Static and Dynamic Considerations RQP Level

Critical Angle Considerations of Technician Level Rigging

Most rope technicians have some understanding of the Static System Safety Factor (SSSF) when analyzing their rope rigging. In short, the SSSF is identifying the weakest link in the system when the load is suspended and in a static state, not moving. A force multiplier is any factor or condition that contributes to the overall stress of a rope system during a dynamic state. Rating this dynamic state or rope movement/stress is best represented as the Dynamic System Safety Factor (DSSF). In other words, what is our weakest link during the operation of our rope system at its point of greatest stress, typically during onset of a hauling process?

During this Module five areas of misunderstanding will be examined that are commonly seen in the rope access and rescue environment: 1) Force Vectors, 2) Tensile Force, 3) Compression Force, 4) Friction, and 5) Torque.

Rigging is not a game of chance; there are no educated guesses, every action and subsequent reaction is completely predictable!

Anchor Physics

How strong must a rescue anchor system be? We can talk about safety margins or the size of the intended load…in terms of a physical answer; the anchor system must be strong enough to support the resulting force applied to it. This is a black and white issue…will it hold? Or is there a chance it can fail? This decision is highly predictable and should be obvious to a qualified rope rescue practitioner. It all starts with a clear understanding of the resulting forces that will be applied to the anchor system during the predicted time of greatest stress of the rope rescue operation.

*In other words…what is the direction and magnitude of the force vector?*
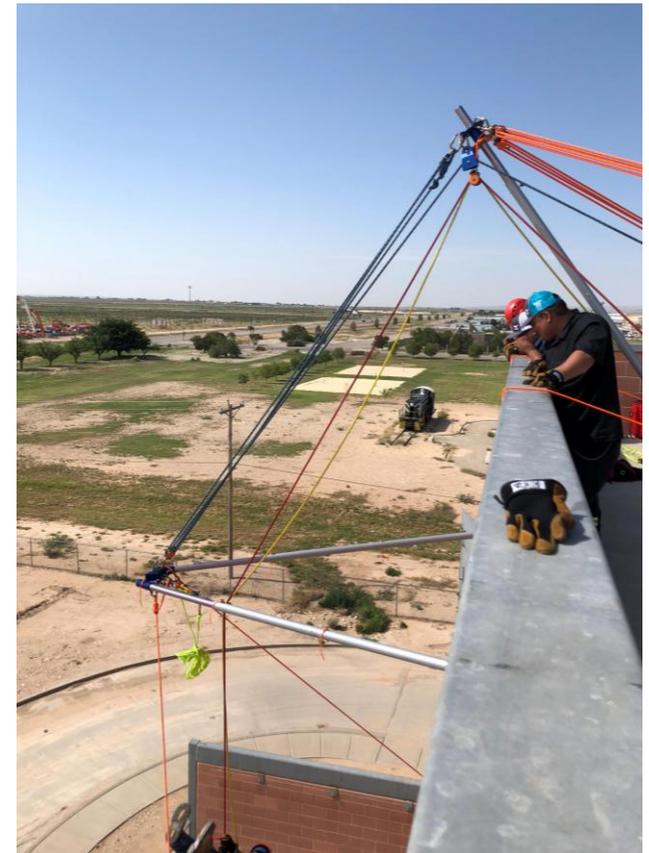
Force Vectors

To have a better understanding on how force acts upon any anchor at least some aspects of trigonometry and vector physics is desirable. The knowledge of angles, components, and resultants is synonymous to quality rope rigging. To study vectors is to study the physical qualities of force that has both direction and magnitude.

A force vector may be graphed or represented as a simple arrow, also more commonly referred to in math as a component. This component will always indicate the direction of the force.
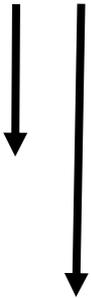
When we compare the length of one force vector component to the length of another force vector component, we not only have the direction of each vector, but we now can compare their magnitude relative to each other. Therefore, the component that is the longest has a greater magnitude. In fact, simply by comparing the two components we could deduce that the second is about 2 times more powerful or stronger than the first.

The force of any resultant/vector acting upon any two components of an angle can be realized by drawing a parallelogram that matches the components and is bisected by the vector component. *Within the boundaries of the parallelogram* we can simply measure each of the three components (C1, C2, and R) and based on the known magnitude of the resultant (R) we can then assign a value to C1 and C2.

