Simply Circus, Inc.

86 Los Angeles Street
Newton, MA 02458
617-527-0667
info@SimplyCircus.com
www.SimplyCircus.com

10/2015

The following article is an early draft from the book *Introduction to Rigging: Existing Structures* by Steven Santos. Given the prevalence of the 'tree rigging' question, the author has chosen to release this draft of the article now. The final version will likely contain a great many changes from this draft.

Rigging Trees

Many aerialists love the idea of rigging to trees, especially the connection to nature that brings with it. But it's not that simple. In this resource guide, we will give you short, medium and long answers to the issues of rigging to trees.

This article is laid out to give different answers to different level readers. From the 140 character twitter appropriate answer, to the slightly longer Reddit appropriate answer, to the several paragraph Facebook appropriate to full blown journal appropriate answer. Each level drills deeper and deeper into the subject matter. The intention is that when you get to a section you don't understand, you should still have a workable answer from the previous section.

It is our hope that this article

1. Answers the tree rigging questions that most commonly come up
2. Gives people a better understanding of why those in the know say tree rigging is a REALLY complex subject
3. Gives those few who are inclined to do it right the tools they need to start the learning process.

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The reader is warned that this is absolutely NOT a “how-to” guide! This article glosses over a large number of important points that can’t be easily described in this format. Additionally a vast amount of the information needed to properly rig trees for aerials is so dependent on the species of trees you are using and the soil conditions in the area you are in. Make sure to see the section on what is NOT included in this article.

The REAL Answer

Tree rigging has long been a dark art of rigging. It’s a dark art not because it’s an impossible art (it’s not) and not because the skills are impossible to learn (they are not). Tree rigging is a dark art because it requires a huge amount of crossover training that very few will ever take the time to get. More importantly, this art requires the rigger to really know and understand how everything in the system impacts everything else. This requires a huge amount of mental manipulation on the riggers part, far more than the average person can easily do. Because of this, tree rigging will likely remain a dark art for the foreseeable future.

As anyone that is actually qualified to rig trees already knows, the information contained in this article is at the same time completely correct, and woefully inadequate for the task. Everything involved with rigging trees has all sorts of nuances to it that takes years of experience with the specific skills involved in both trees and aerial rigging before you should even think about trying this ‘dark art’. By the time any individual has the experience and training in both trees and rigging to be developing these complex systems, they already know more about rigging than could possibly be crammed into these few pages. Every topic covered in this article is a vast topic in its own right, and you really need to understand each and every one of them before you ever think about rigging a tree.

Getting the effect without the live tree

For everyone else, perhaps you want to look at how to get the same effect without the live trees.

Consider building a tree-like structure instead. Here is a great example that has the feel of hanging off a tree, but none of associated problems of dealing with live trees.

The Twitter Appropriate Short Answer

NO! Don’t do it! It’s not safe! Get a freestanding rig from a circus vender! You evil tree killer!

The REDDIT Appropriate Short Answer

If you are reading this, chances are you are not qualified to rig a tree, so for the health and safety of yourself, other aerialists, the general public and the trees, don't rig to them.

Yes, it is possible to rig a tree so that it is safe for the aerialist, bystanders AND the tree. You will spend more money doing the rigging than you would spend on a freestanding aerial rig from one of the major vendors.

The Facebook Appropriate Short Answer

Rigging trees can be a really tough, as the results of our actions are, more often than not, invisible for many years. People will throw apparatus on a branch and get lucky enough that many think it's a safe practice. Poor rigging practices may not lead to the immediate death of the performer, but they usually lead to the slow death of the tree.

Go back to that tree you practiced your fabrics on a few years ago and you will find, more often than not, that your couple of weeks of aerial play on that tree branch caused the collapse of the veins of the branch and that in turn led to the slow death of the branch. If you're lucky, the tree only lost a limb. Often, the death of a large branch can effectively poison the rest of the tree and now a 200 year old tree that had been perfectly healthy is now dead from our aerial play. That's just from improper attachments.

Lets say we do use the proper attachments, but we don't pay attention to the fact that the roots on the opposite side of the tree from the branch we use are grey and slimy. Now we do our aerial thing, including a couple of drops. Those drops caused the root system that was already distressed from disease, to become even more distressed. In response, the tree separated from those roots. Now the tree has effectively lost 40% of its nutrient supply, leading to a slow, irreversible death over the next 2 or 3 years.

Only a handful of aerial riggers have the cross-over skills to do the level of inspection needed to (1) determine if the tree can be rigged safely or not, (2) do the tree care needed and (3) make all of the attachments that will protect the long-term health of the tree at the same time as making it safe for the aerialist.

Think about these questions:

1. How do YOU know if this tree has internal rot?
2. How do YOU know if that tree is ready to drop that branch we want to rig to because the tree has decided that it's the best way to conserve the water it has?
3. What care does this tree need before we rig to it?
4. What kind of attachment is going to protect this tree?
5. What kind of forces do we need to be especially careful with?

Rigging trees is really a much more complex topic than you're going to get a good answer on from Facebook or YouTube. The reality is that properly rigging trees will cost a lot more than buying a freestanding rig.

The Journal Appropriate Version

If you ask most professional riggers about rigging trees for aerials, they will flat out tell you it's a bad idea. Ask the question on the Safety in Aerials group (that's one of the Facebook groups where all the cool kids hang out with the aerial riggers and professional performers – you can join that group at https://www.facebook.com/groups/622174321133562/) and you get a resounding NO. It's not that rigging trees safely is impossible (it's not), but the bottom line is that few professional aerial riggers have the cross-over skills needed to understand and rig trees properly, and even fewer arborists have done the work to learn about the forces aerial rigging places on trees to do it properly. This translates to a VERY small number of people with the requisite skills to do it correctly.

