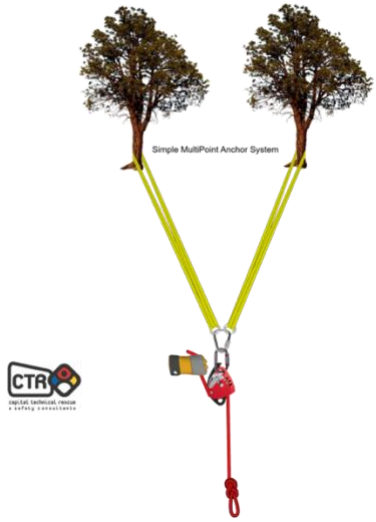
Newer equipment being utilized as anchor slings include sewn prusiks and dyneema slings. These are all rated in the vertical configuration, and whether used in a girth hitch or basket configuration often maintain a high enough rating to be acceptable for our uses.

Load Sharing Anchors

Multi Point Anchors such as trees maybe utilized to help share a load or focus the direction of the load into a specific location. In the example to the right two anchor slings of equal length are used to create a focal point and to share the load between the two trees. If one anchor fails, there will be a shift of the load however there is not a catastrophic failure.

[4] CMC Rescue
[5] CMC Rescue

The Y-Hang is another popular technique and uses a terminal knot or tensionless hitch to one anchor, with a butterfly adjusted out to another anchor and the other leg of the butterfly utilized as a working line or anchor point.



A more complex load sharing anchor would gather multiple anchor points and share the load amongst them. This is especially useful if some of the anchors maybe marginal.

Using rope or a cordellete create a large circle with the ends tied together.

Off set the knot, and create a "W" at the bottom of the circle.

Gather all 4 strands of the "W" and tie a figure 8 on a bight which will give you a forward and rearward facing loop.

Connect the larger loop to the anchors or go around them and then clip the inward loop of the figure 8 with carabiners around the rope that passes around the anchors.

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Picket Anchors System

Picket Systems may be utilized if you are sure you know there are no hazards / utilities below the ground. Pickets should be at least 4' long and should be driven in 2/3 of their length at an angle approximately 15° away from the direction of pull. Pickets should be placed in line, with a minimum of 3 of them, spaced at the length of picket.

Using 1" webbing, cordage, or life safety rope, tying a clove hitch at the top of the leading picket to the base of the picket behind it, and wrap it 2 - 4 times (rope vs webbing) back and forth and then finish with a clove hitch at the base of the rear picket. Using a small piece of rebar and place in the middle of the wraps and tension the wraps like a windlass. Anchor the rebar into the ground so the tension holds. Repeat for another picket, so there is a minimum of 3 inline pickets to make a 1 - 1- 1 picket (3 picket system). Rating is highly dependent on soil, picket materials and webbing vs rope as windlass. CMC estimates a 1 - 1 - 1 to be rated at 1,800 lbs, while other references state a 3 picket system in solid soil can easily hold 5000 lbf (22 kN).

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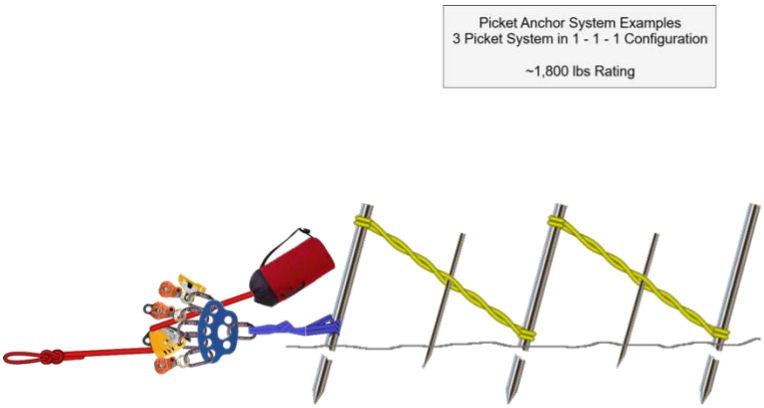

Deadman Anchors

Deadman anchors are typically considered marginal anchors and should have some type of backup / redundancy when utilized. These are common in the canyoneering world where rocks or logs are buried to create an anchor where one does not exist. We also use them in the urban setting where we place a 4x4, 6x6, or strut in a doorway. These kinds of anchors typically require tension to be maintained.

Vehicle Anchors

When utilizing vehicles, it is important to ensure the parking brake is set, the vehicle is turned off, keys are removed and either LOTO is performed, or the technical rescue officer has control of the keys.

Chock wheels if appropriate, and ensure you are anchoring to clean, dry structural parts of the chassis and not just bumpers, suspension systems or areas that are coated with oil and grease. Anchors must be examined prior to use for sharp edges, corrosion, deterioration or anything else that could potentially weaken them or damage the anchor system. Use Edge Protection as needed.

Only use tow hooks that are closed loops and do not have sharp edges.

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Rappelling

Whenever we are going over an edge, into a confined space, or anywhere where rope is the primary means of travel getting to a victim or task, we must maintain two points of connection to our system.

Safety / Backup / Belay Line

- The first point of connection
- Ensures that we can't start an operation without first having a safety / backup / belay in place
- Typically attached to the sternum connection point on the harness
- Options
    - Traditional Belay System
        - Operated by another team member
        - Requires extra person and possibly more gear
        - Relies on proficiency of the belayer
        - Examples
            - Petzl ID Belay
            - Tandem Prusiks
            - Petzl Maestro Belay
    - Backup / Safety Device
        - Operated by rescuer
        - Optionally attached to anchor and tended by another rescuer
        - Automatically locks
        - Examples
            - Petzl ASAP / ASAP Lock
            - Kong Backup

Once a safety / backup / belay is in place, we have fall protection on and may now go closer to the edge. It may still be a good idea to have an edge restraint system on so you can't actually go over the edge.

Rappel Line

- The second point of connection
- Once it is connected and tested, we are ready to begin work (with safety in place)

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- Typically, will attach to the ventral (waist) connection point on the harness

Rappelling Skills Rescuers should have:

- Descent
- Proper use of brake hand
- Locking off
- Working hands free
- Understanding features of device
  - I.e., Panic Mode / Swing plate operation
- Freeing a jammed descender
- Ascending up to 20'

High Point

- Rappel line and anchor are coming from above the rescuer
- Easier and safer transition over the edge
- General Technique
  - Keep feet wide
  - Allow rope through the descender with good brake hand positioning
  - Keep feet planted
  - Lower hips to bend to approximately 90° to feet
  - Walk down in that position, small steps

Low Point / Low Edge Transition

- Rappel line and anchor are at the rescuer's feet when standing at the edge.
- Rappelling from a standing position has resulted in serious injuries to many rescuers and should be avoided.
- More difficult transition, however this method is safer than attempting to rappel from standing position.
- Team Technique
  - Edge person tied off, Rescuer ready for rappel
  - Attaches end of 15' webbing to ventral connection with clove hitch
  - Runs other end of webbing through Rescuers ventral connection
  - Brings both ends together, and lowers rescuer onto their system, with the webbing as a 2:1 lower

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- Pulls webbing back up through out of the rescuers harness

- Single Person Technique
  - Rescuer is attached to belay line / fall protection and / or edge restraint
  - Start in a sitting position at the edge, with legs over the edge
  - Attach descender to main line
    - Ensure there is just enough slack for descender to clear the edge
  - Rope grab with a rope ladder or etrier or foot loop
  - Place it in opposite foot
  - Stand up and pivot into it
  - Tension rope in descender
  - Weight descender
  - Remove foot from loop

Setup – Green: Belay/Safety – Black Main

Rescuer sitting at edge, prepared to transition



Transition process

- Transition on way up over edge is the reverse process

Ascending

There are times when a rescue technician must travel up the rope they have rappelled on, or within the system they are attached to. Some examples would be should their safety / belay line device get locked up, there is a knot to pass, they descended too far, or as part of their duties as a litter attendant.

The process of ascending is typically the same, regardless of the equipment being used. It is a sit-stand-sit technique in which we use our foot to stand up in a loop attached to the rope, while capturing the progress of us standing up with a progress capture device and the sitting back down in our harness to repeat the process. A belay line is always used, however the instructions here are specific to operating only the ascending system.

Ascending with Prusiks

- Traditional way of ascending
- Typically, the chest and waist prusiks should be lengths similar to tandem prusik belays, and overall lengths no more than 6" apart.
    - As an example, a 16" prusik at the waist and a 22" at the chest.
    - Depending on the characteristics of the rope and the compatibility of the prusiks, the rescuers physical size, abilities, and other factors a two wrap prusik may be needed, but normally we try to keep them as a triple wrap prusik.

- 3 Prusik Setup
  - Foot Loop Prusik
    - Attached around your knee level
    - Typically, a longer prusik then the rest
    - May need to girth hitch another prusik onto it to create a longer loop
  - Waist Prusik
    - Shortest prusik attached to your ventral (waist) connection
    - Main prusik your weight will be on
  - Chest Prusik
    - Longer prusik attached to your sternal connection

- 3 Prusik Climbing Technique
  - Attach prusiks as above
  - Push up on both the chest and waist prusiks and sit into harness, allowing prusiks to be loaded
  - Put your foot in the foot loop prusik
  - Stand up by driving your foot down and back under your buttocks
  - Push up on your waist and chest prusiks
  - Sit down and load the waist and chest prusiks
  - Move foot prusik up so you can repeat the process

  - Tips
    - Take small steps initially
    - Breathe
    - Rest as needed

- 3 Prusik Descending / Down Climbing Technique
  - Prusiks attached in the same way. Reverse the process….slowly
  - While sitting with waist and chest prusiks loaded
    - Stand up into foot prusik
    - Slide waist and chest prusiks down approximately 6”
    - Sit down into harness
  - Slide foot prusik down and repeat the process

  - Tips
    - Don’t slide the prusiks too far down

- Take your time and think about the process

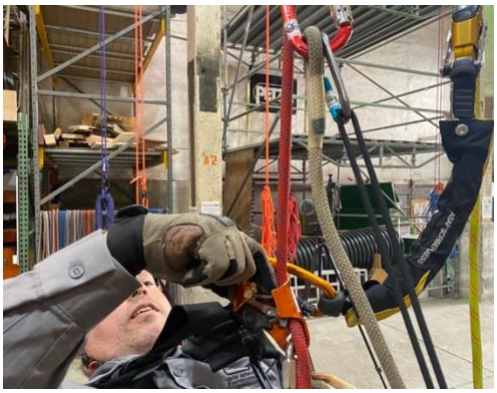
- Can also do this with cam (Rescuecender) and toothed ascenders (Ascension)

Chest & Hand Ascenders

- Faster and more efficient than prusiks
- Preferred method for longer ascents
- Can be difficult to down climb
- Hand ascender is attached to harness with lanyard and has a foot loop or etrier attached

- Climbing Technique
  - Load rope into chest ascender
  - Place hand ascender on rope above chest ascender
  - Place foot into foot loop
  - Slide hand ascender up, and step up into foot loop
  - Rope should slide through chest ascender capturing progress
    - May not slide through initially, you can pull rope through if needed
  - Sit down into harness
  - Slide hand ascender up and repeat process

- Downclimbing Technique
  - While sitting with rope loaded in chest ascender
  - Slide hand ascender down to about 6” above chest ascender
  - Before standing up place index finger on the top of the cam of the chest ascender
  - Stand up into foot loop, and push finger down on the cam of chest ascender
  - While pushing down with finger, slowly sit down, allowing rope to pass through chest ascender
  - Remove finger from chest ascender and sit down
  - Slide hand ascender down and repeat process



  - Tips

- Move slowly and only about 6” at a time
- Breathe
- Rest when needed

Rapid Ascent / Descent (RAD) Climbing

- Good for shorter ascents, litter tending, or anywhere you may have to move up and down the rope several times
- Can be frustrating if rope isn’t compatible with the device
- Hand ascender is attached to harness with lanyard and has a foot loop or etrier attached
- RAD Setup
    - Attach a descent control device (ID or Clutch) to the rope and the ventral (waist) connection on your harness
    - Attach ascender to rope above your descender
    - Place foot in foot loop or redirect through a pulley

- RAD Climbing Technique
    - Stand up in foot loop or haul in line through pulley, unlock DCD (not necessary with Clutch or 2019 and newer ID) and tension the free end of the rope
    - Lock device if you aren’t holding onto the free end of the rope
    - Sit down, slide ascender up and repeat process

- RAD Downclimbing Technique (Rappelling)
    - While sitting in harness, remove and stow your hand ascender and foot loop
    - Rappel with DCD

Changeovers

Changeovers are simply defined as the process of switching from an ascending system into a descending system or a descending system into an ascending system. This process was already described if you are using a RAD system, however if you are using prusiks or chest and hand ascenders the process is different.

Ascending (Climbing) to Descending (Rappelling)

- While sitting in harness attached to chest ascender (prusiks)
- Attach DCD below chest ascender (prusiks)
- Remove any slack, and lock DCD

- Move hand ascender (chest prusik) down just above chest ascender (waist prusik if possible)
- Stand up in foot loop and open chest ascender, remove rope and close chest ascender (remove prusiks)
- Sit down and weight descender
- Remove and stow hand ascender and foot loop (foot prusiks)
- Rappel

Descending (Rappelling) to Ascending (Climbing)

- While sitting in harness attached to DCD
- Lock DCD
- Place hand ascender (prusiks) above DCD
- Stand in footloop, and place chest ascender (attach to prusiks) above descender
- Sit and load chest ascender (prusiks)
- Remove and stow descender
- Climb / Ascend

Knot Passing

Knot Passing on Ascent

- Climb to just below knot (don't push hand ascender up to knot)
- If no shock load is expected
    - Move the hand ascender above the knot
    - Leave space for chest ascender above the knot
    - Stand and move chest ascender above knot
    - Continue climbing
- If shock load is likely
    - Perform change over to descent
    - RAD climb so the descender is just below the knot, but not up against it
    - Ensure hand ascender is above knot
    - Stand and move chest ascender above knot
    - Remove descender
    - Continue climbing

Knot Passing on Descent

- Descend to just above the knot and lock descender
- Changer over to climbing system
- Remove descender and re-install just below knot
    - Remove all slack
    - Lock descender

- Downclimb with ascending system
- Ensure the hand ascender is not too far away
- Remove chest ascender and sit onto descender
- Remove hand ascender
- Descend

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Mechanical Advantage Systems

Definition

Mechanical advantage is defined by Merriam-Webster as:

> the advantage gained by the use of a mechanism in transmitting force
>
> *specifically*: the ratio of the force that performs the useful work of a machine to the force that is applied to the machine

In confined space and rope rescue we often utilize pulleys and rope grabs as our mechanisms to gain advantage to the force we transmit from hauling on our systems. There are three types of mechanical advantage systems, with the first two being the ones that we commonly utilize.

1. Simple
    - Single haul connection between the load and the load line
    - All pulleys in the system travel at the same speed towards the anchor
    - Examples: 2 to 1 mechanical advantage, integrated 3:1, piggyback 4:1
2. Compound
    - Simple mechanical advantage system pulling on the haul line of another simple mechanical advantage system
    - Collapse rates of both systems will be drastically different
    - Multiply the two systems together to give the total advantage
    - Example: 9 to 1 mechanical advantage - simple 3:1 pulling on a simple 3:1
3. Complex
    - Neither a simple nor a compound system
    - Pulleys will collapse towards each other simultaneously as the load moves
    - Determine the mechanical advantage utilizing the "T" method
    - Add the mechanical advantage of systems together to get total advantage
    - Limited practical use in rescue

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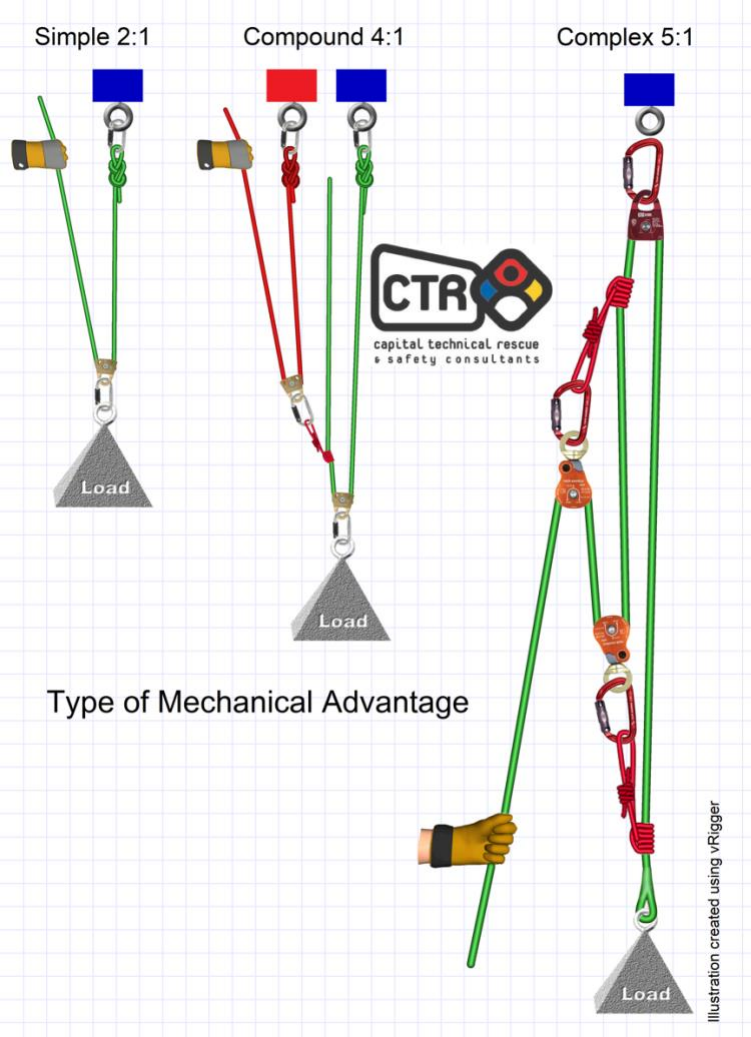


Rules of Mechanical Advantage

1. Pulley at the anchor is only a change of direction
2. If the terminal knot is at the anchor, the mechanical advantage will always be an even number (eg. 2:1, 4:1, 6:1)
3. If the terminal knot is at the load, the mechanical advantage will always be an odd number (eg. 1:1, 3:1, 5:1)
4. To determine the mechanical advantage of a simple pulley system, count the ropes between the anchor and the load.
5. A simple mechanical advantage pulling on the haul line of another simple mechanical advantage is a Compound Mechanical Advantage System.

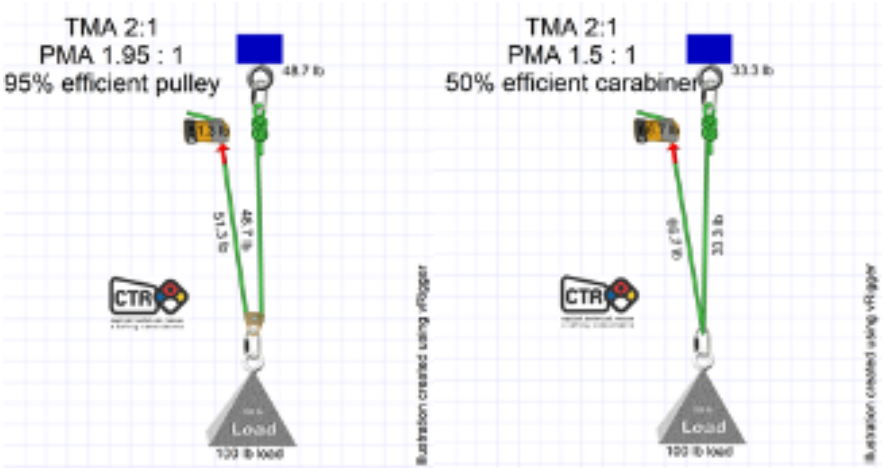
Actual versus Ideal Mechanical Advantage

Friction, rope stretch, and angles all exist in our systems. Some devices are more efficient than others, and we must understand that our mechanical advantage system's efficiencies will vary.