C 1

C 2

R
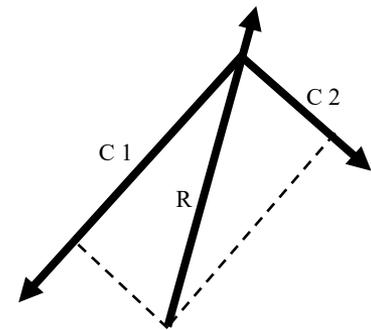
When a rope runs through a pulley to create an angle, the pulley equalizes the components of that angle and renders them equal. The resultant (in this case, the pulley) will always seek the location halfway between the two rope components.

The center of any tensioned pulley will always point to the exact location and direction of the resultant force at work on the associated anchor.

The use of the parallelogram still works well in determining the resultant force, its direction, and magnitude.

Once again, the resultant of any pulley will find the middle point between the legs of rope going in and coming out of the pulley.
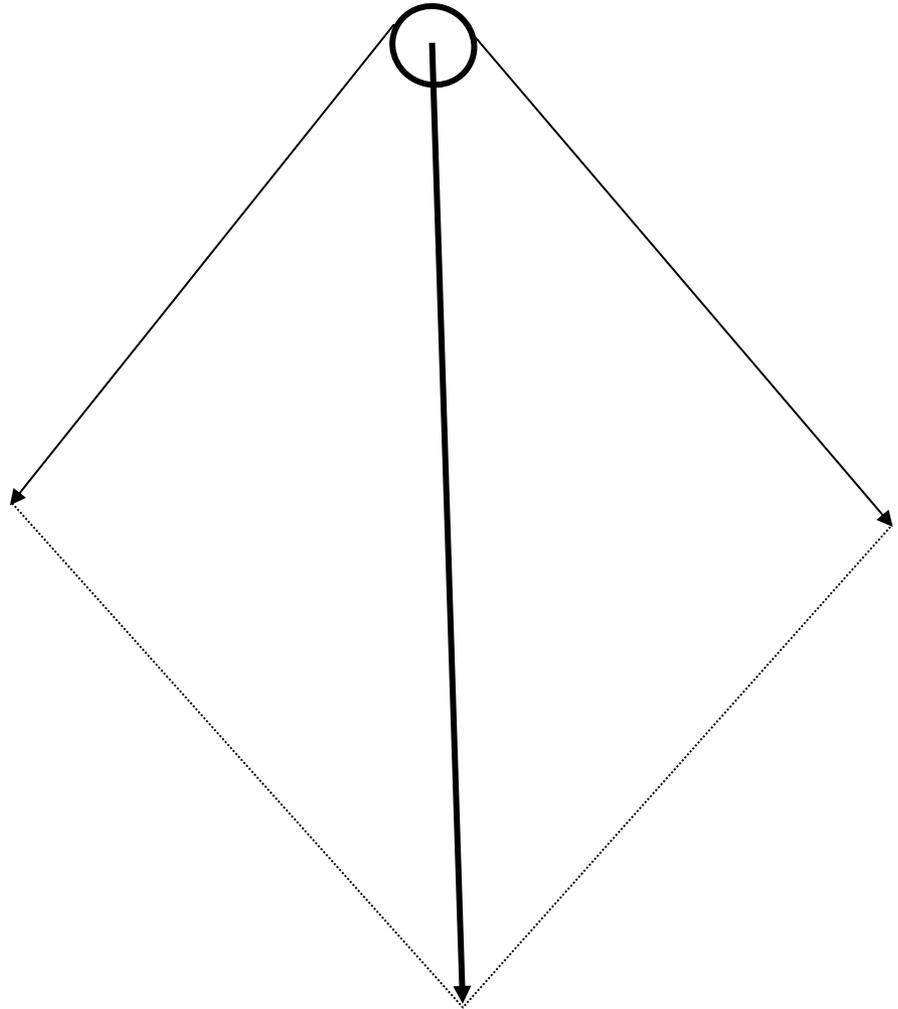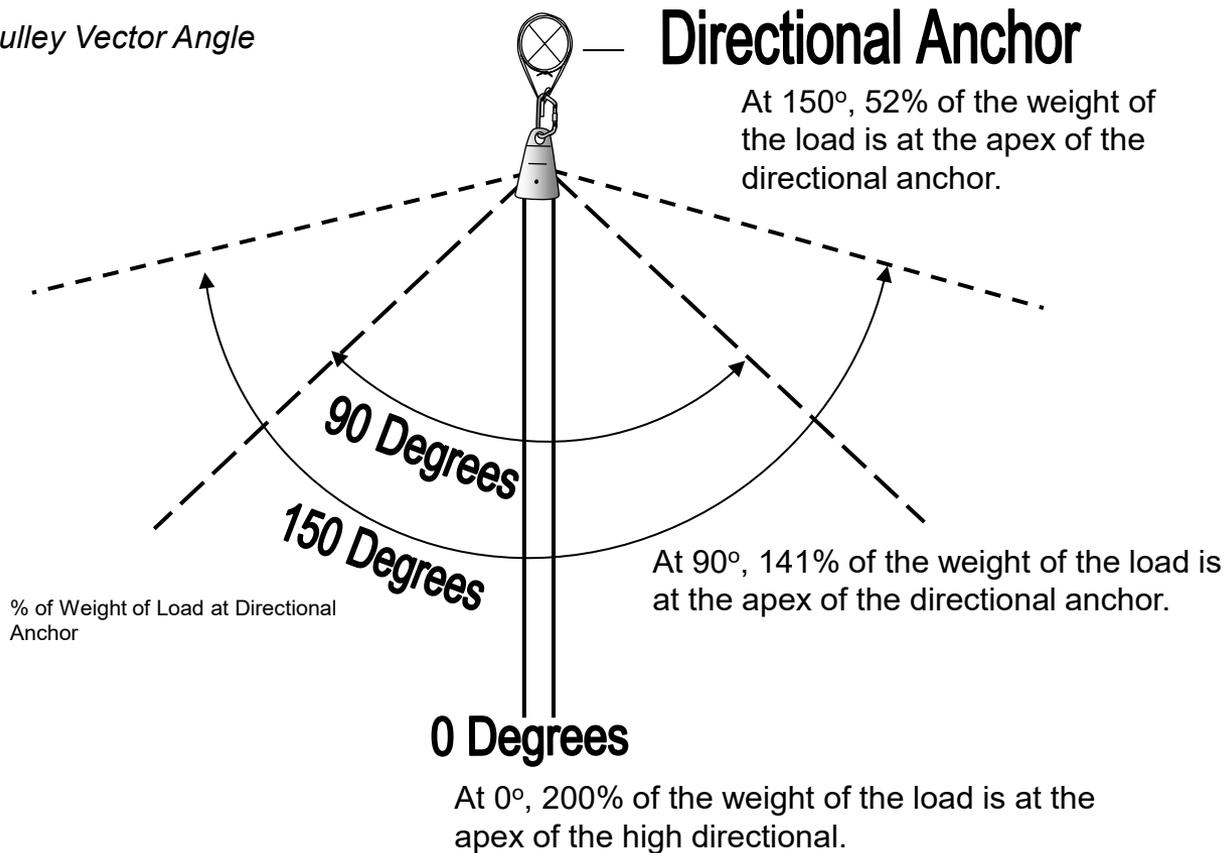
Force Vector Formula for Directional Pulley Anchors