As one of the few aerial riggers that has done this research, that will occasionally rig trees and who will talk about the process, it is my hope that this document will act as a road map for the very few that will put the energy into learning to do it right, as well as to show those looking for a quick and cheap place to rig that trees are not the answer.

Understanding Forces

As a general rule, aerialists will regularly produce 7 times their static body weight while performing aerials, and some maneuvers will produce as much as 10 times their static body weight. Compare that to the average tree swing, which typically sees about twice the static body weight and you start to get the picture.

One major issue that aerial riggers need to understand about the forces that aerials put on to trees is that the force profile of aerial arts is unique. The forces produced by aerials tend to have a large number of shock-loads as we climb and descend, and high shock loads when we do drops.

The load profile of a tire swing fairly closely matches the forces a tree limb will see in a high wind. The load profile an arborist places on the tree during tree care is also an un-natural profile, however arborists generally place only a fraction of the number of shock loads on a tree that an aerialist will.

The loading profile of felling branches may put a similar loading profile on a tree, however this is typically a one off event, with the tree having the entire growing season to fix the damage. Trees used for aerial arts are typically used over and over again, the damage to the tree being cumulative. This makes the loading profile very different from anything the tree will otherwise see.

Nothing in nature and nothing in general tree care presents the same load profile on the trees as we do with aerial arts. As such, we need to take a lot more care when installing aerials than we do when throwing up a tire swing.

A note on Ropes and Slings

A lot of people use ropes to fix aerials on trees so that they "don't hurt the tree", but the damage the ropes actually do is much greater in the long run, especially the damage from the shock loading.

As noted above, ropes and slings are acceptable methods of attaching tire swings because of the load profile those typically see. The load profile of aerial arts make ropes and slings (even with soft padding) an inappropriate method of rigging to trees. The repeated shock loading of the ropes tends to produce significant damage to the cambium, even though such soft padding.

Given our loading profile, anything tied around the trunk or branches will cause damage to the area where the rope comes into contact with the bark (and its underlying cambium) each time it is shock loaded. While any single shock load is no worse than the load an arborist puts on a tree, the cumulative damage from shock loading is significant. The more shock loading that is applied over the same area of cambium, the more damage it causes and the less ability the tree will have to recover from it. If a rope is tied around the whole branch, it will gradually strangle the branch, even well after we remove the rope.

I stress that this cumulative effect of shock loading ropes and slings on a tree is detrimental to the cambium of the trees, and must be avoided. See the section on tree attachments for proper methods of connecting to trees for what to use instead of straight ropes and slings.

The Inspection Process

Tree rigging should ALWAYS start off with a proper inspection. The inspection process needed for assessing a tree for use in aerial arts is a high-end inspection usually reserved for trees that are worth a LOT of money. The definitive and in depth tree inspections needed are a specialty skill within the arborist community. It's not an inspection that most arborists are qualified to do, or one that gets practiced by many arborists. Large, high-end tree care companies may do one or two of these inspections a year. Many, if not most, smaller tree care companies will have never done this level of inspection.

The following is a VERY GENERAL over view of the inspection process. Keep in mind that it will take an experienced professional the better part of a day to inspect a single tree for possible use in aerial arts, and even then, more than half of the trees I have inspected have failed.

If you do the following inspections correctly, it should take an experienced person 6 to 10 hours to do. If you find yourself finishing in a fraction of that time, chances are you have missed a LOT!

Inspect the Soil and General Conditions

A good arborist will spend a significant amount of time inspecting the general area and the soil around an heirloom tree to get an idea of the conditions the roots are living in. This kind of inspection is not usually needed for "run of the mill" trees, however, because of the unusual loading aerials put on a tree, we need to make sure the conditions of the soil and general area will allow the tree to recover from the stresses we will be placing on it.

Inspect the general area

When you inspect the general area, you are looking at the general health of trees over about a 50,000 square foot area. Here you are looking for any systemic problems with the trees in this area. This includes:

- Signs of blight. If the trees in the area are suffering from blight, this is a strong indication that they are not healthy enough
- Significant tree damage in the area. This is often a sign of a localized event that may render the trees unriggable
- The soil conditions in the area. If the soil in the area isn't healthy, the stress of aerials has a much higher chance of killing the tree.
- If the tree is leaning in one direction. This can be an indication that the root-soil system of the tree is failing. Even if it is not failing, our shock loads will stress the roots on the opposite side of the lean significantly more than on a tree that is not leaning over. Any tree with a significant lean should not be rigged to.
- Anything else that calls into question the general health of the trees in the general area. Lots of texts are available online about assessing the general health of trees in an area. If you are thinking about rigging trees, you should be reading up a lot on this subject alone.

Inspect the trees at 2x drip line

The drip line of a tree is the line where the water primarily sheds around the edge of the tree leaf canopy when it rains. This is the beginning of your focused inspection. You are mostly looking at the soil health for your specific tree.

Some specifics to look for include:

- Soil compaction. Soil that is too compact has a significant impact of the trees ability to recover from stress. If the soil is too compacted over a large area at twice the dripline, say from a road or from multiple pathways of people regularly walking under the tree, then it's likely not a good candidate for aerial rigging.
- Ledge. If the tree is on ledge, it's an indication that the roots don't extend down as far as they otherwise would. This can indicate that the tree isn't as strongly rooted as we may want it to be. If you have a significant amount of high ledge, the tree should not be rigged.
- Loss of leaf cover in the crown of the tree. This is a sign of an unhealthy tree, and any tree showing this should not be rigged to.
- Leaf discoloration. Unnatural leaf discoloration is a sign of tree stress. Any tree showing this should not be rigged to.
- Any other conditions that may make the roots of the tree weaker. Depending on the species of tree, a lot of other soil conditions can call the health of a tree into question.

