Compound Haul Lower Device Development Project

By Henry Schneiker
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The purpose of this project is to develop a light weight and simple to use compound haul/lower device that can handle standard rescue loads. The device dissipates high dynamic loads to prevent equipment damage.

Problem Statement

Existing haul and lower systems used in rescue work involve a high level of complexity, training and manpower to operate successfully under field conditions. A typical system uses multiple anchors, an advantage system for hauling, a friction system for lowering, a separate safety belay line for hauling or a second friction system for lowering. A typical 5:1 haul system with belay requires 3 anchors, 3 anchor straps, 3 ropes, 11 carabiners, 2 plates, 5 pulleys, 3 rescue ascenders or corresponding prusik knot sets, several knots, lots of space and plenty of people with at least one highly skilled person present. A typical lower system requires 2 anchors, 2 anchor straps, 2 ropes, 2 carabiners, 2 racks, several knots and 2 skilled operators. Changing between a haul system and a lower system (or vise versa) requires a high level of skill and coordination. The combined total weight of just the hardware - excluding anchors and ropes - is over 25 pounds. There are also operational issues, such as the difficulty in keeping the belay line tensioned during a long haul.

In more recent times sail winches have made some inroads on the raise systems in situations where a vehicle can be driven to the haul point. But the sail winch is far from ideal - having its own set of drawbacks - being weight, size, non-reversible and employment of the weak arm muscles for power.

What is still lacking is a single simple device that is usable for field operations - far from vehicles. The device should be relatively small, light weight, simple to set up, not overly expensive and robust. The device should be a combination haul and lower system and be easily convertible between haul and lower modes of operation. The device should be easily operated by a single person and not require extensive training. The device should handle standard rescue loads, ropes up to 13mm, standard fall factors and be fail-safe (i.e., pass the whistle test).

The optimal situation would be to have two of these devices operating in parallel to form a fully redundant haul and lower system - one device per rope - both systems would share the load and act as a backup (belay) to the other. Each operator would work the device in a fashion similar to riding a recumbent bicycle - using the legs to drive the system. Also, the operator would be able to select from three different drive ratios, selectable using a "gear shift", provided using a standard 3-speed gear arrangement.

Another desired feature in this device is to have it give gracefully when shock loaded. SAR work currently uses climbing "zippers" to try and handle shock loads. However, these are designed for personal loads only. As a result, when a dynamic shock load is seen, these devices often completely unzip and still expose the system to a large dynamic load as well as expose the litter and tender to a descent of excessive distance that can result in injuries.

The Paillardet Rescue Hoist (http://www.paillardet.com/en/indexven.htm) is an excellent first approximation of such a device. However, I think there are significant improvements that can be made to make it a better match for rescue work. It is also rather expensive at $3700 a copy.

Project Significance

Technical rescue work requires substantial training, equipment and manpower. Substantial skilled manpower is needed to move the required equipment into the field, setup the systems and operate them. The time it takes to rescue a person depends on the complexity of the rescue operation and the efficiency of the systems and procedures used. Reducing the rescue time is key to improving survivability after an accident.

The proposed system can change the face of technical rescue, whether the rescue takes place far from the nearest road or in an urban setting. It can reduce the setup time from tens of minutes to just minutes. It can make it easy for individuals or small teams to perform technical rescues where large teams were once required. The proposed system makes it possible to perform rescues safely with less training - allowing people to perform self-rescues immediately instead of calling in specialized rescue teams.

The proposed system improves safety in many ways. It reduces the possibility of incorrectly setting up a system by reducing the complexity of that system. It exposes fewer people to hazardous conditions during a rescue. The system reduces the total exposure time of the rescue team and the persons being rescued. And the system automatically handles high dynamic loads that can cause other systems to fail catastrophically.

The proposed system also reduces costs for a rescue team. Although the initial investment of the device is somewhat higher than the full collection of other gear needed to perform the same task, the on-going training costs are substantially reduced. When you figure how many hours of recurrent training are required each year for each person on the rescue team, it quickly become apparent that within the first year the system can pay for itself in reduced training costs. Add to that the reduced liability of someone making a mistake or taking too long to set up and operate a complex system. It should now be clear that this is a highly desirable system.

The Development Process

The compound haul and lower device is based around a twin grooved drum assembly. The twin grooved drums allow a rope to be continuously fed over the drums while at the same time providing ample traction so the rope will not slip on the drum surface. The grooves allow the device to automatically adapt to rope sizes between 5mm and 13mm and prevent the rope from shifting position on the drum.

The twin drums are driven in a synchronous manner by a gear system. The gear system allows substantial mechanical advantage using one of three different settings. The selection of the mechanical advantage is provided by a sun and planetary gear system similar to that used in a bicycle 3-speed hub. The haul configuration employs a one-way clutch system to prevent backward operation.

