HOW TO TURN A KIDS BIKE INTO A BOMB TRAM FOR AVALANCHE CONTROL WORK

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ABSTRACT: Bomb trams have been used for many years in the ski industry to deliver an explosive air blast to avalanche starting zones. During the last few years, the Heavenly Mountain Resort Ski Patrol has been developing a tram with features for use in specific locations at Heavenly that have been difficult to control with hand-placed charges. The tram is attached to a belay cord and lowered down a fixed cable strung over an avalanche path. A mechanical advantage keeps the explosive charge next to the tram until the tram hits a fixed stop on the line above the avalanche path. As the user continues to feed out the belay cord, the explosive charge is lowered vertically by the lowering cable to the desired height above the snow surface, at which position the charge detonates. As the user winds back the belay cord, it first retracts the lowering cable back into the tram and then pulls the tram back to its original uphill position on the fixed cable where it is ready to be used again. This paper will describe the tram and how to construct one, present results from its use during the 08/09 and 09/10 ski seasons, and discuss its limitations.

1. INTRODUCTION

Bomb trams have been used for many years in the ski industry and by highway departments to deliver an explosive air blast to avalanche starting zones. During the last few years, the Heavenly Mountain Resort Ski Patrol has been developing a bomb tram (hereafter referred to as the tram) with features for use in specific locations at Heavenly that have been difficult to control with hand-placed charges. The goal was to develop a tram that would allow an explosive to be placed in an avalanche starting zone that was traditionally a blind shot, below a convex rollover, or out of sight from teams doing hand charge routes. To accomplish this, a bomb tram was designed to ride along a sloping fixed cable strung over an avalanche starting zone.

The tram works by keeping the hand charge next to the tram, and free of any obstacles on the ground, until it is over the avalanche starting zone. Once over the starting zone, the hand charge is then lowered vertically until it is at the desired height above the snowpack surface. The general principal of this tram is that the force generated by the weight of the tram sliding down the sloping fixed cable is greater than the vertical force exerted by the weight of the single hand charge hanging below

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the tram. This paper will describe the tram, explain how to construct one, present results and lessons learned from its use during the 08/09 and 09/10 ski seasons, and discuss its limitations.

1.1 Terms Used in this Paper

Bomb Tram (or just the tram) - The device that travels down the length of the fixed cable until it is stopped by a cable clamp placed on the fixed cable. Once the tram hits the cable clamp, the explosive charge is lowered vertically below the tram by the lowering cable.
Fixed Cable – The 1/4 " steel sloping cable that is tensioned over the avalanche starting zone. The bomb tram hangs from two pulleys that slide on this cable.
Belay Cord - The parachute cord that is attached to the tram and is used to lower the tram down the fixed cable. A reel is used to let out the belay cord or reel it back in.
Lowering Cable – The 1/16" steel cable that is wound up in the tram. The hand charge hangs from the end of the lowering cable below the tram. The lowering cable lowers the hand charge vertically from the tram towards the snow surface once the tram is over the avalanche starting zone.

2. USING THE TRAM

To operate the tram, the user first attaches a single hand charge to a brass hook on the end of the 1/16" lowering cable dangling below the

tram and lights the charge. The tram, hanging from the fixed cable, is then lowered along the fixed cable to a position above the avalanche starting zone. During this lowering along the fixed cable, the tram moves one foot for every foot of belay cord let out. Over the avalanche starting zone the tram stops when it hits a cable clamp on the fixed cable. As the user continues to feed out the belay cord, the hand charge attached to the end of the lowering cable begins to lower vertically towards the snowpack surface. The user continues to lower the hand charge until it is at the desired height above the snowpack where it will detonate. During this vertical lowering, the hand charge only moves one half a foot for every foot of belay cord let out (Figure 1).

