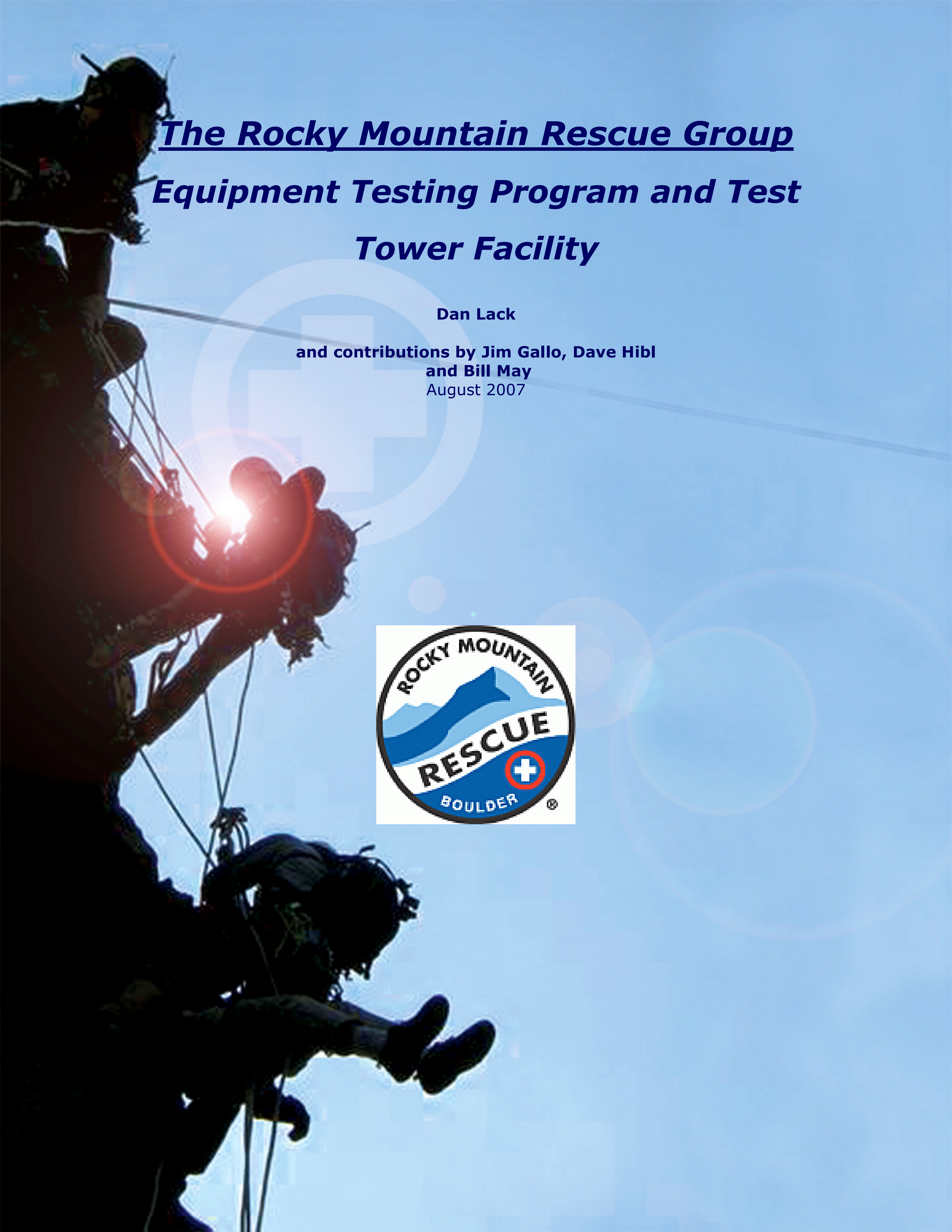


The Rocky Mountain Rescue Group Equipment Testing Program and Test Tower Facility

Dan Lack

and contributions by Jim Gallo, Dave Hibl and Bill May

August 2007

BACKGROUND

Picture this… on a late fall afternoon a middle aged man is hiking in the foothills of the Colorado Rocky Mountains. On a particularly steep section of trail he suffers a seizure, passes out and falls 15 meters ending up just inches away from the edge of a 30 meter high cliff. Hours later a cell phone call by the now conscious, but injured, man alerts rescuers to his fate. Detective work by mountain rescue personnel pinpoints the position of the patient and a team of 25 mountain rescuers spend 5 hours evacuating him to a hospital for the urgent care required.