As a general rule, unhealthy trees should not be rigged, as the additional stress of aerial rigging can push the tree over the edge.

Using an auger, dig out a 5-foot hole and look at the results. What you expect to see will differ by species and location, but the contents of that hole will give you a lot of information on soil health in the area.

Inspect the drip-line of the tree

The condition of a tree's drip-line, when placed in the larger context of the health of the general area, will tell you a lot about the tree. Things to look for include:

- Health of the soil. If the soil is unhealthy, the tree should not be rigged to.
- Soil compaction. If you have significant soil compaction over 20% or more of the area within the tree's drip line, the tree should not be rigged to.
- Insect populations. While insects are normally found on trees, a few things to look out for are:
    - Carpenter Ants. Lines of carpenter ants on a tree are a clear indication of heartwood rot. If you see these on a tree, do not rig to it.
    - Termites. Termites feed on the heartwood of trees. Significant signs of termite damage on a tree is a clear indication that the tree should not be rigged to.
    - Bees and Wasps. They tend to get angry when we shake the trees.
- Signs of birds and animals in the trees.
    - Protected species. If a tree is home to a protected species, don't touch it.
    - Woodpeckers. Woodpeckers are an indication that a tree supports a large insect population, usually carpenter ants. If a tree hosts a carpenter ant nest, it should not be rigged to.
    - Birds living in hollows. Hollows indicate heart wood rot and disqualify the tree from being rigged to.
- Inspect the branches. If they do not generally appear healthy, do not rig to the tree.

The reader is warned that the above list is glossing over the complexities of this inspection. Each of these is a subject you could easily spend months of full-time study learning.

Under Canopy Inspection

Inspect the soil at 1/2 the drip line.

- What kind of traffic does this area see? The closer you get to the trunk of the tree, the larger the impact of soil compaction is. How it affects the health of different trees is a complex subject. What is acceptable for one species of tree is completely unacceptable for another species. The reader should seek out specific training in this for the trees in your area.
- In at least three places around the tree dig down and inspect the roots. The different colors, textures and smells of the roots tell you a great deal about the health of the tree. This is again an area where you will need to seek out local resources for additional training. What is healthy for one species may be unhealthy for other.
- Look at the makeup of the soil. Is it Sandy? Loamy? Rocky? Dry? Moist? Do you find worms? How active is the biology in the area? All of these things matter in terms of what kinds of loads the tree can take, and how the weather will affect the tree.
- What is the water table? How deep the water table is plays a BIG part in how strong the root structure is. This is yet another area where you will need to do some research to learn about.

Inspect the root ball; the 6 foot radius around the tree is critical.
Things to look for include:

- Soil conditions. The soil conditions at the root ball are VERY important. Make sure they are correct for the tree you are using. This is yet another area where you will need to research the trees and conditions specific to your area to determine what is acceptable and what is not.

- Soil compaction. For virtual all species of trees, excess soil compaction in the root ball is an absolute contra-indication for rigging a tree. If you have a road, driveway, walkway or heavily traveled path within the root ball area, the tree cannot be rigged.

Inspecting the trunk of the tree.

If you do the inspections correctly, you will have spent a good 6 hours already looking at the area around this tree, and that's assuming you already know your trees or are doing this with an arborist. At the end of these inspections, you will know a lot about the trees you have inspected. The inspections you have done thus far may disqualify a tree from being rigged, but are still not enough to know if the tree itself is riggable. For that, we need to inspect the tree itself.

Different species of trees have entirely different parameters for what is riggable. You will need to research this extensively before rigging ANY tree, but especially older trees.

Take a good general look at the tree. Is it healthy? Is it in good condition? Is the tree growing at an odd angle? Does the tree have widow makers living in it? Does the tree have fungal fruiting? Does anything seem odd or off about the tree? In order to make these judgments, you will need to know a lot about the species of tree you are inspecting. This is another good area where taking the right class can help a lot.

Inspect the tree for wildlife. We checked this before when we looked at the general area, but now its time to take a closer look. Use your binoculars to carefully look the tree over. It is ESPECIALLY important to check for endangered wildlife. Where you are will determine what wildlife you need to look for, and how you check for it. Remember that bees/wasp living in the tree won't like you rigging to it (and they may painfully tell you so!). Termites and carpenter ants can totally disqualify a tree from being rigged.

Inspect the trunk of the tree. You will need to do the research to determine what is correct for the trees you are looking at:

- Inspect the bottom of the trunk, the first 3 feet from the ground. Is it in good condition? If it is not, do not rig to the tree.
- Inspect the bark of the tree. Is it peeling, have open scares or does it show signs of excess wear? If so, do not rig to this tree.
- Inspect the trunk for signs of burls. These are cancers, and any tree with one should not be rigged.
- Inspect the trunk below where you will attach to. Does it have any obvious hollows or other signs of damage? If so, do not rig to this tree.
- Inspect the tree above where you will attach to. While you are a little more tolerant of flaws above where you will rig (including rigging of any stays), if what you find makes you question the stability of the tree above, do not rig to this tree.
- If the trunk splits, you need to inspect how it splits. Rot issues are common at splits and this can be significant. The parameters for what is and is not acceptable depend on the species of tree you have. You will have to use local resources to research this for your particular species of tree.
- Inspect the trunk for the presence of climbing vines. These can put significant stress on a tree. If a tree has climbing vines, especially if the vines are chocking the tree, do not rig to it.
- Sound the tree. If the sounding shows any signs of internal decay, do NOT rig to the tree.

Inspect the branches. You need to inspect every major branch of the tree (not just the ones you are using). What you are looking for are signs of rot or other damage. Exactly what you should look for depends on the species of tree and the area you are in, but the process is mostly the same as looking at the trunk. The one big difference is that you need to also look closely at where the branch connects to the tree. If the connection of the branch to the trunk shows any signs of damage, do not rig to this tree.