- Ideal or Theoretical Mechanical Advantage (IMA or TMA)
  - assumes that there are not any losses in efficiency in the systems we are building

- Actual or Practical Mechanical Advantage (AMA or PMA)
  - real world where we do have other factors such as losses in efficiency

For example, pulleys vary greatly in efficiency based on the diameter of the sheave and the diameter of the rope. One pulley could be 95% efficient while another may only be 90% efficient. If we utilized a carabiner as a change of direction instead of a pulley, we may only have 50% efficiency. Both systems below have a TMA of 2:1 but based upon the devices we select, the PMA and the amount of force we have to exert varies greatly.



For the simplicity of learning these systems and having an easy method and naming convention we will refer to all of these systems by their Theoretical Mechanical Advantage (TMA).

Calculating Mechanical Advantage – T - Method

To calculate mechanical advantage, we can refer back to the rules of mechanical advantage or we can utilize the widely accepted T-Method. The T-method counts units of tension, hence the "T".

We start at the input or haul side of the system and begin to count theoretical numbers of tension. The input always starts with being assigned 1 unit of tension. From there you trace the system through with the input value and at each pulley you evaluate the force. Whatever tension goes

into the pulley must come out of the pulley. If the pulley is moving, then mechanical advantage is gained. If the pulley does not move, such as a change of direction, then no units of tension are added.

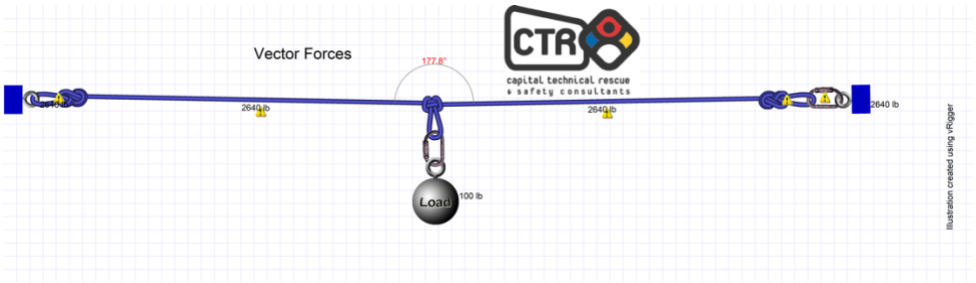
The folks at RopeRescueTraining.com have a great explanation of the T-method as well as a mechanical advantage quiz you can challenge yourself with. The appendix also has practice worksheets from the CMC Forms Page

Vector

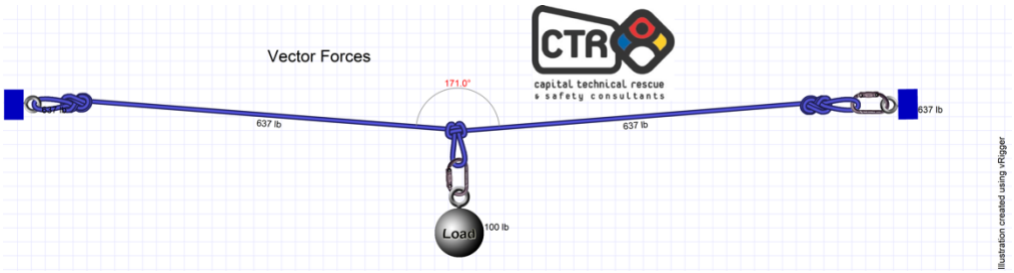
Angles between 180° and 120° create mechanical advantage as well. This is called a vector pull or vectoring. The amount of mechanical advantage created varies depending on the angle. This is good for a quick and short raise when needed and can be done by one to two rescuers with minimal effort.

The closer to 180° the more mechanical advantage will be created with minimal raise, while the closer to 120° the more raising will occur, and less mechanical advantage will exist.

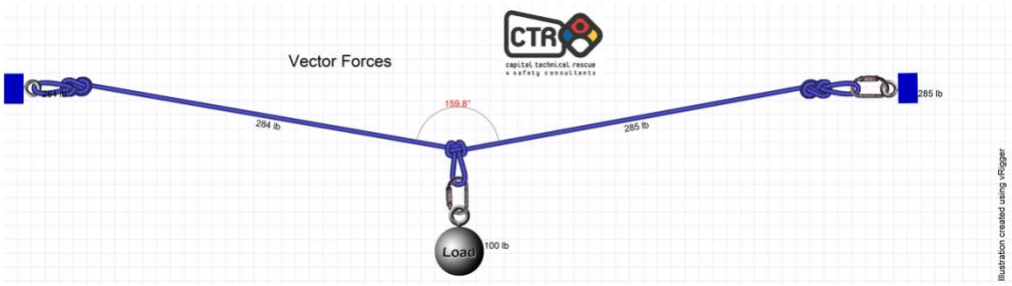
If two rescuers are pulling with 100 lbs of force on a line they can create a vector force at the anchor and the load, raising the load upwards. In the below examples we show the forces on the two anchors without the movement just to show the amount of force that can be generated.



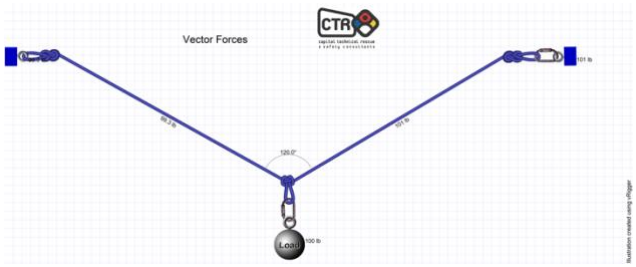
Angle: 178°



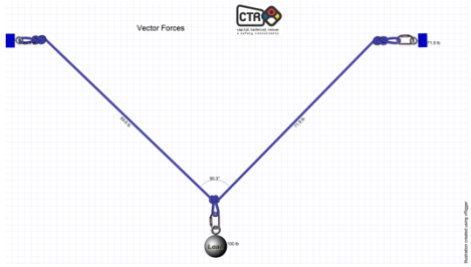
Angle:171°



Angle: 160°



Angle: 120°

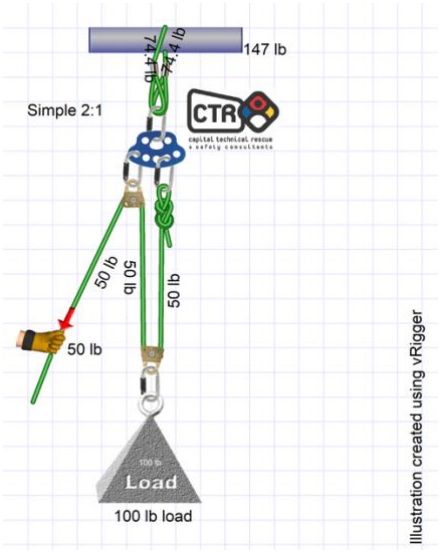


Angle: 90°

2:1

Using a 2:1 anchored to yourself or piggyback onto a rope system can be useful in a confined space where you need to move someone along a horizontal surface or minor grade.

In the picture below, the terminal knot is anchored and run through a pulley at the load. Hauling on that line creates a 2:1 mechanical advantage system. The pulley on the anchor plate is simply a change of direction and the force is unchanged on the hauler.

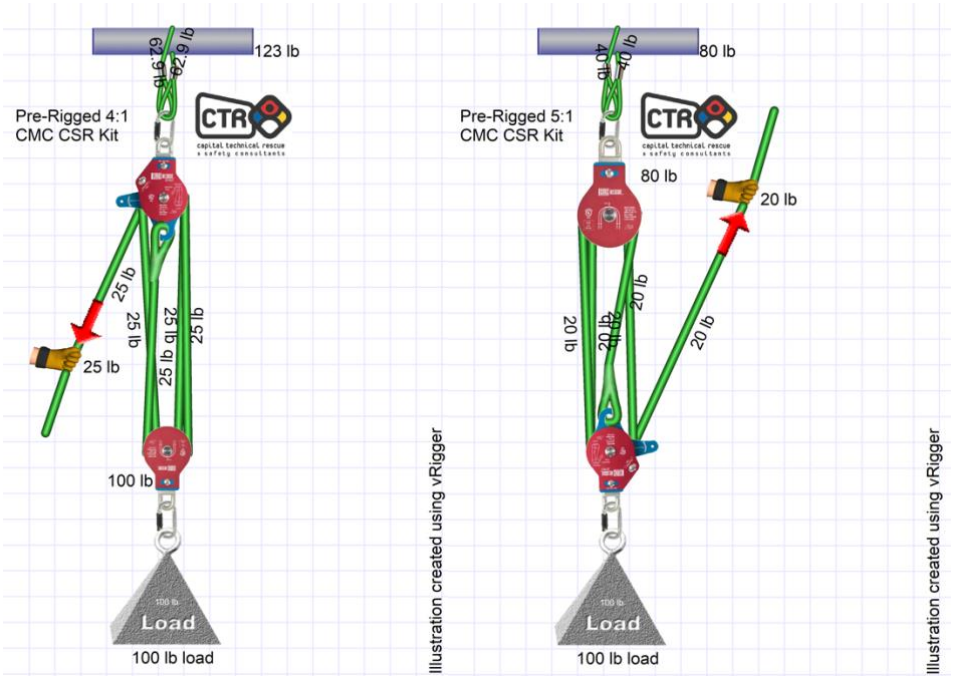


4:1 / 5:1 MA

The 4:1 and 5:1 mechanical advantage systems are built with two double pulleys and 2 or 3 carabiners, depending on how you terminate the rope into the system. It can be done with a terminal knot attached to a carabiner or screw link that is attached to the becket of one of the double pulleys. You can also put a terminal knot directly into the becket or place the terminal knot into one of the carabiners that attaches the pulley to the load or the anchor. For simplicity here, we will attach the terminal end of the rope directly into the becket.

To build the system, we typically start with the double pulleys offset 90° to each other, which allows for the system to have parallel "falls" or "legs" of the rope. Take the terminal end of the rope and attach it to one of the beckets on the double pulley, then trace the rope through the opposite pulley and take care to keep the ropes parallel. Once the rope is through all of the sheaves of both pulleys, place a carabiner on each of the pulleys and you are done.

These systems can be used as an "add-on" or "piggyback" mechanical advantage to a rope system or can use a rope grab or progress capture device to create its own main line system.



In both systems above we can utilize the rules of mechanical advantage to determine the mechanical advantage and can quickly determine if it will be an odd or even system based on the location of the terminal knot on the becket.

This particular system is the CMC Confined Space Rescue Kit which has progress capture built into the double pulley that has a becket. It can be used as an independent system for raising and lowering, or as an add-on mechanical advantage system to another rope.

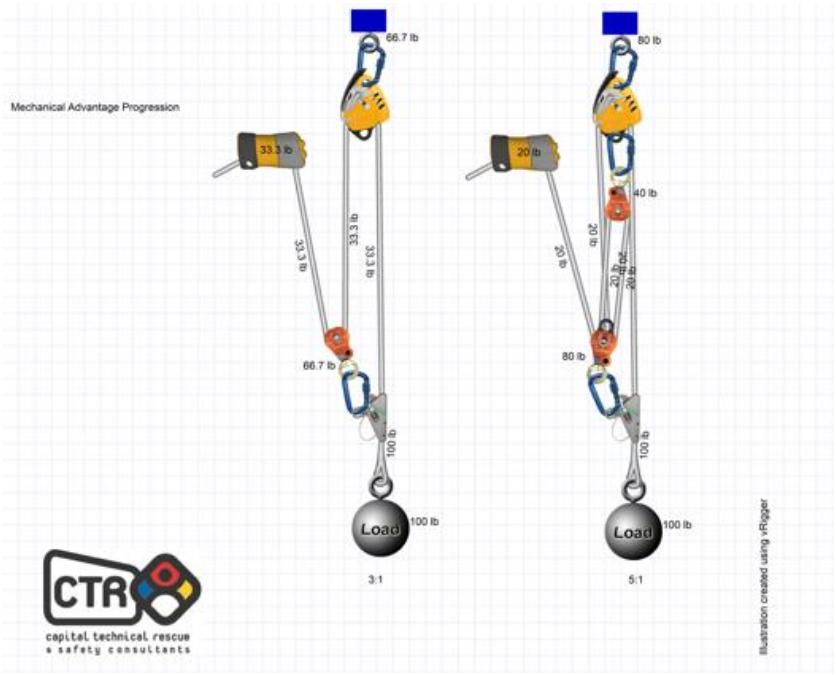
Integrated Simple MA 3:1 / 5:1

The term integrated mechanical advantage simply means that the system is built with the load line. Using a progress capture device or a descent control device that has progress capture built in, we can utilize the tail of the rope to create our system.

The two most common that we utilize are the integrated 3:1 and the integrated 5:1. They are quick and easy to setup and don't require a lot of gear.

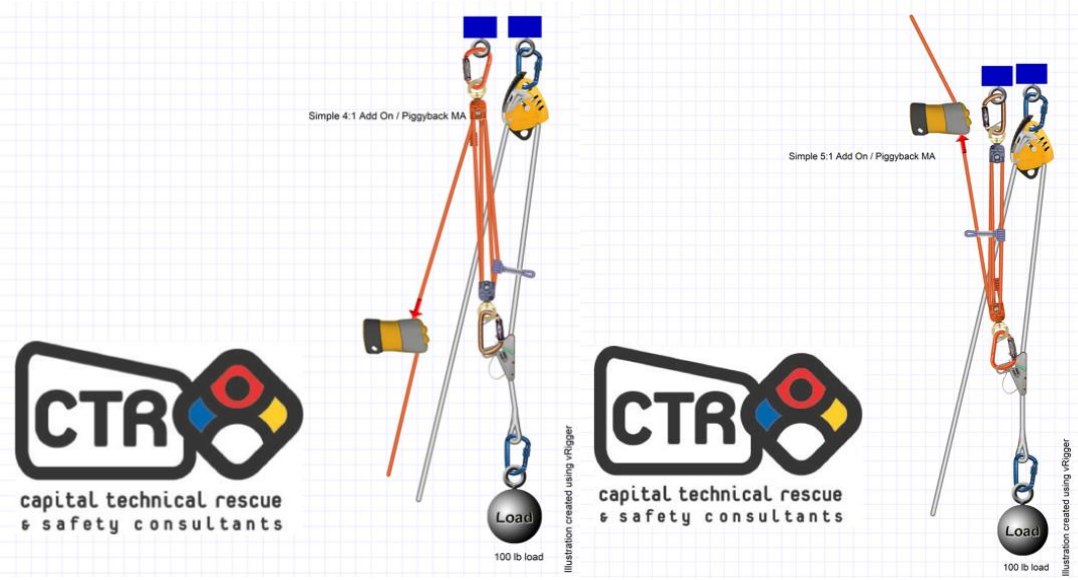
- Integrated 3:1
  - 1 - Single Pulley
  - 1 - Rope Grab
  - 1 - Carabiner
- Integrated 5:1
  - 1 - Single Pulley
  - 1 - Double Pulley

- 1 - Rope Grab
- 2 - Carabiner



Add-On / Piggyback MA 4:1 / 5:1

An add-on or piggyback mechanical advantage system is simply putting an additional system onto the load line. In the examples below, when hauling on either the 4:1 or 5:1, a rescuer must pull on the white line, so the progress is captured of the haul.

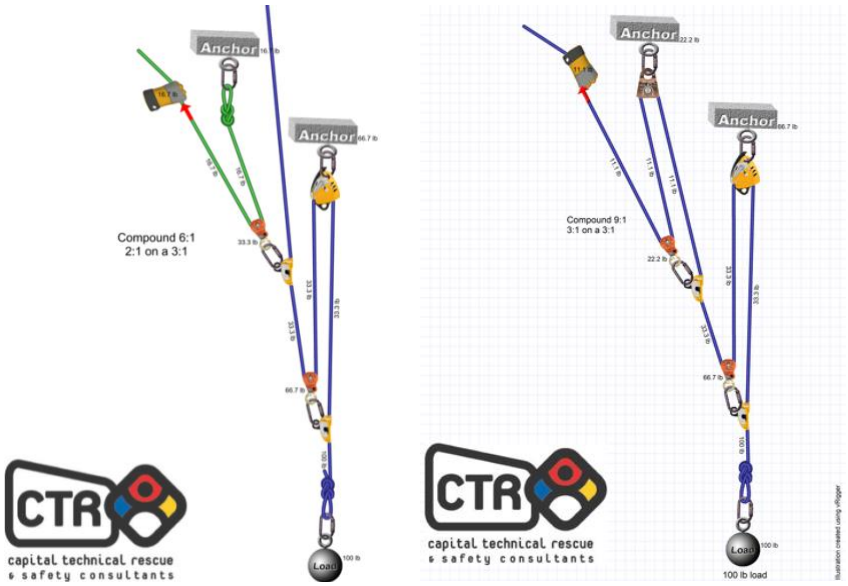


Remember, when hauling with a 4:1 or a 5:1 you are pulling through either 4 or 5 feet of rope to move the load 1 foot. Tensioning the white line for the progress capture doesn't have to be hard.

While not difficult to tend the line, this requirement also differentiates an add-on system from an integrated mechanical advantage system. With the integrated system the rope is tended through the progress capture device automatically.

Compound MA – 6:1 / 9:1

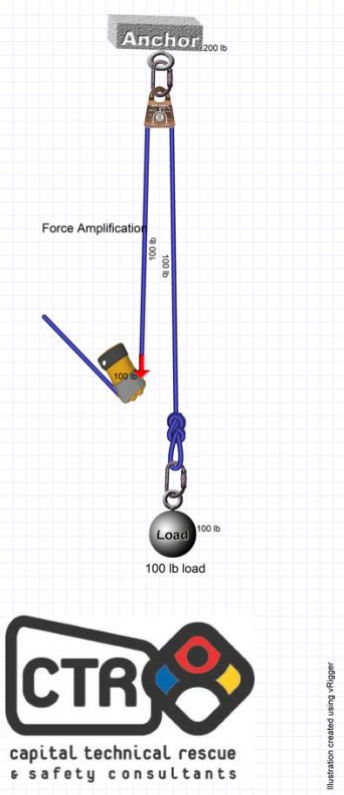
Compound is a Simple MA system pulling on the haul line of another Simple MA. Multiply the two systems together to get the total advantage. This can be either an add-on system, or an integrated system. The collapse rates of both systems will be drastically different, and it is recommended to stagger the anchors when building a compound MA to reduce the number of resets you will need.



Force amplification

In many of the above mechanical advantage examples you may notice that there is more weight on the anchor than the weight of the load. We must anticipate that our anchor will see the most force in the system, especially any time a stationary or change of direction pulley is attached to the anchor.

A change of direction pulley or other stationary pulley will amplify the forces on the anchor they are attached to. We should be careful when we are within the inside angles of that pulley, in case it were to fail.