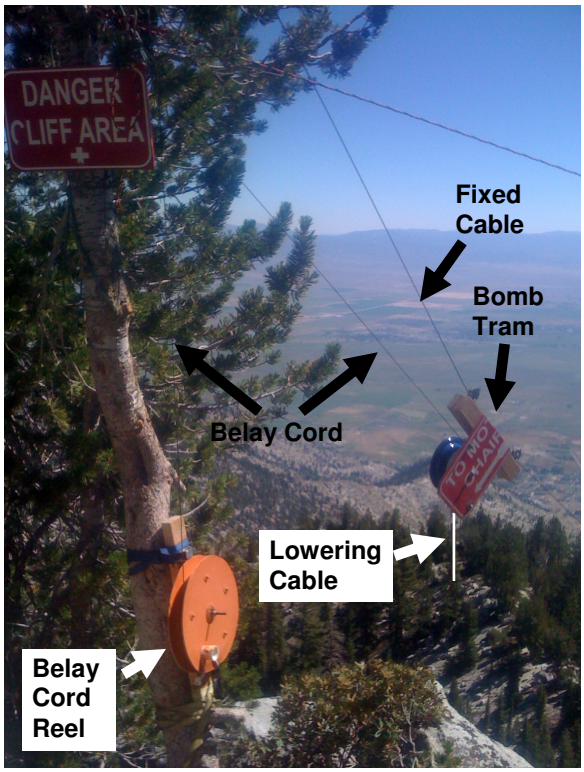

Figure 1: The bomb tram hanging on the fixed cable, ready to use. The hand charge will be attached to the end of the lowering cable.

Once the hand charge detonates, the user then begins to wind back the belay cord. Winding in the belay cord, spools in the lowering cable (that the hand charge was lowered with) back into the tram. Once the lowering cable is fully wound back into the tram, the tram will then be pulled back up the fixed cable to its original uphill position on the fixed cable.

3. BUILDING A BOMB TRAM AND CABLE ON WHICH TO RIDE

There are essentially three main parts in this bomb tram system: the fixed cable that the tram rides along, the tram that transports the hand charge, and the belay cord and reel that lower the tram down along the fixed cable.

3.1 The Fixed Cable

The fixed cable is the ¼" steel cable that hangs in the air above the avalanche starting zone that the bomb tram rides on. A cable clamp is placed on the fixed cable at the location where the tram is going to lower the hand charge to the snow surface. When tensioned, the fixed cable must be steep enough to keep the hand charge from lowering before the tram reaches the cable clamp on the fixed cable. The force generated by the weight of the tram sliding down the fixed cable is what keeps the hand charge off the ground and securely next to the tram. The slope of the fixed cable therefore needs to be steep enough to allow the tram to slide down the fixed cable without the hand charge lowering. If the slope of the fixed cable is too shallow, the tram will not slide down the fixed cable, and the hand charge will lower as soon as the user feeds out the belay cord. The tram successfully used at Heavenly during the 08/09 and 09/10 ski seasons weighed 12 pounds (without a hand charge attached) and rode on a fixed cable with a slope angle of 32 degrees.

The tram used at Heavenly Mt. Resort rides on a fixed cable that is tensioned by a hand crank winch between two trees (Figure 2). The uphill end of the fixed cable (the end of the fixed cable where the belay cord/spool is and the tram starts from) is attached to a tree with cable clamps about eight feet above the ground. The height of the fixed cable needs to be low enough to the ground here to allow the user to be able to attach a hand charge to the lowering cable hanging from the tram.

The downhill end of the fixed cable is strung over some branches high in a tree with the downhill cable end reaching the ground at the tree base. This end of the cable is attached to a winch that is mounted to the base of a tree (the same type of cable winch that is used to pull a boat onto a boat trailer). This winch reels in the cable and tensions it over the avalanche starting zone.

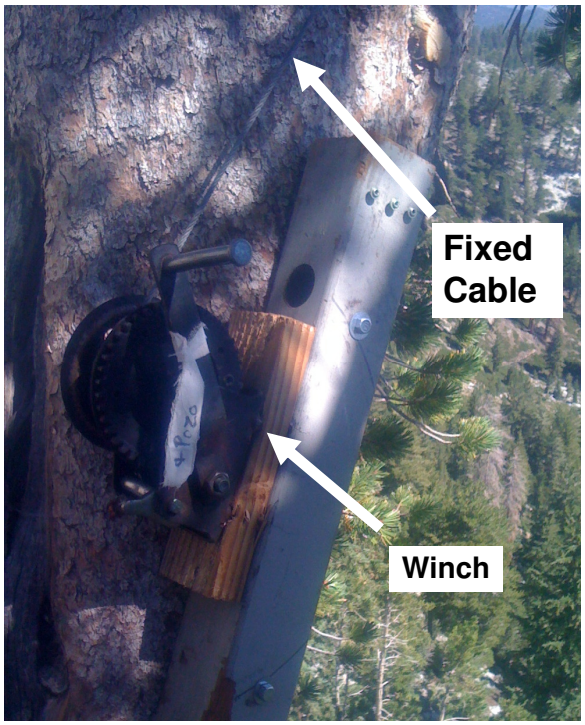

Figure 2: The winch that tensions the fixed cable. The winch is mounted to a 4X4 and the 4X4 is bolted to a tree.