The strongest limb attachment is the 90 degree angle. A 45 degree angle can be ok if properly stress relieved, but limbs with less angle tend to have included / invaginated bark which weakens the joint between forked limbs, or limb and trunk. Also included bark may allow high winds to tear the tree apart at the weak spot.

Sounding a tree

Sounding a tree is the process of using sound vibrations to look for internal damage. As you read this section, be aware that we glosses over a number of important points that can't be easily described in this format, including the sounds different trees and different decays make and the qualities of the different types of decay (dry rot vs wet rot vs insect damage, ect). Anyone attempting the skills described in this article should seek out specific training in this subject from a qualified expert that knows the local trees and that can help you learn the meanings of the various sounds, the qualities of different decays and other specifics of sounding out a tree.

Principals of Sounding

Sounding is the process of using the vibrations of wood to determine the internal health of a trees heart wood. When we strike the tree using a rubber mallet, it causes the tree to vibrate. Intact wood will resonate at fairly consistent frequency, whereas decaying wood is significantly softer and the sound waves don't travel through it as well.

Manual Sounding

The process of manually sounding a tree begins with a rubber mallet. We hit the tree using a moderate strike. This should be a consistent and well-practiced strike, as this makes it easier to compare the sounds you hear across different trees.

The general idea is that healthy, Intact wood will have a consistent sound to it. Decayed wood will have a more hollow and "thuddy" sound to it. The tricky part is hearing those in between sounds where you have some decaying wood. This takes a significant amount of practice to be able to hear and understand what the various sounds mean.

When sounding any tree, the further away from the decaying wood you are, the less obvious the decay sounds will be. For all practical purposes, when inspecting a trunk you should sound the tree every 3 or 4 feet of the trunk to at least 6 feet above the highest part you will use (including for guy lines). If your trunk is more than 24 inches in diameter, not only do you need to sound the length of the trunk, but you should also sound the trunk in multiple places around the circumference of the tree. This will give you the best possible picture of trunk decay, short of spending money on the toys.

How much decay is too much?

This is a tough question to answer, as to some extent, it depends on the age and species of the tree. According to some studies, virtually every tree has SOME decay to it, so at some level if you are rigging trees you can't get away from it. On the other hand, given what we are doing with these trees, our tolerance for decay has to be relatively low. A good general rule of thumb is that you want no more than about 5% decay in any part of the tree that will be supporting your loads. Any more than that and you're getting into the engineering of the tree, something you're very likely not qualified to be doing. Best leave those trees alone.

The Rigging Process

The process of rigging trees is a difficult one. The following basic principles of tree rigging should be observed by all who delve into this art:

1. The tree should be left in better shape than you found it in. This means doing all of the tree care and maintenance the tree reasonably needs, not just before and after you use it, but over the life of the tree.
2. Treat the tree as if it has fallen down. This applies equally to both the trunk and the branches.
3. Use only attachments that will protect cambium (the trees equivalent of vanes and arteries) of the tree. This means learning about Tree Attachment Bolts, J-hooks, through-and-throughs and other methods of protecting the cambium and NEVER choking the tree with a rope or a sling.
4. Understand the force amplification factors present in tree rigging. Shock loads, pulleys and Torque are all forces that apply and that need to be addressed.
5. Understanding column loading of trees
6. Trees can not be left rigged for very long; always derig after use.

The first part of selecting your trees is finding the appropriate species of trees. The following are VERY general statements. Always make sure to learn about the trees in your area before selecting one to rig to.

Avoid:

- Hardwoods, such as oaks and hickory trees. These trees are popular among aerialists because they tend to have branches high up and because they are really strong. They tend not to be so popular with those that rig trees because they are really stiff and generally don't handle the shock loads aerial arts place on them as well as other species of trees do. Hard woods also tend to rot from the inside out, making it a lot harder to detect defects in the tree.
- Trees that are too old. Very old trees often have defects that are hidden.
- Trees that are too young. Very young trees are easily damaged, not yet having built up the extra strength needed for this kind of load.
- Trees that are too small won't survive the loads.
- Trees that are too large usually have hidden defects.

Look for:

- Straight softwoods. Fir trees are often very good choices.
- Large, straight evergreens are good choices
- 12 inch or greater diameter trunk

- Tree that is old enough to have the needed structure
- Young enough to recover from the loads we will place on them.

In general, most states have laws, typically brought about in response to logging industry practices, that require 3 or more tensioned guy wires be used to support any tree used for overhead rigging. Depending on your location these must be made out of 5/8th inch or 3/4th inch wire rope.

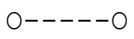
Tree Rigging Concepts

The two basic concepts for rigging trees are trunk to trunk rigging and branch rigging. Each of these presents its own advantages and challenges that the rigger must be aware of.

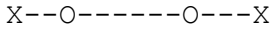
Trunk Rigging

Trunk rigging is generally the preferred temporary method of rigging trees, as it is more bullet proof than branch rigging is. The basic methods of rigging trunks are (1) the trunk-to-trunk method, (2) the anchored trunk method and (3) the fully anchored trunk method.

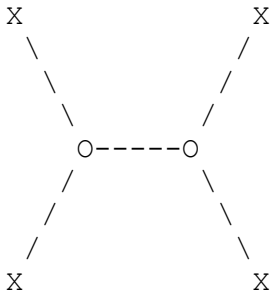
The trunk to trunk. This method of trunk rigging places a bridle point between two existing trunks. One major advantage of this system is that it allows for the natural flexing of the trunk of the tree. A connecting line may also be used. This method works, however it does not offer any protection against wind gusts dropping or throwing the aerialist, and it doesn't protect against unexpected failures of the root-soil system.