Notice that with a 100-pound load that the force on the anchor is 200 pounds. The change of direction pulley at the anchor amplifies the force because the rescuer must also pull with at least 100-pounds of force, just to keep the load from lowering. To raise the load the rescuer would need to apply more than 100 pounds of force, increasing the amount of force the change of direction pulley, carabiner and anchor would see.

Fall Factors

The fall factor is often used to quantify the severity of a fall. It can have a theoretical value between 0 and 2.

The fall factor is the ratio of fall length to rope length.

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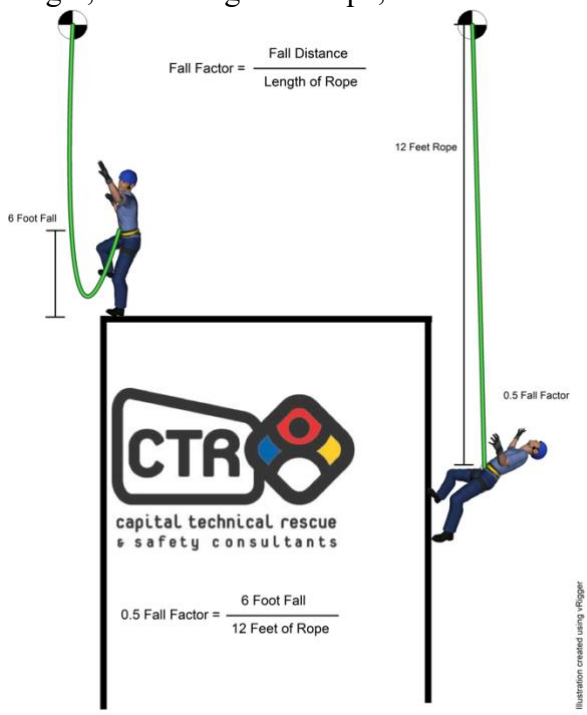
The severity of the fall does not depend on the fall length, as the longer the rope, the more energy it can absorb.



Fall Factor Calculation

F = Fall Length / Rope Length

F = Theoretical Fall Factor

Fall Length = Length of Rescuers (test mass) Fall

Rope Length = Length of rope between belay device and Rescuer (test mass)

The theoretical fall factor does not consider the rope friction against hardware & the environment.

This friction prevents the rope from stretching over its entire length. Thus, only a part of the rope will absorb the energy of the fall: this is called effective rope length.

It is therefore useful to talk about the actual fall factor. If a rescuer does not take the necessary steps to avoid rope drag, the actual fall factor can quickly increase.

In this case, the fall will be more severe for the rescuer.

Fa = actual fall factor

Fall length = length of the climber's fall

Effective rope length = actual length of rope in play

System Safety Factors

It is the responsibility of every Rope Rescue Operator and Technician to determine if the system they are utilizing is “safe”. There has long been the misnomer that our “Safety Factors” for rope rescue in emergency services were required to be 15:1.

This is only anecdotally substantiated in the original version of NFPA 1983-1985 edition and should not be considered valid for our approach to rigging. A Safety Factor of 15:1 and even

10:1 is not possible to achieve, nor do we want to carry the equipment that would be built for such a purpose.

What is achievable is a Dynamic System Safety Factor of between 2:1 and 4:1. This is in line with all our other disciplines and more in line with industrial standards for fall protection.

Organized rescue teams should be diligent in the equipment they acquire ensuring that it serves their mission needs. All equipment, hardware and software, should be tracked and inspected regularly and after each use. Follow guidance from both the manufacturer and current edition of NFPA 1858 for the selection, care and maintenance of this equipment.

All the systems we teach in our rope rescue operations and confined space rescue technician level courses have a Dynamic System Safety Factor between 2:1 and 4:1, with a maximum anticipated load of 6 kN.

We strive to keep the forces considerably lower than 6 kN but do recognize that it is possible to meet or exceed 6kN should a catastrophic failure of a piece of equipment, our rigging, or human error occur.

For a deeper dive into System Safety Factors, see Appendix A – Factors of Safety.

Belaying

A belay is backup or safety that is attached to the rescuer or rescue package, that will arrest a fall should the main line fail.

Our motivation for teaching safe, effective and proper belaying techniques is due to students who have gotten hurt from incorrectly operated belays (human errors) in both escape system training and also from rappelling evolutions. There is no one perfect belay system, however we are always in search of new equipment and techniques.

- Our desired belay system features:
  - Reusable
  - Safe
  - Effective
  - Easy to train on
  - Ability to lift / lower?
  - Low impact forces
  - Automatically engages
  - Provide realistic feel (minimal interference with primary system)

Some raising and lowering systems can be operated as a "twin" or "mirrored" system, and therefore do not have one of the ropes dedicated as a belay, but our two-rope principle is still in full effect. For confined space rescue especially, we rarely use a "twin" system as our main lines are often pre-rigged 4:1 system, winches or a main line setup where we can't have a belay line running through a high point such as a tripod.

- There are many factors to consider when selecting and operating a belay.
  - Rope Construction: Static vs dynamic rope
    - In confined space rescue we are only using static rope, unless you are an advanced team
  - Rope Stretch
    - Static rope can stretch from 2 - 10% under a 300lb static load
  - Fall Factors
    - Depending on where the rope is anchored and in relation to the rescue package, additional forces can be generated on both the anchor and the rescue package
    - Unwanted slack in the belay system will increase the fall factor and the additional forces
  - Distance to the Ground / next lowest level
    - Some belay / fall arrest systems have a minimum clearance distance
    - Select a belay system that will prevent a fall to the ground / next lowest level
  - Amount of rope in-service
    - The more rope in-service between the rescue package and the anchor, the more rope stretch that can occur to a point and the more the rope can absorb some of the shock force
  - Belay anchor location
    - If a belay is anchored low to ground, but operated above the anchor, the belay device will travel towards the ground if activated and increase the fall distance
    - Typically, we do not run belays through high points
  - Harness Stretch
    - Adjustments on harnesses and some harness material may stretch, increasing the overall fall distance
    - This could also happen with a bridle on a patient packaging device
  - Overall anticipated weight
    - The belay must be capable of handling the overall anticipated weight of the system and the forces generated in a fall
  - Belay Competency / Belayer Attentiveness
    - Almost all belay failures are due to human error
    - Could be because a belayer is not competent in utilizing the belay device

        - Belayer may not be paying attention to the operation and have too much slack in the system
    - Belay device slippage
        - Belay devices are typically designed to slip at a certain force to limit damage to the rope. Many are designed to slip around 6 kN.
    - Friction through change of directions - pulleys vs carabiners
        - In belay systems we typically want additional friction, as opposed to efficiency
        - Pulleys offer efficiency, and have pin through the sheave that may not be rated for a shock load
        - Carabiners offer friction and are typically a better choice for our change of directions

The technique of belaying varies depending on the device being utilized. Some devices operate better than others for belay. There is also some personal preference to performance of belay devices, as some are easier or more comfortable to utilize based on your physical attributes.

Refer to the rappelling section for a list of common belay / backup devices.

Raising and lowering systems

With the belay line being the first point of attachment in a two-rope system, the main line is the second. The main line is typically what we utilize to create raising and lowering systems. There are a variety of systems, types of systems and equipment that can be utilized to accomplish these tasks.

For confined space rescue applications, we will be focusing on systems that utilize a main and a belay line, which some refer to as a Single Tension Rope System, as opposed to other rope rescue techniques such as the Twin Tension Rope Systems (TTRS). TTRS is not as applicable for many confined space rescues, however, could be utilized in more advanced lowering situations, such as where you need to lower someone from the top of a tank to the ground level. These techniques are covered in our rope rescue operations and advanced confined space rescue courses.

One of the fastest and widely used raising and lowering system for vertical confined space rescue is to use a pre-rigged mechanical advantage system with progress capture built in. Probably one of the most popular systems on the market is CMC's CSR2 Pulley System. This system has a lever on it that can be activated with a piece of utility cord attached to it so the operator may release or lower the system down. As soon as the operator releases tension on the utility cord the rescue package stops in place, and a haul is ready to begin. There is no additional hardware or software that needs to be integrated into this setup to switch between raising to lowering in any

direction. The downside of this system is it utilizes a lot of rope. A 200' rope bag only ends up having a working length of 40 - 50', so longer descents either require longer ropes or another type of system.

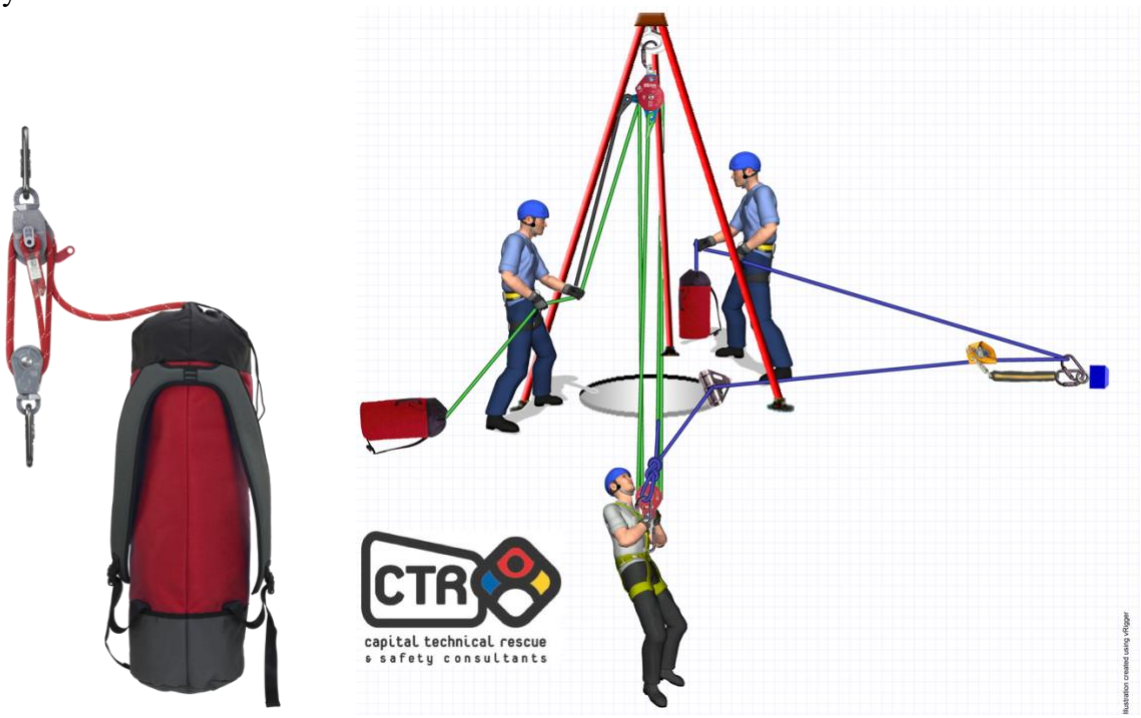


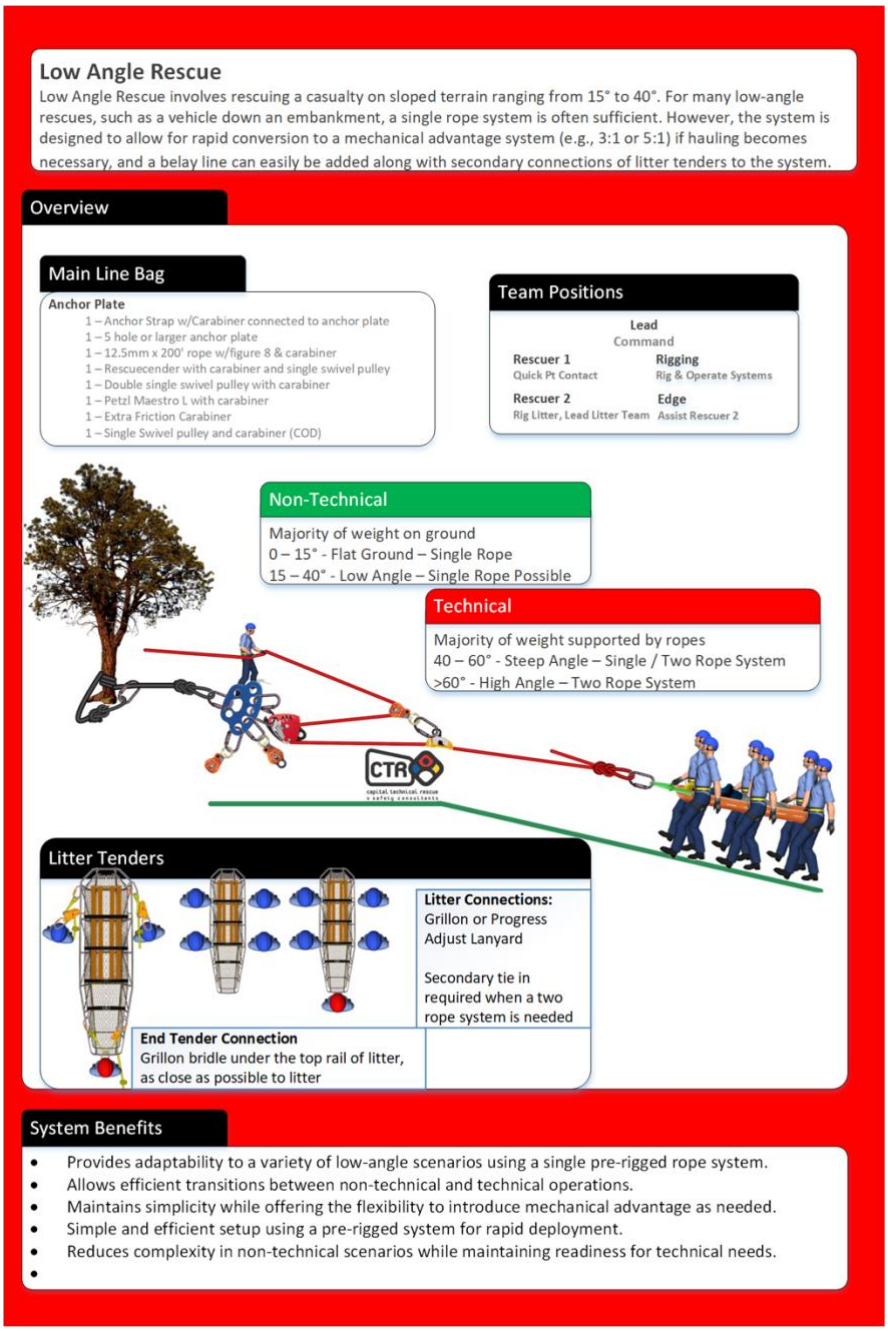
Photo Credit: CMC Stock Photo - CSR2 Pulley System

Low Angle Rescue

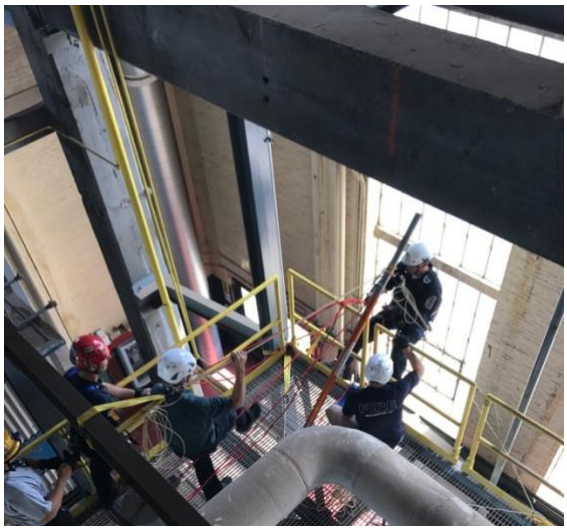
Low angle rescue is commonly defined by the terrain type being from 0° to 40° in steepness and may be considered non-technical since most of the weight is being supported by the ground. Often only one rope maybe necessary, rescuers may be able to just carry a litter and not tie into a rope system. Of course, the condition of the terrain may still dictate a technical rope rescue regardless of how steep it is.

For example, a car down a 30° embankment in the summertime may only require a single rope to assist the rescuers with bringing the litter back up to the roadway while they are walking it up and supporting much of the load themselves. However, that same embankment after a snowstorm, or heavy rains may require a haul team to do much of the work

bringing the litter up if the rescue crew is unable to maintain adequate footing to safely walk up the slope unassisted.



High Angle Rescue



A high angle rescue is anywhere the terrain is greater than 40° all the way up to 90°, and any other conditions where a two-rope system will be necessary, and the main line will be the primary means of support.

Confined space rescues utilizing a tripod are always considered a high angle rescue, as are most industrial rescues from fall protection.

These days there are a lot of references to single vs twin tension rope systems and how one is superior to the other. Often, we find that those who are saying one is the preferred way over another is doing so with one or more reasons such as a limited scope of applications, minimal real-world experience or have a financial gain in one versus the other. We utilize and teach both systems, because they each have their places and because to limit you and your team to just one of them is an unnecessary handicap.

It should be noted that both systems are “Two Rope Systems”, meaning they each have the two independent and redundant points of connection that we desire for a safe system.

Single Tension Rope System

Single Tension Rope System (STRS) is a fancy name for some of the most traditional rope systems we have utilized, as well as some of the most modern and efficient systems we use.

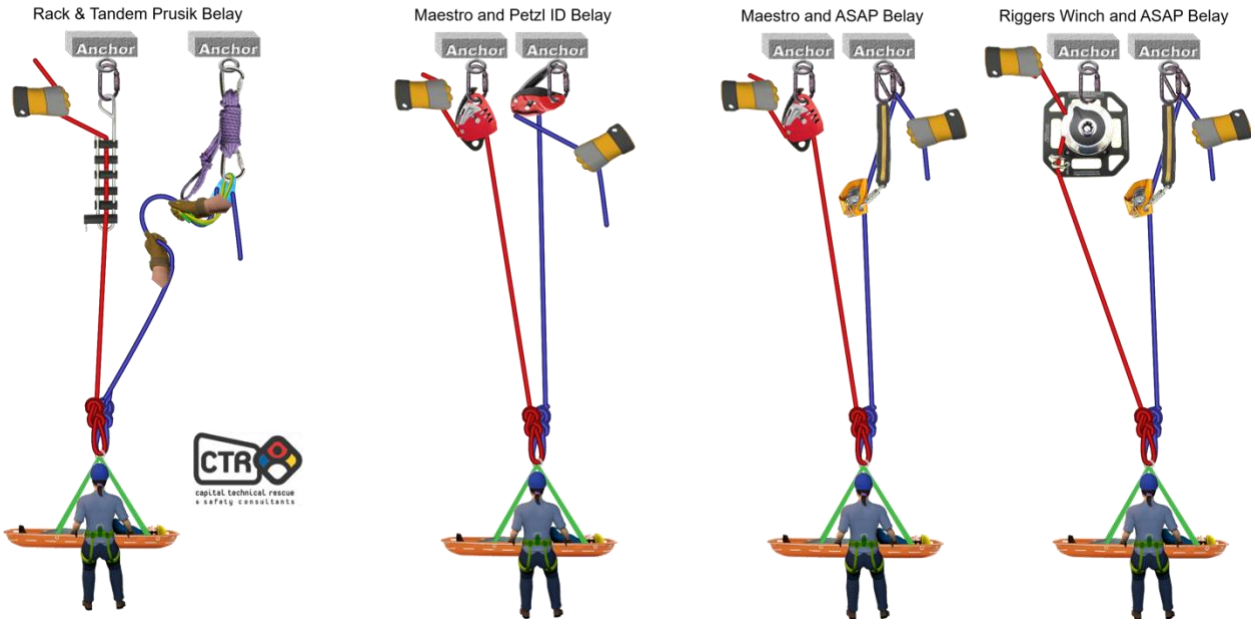
STRS is simply the idea of a main line that supports the load under tension, while some type of belay is used with minimal slack in it so that the belay line does not support any of the load during normal operation.