For the all-volunteer Rocky Mountain Rescue Group (RMRG), based in Boulder, Colorado, this is an example of one of the more difficult rescues they perform up to 130 times a year. The initial search, precarious position of the patient, the 30 meter vertical evacuation and the 800 meter scree evacuation that followed would be a challenge for any mountain rescue team in the world. As is true for all search and rescue teams, rescuer and patient safety is paramount for RMRG; this rescue was no exception, and as a result, was executed without harm to rescuers and no further injury to the patient.

RMRG is the oldest Mountain Rescue team in Colorado, and is made up of about 70 all-volunteer personnel. For 60 years RMRG has been rescuing throughout the Colorado mountains and for almost this long they have quietly been leading the way in development and testing of innovative techniques and specialized equipment used in mountain search and rescue.

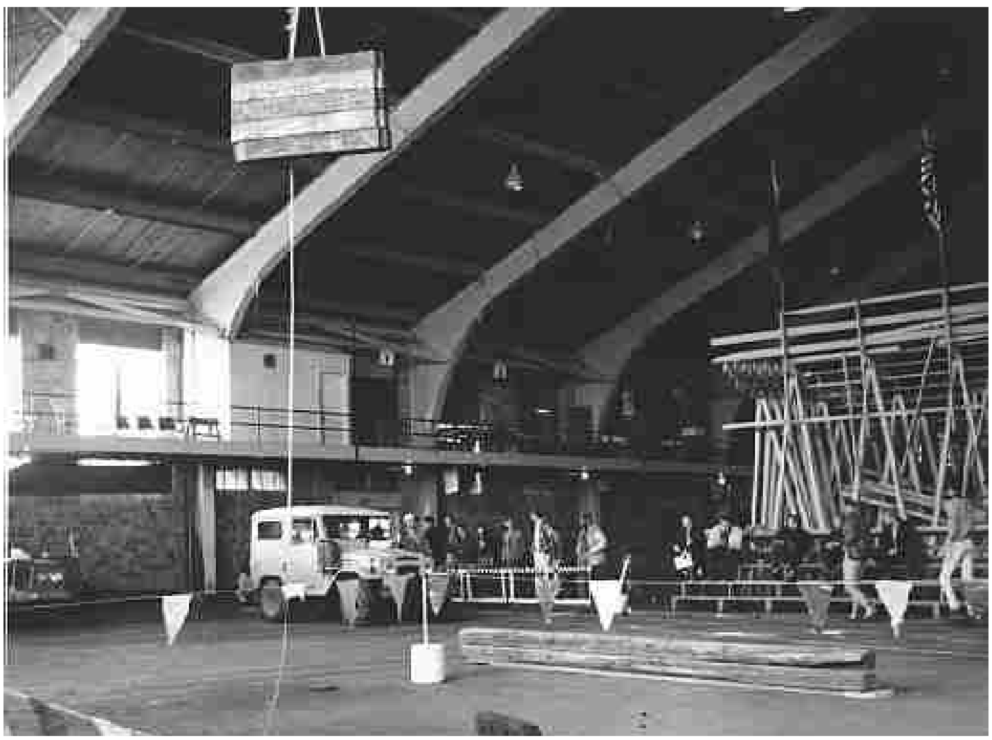
"As a mountain rescue team, it is essential for safety that we (RMRG) understand the rescue loads encountered and the behavior of all of our rescue equipment under these loads, especially ropes, knots, carabiners, anchor materials and descending devices, as well as the breaking strengths and failure modes of this equipment" says Bill May, a retired University of Colorado engineering professor, and 38+ year RMRG member. ***"For decades the Rocky Mountain Rescue Group has been recognized nationwide for its development and testing of mountain rescue techniques and equipment. Much of our operational equipment is of our own design, and we are serious about its evaluation."***

To assure appropriate safety margins, RMRG must make quantitative measurements of loads encountered in actual field situations. Conducting and evaluating failure tests under controlled conditions at a specialized test facility allows RMRG to design for appropriate rescue safety factors.

Rocky Mountain Rescue Group Evacuating a Patient Across Boulder Falls, Boulder, Colorado.