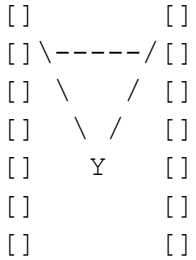
The Anchored Trunk to Trunk. This method is generally considered a step up from the trunk to trunk method. This method adds two guy lines (typically 3/4 of an inch 7x19 wire rope) to the center line. This method effectively stiffens the system, greatly reducing the sway and bounce of the rigging. It does not protect against unexpected failures of the root-soil system.



The Fully Anchored Trunk to Trunk. This method is generally considered the safest, most bomb-proof method of trunk rigging. This system effectively arrests all movement of the tree and it protects against any unexpected failures of the root-soil system.

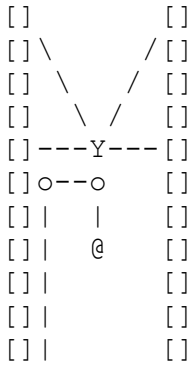


Center Guy



Center guys should be used for all trunk rigging setups. Here, a ¾" wire rope is run between the two trees

Pulley Points in Trunk Rigging

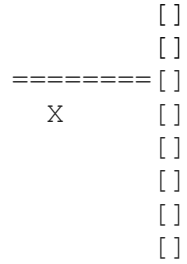


Branch Rigging

Like trunk rigging, all branch rigging is temporary. When we rig branches, we are building gantry cranes. See OSHA 1910. In most states, laws exist about this type of rigging that tend to make rigging them costly. Always make sure to read, understand and follow the applicable laws in your area reguarding the rigging of trees.

Most states laws on gantry rigging require that a branch used be supported by a guy wire located at or past the point, up to a location on the trunk at an upward angle of 45 degrees. This connection must be made using 5/8th inch or 3/4th inch wire rope. A second connection must be made between the trunk and the branch at a location just past the stem of the branch. In general, these laws also require three or more down-guys to stabilize the tree. These requirements are part of what makes tree rigging so expensive.

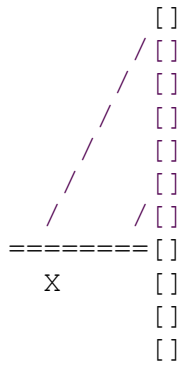
Unacceptable



The two big problems with this method is (1) that no one can quantify the strength of any given branch joint and (2) the further out from the trunk you are, the larger the lever effect is on the branch-tree connection.

The only thing you are relying on is the strength of that connection, which cannot be quantified, at the same time as you are placing a huge lever force on that connection. This is not acceptable for aerial rigging.

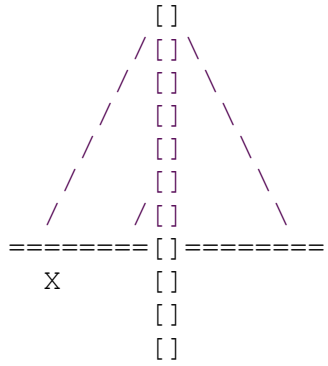
Sometimes acceptable



This method adds a stabilizing guy from the branch at the point up to a spot on the trunk. A second guy is added from the trunk to the branch at a point close to the trunk, but past the stem wood of the branch. The supporting guys must be able to take the load of the branch, plus the aerialist and related equipment.

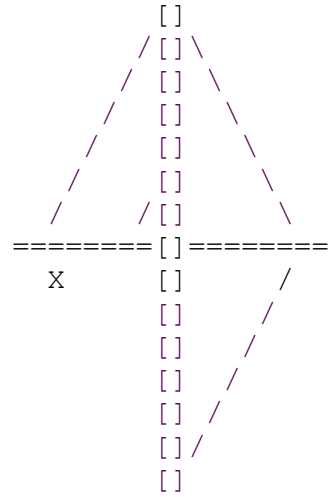
When rigging this way, we must understand that this is a temporary rigging method. It should not be used for more than a few days a year.

A little More acceptable

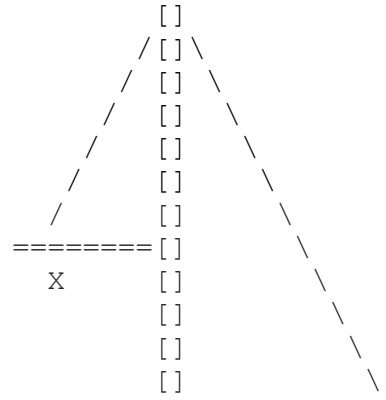


This adds an additional guy down to another branch of equal size. This resolves the bending moment in the trunk created by any possible failure of the branch by opposing it with the other branch.

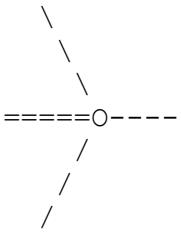
Still more acceptable



Actually acceptable



NOTE: the above diagram shows one guy line to the ground. In actuality it should have 3 at 120 degrees around the circumference of the tree, as shown below:



When done with proper connections, this can often be used for as long as a season, however, it still needs to be de-rigged each day so that the branches can move with the wind when not in use.

Torque

Torque is defined as the cross product of the lever-arm distance vector and the force vector. This is usually measured in foot-pounds. In terms of tree rigging, this mostly comes into play in branch rigging, where the branch acts as a leaver. To calculate out this force, we have to multiply the forces created by

the aerialist with the distance from the trunk to determine how much force we are actually placing on the stem of the branch where it connects to the trunk.

A 100lbs force applied 10 feet away from the branch creates 1,000 foot-pounds of torque on the stem of the branch.