3.2 The Bomb Tram

The tram is built from pieces readily available at hardware and department stores. The tram hangs off of the fixed cable on two wall mount pulleys attached to a 24" long wood 4X4. A piece of ½" thick plywood 12"X16" is attached to the side of the 4X4. This forms the frame of the tram (Figure 3).

The piece of the tram that provides the mechanical advantage to keep the hand charge from lowering until it is over the avalanche starting zone will attach to this frame. It is made from two 12" plastic mag style kids bicycle wheels (with tires removed), a 2" long piece of 4" diameter black ABS plastic pipe, and a blue metal dinner plate (like might be used while camping). Two bicycle wheels are needed as the axle out of the rear wheel is longer than the axle in the front wheel. The tram requires that the longer rear axle (or any longer axle from a bike shop) be put into the front wheel. When installing the axle, it should be offset as far to one side as possible. This will allow the longer side of the axle to stick out far enough to pass through a hole drilled in the middle of the ½" piece of plywood sticking out below the 4X4 of the tram frame.

The longer side of the bicycle wheel axle is attached to the plywood with the axle nut. On the other side of the bicycle wheel we attach the 2" long piece of 4" diameter black ABS plastic pipe, centered on the side of the wheel. To this we attach the blue dinner plate centered on the plastic pipe. These three pieces are then bolted together by three longer bolts. Once bolted together, they can spin freely on the bicycle wheel axle mounted to the plywood.

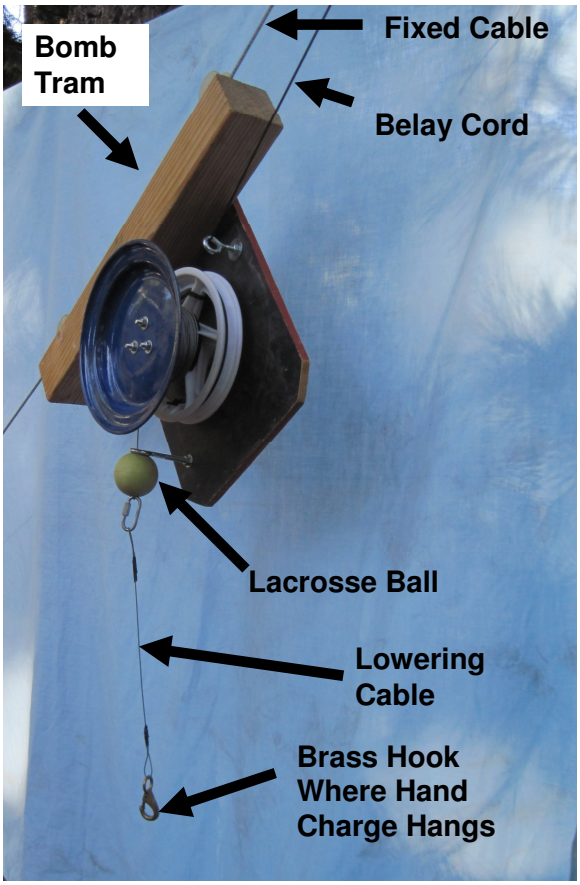

Figure 3: The tram as it hangs on the fixed cable.

To finish the tram we will need to mount two eye bolts to the plywood that will guide the belay cord and lowering cable as they are wound onto the bicycle wheel and black pipe. The first eye bolt is mounted on the plywood a few inches under the 4X4. This bolt should be placed so that it will guide the belay cord onto the rim of the bicycle wheel. The edge of the bicycle wheel rim and the eye bolt should both be the same distance from the 4X4. The other eye bolt is bolted to the plywood to guide the lowering cable as it is wound onto the black plastic ABS

pipe. The location of this eye bolt will be determined by the angle of the fixed cable. The eye bolt should be placed so that the lowering cable (hanging vertically below the tram) passes through the eye when the tram is riding on the sloping fixed cable.