RESCUE TEST TOWER FACILITY

Equipment testing started in the 1950's in the shadow of the Flatirons. Three pine trees in Boulders Chautauqua area were used as test anchors. In the 1960's testing moved to the Field House on the University of Colorado Boulder campus. Test loads were elevator weights rigged through pulleys attached to building rafters, enabling crude measurements of failure of rope (a rescuer's lifeline) and other equipment by using mechanical dynamometers.



Early RMRG Testing Facility in the Field House on the University of Colorado Campus, 1966

In 2000 RMRG retro-fitted the upper 10 meter section of a donated high-tension power line tower as its own drop test facility. A remotely operated winch on the tower can lift loads of up to 450 kg, with remote release for drop tests. Honeywell/Sensotec load cells are used to measure up to 45 KN of force, and the output of these is conditioned with high-speed in-line amplifiers which provide analog signals to a National Instrument (NI) DAQ1200 PCI-MCA card in a laptop computer running LabView 5.0. Two of the four analog input channels can be used to measure temperature changes, load position or position of other moving points in the system. Currently this is done using linear translation transducers known as 'string pots' that convert a 1 meter change in position to a 3.3 volt change in signal level. LabView software was written by RMRG members who were engineers at the University of Colorado. Using this test facility RMRG can measure failure strengths, rope elongation, rope recovery after being loaded, and the deployment of load limiters (or shock absorbers). New equipment can also be tested for ultimate failure strengths.

Bill May explains in more detail the ultimate reason for RMRG's testing program. ***"Failure of equipment on a rescue is likely to be from a drop, that is, a sudden deceleration, not quasi-statically applied loading. The old mechanical dynamometers we used did not give a reliable indication of peak loads which can now be sensed by high-speed load cells and recorded by LabView. Measurements that we make sometimes show very sudden and large peak forces, which could cause abrupt failure of a rescue system. These dynamic measurements have proven to be invaluable towards giving us a deep understanding of our SAR equipment and possible modes of failure, leading to improved safety on rescue operations, which by their very nature are potentially hazardous.***

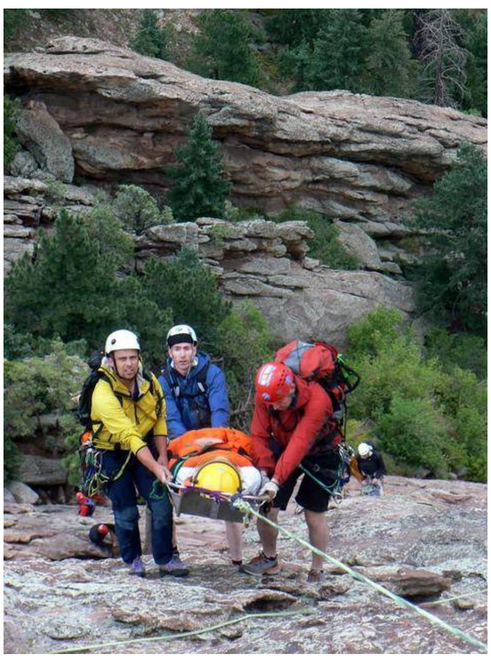
Equipment manufacturers usually do not test their equipment using dynamic tests (catching a falling weight) but only by applying loads quasi-statically, if these manufacturers give a failure load specification at all. RMRG has been using LabView and the DAQ1200 for years to instrument tests of realistic rescue loads that are routinely encountered in real-world rescue operations."

THE ROCKY MOUNTAIN RESCUE GROUP TEST TOWER

TESTING RESULTS ON PARALOC™ ROPE

DROP TESTS

RMRG recently undertook another step in mountain rescue safety advances by thoroughly testing a new rope, ***Paraloc™***, designed by Mamutec AG, of Switzerland (www.mamutec.com). RMRG members Jim Gallo and Bill May spent many months during 2005 and 2006 extensively testing this new rope and comparing it to other products.



Among the most important experiments are the drop tests done to evaluate the ultimate strength of a rescue rope. A typical test involves dropping a 270 kg weight on a length of rope with knots to simulate a severe rescue situation involving six rescuers transporting a patient. The load on the tested rope shows large, brief, spikes, often enough to break the rope. The position of the weight during the drop and settling of the knots, from hand tight to loaded, is recorded. Distances are measured with conventional string pots. From the results of these high-speed tests, RMRG can assess the overall quality of the rope and the need for including load-limiting shock absorbers in the rescue rigging. One example of a shock absorber is the 'prussic' knot which in Figure 1, slipped at 11 KN on the first drop. In this extreme environment, the prussic knot limited the load but actually melted the material of the prussic and the rope, effectively welding the system. On the second drop the prussic knot provided no load limiting.