Traditional systems used a rappel rack to lower on the main line, with a tandem prusik belay as the second point of connection.

A more modern version of this is using a I’D, Maestro or Clutch on the main line and a mobile fall arrester such as a Petzl ASAP on the belay (aka safety) line.

For some teams, a STRS using a capstan rope winch, such as a Skyhook or Harken LokHead on the main line and a Petzl ASAP as a belay is considered cutting edge, while others this is a basic go-to setup.

Single Tension Rope System Examples



One downside to the single tension rope system is that a main line failure can result in a shock load of the belay line. It is imperative slack be managed appropriately in these systems to minimize the impact forces of a shock load. There must also be a plan to be able to transfer the load to a new main line and/or be able to raise or lower the load to a successful conclusion.

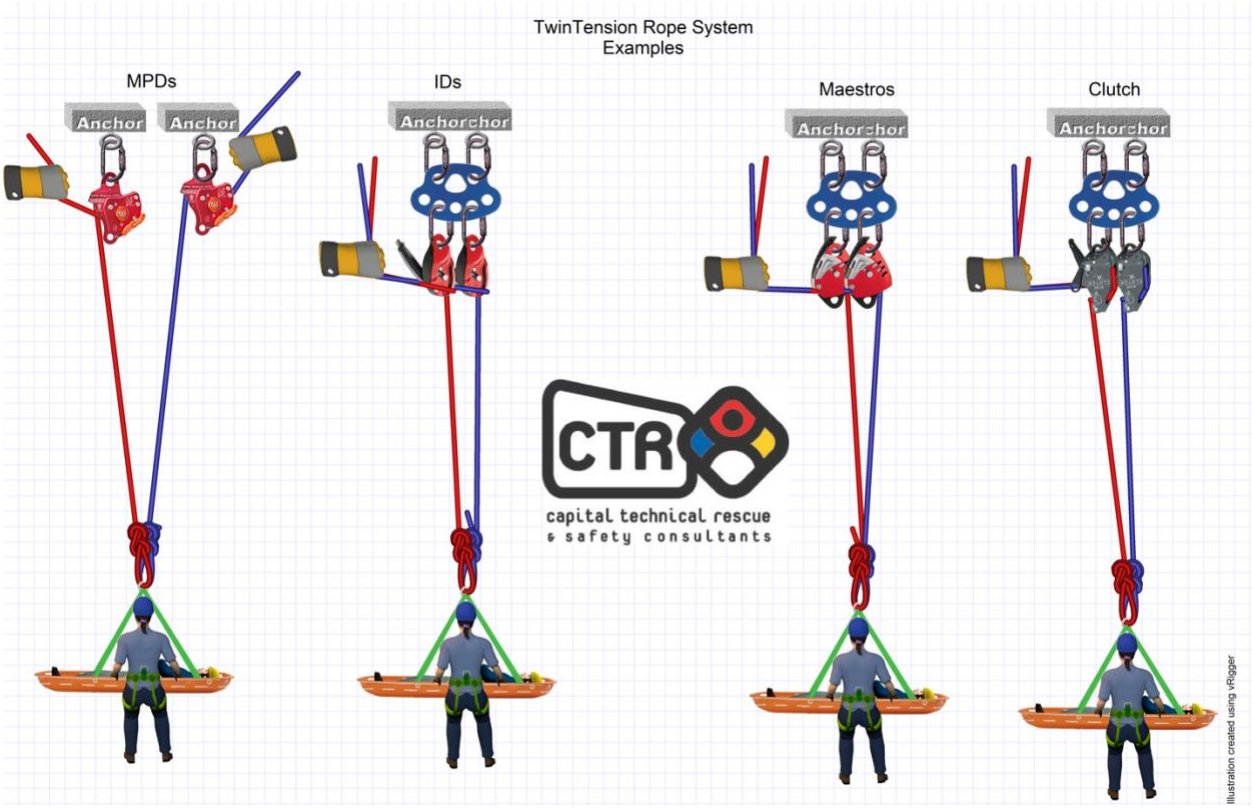
Dual Main / Twin Tension Rope System

A Dual Main / Twin Tension Rope System (TTRS) is simply where both ropes that connect to the load are sharing the tension and supporting the weight of the load. There is no slack in this system at all, and neither of the two ropes are truly just a main or just a belay line. Some teams will refer to this as a "mirrored system" since both the lines are basically mirror images of each other.

This technique is not new at all, although some manufacturers have been touting it that way. An old technique was to use two rappel racks in what was often referred to as a double line litter lower. We would be able to control the head and foot end of a litter independently while still having two points of connection to the rescue package.

The introduction of the CMC MPD brought this technique back into favor since the MPD does not, in our opinion and testing, work well as a traditional belay device.

Lowering and raising with a Dual Main requires that the speed of both devices is equalized so no slack is introduced into the system. This is not a difficult task but must be monitored. One potential pitfall with this system is should a failure occur on one of the lines, the operator of the second line may not recognize that a failure has occurred. Communication and attentiveness is imperative throughout the operation.



A single operator can control a Dual Main with devices such as IDs and Clutches if they can be anchored close together. Since the ID and Clutch both are handled devices, the operator can control the tails of both ropes while using a technique known as “shark finning” the handles. Due to the T-Handle on the MPD, a single operator cannot control two of them at a time.

The single operator is often preferred as they find it easier to control the tension in both sets of lines at the same time, and should one of the systems fail, the single operator is aware immediately.

A dual main system should always have a “tailer” backing up the single operator. The dual main ropes should also be directed behind the device in the proper braking configuration for that device. A re-direct carabiner may also be helpful for the operator to utilize in maintaining the ropes in the proper position and for more comfort and control during long lowers.

The 1 – 2 (Single Operator Dual Main)

The 1-2 is a dual main system operated by a single rescuer, who manages both descent control devices simultaneously to ensure redundancy and efficiency. A tailer supports the operation by maintaining proper rope flow, ensuring ropes are clear, and assisting with non-fouled rope management as they approach the devices.

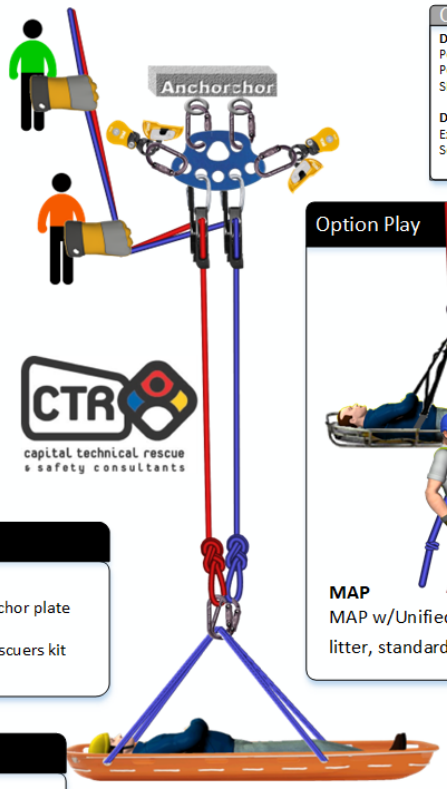
Overview

Connectors
DNA Carabiners (x2)
Oval Carabiners (x4)

Anchor Plate
1 – 3 Hole or Larger Anchor Plate

Descent Control Devices
2 – 11mm Clutches

Rope
2 – 11mm x 300'



Option Gear

DCDs
Petzl Maestro
Petzl ID / RIG
Skylotec Sirius / Spark

DNA Replacement
Extra Carabiners
Sewn Prusik / Sling

Option Play

MAP
MAP w/Unified Butterflies to litter, standard kit for tender.

Rigging for Raise

Build 2 – 3:1 using equipment on anchor plate

OP: Build 2 – 3:1 systems utilizing rescuers kit

Team Positions

Lead
Command

Rescuer 1
Quick Pt Contact

Rescuer 2
Pt Packaging / Litter Tender

Rigging
Rig System / Lead Haul Team

Edge
Assist Rigging

System Benefits

- Ensures full redundancy throughout the load path, from the anchors to the rescue package.
- Allows for efficient operation with a single operator controlling both devices while maintaining safety.
- The tailer provides additional oversight, ensuring smooth rope flow and preventing fouling, which enhances operational reliability.

Patient Care

NFPA refers to the Authority Having Jurisdiction (AHJ) when it comes to the emergency medical care requirements for technical rescue. This could vary anywhere from basic first aid and CPR class to rescue paramedics. In technical rescue it is important to remember that we are not providing definitive care, however for the rescue to not become a recovery, we must all be able to quickly deal with true live saving interventions. There are times we must also ensure that paramedics are available and trained in technical rescue so they may stabilize a patient as much as possible before a technical rescue evacuation begins.

Care may involve splinting, bandaging, packaging to prevent hypothermia, IV fluid therapy or pain management. Protocols vary from region to region, and we mostly recommend you refer to your local protocols. The medical needs and capabilities of a wilderness rescue team are likely much different than that of an urban fire department. One area we feel it important that all teams ensure they are trained for and properly equipped is dealing with major hemorrhages (bleeding).

Patient Comfort Kit (PACK)

Incorporating a Patient Comfort Kit (PACK) into our rescue operations is essential for enhancing the well-being of patients during low or high angle rescues. The PACK includes safety glasses, a small pillow, a Therm-a-rest folding pad, a waterproof thermal tarp, a woobie (a versatile blanket), and a balaclava, all designed to address the physical and psychological needs of the patient. Safety glasses protect the patient's eyes from debris and environmental hazards, while the small pillow and folding pad provide support and cushioning, ensuring a more comfortable position in the litter. The waterproof thermal tarp helps shield the patient from adverse weather conditions, and the woobie offers warmth and reassurance, promoting a sense of security. Lastly, the balaclava helps maintain body heat, particularly in colder environments. Of course, a helmet or shield system should also be utilized. By prioritizing patient comfort, we not only improve their overall experience during a critical time but also reduce stress and anxiety, ultimately facilitating a more effective and humane rescue operation.

- PACK Contents
  - Safety Glasses/Case
  - Small Pillow
  - Therm-a-rest Folding Pad
  - Waterproof Thermal Tarp
  - Woobie
  - Balaclava

Bleeding Control / IFAK

Modern bleeding control has changed significantly and injuries that were once a sure fatality may now be easily and rapidly addressed with the proper equipment and training. A simple IFAK or Individual First Aid Kit should be on hand at a minimum that addresses hazards such as bleeding control.

These kits are small and can be kept on the attendant's body or attached to a piece of gear close to the point of entry. Kits can be customized to your needs or be a standardized kit.

Photo Credit: Tac-Med Solutions Operator IFAK, Stock photo

- Example IFAK contents:
  - Tourniquet
  - Emergency Trauma Dressing (i.e. OLAES Modular Bandage or similar)
  - Petrolatum Gauze
  - Nasal airway
  - Surgical Tape
  - Nitrile gloves
  - Face Shield
  - Trauma Sheers
  - Casualty Card

When purchasing first aid equipment, be sure to do so from a reputable source. Many sites such as Amazon and eBay have been known to have counterfeit products that cannot hold up to the environments, we work in. This is an area where trying to save a few dollars could end up costing a life.

For more information or training on IFAKs, contact us about our Stop the Bleed programs and integrated training modules.

Suspension Trauma

First noted in the 1960's it is also referred to as Harness Hang Syndrome, Harness Syncope, and Suspension Syncope. This occurs in victims irrespective of physical conditioning. This is a true emergency and a rapid rescue is required.

Presentation;
When a person is suspended vertically and immobile for a period of time (under 20 minutes), whether in a harness or tied vertically, the gravitational pull on the circulatory system causes

pooling of blood in the lower extremities. The veinous return of blood amounts to only 20% of an 80% arterial push in this condition, resulting in hypotension (low blood pressure), and eventually in cerebral hypoxia (oxygen deprivation of the brain), which can cause respiratory failure and subsequent cardiac arrest.

To prevent suspension trauma:

- Avoid sitting/hanging in a harness motionless for extended periods.
- Move/use leg muscles to maintain circulation and combat gravitational pooling of blood in the lower extremities.
- Ensure shoulder straps are not occluding the neck.
- Harnesses should have flat, wide webbing leg loops and be correctly adjusted.

Treatment;

- Any on-rope personnel developing light-headedness, nausea, vomiting, or vertigo, or changes in mental status, should be immediately lowered to the ground. Restoration of unimpeded blood flow to the heart is the priority.
- Once on a flat surface, victims should be laid supine, and harness removed. Airway, breathing, and cardiac abnormalities should be assessed. Harness location, tension, manufacturer, and model should be noted.
- Check pulse and note character.
- Place on oxygen. If ALS is available, an EKG should be obtained, and ALS protocols followed in the event of hypotension.
- Vital signs should be assessed every 5 minutes until transfer to next higher level of medical care.

Other Rope Rescue Medical Concerns

Many other medical conditions may arise that require a rope rescue technician to respond to. Not all of them maybe physical ailments and the rescuer chosen to make patient contact should be familiar with the basics of how to handle a variety of medical concerns including but not limited to:

- Vertigo
- Acrophobia (fear of heights)
- Panic
- Suicidal Ideations
- Environmental (i.e. hypothermia)
- Medical Conditions (i.e. diabetic shock, cardiac issues)
- Trauma / bleeding

Triage

Triage is defined by the American Heritage Dictionary as "A process for sorting injured people into groups based on their need for or likely benefit from immediate medical treatment." In technical rescue those groups may also prioritize patients from rescue to recovery based on how technical it maybe to administer "immediate medical treatment". Additional factors are now placed on the triage decision such as: the patient's location, condition and how difficult it is going to be to access that patient and either treat them in place or remove them to an area where they can be safety treated.

There are various triage systems in use throughout the world. Two of the most common are the START and SALT methods. For more info on each see the sidebar.

MCI triage: START or SALT?

START method makes MCI patient triage fast, simple

How to use SALT to triage MCI Patients

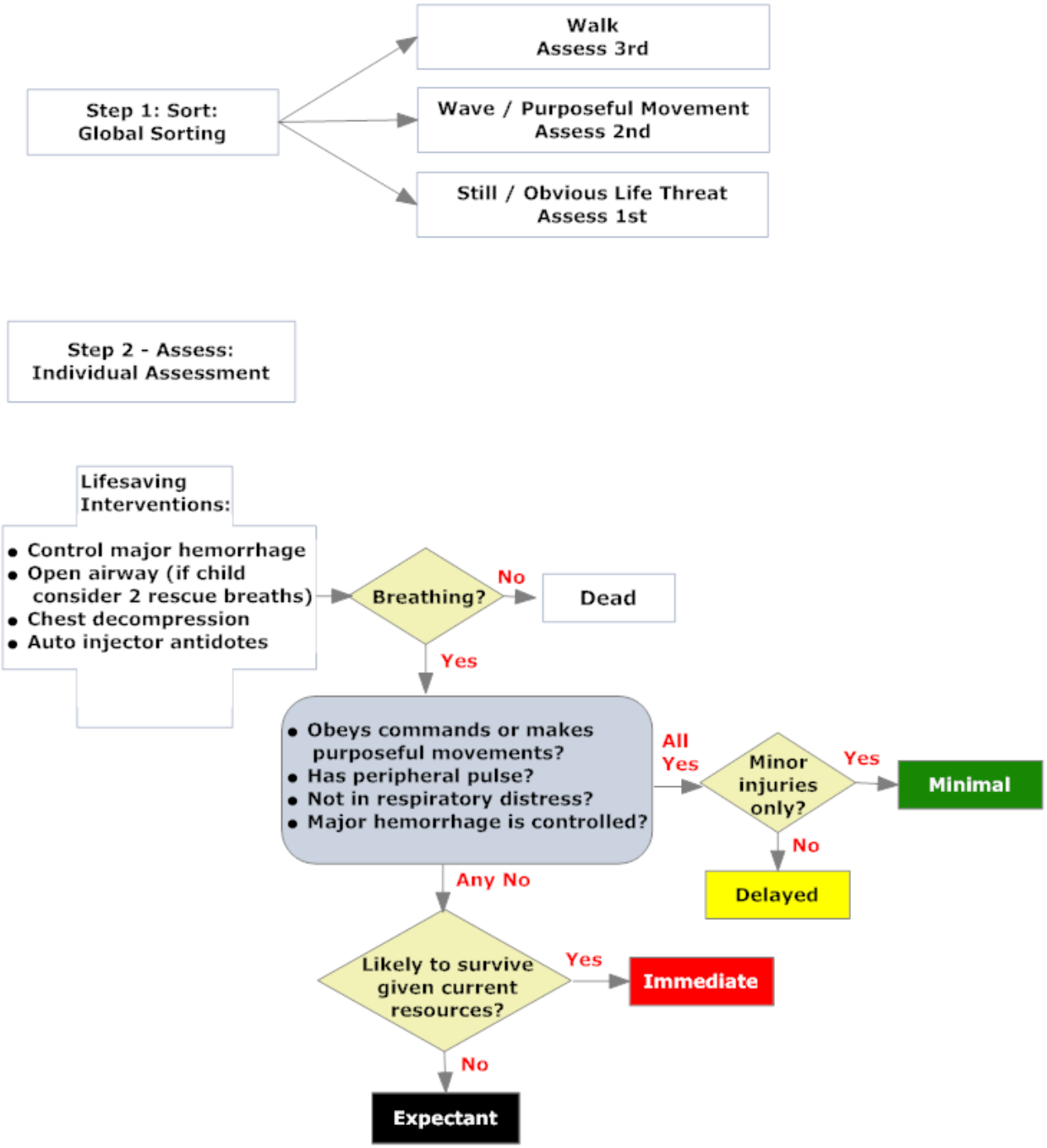


Figure: SALT Mass Casualty Triage Algorithm (Sort, Assess, Lifesaving Interventions, Treatment/Transport) - Source: US Department of Health and Human Services

Helicopter Operations

Technical rescue operations may also involve a helicopter operation for either medical evacuation, technical rescue, or both. Various aircraft platforms have different requirements when it comes to landing zones, what areas and directions are safe to approach them from and what areas are immediately hazardous. You should become familiar with aircraft that are likely to respond to your incidents ahead of time and perform drills with them that will ensure everyone knows how to communicate and operate with each other safely and efficiently.

When selecting a landing zone ensure that the area is flat and is large enough for the type of helicopter you are expecting. This is typically 75' – 110' in diameter. The area should be clear of people, vehicles, and obstructions such as trees, wires and poles. Brush, rocks, stumps, and anything over 18" high can cause problems for aircraft as well as those operating outside around them.

Helicopters take off and land into the wind, so consider the wind direction when you establish a landing zone. Ensure any loose items are secured. Blankets, pads from stretchers, trash, hats and more have all been blown around wildly from the rotor wash. Ensure any approach path to the helicopter is free from obstructions and that you make visible contact with the pilot or crew before approaching the aircraft.