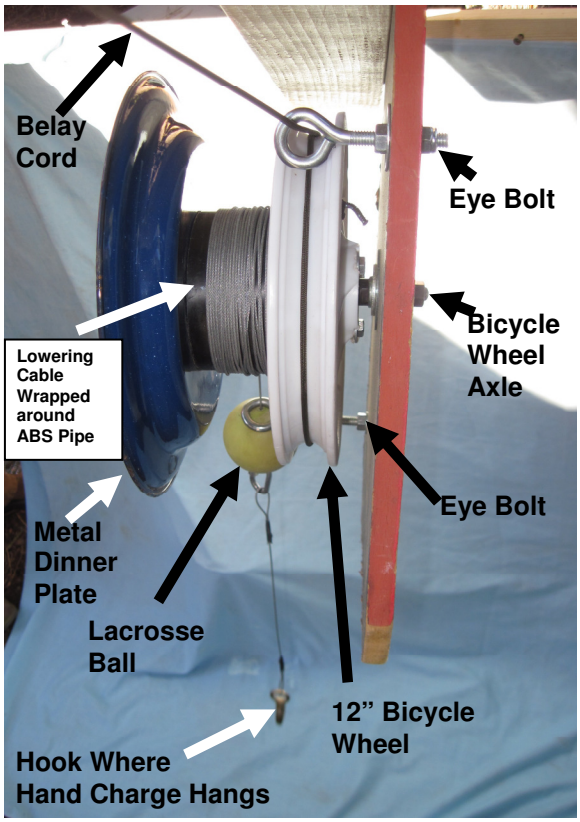

Figure 4: Looking down along the belay cord at the tram. The lowering cable is would up on the black ABS pipe piece and ready to lower over the avalanche starting zone.

Once the bicycle wheel assembly and the eye bolts are attached to the ½" plywood, we can attach the lowering cable. This 1/16" diameter steel cable needs to be long enough to lower the hand charge from the tram down to the snow surface at the avalanche starting zone. One end of the lowering cable is attached to the plastic pipe by drilling a hole in the outside of the pipe, inserting one end of the lowering cable and attaching a cable clamp. The lowering cable can then be wound around the plastic pipe by spinning the bicycle wheel (Figure 4).

On the end of the lowering cable where the hand charge will hang, we need to add some weight. This weight holds tension on the lowering cable once the hand charge detonates. Drill a hole through the center of a rubber lacrosse ball and slide the ball onto the end of the lowering cable. Once the lacrosse ball is on, we will create a loop in the end of the lowering cable by folding the cable back upon itself and securing with a cable clamp. Alternately you can splice a Molly Hogan in the cable end to make a loop. Look it up on Google if interested. Below the lacrosse ball we will attach an 18" long piece of 1/16" steel cable with a loop in each end. One end of the 18" long cable is attached to the loop next to the lacrosse ball with a screw link. To the loop on the other end of the 18" long cable we will attach a brass snap hook that the hand charge will hang from. If the tram is hung off of a fixed cable high off the ground, the 18" long piece of cable can be longer to allow the user to arm the tram while standing on the ground (Figure 5).

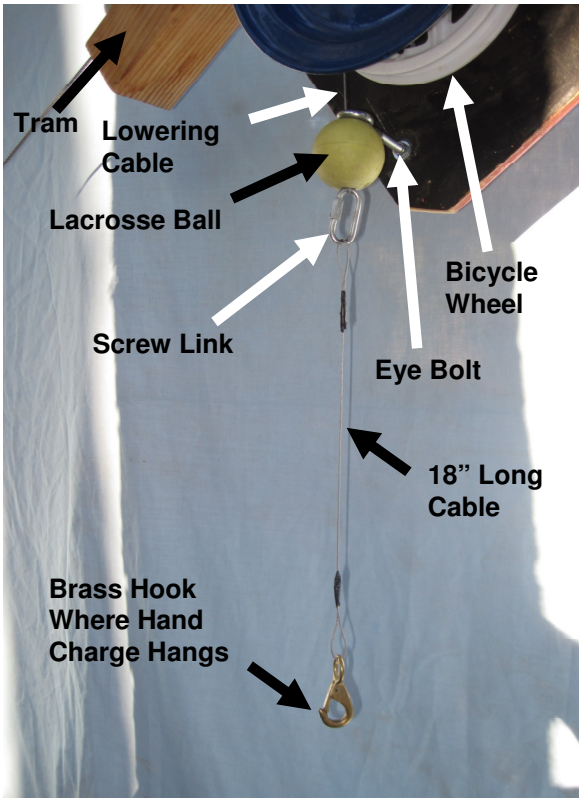

Figure 5: Looking at the end of the lowering cable where the hand charge hangs from the tram.