"Using 270 kg loads repeatedly dropped onto rope samples, we found that the Paraloc™ rope could withstand at least 2 more drops than our previous rope" (Figure 1) said Jim Gallo, the rope-testing project lead, mountaineer and former RMRG group leader.

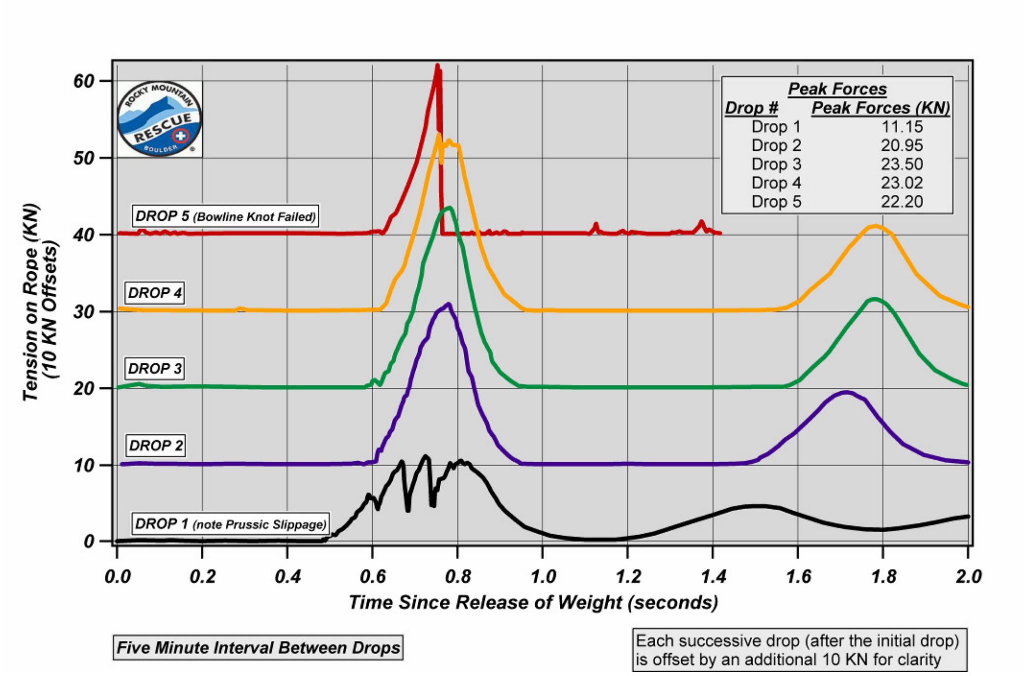


Figure 1. A 5-drop test of Mamutec Paraloc™ rope with a 270 kg load dropped 1 meter onto 3 meters of rope. The first drop in this series shows the load limiting characteristics of the 'prussic knots', also used in many rescue applications.

ELONGATION TESTS

Elongation, a property that can both help and hinder during rescue operations, was measured during the first series of tests on this rope. Too much elongation of a rope under load will introduce undesirable stretch when long lengths of rope are in use on vertical walls and steep slopes. Too little elongation will not provide any shock absorption, increasing the possibility for shock loads to cause catastrophic failure. Figure 2 shows the elongation and recovery properties of a few tested ropes and steel cable. The steel cable is considered very static, at less than 1% maximum elongation. RMRGs rope of choice up until a few years ago, ***Goldline™***, is considered dynamic with elongation ranging from 10 – 15% at RMRGs maximum working load of 450 kg (~ 4.4 KN). The new ***Paraloc™*** rope has elongation characteristics that are ideal for RMRG operations (6 – 8% at maximum working load), providing just the right combination of dynamic and static properties.