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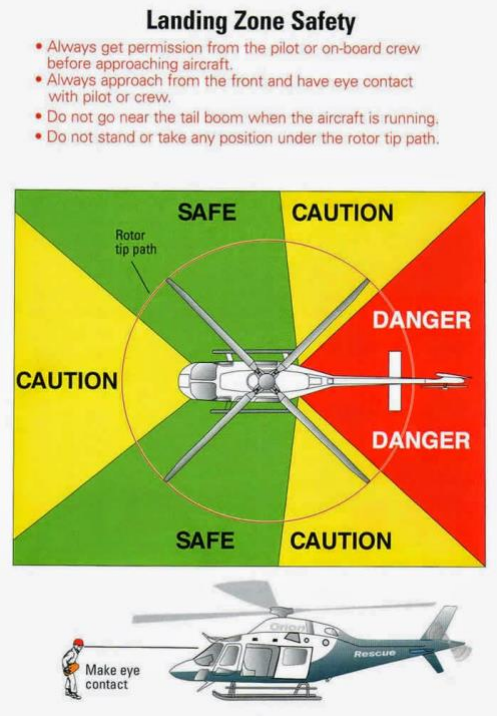


Figure Google Images

Patient Packaging Devices

There are many patient packaging devices that can be used in rope rescue. Here we are just listing a few of the most popular ones and what we typically carry. That being said, we still carry litters or baskets, Reeves sleeves, FAST boards and other devices. A simple hasty harness may also work either alone or in conjunction with some of these devices.

Petzl Pitagor / Triangle Harnesses

Petzl and other manufacturers have made harnesses for victims that are very easy to put on quickly and secure them. Often, they are a "one size fits most". The newer Petzl Pitagor and the Petzl Thales both have shoulder straps and adjustments that allow for a wide range of victim sizes including children to large adults.

Older models without shoulder straps, and some designs were uncomfortable for victims, but these newer models have been redesigned with the victims comfort in mind.

The newer Petzl models also have an attachment point for a tag line on the rear.

Photo Credit: Petzl, Stock Photo

CMC LifeSaver Victim Harness

Packaged inside its own storage bag, this harness is deployed easily and quickly. Pre-connect the yellow victim waist loop to your system. Then when you get to the victim you can secure the waist belt around the victims waist, then you can add in the leg loops, and you have the victim secured in a class II harness.

This harness was also designed to fit small children to large adults. The storage bag is attached to the harness so it can't be lost. There is also now a chest harness attachment that can be used to assist in vertical lifts.

Photo Credit: CMC, Stock Photo

Yates Spec Pak

The Yates Spec Pak is one of our go to patient packaging devices for confined space rescue and offers a lot of flexibility. It is also rated as a spinal immobilization device.

The Spec Pak has drag and carry handles, is rated as a Class 3 harness with a maximum capacity of 400 lbs and can be utilized for both vertical and horizontal rescues.

Photo Credit: Yates Gear, Stock Photo

If the victim has a harness on and/or thicker clothing / gear, remove them first, if possible.

WLCH - Acronym for securing the Spec Pak:
Waist - Legs - Chest - Head

Video
SPEC Pak
https://youtu.be/7LVfRzvE6Cw

Leg straps should be tightened before securing shoulder straps.

Should be able to get two fingers under a tightened strap.

If using the dorsal lifting ring to perform a vertical lift - DO NOT use chin strap. If suspension is going to be more than 7 minutes you must use the spreader bar or standard lifting bridle. NEVER lift from the drag handles.

Standard Lifting Bridles - Bull ring with adjustable straps.

Spreader bar for horizontal and semi-vertical lifting is available as an accessory. It is more comfortable for longer suspension times.

Leg rest - slide from foot end down to below the knees and secure the yellow strap and tighten, put the red foot loops over the feet.

Cleaning accomplished by completely disassembling and removing the screws, head piece, back board. Front loading commercial washers should be used.

SKED

The SKED is one of the most iconic and popular confined space rescue packaging devices. This device works great for dragging and protecting victims inside of confined spaces.

Photo Credit: SKEDCO, Stock Photo

The SKED is rated for both vertical and horizontal lifting however it provides no spinal immobilization and no rigidity. To get spinal immobilization it is recommended to use a short spinal device such as a KED or Oregon Spine Splint. These will also help a bit with rigidity. Some departments will also use a backboard inside of the SKED when packaging, however not all backboards fit well into the SKED, so you must be aware of this ahead of time.

Never crisscross the straps on the SKED as it will cause buckling. Never send the SKED down in the bag unless it is requested that way. Help the rescuers inside the space by having it rigged and ready for patient packaging.

CMC Drag-N-Lift

Photo Credit: CMC Rescue, Stock Photo

The CMC Drag-N-Lift is the newest device on the market and was designed in conjunction with SKEDCO. It is a NFPA 1983 rated Class III Victim Extrication Device, and works for both vertical lifts or horizontal drags.

It can also be used with short immobilization devices like the SKED, is easy to clean and fast to package a victim. There is padding for victim comfort, color coded straps with quick buckles that are part of the integrated harness, as well as multiple handles for dragging.

The device is easy to clean, and the end user can also replace the orange drag sheet when it is worn. A spreader bar is also available and recommended when using the device for a vertical lift.

Litters / Stokes Baskets

Photo Credit: CMC Rescue, Stock Photo

Patient litters, which are commonly referred to as Stokes Baskets date back to the early 1900s, when Dr. Charles F. Stokes created and patented the Stokes Splint-Stretcher.

Since that time, litters have evolved, becoming lighter and stronger with some designed for specialty applications. Specialty applications include confined space litters, mountain rescue, and may include accessories such as tie-in systems or transport wheels. These litters vary in construction, materials, and features. This includes two-piece litters, aluminum frames with plastic shells, stainless steel and titanium litters. A variety of attachment points may exist.

Litters with only a rivetted top rail and no other reinforcement may not be rated for a two-person load. Only in recent NFPA 1983 editions were litters addressed and able to receive NFPA classification. Other standards did exist including ASTM and military specifications, but none specifically for the roles that many rescue teams use them for in technical rescue.

NFPA Rated litters test the top rails to 11 kN, and if they are equipped with articulating lifting points (ALPs) those are rated at 9 kN. There is no difference in NFPA rating for a two-piece litter compared to a single piece litter. The 1" vertical posts that are at the head are also tested and rated for 11 kN and are acceptable rigging points as well.

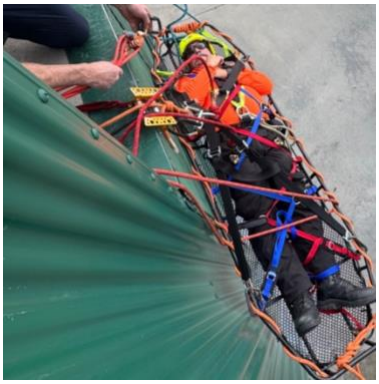
Construction is one of the most important factors when considering a litter, as not all maybe suitable for high angle rescue. Features we like in our litters:

- Lightweight
- Stainless steel or titanium

- Frame rail that wraps under patient
- Rated lifting points (4 minimum)
- Comfortable for victim (no metal chicken wire)
- Compatible with a commercial patient tie in system

Litters in Raising & Lowering Systems

When packaging a patient in a litter, there are many factors to consider in how they will become part of the raising and lowering system. This includes if the litter will be rigged horizontally or vertically, what bridle will be used to attach them to the system and is there a need for tag lines or a litter attendant to ride with the victim? All of these are considerations when we also look at the environment the rescue is taking place in. If the patient is being raised back up, is there a high point to help with the edge transition or are the ropes low and on the edge, making it more difficult to transition the litter up and over it?



The first step is to ensure the patient is secured into the litter so they cannot fall out. Most litters that come with straps that only go across the patient are not sufficient. Instead, diamond lashing with webbing or a commercially available patient tie in system must be used.

Our rules of engagement state:

> Patients with a pulse will have a manufactured harness (victim or Class 3) to a redundant rope system when packaged. Patients packaged in litters (baskets) **shall be** secured with a commercial harness to the litter, with an outer lash for securement, and all extremities secured. Any suspected airway concern will mandate lateral packaging for the pt.
>
> Litter patient packaging and litter bridles with a master attachment point deemed acceptable by two competent rescuers **will not** require a direct patient attachment to the rope system.

Bridles can be constructed by the rescue technicians or purchased commercially. For most operational level teams, a commercially available product will likely suit your needs. Some of these bridles can be used both horizontally or vertically and have adjustable legs. The main and belay lines attach directly to the bull ring on the bridle.

Patient tied into litter with CMC Patient Tie In System and directly connected to the litter with the Pelvic Attachment Strap (yellow). Attendant on "Long Tails" from the MAP (Master Attachment Point). If the victim is in a low angle scenario or anywhere that their head maybe lower than their feet, they should have a second Pelvic Attachment Strap keeping tension towards their feet so they can't slide upwards.

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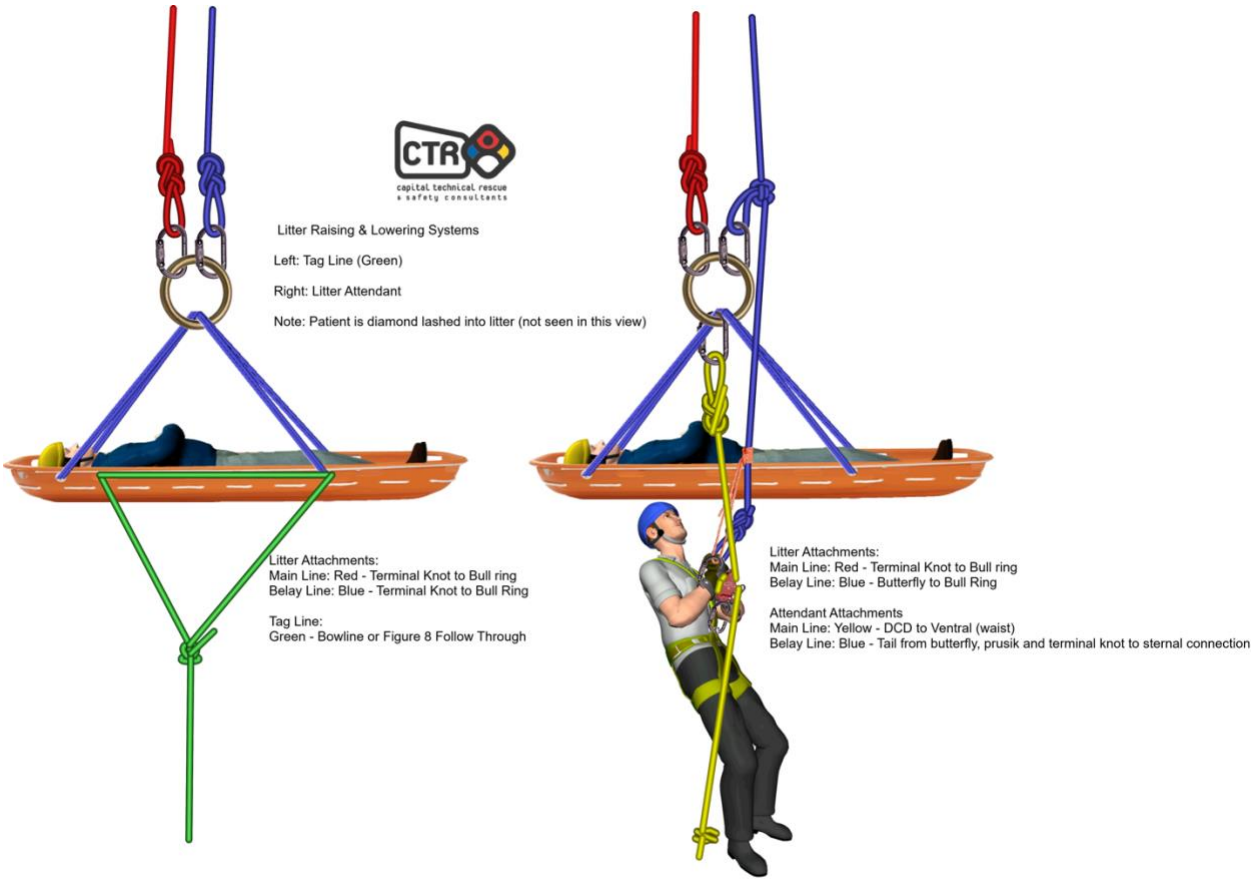


Other options include using a head and foot end tag line, attendant may also choose to attach with a Set of Fours as their main and an ASAP as a belay. We are always maintaining two points of contact within the system.

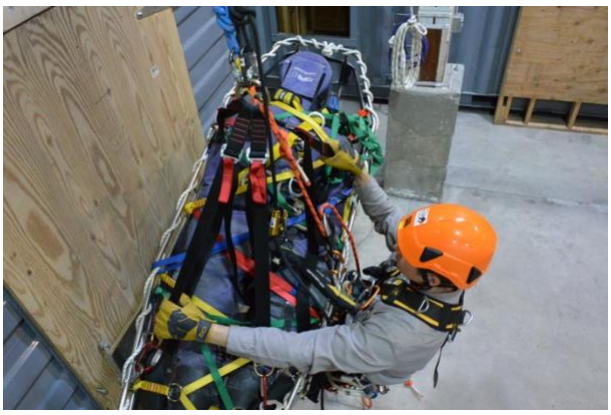
Belay / Safety - Butterfly to bridle, terminates with a Figure 8 with a long loop to attendant (if there is one). The attendant is also connected to a prusik they can adjust in the loop so they can move around. This could also be a long tail with a stopper knot with a Petzl ASAP attached as the attendant's belay.

Main line - Terminates to Figure 8 at Bridle Connection Point (ie Bull Ring)

Attendant Line - Can be a SOF attached to bridle, an approximately 15' rope tied into the bull ring with a stopper knot. The attendant can move up and down the rope with a RAD system.

Vertical Litter with Tag Line

Horizontal Litter with Tag Line



Horizontal Litter with Litter Attendant using a DCD and ASAP

Horizontal Litter with Litter Attendant using a SOFs and a Prusik Safety

Vertical Litter with Litter Attendant using a SOFs and ASAP

Vertical Litter with Tag Line

High Point Edge Transitions

Raising or lowering a litter when the rope comes from above is typically quite simple, as there is little or no edge that the raising and lowering system can't overcome. This high point could be a rope coming from the rooftop of a building, an artificial high point, such as a Terradaptor or Arizona Vortex, structural steel, or even from a window in the floor above the point where the patient is located.

Communication and coordination are key to negotiate the edge successfully and safely. In the photo below, the rope system is coming from above, creating a high point. This allows the rescuer with the patient to negotiate the edge by simply calling for a haul and assisting the litter up and over the edge. With a tag line here, no litter attendant is needed, and the team can begin a lower operation almost immediately.

High Point Transition

Low Edge Transitions

Low edge transitions are the culmination of everything learned - using a litter system without a high point is extremely challenging, and safely making the transition in a raising or lowering situation requires teamwork, coordination, and good communication.

Methods:

There are various ways that teams utilize to help negotiate a low edge with a litter system. These may vary quite a bit depending on the environment. As an example, a parapet roof with a perfect 90° edge over a long distance is much different than an uneven cliff with outcroppings, vegetation, and other challenges. Some teams use 6 ft hooks / attic ladders / 2x4 /

signposts to lever a litter up and over the edge, however the consensus amongst our staff is that it often doesn't work well and that these are additional items outside of our normal equipment cache that we would bring on a rescue.

Webbing, on the other hand, is something that almost every team has an abundance of, is light weight, and gives us a lot of options in how we use it. The downside to the webbing method is we must often turn the litter in a way that doesn't take the victims comfort into consideration. Therefore, we now prefer to have an edge attendant on the head end of the litter and one on the foot end of the litter. These edge attendants are on a two rope system, but the ropes only need to be long enough for them to achieve their objectives. This will allow for the litter to remain horizontal throughout the transition.

Horizontal Low Edge Transition – Edge Attendants

Edge Attendant Setup:

- 2 – Two Rope Systems (1 at head, 1 at foot)
- 20' webbing or use excess tail of rope

Procedure:
Once the litter bridle is at the edge and possibly into the edge rollers, the litter tender can take the webbing or rope from the edge attendants and loop a portion around the head and foot of the litter, handing it back up to the edge attendants creating a large bight the edge attendants can use. The litter tender can then climb up and come off the litter. The edge attendants will position themselves on the edge as if they were about to rappel and acting as an artificial high point. Coordinating with the haul team the edge attendants lift on the webbing/rope while pushing themselves out and away from the edge with their legs, and keeping the head end higher than the foot end to make the transition easier. The haul team keeps tension in the systems and only hauls enough to assist and not pull the litter into the edge.

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Two Edge Attendants In Position

Horizontal Low Edge Transition – Webbing Based

Litter Setup:

- Commercial Bridle attached to litter lifting rings / boxed keepers. Attach Main & Safety as below
- Patient diamond lashed into litter with a 30' piece of webbing that is split in half and girth hitched at the bottom of the litter and kept daisy chained. Or use a commercial lashing system.
- Two - 20' Piece of webbing split in half and girth hitched to outside rail. One in area of patient shoulders, and the other in area of patient's thighs / knees. Keep daisy chained until needed.

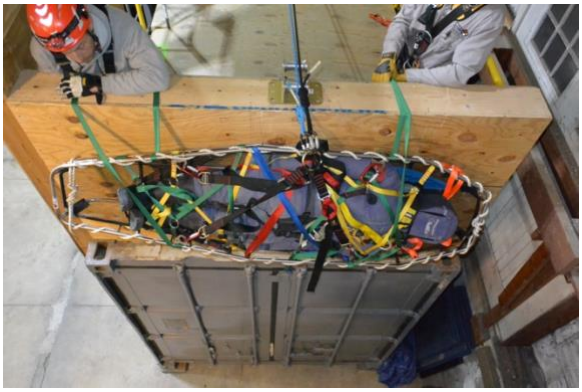
Procedure:
Attempt to bring litter up and over the edge using webbing. Setup webbing so that the 20' pieces on the outside rail and loop under the litter and come back up through the litter. Take a round turn on the inside top rail. If not using a litter attendant, then place the webbing in the litter or let it hang where edge personnel will be able to grab it.

During a raise, the litter attendant must climb up and over the litter, without stepping on the victim and come off the system. Prior to climbing up, the litter attendant will pass up the ends of the webbing to the edge personnel.

- Raising:

- Raise litter so the knots are pulled up into the edge protection.
- Edge personnel then grab the 4 ends of webbing and begin to pull up on the webbing for the inside rail, rotating the litter away from the edge.
- Haul team then ordered to haul slowly while edge personnel keep litter turned until they can complete the transition.
- This can be very difficult and may require they pull up on the head of litter more or vice versa. They may also need to use the webbing from the outside rails to help negotiate different edges.

- Lowering:
  - With litter locked off on main and belay, two edge personnel take control of all 4 ends of webbing and push litter out enough so that the patients' shoulders are just over the edge, but most of weight remains on the edge and the webbing is under tension.
  - The foot end is then pushed out and over the edge, while the inside webbing is kept under tension, and the victim rotates outward away from the edge.
  - Main and belay are ordered to lower as needed, edge personnel place any edge protection needed and use the webbing to fully load the bridle and get the litter horizontal again.
  - Attendant may then climb out and onto system.



Vertical Low Edge Transition – Pike & Pivot

Litter Setup:

- Rope barber pole bridle or commercial vertical bridle attached to litter lifting rings / boxed keepers. Attach Main & Safety
- Create a Pike & Pivot Yoke Bridle from two 150cm wire strops, ~20' of webbing, rope or technora cord, attached on outside rails of litter at approximately patient's thigh

- If using rope or webbing, center a Figure 8 on a bight or butterfly and using an auxiliary carabiner connect it to either the mainline or belay line bridle.

Procedure:
Prior to climbing up, the litter attendant will first disconnect the auxiliary carabiner that attaches the Pike and Pivot Yoke Bridle to the main rope rescue system bridle and hand it up to the edge attendant so they may connect a second hauling system to the yoke bridle.