When the tram is hanging on the fixed cable and ready for use, the lowering cable is wound up on the 4" black pipe until the lacrosse ball makes contact with the eye bolt that the lowering cable passes through. This leaves the 18" length of cable dangling below the tram with the brass hook on the end. To arm the tram the user

hangs a hand charge from the brass hook. The charge can either be hung in a plastic grocery bag or hung off of a short piece of cord that gives about a foot of distance between the hand charge and the brass hook. This will keep the brass hook from being destroyed by the explosion. Once lit, the user uses the belay cord reel to feed out the belay cord, lowering the tram down the length of the fixed cable. When the tram is stopped by the cable clamp on the fixed cable, the user continues to feed out the belay cord. The lacrosse ball and the hand charge hanging below it are hanging on the lowering cable. As the user continues to pay out additional belay cord, this additional belay cord is wound up on the rim of the 12" bicycle wheel. This winding up of the belay cord on the bicycle wheel causes the lowering cable to unwind and lower the hand charge vertically down to the avalanche starting zone below the tram.

3.3 The Belay Cord and Reel

The belay cord reel (hereafter referred to as the reel) holds the length of belay cord used to lower the tram down the fixed cable to the avalanche starting zone and pull it back up when done. The reel is built from a pair of 16" kids bicycle wheels (with the tires removed). The longer axle (or any longer bicycle axle from a bike shop) from the rear wheel should be removed and used to replace the shorter front wheel axle (similar to how the 12" bicycle wheel was built for the tram). When installing the axle, it should be offset as far as possible so the axle is sticking out farther on one side of the wheel than the other. Cut two disks of thin plywood that are 4" larger in diameter than the diameter of the bicycle wheel rim (the 16" wheel refers to the tire diameter, not the rim diameter). Cut a hole out of the center of each disk that is large enough that one disk will fit on each side of the bicycle wheel and touch the rim. These disks are then bolted onto the wheel to provide a deep groove that will hold the belay cord within the bicycle wheel rim where the tire would normally sit (Figure 6).

Attach a handle to the thin plywood on the side of the reel that has the shorter piece of axle exposed. Anything will work, but our tram uses a 1 ½" PVC plastic pipe end cap. Drill a hole in the center of the end cap and bolt it onto the wood disk in such a way that the cap can rotate when reeling in or out the belay cord. The longer side of the axle is then bolted to the middle of a 30" long piece of 2X4 wood. This piece of wood is then mounted, with two cam straps, to the same tree that the uphill end of the fixed cable is attached to.

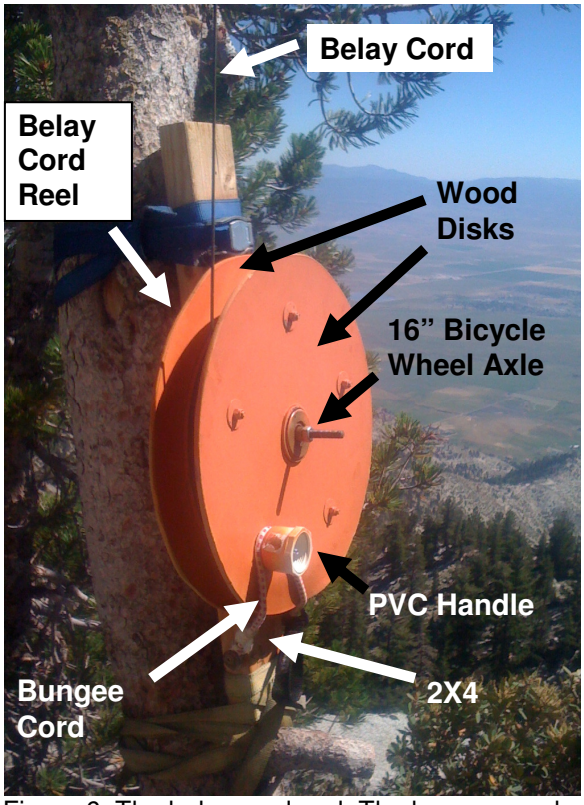

Figure 6: The belay cord reel. The bungee cord secures the reel when not in use.