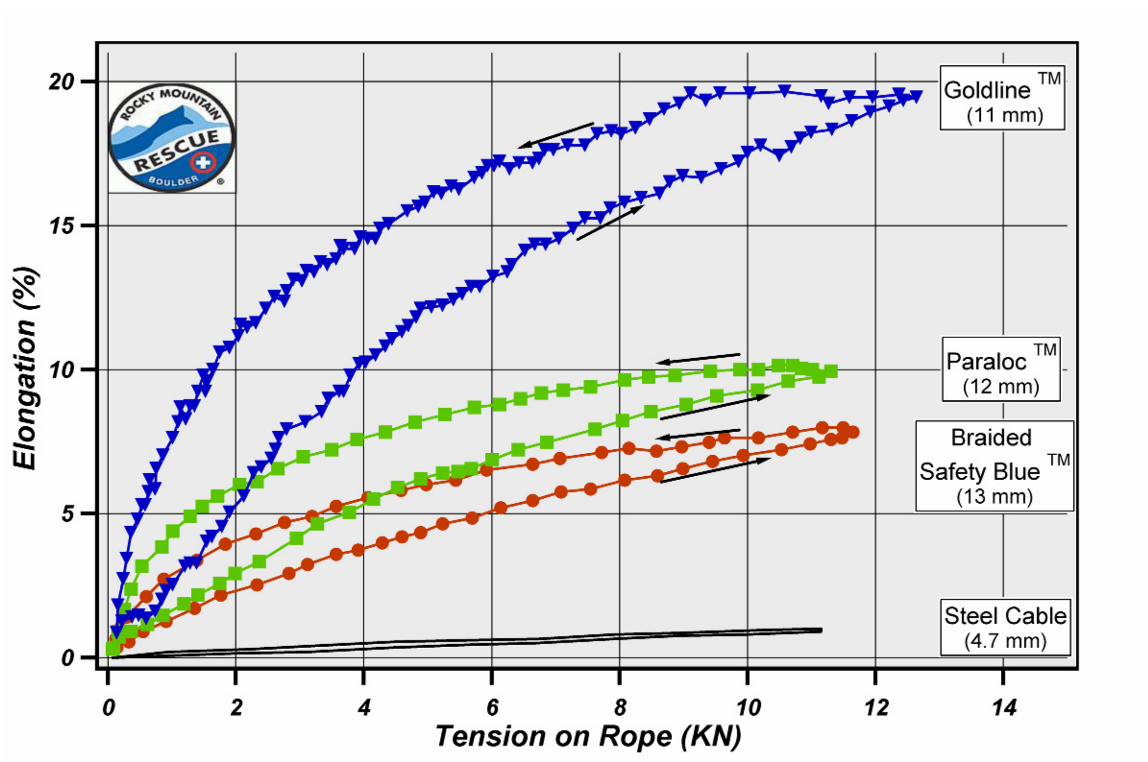
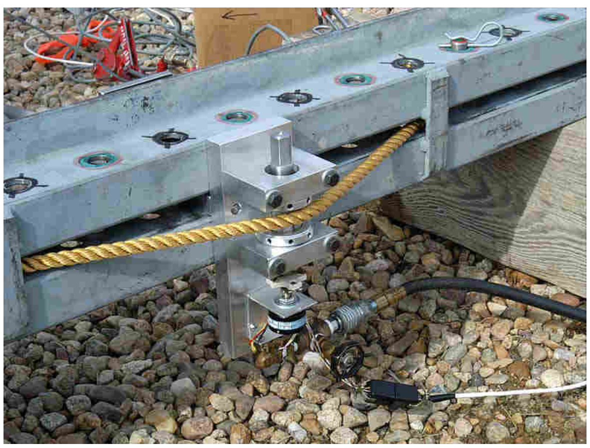


Figure 2. Rope and Cable Elongation Tests with a Quasi-Static Variation of Increasing and Decreasing Load. This plot includes three different ropes and steel cable.

ABRASION TESTS

In another series of tests, RMRG members built an abrasion device using a rotary metal file with tungsten carbide grit and found the new rope lasted fully twice as long as any other rope the group has tested (19 ropes in all). Other members took the ropes out onto rock ledges and investigated rope abrasion across sharp rock edges, providing some qualitative support for the research on the new rope.

"The experiments we ran on this new rope are extremes in terms of what we would see on a mountain rescue but these noteworthy results represent a huge advance in rope design for rescue applications and safety for our members" said Gallo.



RMRG's Rope Abrasion Device. Shown with an older style rope ready for testing.