Raising:

Raise litter so the knots are pulled up into the edge protection.

Edge personnel then take the Pike and Pivot Yoke Bridle and attach it to an additional hauling system, ensuring it stays below all of the other rigging.

Haul team then ordered to haul slowly on the Pike and Pivot Hauling system while edge personnel begin to guide the litter up and over the edge, haul until almost at the point of attachment of the Pike and Pivot Yoke Bridle and then pivot the litter down. Do not haul up on the main line system, but can reduce the amount of slack in the main and belay lines. May also need to lower on the main and belay to complete this.

They may also need to use the webbing from the outside rails to help negotiate different edges.

Lowering:

Reverse the steps above.
Lower out on Pike and Pivot Hauling System
Maintain tension / slack in main and belay as needed
When main and belay knots are at the edge
lock off main & belay
Slack the Pike and Pivot Haul system
Disconnect the Pike and Pivot Haul System, connect the Pike and Pivot Bridle to the main or belay line attachment with an additional carabiner (odd color or type)

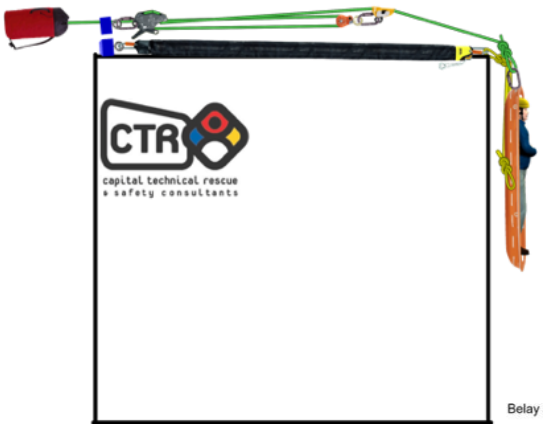
The litter attendant may now climb out and load the system.

If anchors are a distance away, or if the terrain requires multiple pike and pivots along the way, the Pike and Pivot Hauling system could be a single rope system as opposed to a set of fours as shown in the diagram.

Pike & Pivot

Belay and Attendants Omitted for Clarity

Once connected - tension SOFs (JAG) & slack main (green) & belay (omitted)
Begin hauling on SOFs

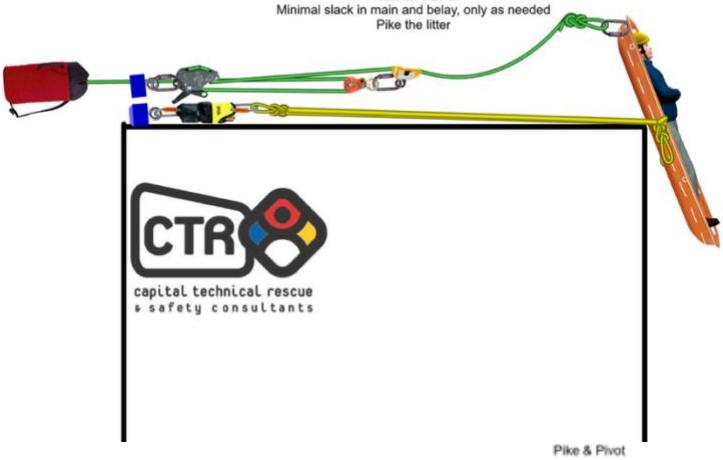


Pike & Pivot
Yoke Bridle
~20' webbing, rope, or technora cord
Connect on outside of rails of litter
at approximately patient's thigh

Pike & Pivot

Belay and Attendants Omitted for Clarity

Step 2
Haul on SOFs
Minimal slack in main and belay, only as needed
Pike the litter



Pike & Pivot

Belay and Attendants Omitted for Clarity

Step 3
Continue Haul on SOF
Tension Main & Belay
Pivot Litter

Vertical Low Edge Transition – Webbing Only Method

Litter Setup:

- Rope barber pole bridle or commercial vertical bridle attached to litter lifting rings / boxed keepers. Attach Main & Safety as below
- Patient diamond lashed into litter with a 30' piece of webbing that is split in half and girth hitched at the bottom of the litter and kept daisy chained. Or use a commercial lashing system.
- Two - 20' Piece of webbing split in half and girth hitched to rails. In the area of the patient's thighs / knees, place these on either side of the patient. If possible, keep inside one of the boxed framework of the litter. Keep daisy chained until needed.

Procedure:

During a raise, the litter attendant must climb up and over the litter, without stepping on the victim and come off the system. Prior to climbing up, the litter attendant will first take a round turn in one piece of webbing on either side of the litter in the area of the upper box frame near the patients shoulders and then pass up the ends of the webbing to the edge personnel.

- Raising:
  - Raise litter so the knots are pulled up into the edge protection.
  - Edge personnel then grab the 4 ends of webbing and begin to pull up on the upper webbing, lifting upwards as high as they can.
  - Haul team then ordered to haul slowly while edge personnel begin to pull up on the lower webbing until they can complete the transition.
  - This can be very difficult and may require they pull up on the head of litter more or vice versa. They may also need to use the webbing from the outside rails to help negotiate different edges.

- Lowering:
  - With litter locked off on main and belay, two edge personnel take control of all 4 ends of webbing and push litter out enough so that the patient's lower body is over the edge, but most of weight still remains on the edge and the webbing is under tension.
  - The litter is then pushed out and over the edge, while the webbing is kept under tension, and the victim rotates downwards and loads the system when completely vertical.
  - Main and belay are ordered to lower as needed, edge personnel place any edge protection needed and use the webbing to fully load the bridle.
  - The litter attendant may now climb out and load the system.

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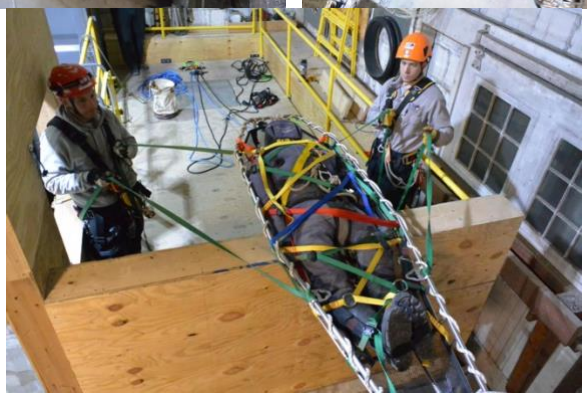

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Pick Offs

A pickoff is a high angle rescue where typically a litter is not used, and a rescuer makes physical contact with the victim. The rescuer will typically apply a victim harness to the victim and then proceed with the rescue.

There are several flavor combinations of pick offs, including whether the victim is suspended by rope, or clinging onto an object. Each of these types of rescues may be performed with a system (team based) approach or a rappel (individual based) approach.

Suspended pickoffs are life threatening to the victim due to suspension trauma and victims must be accessed and removed as quickly as possible.

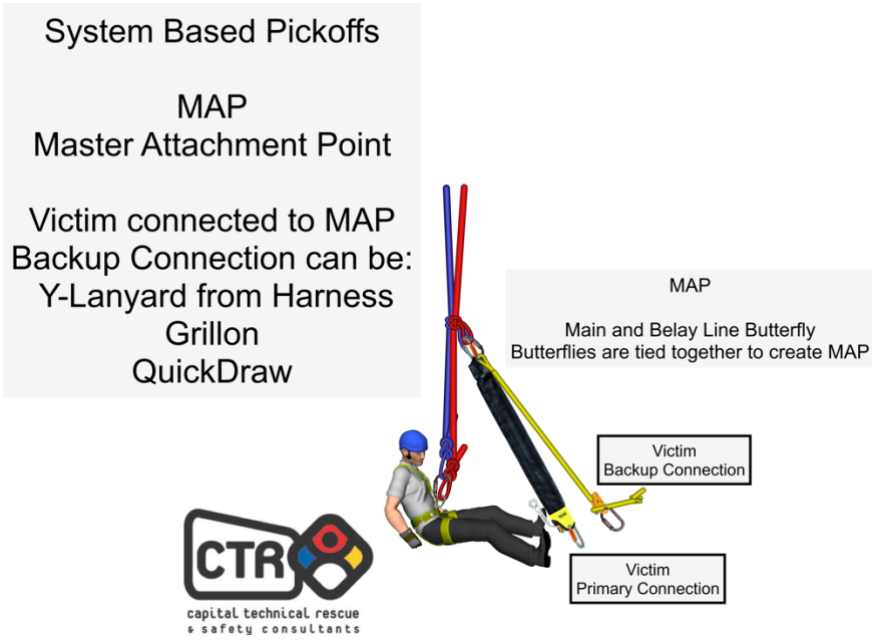
System (Team) Based Supported (Suspended) Pick Off

- Utilizing a standard two rope lowering and raising system a rescuer is attached to the ropes and lowered to approximately 6' above the victim
- Rescuer makes verbal and visual contact with the victim
    - Keep the victim calm, stress the importance of following instructions and not reaching or grabbing out for rope or the rescuer
    - Explain to the victim each step of the rescue so they know what to expect
- Rescuer then descends to a point where they can reach down to access the victim's harness and connections.
- Victim is attached directly to the main and safety lines using any of these options:
    - Carabiner
    - Carabiner with short tether
    - Pick off strap / work positioning lanyard / Set of Fours
- Rescue package is raised just enough to disconnect victim from the system they were suspended on
    - Cutting the victims system, especially under tension is a last resort
- Rescue package can then be raised or lowered depending on the environment to complete the rescue. Typically, it is easier and safer to lower when possible.
- Rescuer with the victim attached
    - Keep legs high and straight to provide space for victim to hang between wall and rescuer
    - Mindful of the victims fall line and any other obstacles that must be navigated

System (Team) Based Unsupported (Clinging) Pick Off

- Utilizing a standard two rope lowering and raising system a rescuer is attached to the ropes and lowered to approximately 6' above victim
- Rescuer makes verbal and visual contact with the victim

    - Keep the victim calm, stress the importance of following instructions and not reaching or grabbing out for rope or the rescuer
    - Explain to the victim each step of the rescue so they know what to expect
- Rescuer is lowered to a point where their waist is at the victim's chest level
- If possible, the rescuer should position themselves so the victim's exposure to the edge is minimized until they are secured.
- Rescuer applies victim harness per manufacturer's instructions, always keeping it on one connection so it can't be dropped.
- Victim is attached directly to the main and safety lines using the victim harness
- Rescue package can then be raised or lowered depending on the environment to complete the rescue. Typically, it is easier and safer to lower when possible.
- Rescuer
    - Instructs victim to hold onto their harness straps
    - Can call for a short raise if needed to tension connections
    - Pushes back and calls for a raise or lower
    - Keeps legs high and straight to provide space for the victim to hang between the wall and the rescuer
    - Mindful of any obstacles that need to be navigated



Alternative rigging options are in the appendix.

Rappel Based Suspended Pick Off

- Utilizing a static two rope system a rescuer rappels to approximately 6' above victim
  - Depending on victim's status, rescuer may need to rappel with the rope bag on their back so the victim can't access the rescuers rope
  - Rescuer could still rappel, but have a team-based belay
- Rescuer makes verbal and visual contact with the victim
  - Keep the victim calm, stress the importance of following instructions and not reaching or grabbing out for rope or the rescuer
  - Explain to the victim each step of the rescue so they know what to expect
- Rescuer descends to a point where they can reach the victims harness connections
- Rescuer connects a pick off strap / work positioning strap / AZTEK / Set of Fours to:
  - DCD Carabiner and the victim's harness
  - The victim should never be attached directly to the rescuers harness
- Rescuer connects a prusik / short sling between the rescuers safety (ASAP) / belay carabiner and the victim's harness.
- Rescue package is raised just enough by rescuer to disconnect victim from the system they were suspended on
  - Cutting the victims system, especially under tension is a last resort
- Rescuer descends with the victim attached
  - Keep legs high and straight to provide space for victim to hang between wall and rescuer
  - Mindful of the victims fall line and any other obstacles that must be navigated

Rappel Based Clinging Pick Off

- Utilizing a static two rope system a rescuer rappels to approximately 6' above victim
  - Depending on victim's status, rescuer may need to rappel with the rope bag on their back so the victim can't access the rescuers rope
  - Rescuer could still rappel, but have a team-based belay
- Rescuer makes verbal and visual contact with the victim
  - Keep the victim calm, stress the importance of following instructions and not reaching or grabbing out for rope or the rescuer
  - Explain to the victim each step of the rescue so they know what to expect
- Rescuer descends to a point where their waist is at the victim's chest level
- If possible, the rescuer should position themselves so the victim's exposure to the edge is minimized until they are secured.
- Rescuer applies victim harness per manufacturer's instructions, always keeping it on one connection so it can't be dropped.
- Victim harness is connected to the rescuers DCD carabiner and safety (ASAP) / belay carabiner

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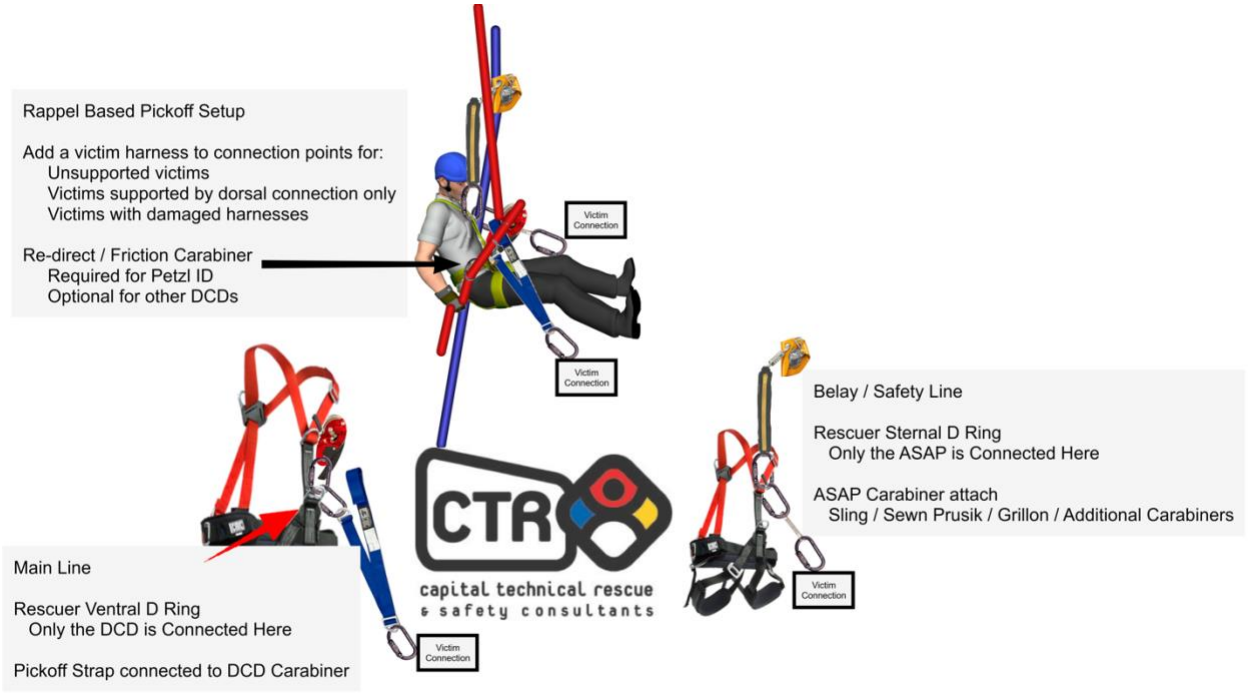
- Rescuer
  - Instructs victim to hold onto their harness straps
  - Tension connections as much as possible, can call for a vector to assist
  - Pushes back and descends
  - Keeps legs high and straight to provide space for the victim to hang between the wall and the rescuer
  - Mindful of any obstacles that need to be navigated



Alternative rigging options are in the appendix.

System Failures / Complications

Competent technical rescuers not only know how to correctly perform a rescue, but also how to react when something goes wrong. Complications in our systems may occur naturally or something we induce to mitigate another problem. Failures in rope rescue systems are extremely rare, with most attributed to human factors. Regardless we must figure out the best and safest solution to complete the rescue when failures and complications arise. Two of the most common scenarios are the need to pass a knot, or a complete main line failure.

Knot Passing

Knots may end up in a rescue system and must be "passed" through a DCD to complete a lower or a raise. When we "pass" the knot, we often must re-reeve it through a DCD, potentially removing one of our two points of connection in the system. Therefore, we must ensure that the technique we utilize does not compromise the safety of our system.

Knots are found in rescue systems for a variety of reasons:

- Two ropes tied together to make a rope longer
- Rope packed incorrectly
- Damaged section of rope, isolated with a butterfly knot

Passing a knot may be done with a variety of equipment and techniques. For the purposes of this course, we are using a Set of Fours (SOFs), however other equipment maybe used to control the load.

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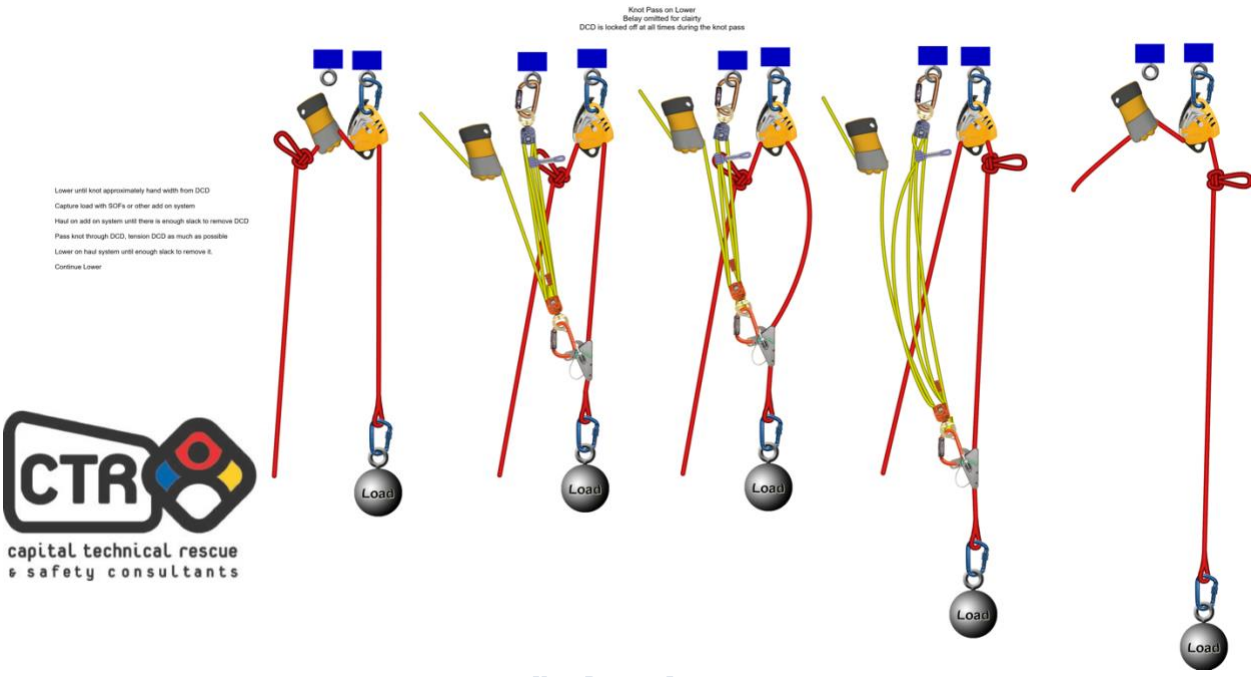
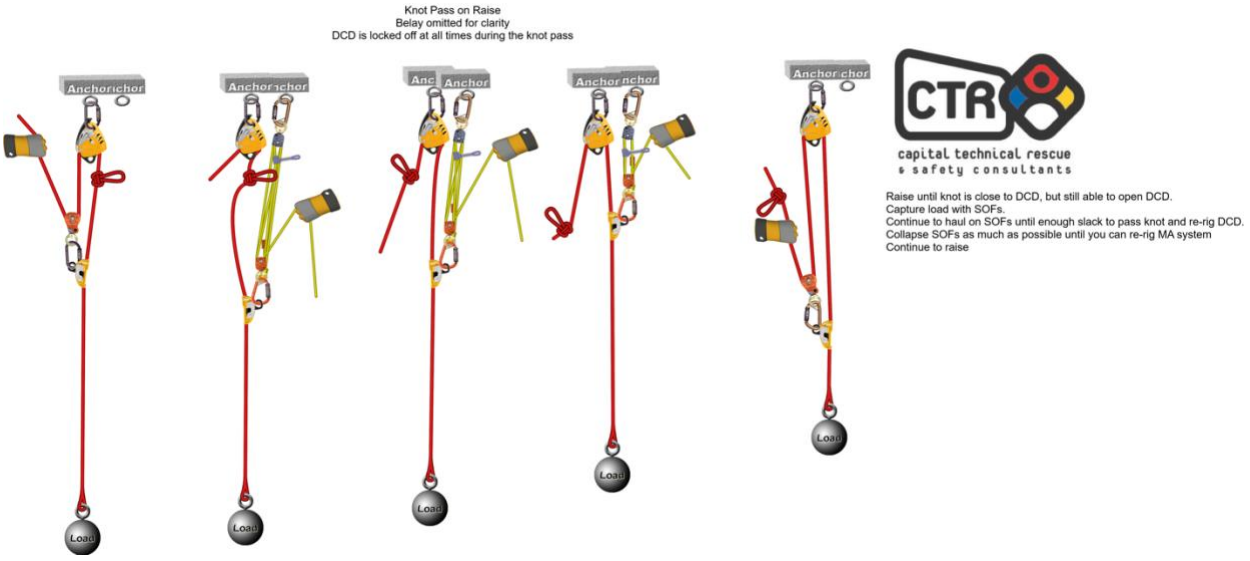


Knot Pass on Lower



Knot Pass on Raise

Main Line Failure

Failures of the main line is a serious emergency and there are several factors we must consider.