100lbs x 10 feet = 1,000 foot-pounds of force

This can add up FAST in the world of aerials. Take for example a 125lbs aerialist doing a bomb drop that creates a shock load seven times their static body weight, or 875bls of force. If this is applied 10 feet out on a branch, you get 8,750 foot-pounds of torque.

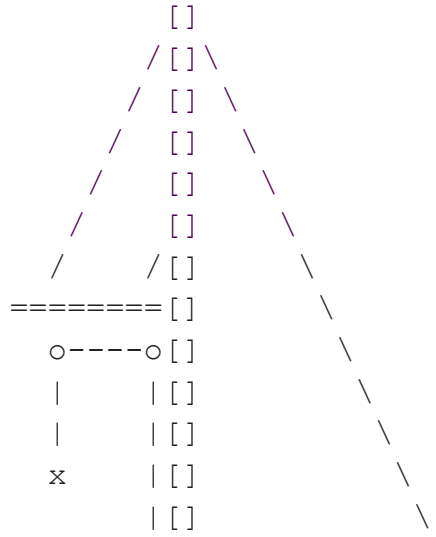
Now in reality branches flex, absorbing some of the force from the shock load. If we were to conservatively assume that half of the shock load reaches the stem of the branch, that's still almost a 2-ton load on that stem, a force that can easily damage the stem and cause a tree great stress, especially when repeated over and over again as we do in aerial arts.

Pulleys

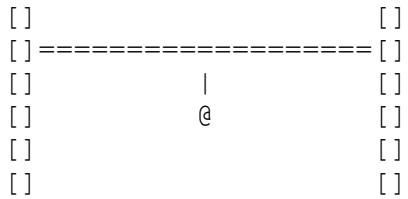
Pulleys are a force amplifier. This is especially important when combined with the lever arm effect. Depending on the angles involved, a pulley system can as much as double the forces the aerialist puts on the branch.

Lets say you have a 125lbs aerialist that does a drop generating only 5x her body weight, or (125 x 5 = 625) 625lbs. The pulley system doubles that to 1250lbs. Our pulley is 10 feet out on the branch. That gives us a torque multiplier of 10, which translates to 12,500 foot-pounds of shock load force being placed on the branch connection to the tree. That's a LOT of force.

When using a pulley, always make sure you use a double pulley system to put as little force as possible on the point and have a guy wire up from the point to the trunk to take the force off the branch connection as much as possible.



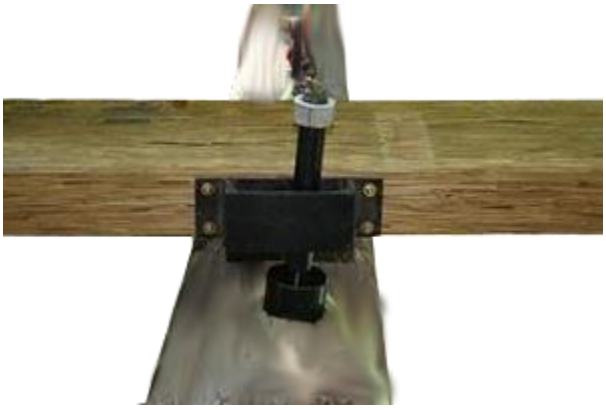
Treehouse Rigging



Treehouse rigging is the only perminant method of rigging trees for aerials. Treehouse rigging is where you attach beams to trees à la a tree house. The two main variations on how to do this depends on if you are putting a beam on only one side of the trunk, or on both sides of the trunk. Treehouse rigging effectively column loads the tree, taking forces off of the weaker branch connections without damaging the tree. This also splits the load between both of the trees, making it easier to carry. This method is preffered for any long-term installation.

Single Side

Single side attachments are typically used with larger diameter tree trunks (14 inches and larger). Here the Tree Attachment Bolts (or "TAB") are placed into the trunks of two trees, typically between 15 and 20 feet apart. A treehouse bracket, such as the one pictured here, is used to secure the beam to the treehouse attachment bolts on each tree. A tension device, usually a rated, forged turnbuckle, then connects the outer edge of the TAB to a second TAB a few feet above the first TAB. This prevents the TAB from torqueing down over time.



Be aware that the beam you use must be strong enough to take the expected shock-loads. Check the load tables for the beam you plan to use. Wood and steel load tables typically specify a Uniform Distributed Load (UDL) for the beam. Make sure to convert UDL of a wooden beam to Center Point Load (CPL) using the following formula:

UDL / 2 = CPL

Double Side

Double side attachments are where you have two boards sandwiching two trees, and a filler material taking up the space between the outer boards. This filler material prevents the boards from pulling in towards each other and it greatly stiffens up the entire beam. NEVER use a double side attachment without a center filler, as the inward forces created by slinging the two beams will quickly destroy both beams and create a major hazard for the aerialist.

Treehouse Roofs

If you are going to the extent of building a treehouse rig, make sure to put a roof over the beam to protect it from the weather. Even pressure treated wood won't hold up for aerials when left exposed to the weather.

Tree Attachments

When attaching to a tree for aerial rigging, extra care must be taken to protect the cambium of the tree you are rigging to, as our load profile is extremely harmful to the delicate cambium.

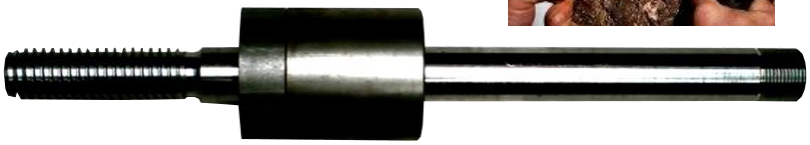
There are three acceptable methods of attaching to a tree for aerial rigging. The first is the Tree Attachment Bolt or TAB. The second is a through-and-through bolt. The third is with slats and J-hooks.

Ropes and slings are NOT acceptable connections for aerial usage due to the effects of these devices in combination with our load patterns on the delicate cambium of the tree.