This topic will be addressed in detail during the hands-on segment of this training.

% of Load on Pulley Anchor = $\cos\{_<(0.5)\}$ **(2)**

< = Pulley Vector Angle

Directional Anchor

At 150º, 52% of the weight of the load is at the apex of the directional anchor.

90 Degrees

150 Degrees

% of Weight of Load at Directional Anchor

At 90º, 141% of the weight of the load is at the apex of the directional anchor.

0 Degrees

At 0º, 200% of the weight of the load is at the apex of the high directional.

Force Vector Formula for Multipoint Anchors
This topic will be addressed in detail during the hands-on segment of this training.

By using this trigonometry function, we can look at ½ of the entire system. Doing so, we can derive the amount of tension at one anchor by creating a right angle between the resultant component of the load and one leg of the system.

$$T = \frac{(L)(.5)}{\cos \phi}$$

The tension of one leg of the vector angle is realized by dividing ½ the load by cos ϕ (the ratio of the sag over one leg of the vector angle; adjacent/hypotenuse).

Resultant

T

ϕ

L
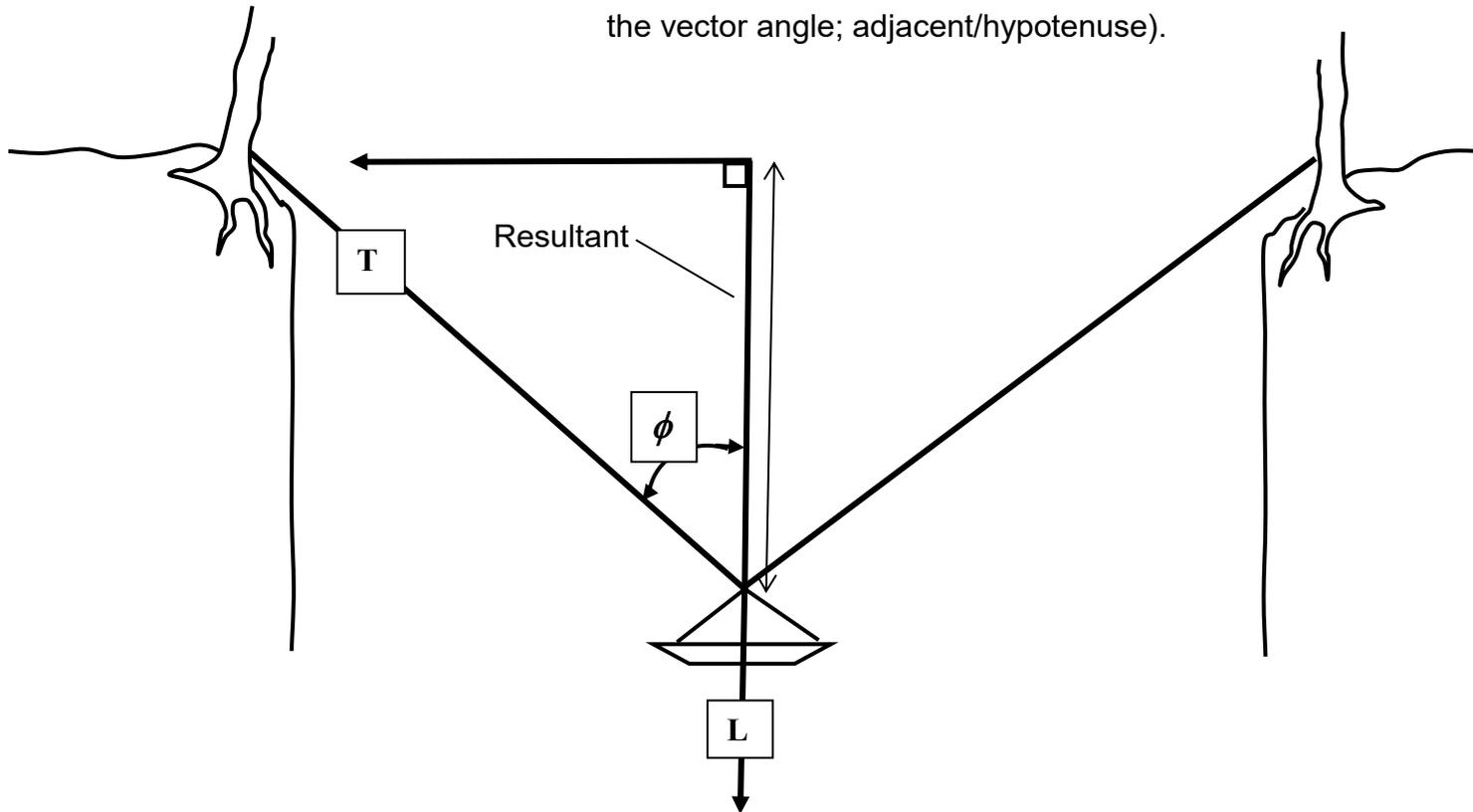
Tensile and Compression Force

Footprints – A Prelude to Understanding Compression

What is meant by the *"footprint"* of a tripod? Most rescue techs understand this term when using a tripod…but what about other forms of anchors, especially elevated anchor systems?

The footprint is exactly what it says. The footprint you make in the sand is created by the compression of your body weight on your legs and down to your feet. Therefore, we can say the footprint represents compression. The same criterion applies to all artificial high directionals (AHDs) such as tripods, bi-pods, and monopods. The footprint defines the area of compression between the legs of these anchors.

Tripods
The resultant must stay within the triangle area 'footprint' created by the legs.