- Current victim / rescuer status
  - Injured further / life threatening

- What caused the failure?
  - Rope broke
    - Sharp edges / objects along the way? Will they affect belay?
  - Anchor failure
    - Does this compromise the belay system?
  - Hardware failure
    - Unlikely
  - Human error
    - What is status of main line?
    - Can we recover?

- What kind of belay system was used?
  - Slack belay
    - Consider shock loads
    - If we re-establish a main line, how do we transfer load back to main line?
  - ASAP belay
    - Can we convert belay line to a main line system?
    - If we re-establish a main line, how do we transfer load back to main line?
  - Twin tension system
    - If edge protection isn't an issue, can we continue operation only using the belay line?

- What are the best options to continue a safe, efficient, and effective rescue?
  - Establish new main line system
    - Lower new main line to rescuer to attach
    - Raise on main / lower on belay to transfer weight onto main line system
  - Continue the operation on single line (belay becomes main)
    - Only if rescue is almost complete or life threatening
    - Must be sure that we know what caused the failure and we've mitigated it from occurring again

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Operational Considerations

Incident Command System

The Incident Command System (ICS) or Incident Management System (IMS) are terms utilized interchangeably that organize and help manage incidents from the smallest scale singular incident to large scale disaster response. It's framework is well known within North America and we will only highlight a few aspects that should be considered for rescue teams so that they may respond within their own agency as well as part of a larger response involving multiple agencies.

- Maintain a span of control of no more than 7:1, with 5:1 being ideal.
- Incident Safety Officer
  - Must be familiar with Rope Rescue Operations and equipment
  - If possible, should not be involved in rescue operations
- Good communications up and down the chain of command

Local Laws and Policies

Local Laws and policies may exist specific to technical rescue disciplines, and you should be familiar with them. There may be laws, such as OSHA or Department of Labor that may apply, even though it may not be within your typical industry. For example, lock out / tag out, or utilizing fall restraint when with 6' of an edge. Different states, counties and local municipalities may have their own requirements that you should become familiar with.

Risk Management

The old adage of "Risk a little to save a little…" still holds true, however we must calculate the risks we take and try to mitigate as many of the hazards as we possibly can. In order to do this, we need a system to rate the risks. One such model that is widely accepted is the GAR Model.

GAR stands for Green, Amber, and Red. Each of these colors represent a risk category to help make a Go / No Go decision. By answering a few questions, a numerical score is tallied, and the result will fall into one of the color categories. A score in the Red is a high-risk mission and maybe a No Go decision, while Green scores are a low risk mission and Amber being in the middle. Think of it like a stop light. While red typically means stop, there can also be a flashing red light, in which you must stop, before proceeding with caution. The same could be true with a rescue. A score in the Red may make you stop, revaluate, see how to mitigate some of the hazards and then proceed with caution.

There is a free Risk Calculator App that maybe downloaded to mobile devices, and lots of great information in texts and online about the GAR Model.

Recommended Training / Continuing Education

Technical rescue, regardless of the discipline, is a perishable skill set. Without regular and consistent training, the skills taught will diminish to a point that could be harmful to yourself and your team members. This includes but is not limited to severe injuries or death due to human errors in not operating or rigging equipment properly.

We can assist in any of these skills sets, and have clients who we work with monthly, quarterly and annually to ensure they stay sharp on their skill sets.

Weekly

Recommended Minimum Time Commitment: 1 Hour

It is recommended that team members practice some type of skill at least weekly. This can be a self-guided focused review or lead by a team member who has proficiency in that particular skill.

Example topics:

- Knots
- Donning Harnesses
- Patient Packaging
- New Equipment Review
- Raising and Lowering Setups
- Equipment Inspections

Monthly

Recommended Minimum Time Commitment: 1 - 4 Hours

It is recommended that team members meet and practice some type of skill at least monthly. This can be a self-guided focused review or lead by a team member who has proficiency in that skill.

Example topics:

- Knots
- Patient Packaging
- Raising and Lowering Setups
- Mechanical Advantage
- Belaying
- Pre-Planning
- Equipment Inspections

Monthly training may take place at your location or CTR's indoor training facility in Albany, NY.

Quarterly

Recommended Minimum Time Commitment: 4 Hours

It is recommended that team members meet and practice some type of simple rescue scenario at least quarterly. This should not be too complicated of a scenario but rather focus on overall team dynamics and putting together all the topics they have worked on over the past few monthly drills.

These scenarios can be guided by CTR or a team member who has shown proficiency in all systems the team uses. These should be low risk scenarios that have been pre-planned and well thought out by the team member to ensure that no one can get hurt during training.

Quarterly training may take place at your location or CTR's indoor training facility in Albany, NY.

Annual

Recommended Minimum Time Commitment: 8 - 24 Hours

Annual training is not only a great time for refresher training but also to introduce new equipment, techniques and advancements. The minimum time is typically 8 hours, however if your team does not partake in weekly, monthly and/or quarterly training than you may need up to 24 hours of refresher training.

We recommend that you bring in a trainer such as CTR to perform this refresher training. This will allow for an independent evaluation of your team as well as ensuring that the latest techniques and/or equipment can be taught.

Our most popular option for teams that train is for a 16-hour refresher annually. This allows for time to review equipment and techniques and introduce new techniques and equipment, while still allowing plenty of time for OSHA and NFPA recommended scenarios.

Example topics:

- Knot Review
- Equipment Review

- New Equipment
- New Techniques
- Simple and more complicated scenarios

Annual training may take place at your location or CTR's indoor training facility in Albany, NY.

Other recommended training courses available

CTR has many other training courses and topics that may interest you and / or your team depending on your needs. See our website for the most up to date information. www.capitaltechrescue.com

- Emergency Response Team Training
  - Team Evaluations
  - Site-Specific Rescue Operations
  - Stop the Bleed / Trauma Response
  - Fire Extinguisher Training
  - Structural and Industrial Live Fire Training
  - Rescue from fall protection
- PPE Competent Person Inspectors Course
- Rope Rescue
  - Operations
  - Technician
  - Refresher
  - Artificial High Directional
  - Lead Climbing
  - Tower Rescue
- Industrial Escape Systems
- Confined Space
  - Entry
  - Awareness
  - Operations (non-IDLH)
  - Operations (IDLH)
  - Technician
  - Rigging Challenges
  - Small Team Operations
- sUAS (Drones)
- Water Rescue
  - Rescue Boat Operator for OSHA 1926.106
  - Ice Rescue
  - Swiftwater Rescue

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Advanced rigging / small team intro

These are all topics covered in advanced classes that we offer. Contact us for more information

Tie Backs

Focused Anchors

Removable Anchors

Removable Bolts

Beam Clamps

Pull Through Anchors

Split 4:1

Batwing 6:1

Capstan / Harken winches

Crane rigging

Artificial High Directionals (AHD)

Monopods / bipods

Body Weight Anchors

Twin tension anchor systems

Ground Based Lowers

Small Team Clinics

Rescues Gone Wrong Clinic

Rigging Challenges Clinics

Skate Blocks, Hybrid Skate Blocks, Offsets & Crosshauls

Tower Rescue

Reeving & Non-Reeving Highlines

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Definitions

This section provides standardized terminology used throughout rope rescue operations. Definitions are drawn from Capital Technical Rescue's curriculum, NFPA standards (1006, 1983, 1670, 1858), SPRAT guidelines, ITRA syllabi, and industry best practices. Where applicable, references are included.

Anchor

A secure point of attachment for rope systems. Anchors may be natural (e.g., trees, rocks) or man-made (e.g., vehicles, structural steel). Must be capable of supporting anticipated loads.
[NFPA 1670, NFPA 1006]

AZTEK / Set of Fours (SOF)

A compact, pre-rigged mechanical advantage system typically using 8mm cord and double pulleys. Used for pickoffs, tensioning, and short-haul applications.
[NFPA 1006]

Belay

A secondary rope system designed to arrest a fall in the event of main line failure. May be operated manually or with an automatic device.
[NFPA 1983, SPRAT]

Carabiner

A metal connector with a spring-loaded gate used to quickly and reversibly connect components. Available in various shapes (D, oval, pear) and locking mechanisms (screw-lock, auto-lock).
[NFPA 1983]

Descent Control Device (DCD)

A device that allows controlled lowering on a rope. Modern DCDs often include auto-locking and progress capture features. Examples: Petzl ID, CMC MPD, Harken Clutch.
[NFPA 1983]

Dynamic Rope

A kernmantle rope with high elongation (>25%) designed to absorb energy in the event of a fall.
[NFPA 1983]

Edge Protection

Materials or devices used to protect ropes from abrasion or cutting at edges. Includes canvas pads, rollers, and plastic guards.
[NFPA 1006]

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Fall Factor

A measure of fall severity: Fall Factor = Fall Distance / Rope Length. Range: 0 (low severity) to 2 (high severity).
[NFPA 1983]

Harness

A body-worn device used to secure a person to a rope system. Class II: Seat harness. Class III: Full-body harness.
[NFPA 1983]

Kernmantle Rope

A rope construction with an inner core (kern) and outer sheath (mantle). Static: <6% elongation. Dynamic: >25% elongation.
[NFPA 1983]

kN (Kilonewton)

A unit of force. 1 kN = 224.8 lbf. Used to rate the strength of rescue equipment.

Load Sharing Anchor (LSA)

An anchor system that distributes load between multiple anchor points to reduce the risk of failure.
[NFPA 1006]

Mechanical Advantage (MA)

A system of pulleys and rope that reduces the effort needed to lift a load.
Simple: All pulleys move at the same rate.
Compound: One Simple MA system pulls on another.
Complex: Pulleys collapse toward each other.
[NFPA 1006]

Minimum Breaking Strength (MBS)

The lowest force at which a component will fail under load.
[NFPA 1983]

Prusik

A friction hitch made from a loop of cord that grips the main rope when loaded. Used for ascending, belaying, and progress capture.
[NFPA 1983]

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Progress Capture Device (PCD)

A device that allows rope to move in one direction but locks in the opposite direction, preventing loss of progress. Examples: Petzl ID, Petzl Maestro, MPD.
[NFPA 1983]

Rappelling

Controlled descent on a rope using a descent control device.
[NFPA 1006]

Rescue Litter

A rigid or semi-rigid device used to transport a patient during rope rescue. Examples: SKED, Spec Pak, Stokes Basket.
[NFPA 1983]

Rope Grab

A device or knot that attaches to a rope and allows movement in one direction while locking in the other. Examples: Prusik, Rescuecender, Croll.
[NFPA 1983]

Static Rope

A kernmantle rope with low elongation (<6%) used in rescue systems for raising and lowering.
[NFPA 1983]

System Safety Factor (SSF)

The ratio of the lowest-rated component's MBS to the maximum anticipated load (typically 6 kN).
[NFPA 1983, NFPA 1858]

Twin Tension Rope System (TTRS) / Dual Main System

A rope rescue system where both ropes are tensioned equally and share the load. Each rope is independently capable of supporting the full load. This system provides redundancy and minimizes shock loads. Also referred to as a 'mirrored system'.
[NFPA 1006, SPRAT, ITRA]

Vector Pull

A technique that uses angled rope pulls to create mechanical advantage.
[CMC Rescue, RopeLab]

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Appendix

Appendix A - Factors of Safety

Factors of Safety, By Cliff Freer

Glossary of Terms

DCD - Descent Control Device

De-Rating - The act of reducing the MBS of a piece of equipment when it is not used in accordance with its intended design. (rope to 50% after knotting, carabiners to 50% for tri-loading, carabiners to 75% for wide or excessive webbing)

Dynamic System Safety Factor – The force of the Maximum Anticipated Load divided into the piece of equipment with the lowest MBS in the system.

Load Limiters - Stacked and stitched webbing intended to deploy at predictable loads to absorb and limit the energy transferred to the people using the equipment.
(Petzl ASAP Sorber Axess, Yates Rescue Load Limiter)

Maximum Anticipated Load - Estimated at 6kN based on the absorbing force of the ASAP with energy absorbing lanyard and published slip-testing data of DCDs.

MBS - Minimum Breaking Strength

Proof Loading/Testing - A load test performed by some manufacturers testing individual pieces of equipment before releasing the equipment for use. One-quarter of the MBS appears to be the common load used (Kong, Rock Exotica).

Static System Safety Factor - The force of the load at rest divided into piece of equipment with the lowest MBS in the system.

Unplanned Dynamic Event - Any event that causes a shock load or jolt force to the system.

Working Load Limit - Provided by some manufacturers and acceptable for use up to that load. Used in lieu of the Static and Dynamic safety formulas.

It is the responsibility of every Rope Rescue Operator and Technician to determine if the system they are utilizing is “safe”. There has long been the misnomer that our “Safety Factors” for rope rescue in the fire service were required to be 15:1. This is only anecdotally substantiated in the original version of NFPA 1983-1985 and should not be considered valid for our approach to

rigging. A Safety Factor of 15:1 and even 10:1 is not possible to achieve, nor do we want to carry the equipment that would be built for such a purpose. What is achievable is a Dynamic System Safety Factor of between 2:1 and 4:1. This is in line with all our other disciplines and more in line with industrial standards for fall protection.

Organized rescue teams should be diligent in the equipment they acquire ensuring that it serves their mission needs. All equipment, hardware and software, should be tracked and inspected regularly and after each use. Follow guidance from both the manufacturer and NFPA 1858-2018 for the selection, care and maintenance of this equipment. The manufacturer Kong states in their literature that a connector should be retired if it saw a load greater than one-quarter of its MBS or the load it received when Proof Loaded.

The practice of tying prusiks should be eliminated completely. Sewn bound loop prusiks offer a level of safety that far exceeds the cost savings of making your own. Rated sewn terminations can be used as anchor straps with a degree of certainty that un-accounted for tied prusiks cannot. Sewn anchor slings should be used wherever possible for the same reasons. Understanding that rigging can vary from response to response, having some bulk webbing for this purpose is warranted as a backup. The availability and low cost of various length sewn webbing loops should be considered as well.

We are going to assume that the Maximum Anticipated Load will be 6kN, which should be thought of as an injury-producing amount of force. Our training will hopefully keep the actual forces to considerably less than 6kN, but we will use this number to keep our figures conservative and safe by estimating a high worst-case scenario.

We will now determine the Dynamic Factor of Safety of rigging systems of commonly used equipment. To determine a Static Factor of Safety will only engender a false sense of security, as an Unplanned Dynamic Event (UDE) will always generate more force than a static load. All modern DCDs are designed to slip when put under load to absorb some of the energy from an UDE. Unfortunately, the load at which these devices slip will not be as consistent as we would hope for. The construction and condition of the rope may not match the ropes used in the tests, the wear on the DCD and even atmospheric conditions will affect the friction and the reaction of the device to the event. Installing a Load Limiter is a safe and predictable option for any situation where a UDE is a concern. The PETZL ASAP always requires the use of one and the Yates Rescue Load Limiter can be installed in any system to limit the force from 6kN to 2kN if one is used or 4kN if 2 are ganged together. These load limiters do not rely on friction, which can vary considerably between component interfaces, making them more predictable.

Configuration #1
Used to lower an injured worker from the top of a water tower horizontally in a rated stokes basket.

12.5 mm rope with knots	40kN
SMC steel D x 6	40kN
Petzl I'D L x 2	22kN
anchor plates x 2	36kN
anchor straps x 2	45kN
stokes basket w/ rigging	11kN

In this configuration there is no need to de-rate any equipment other than the rope, as it is all being used properly. I put the stokes basket in there intentionally to point out that personal harnesses and patient packaging devices should not be included in the formula. These devices should only be seeing the weight of a single person and are not part of the system, they are hanging on the system. That leaves the rope as the component with the lowest MBS at 20kN after de-rating.

20kN / 6kN = 3.3:1 DSSF.

That's a considerably safe Dynamic System Factor of Safety. By purchasing ropes with sewn terminations, we can increase the strength of the rope from 50% to 85% but the DCD will keep our DSSF still under 4:1.

22kN / 6kN = 3.6:1 DSSF

This may not make our system much stronger, but it does remove some of the possibility that a knot was tied improperly and can increase the speed at which a system is installed and deployed at an emergency.

Configuration #2
Used to raise an injured hiker up a muddy hill vertically in a stokes basket.

11mm rope with knots	32kN
Rock Exotica Rock O x 6	24kN
CMC MPD	14kN
Petzl I'D S	14kN
Rock Exotica 1.5" Omni	36kN
Rock Exotica 1.5" Omni double	36kN
Petzl Basic hand ascender	5kN

In this configuration it's obvious that the Petzl Basic has the lowest MBS of any of the other equipment, but how does it fit into the system, and can it be affected by an UDE? No, it can't. Because the hand ascender is only used while hauling it prevents the rope grab from seeing an impact load, which no rope grab should ever do. Even when loaded the Basic will only see 2/3 of the load. Estimating that at 2.6kN (600lbs) for a 2-

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person load keeps the Basic at a 1.9:1 SSSF and at no time is the load solely the responsibility of the Basic. The MPD has the main strand of the system captive the entire operation.