The belay cord is a length of seven-strand parachute cord rated to a breaking strength of 550 pounds. This cord needs to be long enough to extend from the belay cord reel to the cable clamp on the fixed cable with enough cord left over to un-reel the lowering cable as it lowers the hand charge to the ground. A single carabineer or pulley is then hung above the belay cord reel at the same elevation as the fixed cable. This carabineer allows the user to pull the tram back completely to the uphill end of the fixed cable. Finally, a loop of bungee cord is attached to one end of the 30" long 2X4. This loop is stretched over the 1 ½" PVC end cap handle so the reel will not turn while the tram is not in use.

When setting up the tram at its location, you must first wind the lowering cable up onto the black pipe. This is done by spinning the 12" wheel assembly until the lacrosse ball touches the eye bolt that the lowering cable passes through. Then the lowering cord is threaded off

of the lowering cord reel, through the carabineer hanging at the fixed cable, through the eye bolt on the tram that guides the lowering cord onto the 12" bicycle wheel, around the bicycle wheel at least one full revolution, and then through the hole where the valve stem would go through the bicycle wheel rim. The cord is then tied off to one spoke of the wheel. When first setting up the tram, it is useful to place a piece of tape on the lowering cord to mark when the hand charge is hanging at an ideal height above the snowpack. This will allow the user to use the tram in poor visibility or in locations where the hand charge detonates out of sight from the user.

4. LESSONS LEARNED AND FUTURE WORK

A tram built as described above is what has been used for two winters in Killebrew Canyon at Heavenly Mt. Resort. During this time, through trial and error, several lessons have been learned. Rope did not work well for setting up a line for the tram to ride down. The stretch inherent in most rope before it breaks caused the line to sag under the weight of the tram once it reached a point above the starting zone. The fixed cable needs to be taught enough so that the cable will not sag excessively as the tram is lowered down the fixed cable. If the fixed cable sags enough, the tram could stop before it hits the cable clamp on the fixed cable and lower the hand charge prematurely. There is a balance between the weight of the tram and the slope of the fixed cable that needs to be achieved for the tram to function properly. A steeper fixed cable can use a lighter weight tram and still function properly, while a less steep fixed cable may require a heavier tram.

Care should be used when using larger explosives than the tram was designed for. The tram used at Heavenly has reliably carried a single (1 Kg) and a double (2 Kg) charge. Experiments with heavier charges were less reliable as the tram would sometimes start to lower the explosive charge before the tram would reach the cable clamp on the fixed cable. In order to use larger explosives, the tram or cable would need to be changed. One change would be to make the tram heavier or the fixed cable would need to be installed with a steeper slope than for a smaller explosive charge. Another method that was experimented with was to replace the 4" diameter black ABS pipe with a smaller diameter piece of pipe. Initial testing of this modification shows promises. Further testing will be needed to show if this is a better design for the tram.

The tram has some limitation to its use. In freezing rain, or heavy riming, the fixed cable may provide drag to the tram that could cause the hand charge to lower before it reaches the cable clamp on the fixed cable. The method for using the tram described in this paper requires that the user is able to get to a position where they can hang a hand charge from the tram. This requires that one end of the fixed cable is near the ground and could present a hazard to skiers. Another limit of this tram is that it consistently places the hand charge in the same location each time it is used. While the user can decide how high above the snowpack to place the hand charge, the tram will drop the hand charge in the same location each time.

5. CONCLUSION

Controlling avalanche paths that are difficult to access or that have traditionally been controlled by a blind shot pose a real challenge to ski patrollers. In order to more reliably place a hand charge in a starting zone and provide a more effective air blast, a bomb tram was developed and used at Heavenly Mt. Resort. During its initial two seasons of use, the bomb tram described in this paper has proven to be a reliable and effective means of delivering a powerful air blast to an avalanche starting zone in Killebrew Canyon.

It is hard to describe in words and a few photos the design of this tram and how to build one. Currently one video is available on YouTube that shows the tram working at Heavenly Mt Resort. This winter I hope to take some more video to show how this tram works. If more videos are created they will be posted and linked to the one already there.

REFERENCES

YouTube.com "Heavenly Bomb Tram for Avalanche Control Work 1" copy and paste the link: http://www.youtube.com/watch?v=zHwucUZFZ5k or search for title on YouTube