Tree Attachment Bolts

Tree Attachment Bolts (TABS) are designed to hold to a tree more like a branch stem does. This is effectively the strongest we can make to a tree or branch. TABS are installed by first drilling into the tree with a specially designed drill bit. This bit makes a narrow but deep hole for the threaded portion of the TAB that keeps the TAB from ever pulling out. The bit also makes a second hole that is wide but relatively shallow. This cavity allows the bolt to take significant forces and effectively transfer them to the trunk of the tree.

The TAB itself is then screwed in to this hole and seats VERY snugly.



Once installed, a second, usually much smaller, TAB is installed a little ways above the main TAB. The two tabs are connected, typically with a turnbuckle, to keep the primary TAB from being levered downwards through repeated shock loading.

TAB's are THE preferred method for putting an aerial load on a tree. They can (and should) be used to make both trunk to branch and trunk to guywire connections.

When making a trunk to guywire connection, it is best to put in two TABs 180 degrees apart from each other so that each TAB is 90 degrees from the point it will be pulling from. A sling can then be attached to either TAB. A shackle is then used to create a bridle point between the two slings, giving you an appropriate place to connect your guywire. Additional TABs and turnbuckles are used here to keep the ends of the primary TABs from sagging over time.

Through and Through

Through and Through bolting is the process of drilling a hole all the way through the trunk or a branch to support a load. The three variants on this technique that can be used for aerial rigging are (1) The Tube technique; (2) the galvanized rod technique and (3) the galvanized eye bolt technique. All through and through bolting should be pulled in line with the bolts.

The Tube Technique

This technique is used when you have a tree that will occasionally be used for aerial rigging over several years. Here a hole is drilled through the tree, and a steel tube with AT LEAST a ½"ID (and in some cases, as much as a 1"ID) is driven through the hole. The tube should be VERY snug, and you should need to use a hammer to drive the tube through the hole. The excess pipe is then cut off and the ends of the tube capped with a plastic or rubber endcap.

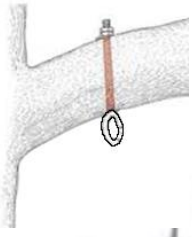
When this point gets used, a rated threaded rod gets run through the tube. Large fender washers are placed over the threaded rod and then a shouldered lifting eye gets placed on the end of the rod to take the load. Depending on the angle of the install and the needs of the point, the other end is either fitted with a second set of fender washers and lifting eye (or swivel eye), or with the fender washers and locking nuts to secure it.

The Galvanized Rod Technique

This technique is used for both one-off and very long-term installs. Here, a hole is drilled through the trunk or branch to accommodate the threaded rod. On either side of the through hole, an additional hole is drilled into the tree (enlarging the entrance to the through hole) to accommodate the fender washers. The threaded rod is screwed through the hole (this should require a large wrench). Fender washers are seated in the holes and either a lifting eye or locking nuts are used to secure the ends. Once the ends are secured, liberal amounts of an appropriate tree sealant is used to close the wound, preventing insects or water damage to the area.

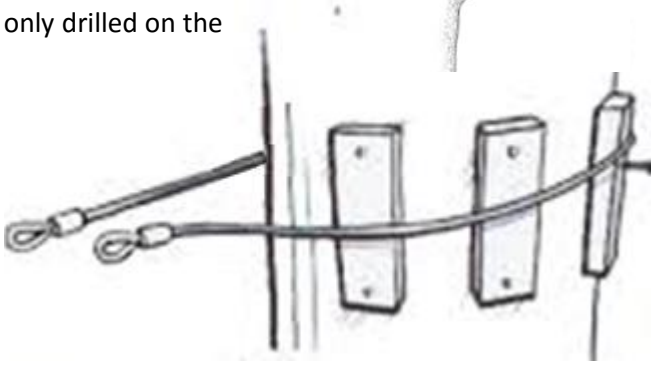
The Galvanized Eye Bolt Technique

This technique is virtually identical to the galvanized rod technique. Instead of using separate threaded rod and lifting eye, a galvanized eye bolt is used. The second, larger hole used for the fender washers is only drilled on the side that will see the nut.



Slats and J hooks

Slats are wooden spacers used to keep ropes and slings off of the trunk and branches of a tree. This allows clear pathways between the



slats where the cambium will remain untouched and the sap will flow. Slats also spread the load of the sling over a much greater surface area, further protecting the cambium of the tree. This technique will still cause some damage to the cambium, however the combination of undamaged sections next to sections with considerably less damage than using slings alone gives the tree a much better chance at recovering. Slats should always be set so as to leave as much undamaged area as possible between the slats, balanced with spreading the load over a sufficiently large area to minimize the damage to the tree.

J-hooks are a variation of slats with a j shaped on the bottom. This hook helps keep a sling in place when it doesn't have tension on it, allowing the rigger to use less force. This in turn reduces the damage to the tree.

Cambium Savers

Many commercial cambium savers exist on the market. By and large these are designed for different load profiles than aerial rigging exerts on the tree. While some of them may be useful, others are not. Riggers must be extremely cautious of these.

Guying Out Trees for Rigging

We have discussed some of the basic concepts of guying out a tree. It is important to understand that in most jurisdictions, when we rig trees, especially tree branches, we are building a form of a jib crane. State and federal regulations play a role in the building and operation of jib cranes, especially how they must be guyed out. Make sure to check your local regulations, as well as the requirements of CFR 1910.179.

Reducing Shock Loads on Trees

Any time you are rigging trees, you need to look for ways to reduce the shock loads the tree sees. This typically means designing your rigging with some flex in it to absorb some of that shock loading. Bungee packs should always be considered when rigging trees. Depending on the setup of the bungee pack, you can reduce a shock load of a drop from 7 times the performers' static weight, down to about 3 times the performers' static weight.