The rope is at 50% making it 16kN but the DCDs still have a lower MBS at 14kN. 14kN / 6kN = 2.3kN DSSF

Many have been saying that the T rated gear isn't safe, the difference in the DSSF from a traditional G Rated system to a T Rated system is minimal and the T Rated system is still at or above all the other disciplines that we train in. The lightweight gear is not for every team and strong consideration must be given to switching or purchasing gear of that type.

Configuration #3
A high school senior while attempting to hang the school flag from a communications tower, becomes spooked as he encounters a hawk protecting its nest and freezes while climbing the tower.

11mm rope with sewn eyes	32kN
Harken Clutch x 2	22kN
Petzl William x 8	24kN
Anchor plate	36kn
Anchor straps x 4	22kN
Petzl Rescue Pulley x 4	36kN

Rescue team arrives and sets up for a mirrored skate block. Let's de-rate our gear as needed. The rope will keep 85% of its strength because of the sewn termination and no other knots are needed for the operation, 32kN becomes 27kN. All the anchor straps are being used in a basket configuration so 22kN now doubles to 44kN leaving the DCD with the lowest MBS at 22kN.

22kN / 6kN = 3.6:1 DSSF

There are a couple of G Rated 11mm ropes currently on the market, but it won't drastically change your DSSF with either sewn terminations or knots. (3.6:1 sewn as the DCD will have the lowest MBS or 3.3:1 using knots). 11mm rope with knots will produce the lowest DSSF with 32kN de-rated to 16kN for the knots, 16kN / 6kN = 2.6:1 DSSF.

With all the examples provided you can see that even when anticipating a rather large impact and worst-case scenario our gear, when used properly, is incredibly strong. This statement is supported by the reality that we don't read about equipment failures in our industry. We read of

mistakes made by people when they don't have the proper training, the needed practice with the skills to do the job, or all too often, fatigue and stress has played a role in the accident.

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Appendix B – Reference Materials / Apps

Title: ***Physics for Roping Technicians***
Publisher: RopeLab
Author: Richard Delaney
Notes: Constantly updated by the author, at no cost. In depth look at equipment, systems and the physics and math in rope rescue systems.
Link: https://www.ropelab.com.au/files/physics.pdf

Title: ***Technical Rescue Field Operations Guide***
Publisher: Desert Rescue Research
Author: Tom Pendley
Notes: App or Paper guide. Covers rope rescue, confined space rescue, swiftwater rescue, trench rescue, structural collapse and helicopter operations
Link: https://www.desertrescue.com

Title: ***CMC Field Guide App***
Publisher: CMC
Author: CMC
Notes: App with charts, diagrams, videos but heavily leans towards CMC products.
Link: https://www.cmcpro.com/app/

Title: ***Animated Knots by Grog (Grog Knots)***
Publisher: Animated Knots
Author: Animated Knots
Notes: Easy to follow, no internet required.
Link: https://www.animatedknots.com/shop

Title: ***RigRite***
Publisher: RigRite
Author: RigRite
Notes: App to calculate complex vector forces easily.
Link: http://rigriteapp.com

Title: ***Risk: SPE, ORMA, and GAR Calculator***
Publisher: NCPTT National Park Service
Author: NCPTT National Park Service
Notes: App to calculate risk assessment scores (GAR Model)
Link: https://ncptt.nps.gov/blog/risk-spe-orma-and-gar-calculator/

Title: ***TerrAdaptor Portable Anchor System Manual***
SMC Gear
Notes: Select which version of the manual you need
Link: https://smcgear.com/terradaptor-portable-anchor-system.html

Title: ***Arizona Vortex User Manual***
CMC Rescue
Notes: Select under the Resources Drop Down for the latest version
Link: https://www.cmcpro.com/equipment/arizona-az-vortex/

Petzl Rope Systems – Second Edition

Appendix C – Mechanical Advantage Practice

RopeRescueTraining.com T-Method Article

CMC T-Method Practice Form

CMC T-Method Practice Answers

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Appendix D – Inventory & Forms

CMC Forms - Rope Log, Hardware Inspection Log etc

Scannable Inventory App

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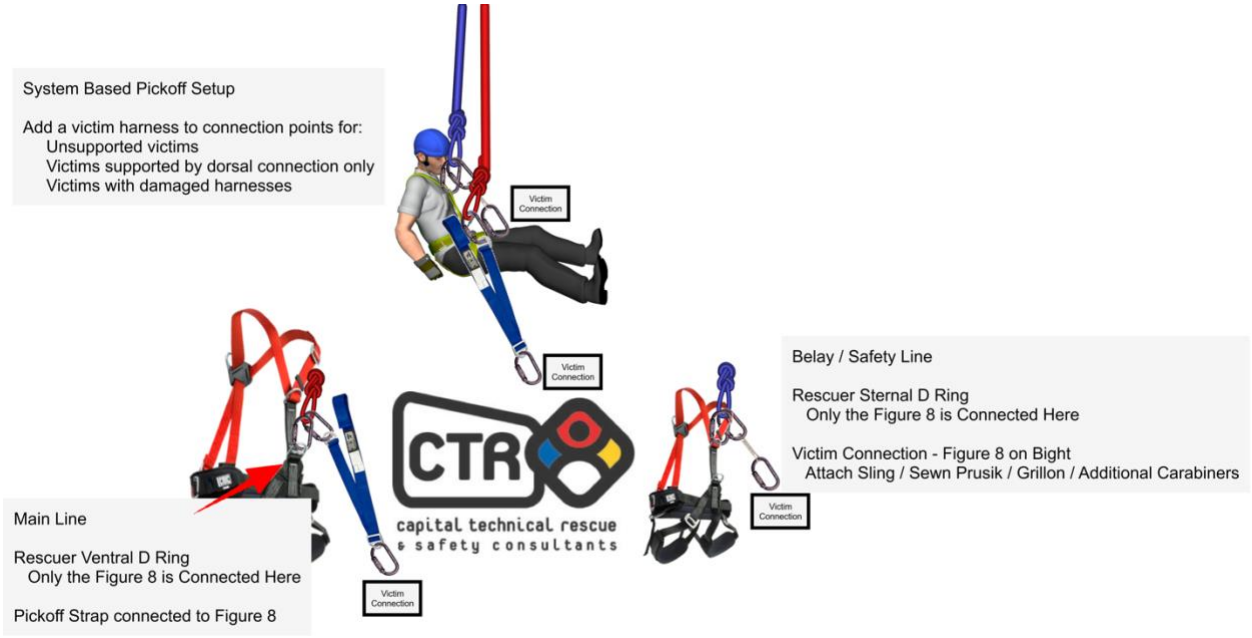
Appendix E – Manufacturer Video Links

Petzl Professional Videos

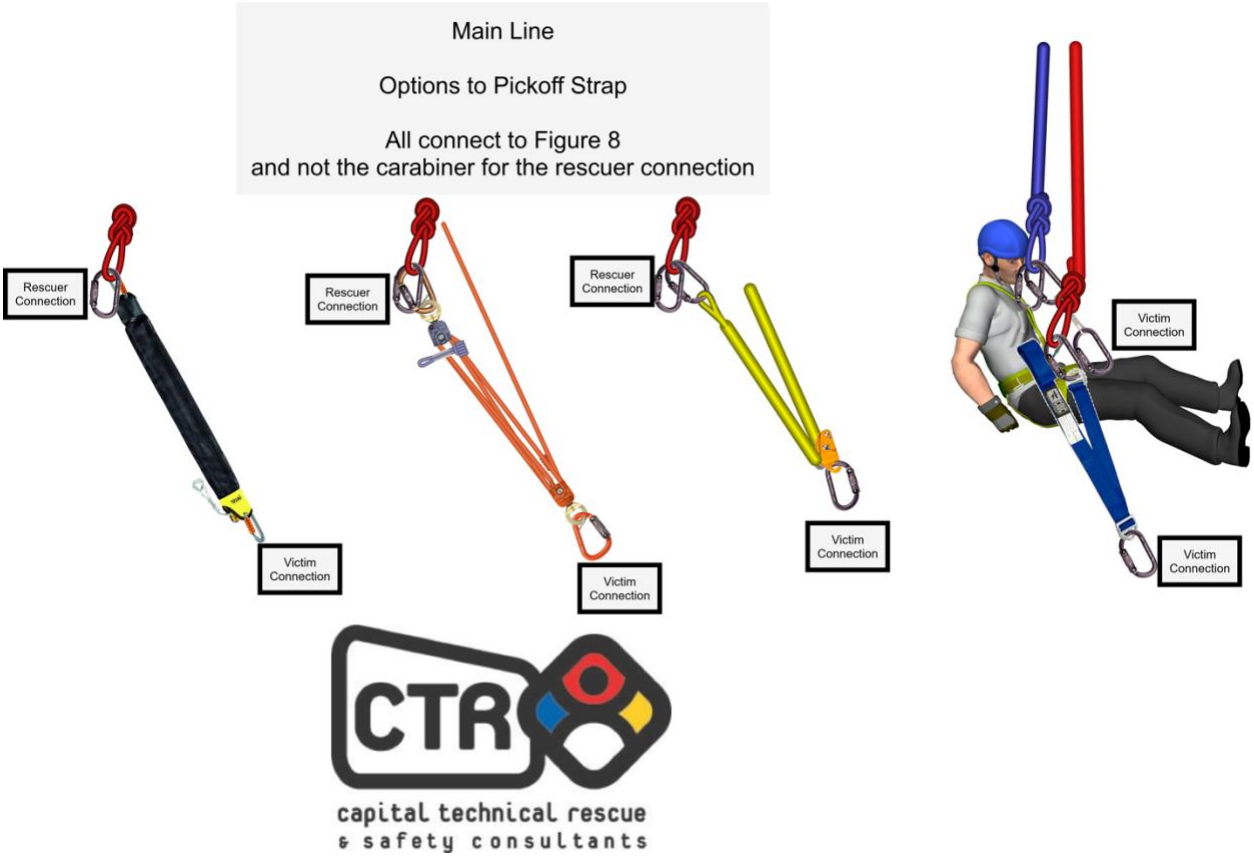
Appendix F – Alternative Rigging Diagrams

Pickoff – System Based Alternatives



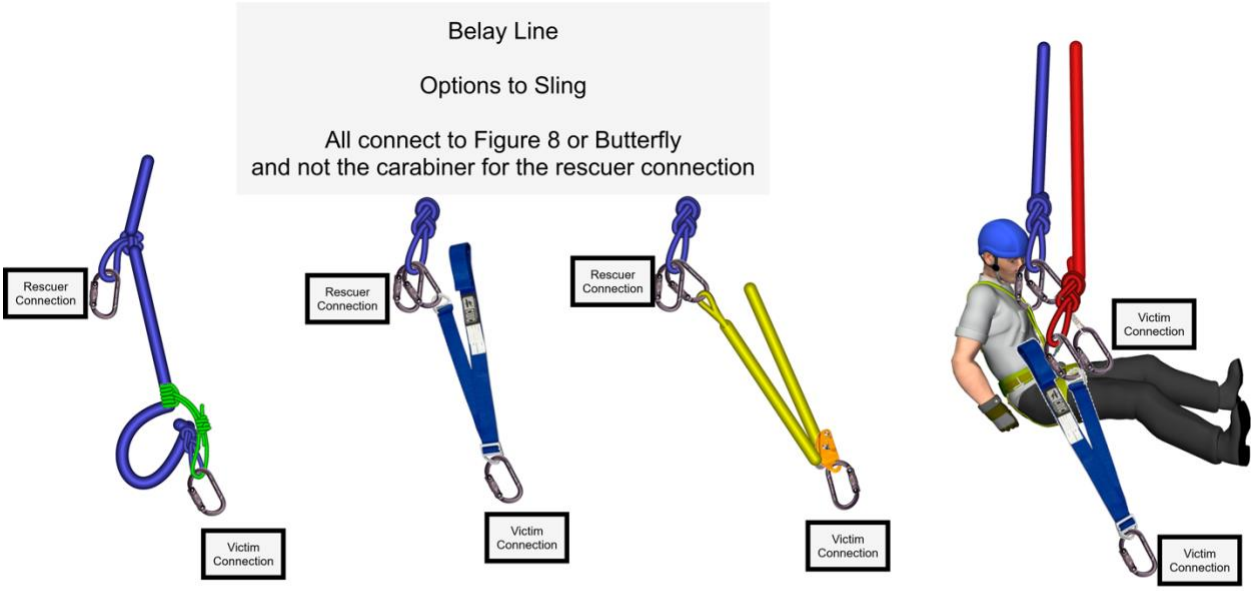
This is the traditional way a system based pickoff has been done. While it works and is safe, it can be a challenge when your victim is larger or you have a rescuer who has shorter legs and can't protect the victim as easily as when you attach them to a MAP that is higher than the rescuer.

Pickoff – System Based Alternatives – Main Line



The same devices maybe used for a rappel based pickoff, with the connecting carabiner of the device connecting directly into the DCD carabiner and NOT the rescuers harness.

Pickoff – System Based Alternatives – Belay Line



The same devices and techniques maybe used for a rappel based pickoff, with the connecting carabiner of the device connecting directly into the backup carabiner (ASAP carabiner) or knot and NOT the rescuers harness.

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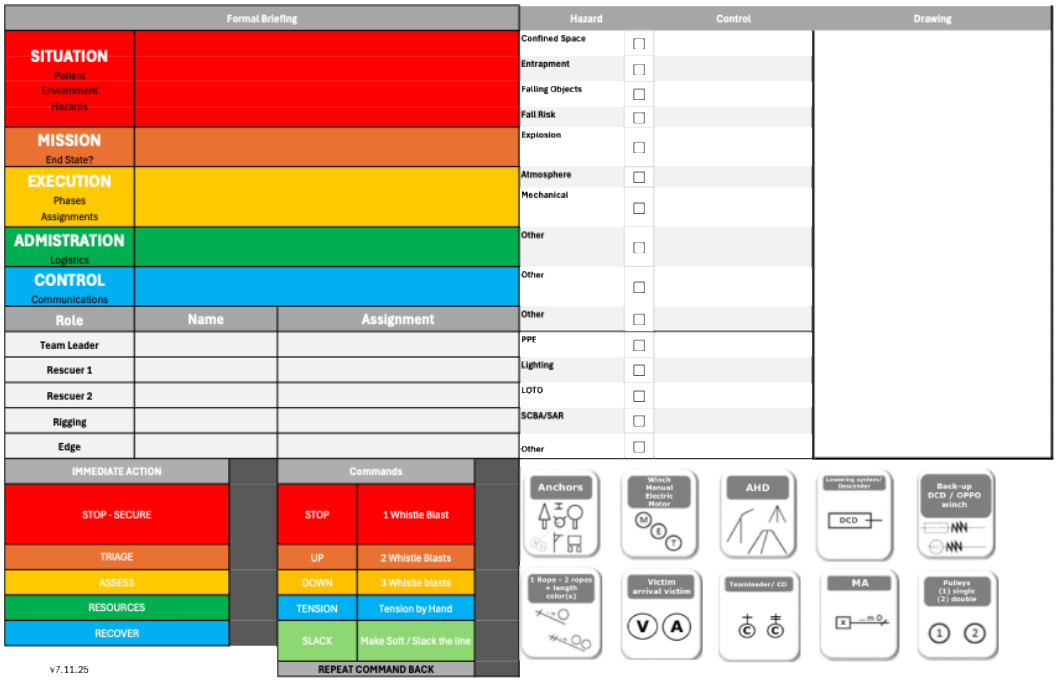
Appendix G – CTR Tactical Worksheet



[Click Here to Download Latest Version (PDF)]

Appendix H – CTR Rules of Engagement

Starts on next page

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2025 Rope R.O.E. (Rules of Engagement)

Live: *With pulse*	***Unquestionable/Certified*** *Will not fail / Tested, Rated*
Redundant: *Will be uneventful if a single failure occurs*	***Non-Certified:*** *No known actual strength rating*
Exposure/Consequence: *Potential for (harm injury to humans) or (damage or failure of gear)*	***Competent:*** *Educated, Experienced Rescuer*
PC: *Progress capture (mechanical or soft)*	***Force Multiplier:*** *Increased force, applies more than the actual load*
Temporary PC: *Two or more rescuers controlling the load*	***Protection:*** *Durable secured material*
Load Path: *All components from anchor to load, including the anchor and load (rescuer/victim).*	***Qualified Anchor:*** *Non-Certified Anchor deemed useable by two or more competent rescuers*

Personal Rules

1. Personal loads ≤ 140 kg. (308lb) shall not be exposed to greater than 12" of system slack or fall potential.

2. Rescuers shall be secured with 2 points of contact. Points of contact: (A&Ox4 rescuer with 3 human points, DCDs, knots, tensioned hitches, **Zero slack** ascenders or hard cams, soft goods, Carabiners, ASAPs, dynamic lead climb concepts). Rescuer SRT may be allowed if deemed to reduce risk to rescuer and/or patient and at the discretion and agreement of 2 competent rescuers.

3. When within 1.5x body lengths of a fall potential greater than 6' rescuers shall take a knee. Any closer shall be on the belly unless secured with work restraint, rope systems or fall protection "100% tie off". (Fall protection may be required by local industry, rules, and/or distances may be greater for sloping, slippery or loose edge areas).

4. Rescuer climbs made in vertical or sloped environments >40°, cages, or confined shafts shall follow the rules of competent climbing, unless deemed to do greater harm.

5. Low angle environments may dictate redundant systems if the consequence/exposure is significant.

6. Rescuers **shall not** rappel without ascent/self-rescue gear appropriate for the task/environment.

Anchors & Rigging

1. Anchors will be Unquestionable**/Certified** or **Non-Certified.** Non-certified anchors will be deemed capable of withstanding the anticipated forces by two or more competent rescuers.

2. Redundant load paths shall be identified for live loads with greater than 6' of fall exposure, **unless deemed to do greater harm** *(Rigging plates, solid or screwed shut rings, Kootenays, and approved anchor points require no redundancy) (Inspect the Rock Exotica Bolt plate).*

3. Reduction of consequence deemed by two competent rescuers may replace redundancy. **(CTR Oversite required)**

4. Live loads ≥ 204 kg. (450lb) shall not be exposed to greater than 12" of fall potential.

5. Single point failure shall not result in load shift or extension beyond 12" vertical, or lateral movement that has potential for harm or damage to the load path.

6. Internal rigging angles ≥ 120° and COD angles ≤ 90° will be considered force multiplying and **shall be** recognized by the rigging group leader (rope angles < 60° will be considered deviations).

7. All live loads shall maintain tool or hitch based PC during suspension, lowering, or hauling operations. (Two rescuers' hands on software may be considered **temporary PC**)

8. All potentially harmful surfaces to rope or rigging shall require protection and or be evaluated by two competent rescuers.

9. All system force resultants shall be identified prior to loading.

10. Dual Main / TTRS systems will attach to the same physical location of all loads, unless deemed to do greater harm.

Patient Packaging & Rescue

1. Patients with a pulse will have a manufactured harness (victim or Class 3) to a redundant rope system when packaged. Patients packaged in litters (baskets) **shall be** secured with a commercial harness to the litter, with an outer lash for securement, and all extremities secured. Any suspected airway concern will mandate lateral packaging for the pt. Litter patient packaging and litter bridles with a master attachment point deemed acceptable by two competent rescuers **will not** require a direct patient attachment to the rope system.

2. Pulse-less patients may be moved by any method that allows for rapid, life-saving treatment.

Original Concept Arnold Peña – AERT - 2024