Mainline Anchor

Load
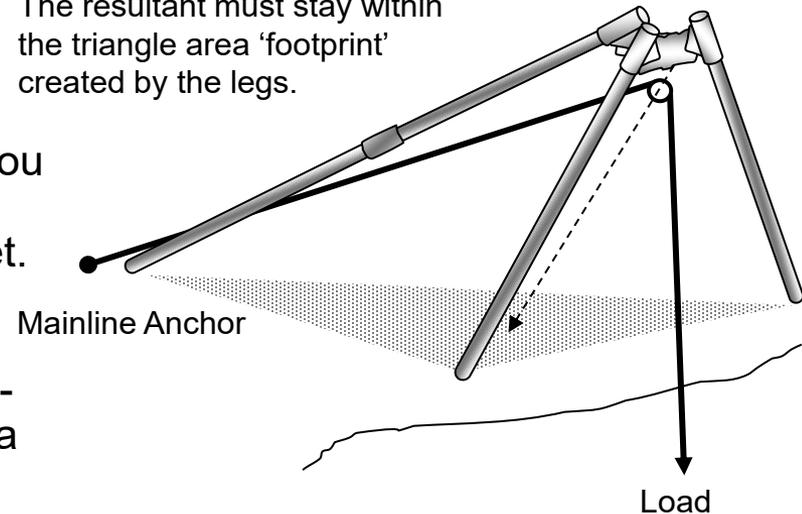
Tensile and Compression Force Continued…

Stand up and look at your feet…why do you not fall over? The answer is that the resultant force of your body is perfectly focused on that invisible line that defines the area of compression between your feet (footprint). The moment that you lean your body backwards you focus your body weight (resultant force) backwards and you start to fall, thus the need for something to grab a hold of to prevent the fall (a back-tie). In a hypothetical perfect world of balance, we would be able to keep our high directional pulley focused right on that single line defining the footprint of an 'A' frame and it would never tip over, or we could keep our gin pole from falling simply by focusing the high directional pulley straight down the pole on its single footprint.
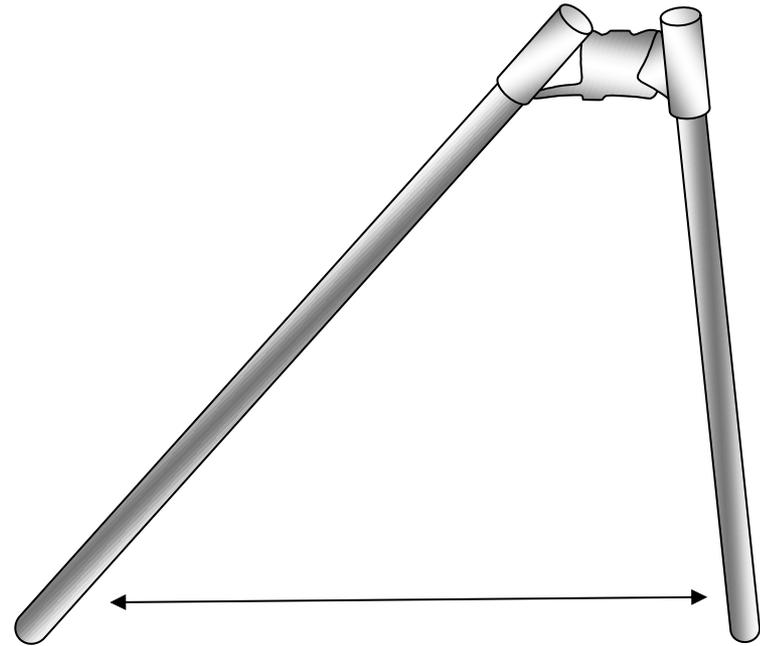
The footprint of an 'A' Frame is a single line between the legs.

Tensile and Compression Force
Continued...

Of course, this is virtually impossible. There will always have some movement due to elongation of the ropes in the back-ties, and inefficiencies of the pulleys. Therefore, the ability to rigging quality back-ties and accurately engineer the resultant of the pulleys to maximize the compression of the legs is vital for advance use of AHDs.

In the world of rigging, tension and compression must be addressed at the same time. Most rope technicians associate units of tension with the study of pulleys and mechanical advantage systems. While this is indeed a critical factor of pulley systems, it is important to remember that the same physics that characterize tension in the study of pulley systems is also applicable to every single act of rope rigging. The instant a single piece of rope is tied and loaded; units of tension become a factor.

Compressive and tensile forces are symbiotic. As with all forms of construction, (rope rigging included) one cannot exist without the other. Not only must harmony exist between tension and compression, there must be equal synchronization with all aspects of rigging physics. The bottom line revolves around the anchors. Will they hold, or won't they? What is the exact force vector being applied to the anchor? What is the resultant on the anchor? Is there an adequate amount of tension/compression at work to guarantee the integrity of the anchor?