The use of a counter weight that weighs more than the performer (performer + line + apparatus) in a 1:1 pulley system can also be very effective in dealing with shock loads. In these cases, the shock load that can be put on the tree is effectively limited to the counter weight plus the force amplification due to the angle of the pulley. Any shock load is transferred along the length of the line, causing a momentary lifting of the counterweight to absorb the force. Because the counterweight has more mass to it than the performer does, when the shock load has passed, the weight will return to the ground.

A note on Ethics

More than one rigger will read through this article and come to the conclusion that if they don't care about the tree dying in a few years, they can do what they want. A few things to consider before taking this position:

- Riggers and aerialists who kill trees with impunity will not be respected by the community for it.

- Riggers and aerialists who cause the death of a tree can potentially be held responsible for the death of that tree (old trees are worth a lot of money).
- Riggers and aerialists can be held liable for the damage done when the tree falls down, potentially a HUGE liability.
- Now that you have read this, you can't claim not to know the risks you're putting the tree and anyone that comes into contact with the tree at.

As a rigger, you also want to think about what might happen if someone else attempts to rig from that tree which is now damaged. What happens when that branch falls off? Not only will the aerialist fall, but the branch will also fall on top of them, potentially injuring or killing them.

Topics NOT covered in this article

At well over 9,000 words, this is a long article. As long as it is, it is missing huge volumes of information necessary for the proper rigging of trees. To write out EVERYTRHING one would need to know to properly rig a tree, the author estimates it would take somewhere in the neighborhood of 1,500 pages of text and photos. In place of those 1,500 pages, the author chooses to make clear some of what is not covered in this article. The author warns that this is NOT a complete list of the topics left out of this article!

- We did not adequately cover what trees to rig to. We did not cover in any detail what species of trees are most able to handle aerial arts, and what species will die most easily from this use. This is an enormous topic in its own right.
- We did not adequately cover the inspection process. While we tell you in very general terms what you are looking for and what absolutely rules a tree out, we did not cover any of the subtleties of the inspection process or how each piece of an inspection impacts how you evaluate the next part. Again, this is an enormous topic in its own right.
- We did not adequately cover how the different blights affect tree health. Some can be far more or less detrimental to a trees health than others.
- We did not adequately cover the different types of burl and how they affect the strength of the tree. Not all burls are cancers, but if you don't know the difference, you're best treating them all as if they were.
- We did not adequately cover the process of laying out rigging points for a tree. There are a huge number of factors that goes into that, and we only glossed over that subject.
- We did not adequately cover wind loads and the effects of these on rigging aerials in trees. This is a serious issue, as it can throw or drop an aerialist when in the air. Those rigging to trees need to be aware of these things and know how to watch for it and how to deal with it.
- We did not adequately covered risk management in terms of trees and especially the risk management involved in having the public around a tree you have rigged.
- We did not cover any of the tree and soil care issues. The moral and ethical obligation of anyone rigging a tree for aerial use is to leave the tree better off than you found it. This means doing a substantial amount of tree care for this tree and we did not cover that care at all.

- We didn't cover the complexities of the root-soil system. This system is literally the foundation of the tree, and how that system works and interacts is a major part of knowing if a tree is safe to rig to and in knowing what care the tree needs, both short and long term.
- We did not cover how trees develop their strength. How trees grow to adapt to the loads they have is yet another huge topic that riggers must know about.
- We didn't cover why adding structure to a tree can be really bad for the tree if left in place too long.
- We didn't cover methods of accessing the trees. Safe access is very important.
- We didn't cover 3D trunk bridling.
- We didn't cover the difference between branches at 90 degrees and those at 45 degrees, nor did we cover the differences in how they are supported.
- We didn't cover reinforcing angles for branches or split trunks. This is an essential skill for any tree rigger.
- We didn't cover the kind of tree care that should be done for trees being used for aerial arts.
- We didn't cover the removal of dead branches or widow makers.
- We didn't cover how each element of tree rigging interacts with and affects the other elements. This is where it gets really complex.

As we noted at the start of this article, this article is woefully inadequate for the task of tree rigging. But we hope it's enough to begin your research and learning process to do it right.

Costs of Properly Rigging Trees

Throughout this article, we have talked about tree rigging being more expensive to do properly than buying a freestanding aerial rig. The following are the material and labor costs from the last tree rigging project the author did. This project involved rigging the branch of a tree for a commercial. These costs are fairly typical.

Item	Qty	Per	Total
Inspection Labor	10	$125/hr	$1,250
Pre-Rigging Tree Care (contracted)	1	$475	$475
¾" Wire Rope for ground guy wires	200'	$2.70/ft	$550
Termination Hardware	8	$35ea	$420
2-ton Cable Pullers	4	$450ea	$1,350
Large TABs	5	$150ea	$750
Medium TABs	4	$85ea	$340
Misc Hardware	1	$650	$650
Rigging Labor - setup	12	$125	$1,500
Rigging Labor – Take Down	6	$125	$750
Total (not including shipping charges)			$8,035

It should be noted that this does not include the cost of any of the specialty tools needed for this job. That could easily add another $2,000 to the cost of the job.

At the time of this writing, a freestanding aerial rig can be purchased new for $2,750, including shipping.

Conclusion

Tree rigging is a much more complicated subject than most people think it is. If you have gotten this far and feel that tree rigging is for you, your next step is to make sure you have the equivalent of at least 3 years (full time) experience of circus rigging and 3 years (full time) experience of tree care. If you meet those requirements, you are invited to give the author a call to discuss some of the things not covered in this article.

Final Thoughts

Here are some tree rigging pictures collected from around the internet. What's wrong with each of these pictures?