The drive system also employs a torque clutch system to bypass high dynamic loads. The torque clutch is designed to absorb and dissipate high dynamic loads to keep system loads within tolerable limits as well as to minimize downward travel of the load. The torque clutch also prevents an over enthusiastic operator from placing excessive loads on the haul system should the load become caught.

The operator provides energy for the haul with the strong leg muscles. The legs can be used to generate up to a couple of hundred pounds of force for long periods of time. The operator sits in a harness chair and extends each leg in turn. It is the difference in force between the back of the chair and the foot that generates the power stroke. A continuous output of 100 pounds from each of two operators can easily haul a 600 pound load even accounting for edge resistance.

The lower mode of operation bypasses the one-way clutch system to present the load to a resistance system. The resistance system dissipates the kinetic energy in the load in an easily controlled fashion, allowing the operator to smoothly control the lowering of the load. The maximum lower rate can be governed by a centrifugal clutch.

The basic configuration is a horizontal base to which are attached two vertical grooved drums. The loaded end of the rope feeds to the bottom groove of the front drum via guide rollers so as to ensure the rope is smoothly fed regardless of any misalignment of the device relative to the load. The tail end of the rope exits from the top groove of the rear drum using a tensioning guide roller to ensure the rope maintains proper tension and position on the drums.

The break, clutches and gear drive systems are built into the base and are sealed against major contamination. As the majority of force is being applied to the bottom end of the drums, this is where most of the structural design takes place. Relatively small forces are applied to the upper ends of the drums. However, the tops of the drums are connected by a narrow plate for added rigidity and structural integrity.

Drive power is supplied to the top of the rear drum through a hollow shaft. The drive mechanism converts the operator's leg extension motions into rotary motions. Only torsional forces are transmitted between the drive shaft and the hollow shaft.

The finished system will be fully tested to meet all current safety standards. This requires a full suite of instrumented tests to verify static and dynamic performance. Further, field test will need to be performed under a variety of conditions to ensure proper operations in dry, dusty, sandy, wet, muddy and snowy conditions. Any problems will be investigated and appropriate changes made.

Project Schedule

The tentative project schedule covers about 10 months as follows:

- 2 months: Design and draw up preliminary design documents. Perform basic stress analysis.
- 1 month: Order parts and materials. Formalize documents and write CNC programs.
- 1 month: Machine parts.
- 1 month: Assemble parts. Testing. Publish preliminary project report when this phase is completed.
- 2 months: Second iteration. Analyze test results. Modify design and update documents. Build new parts as needed. Assemble parts. Testing.
- 2 months: Third iteration. Analyze test results. Modify design and update documents. Build new parts as needed. Assemble parts. Testing.
- 1 month: Publish a final report. Official end of project.

Project Budget

Travel

Miscellaneous travel (400 miles at $0.345/mile)	138	Grant
Subtotal:	**138**	Grant

Facilities, Equipment and labor

Office and labs		Facility	HDS
Test equipment		Equipment	HDS
Labor (35 weeks @ $75/hour including overhead)		$105,000	Grant

Components and fabrication services

Materials		$4,000	Grant
Parts		$5,000	Grant
Metal treatments		$4,000	Grant
Miscellaneous expenses		$3,000	Grant
	Subtotal:	**$16,000**	
	Total:	**$121,000**	Grant

Notes: Grant is funds provided by the grant, HDS is HDS Systems.

The deliverables are: One completed compound haul and lower system, preliminary report and final report.

Participants

HDS Systems, Inc. is a consulting firm specializing in custom projects and light manufacturing. The company was first started in 1986 as a sole proprietor business and incorporated in 1997 to reflect its changing character. HDS Systems is owned and operated by Henry Schneiker (see below). HDS Systems has been involved with a wide variety of projects including the Kartchner Caverns Environmental Monitoring Station, Action Light, custom printing system, custom artwork production system and numerous software projects. These projects include hardware design, embedded controller programming and debugging, sensing systems, numerous operating systems, development systems and programming languages.

Henry Schneiker has been involved in technical rescue for over 20 years and has over 30 years of SRT experience. That experience includes building and testing custom hardware. Henry has successfully run a consulting firm for over18 years and has extensive experience in managing development projects from R&D through manufacturing and sales and a solid background in business management.

Bert Hall, CB Technical, Tucson (CNC) has over 20 year experience in drafting, CAD/CAM, machining, materials and mechanical engineering.

Other consulting participants are Bob Buecher and Scott Clemans. Bob Buecher is a civil engineer with over 20 years of technical rescue experience. Scott Clemans is a mechanical engineer with over 15 years of technical rescue experience.