Paraloc™ Rope with 4.4 KN Tension, not yet Failed after 22 Passes on the Rope Abrasion Tester

TEST RESULTS – DOWNED AIRCRAFT LOCATION

RMRG members are also experts in the location of aircraft that have crashed in mountainous terrain, by performing Direction Finding on the Emergency Locator Transmissions (ELT) radiated from the downed aircraft. RMRG has been involved since the early days of ELT's in developing and using special equipment for the location of downed aircraft in the mountains, even during winter storms that prevent rescue aircraft from flying.

"When an aircraft goes down in the mountains", explains Dave Hibl, a 36 year RMRG member and DAL project lead, ***"the ELT transmits an emergency radio signal for which we have specially-designed antennas and receivers. This polarized radio signal will bounce, reflect or be absorbed in different ways, depending on the terrain (e.g.: valleys, canyons or peaks). By sending out rescuers out with our sensitive antennas, we can now more-quickly pinpoint a remote crash site".***

The item of greatest importance in this technology is the portable collapsible antenna for direction-finding in multi-path conditions. By setting up antennas on a rotating platform near a 'practice ELT' and acquiring data using the data acquisition equipment (NI-DAQ1200 card and LabView 5.0) (Figure 3), RMRG was able to characterize the antenna efficiency patterns and subsequently improve on antenna design, marking yet another advance that RMRG has made to mountain rescue. These measurements will be continued in the very near future to evaluate and understand similar equipment that is just becoming available for location of PLB's (Personal Locator Beacons).

Through custom design, testing and training, RMRG's specialized downed-aircraft technology has found numerous survivors of back-country aircraft crashes and helped bring closure to many families by quickly locating the remains of crash victims.

RMRG Member Acquiring ELT Signal Using RMRG Designed Antenna

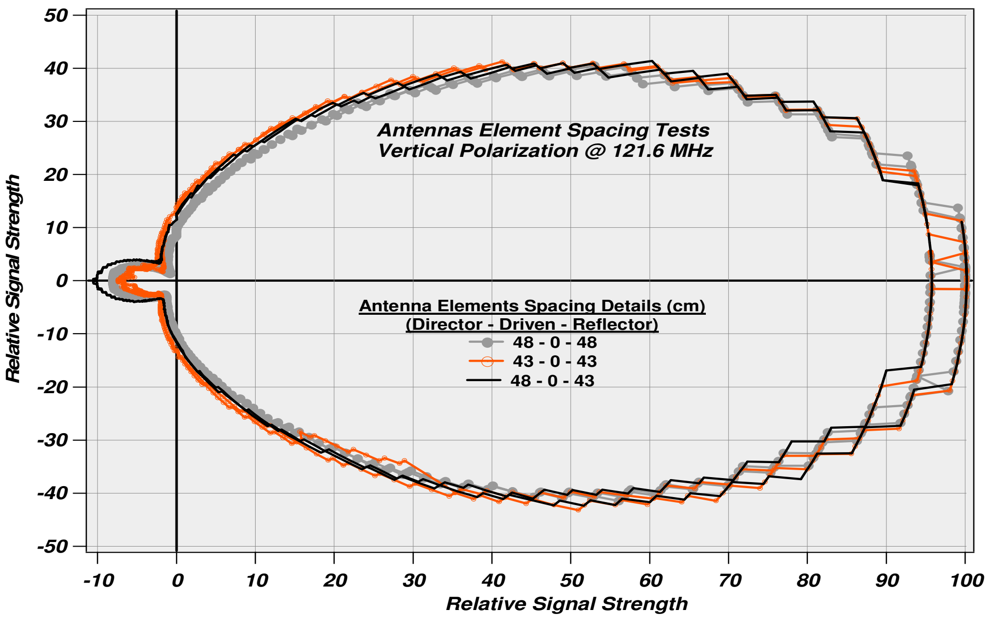


Figure 3. Polar Plot Showing Radiation Patterns for ELT Detection Antennas Designed by RMRG. Multiple traces show sensitivity to antenna element spacing.

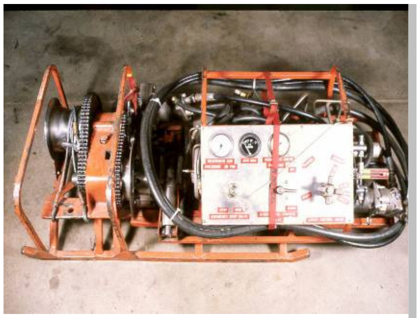
PAST AND FUTURE DEVELOPMENT

RMRG Brake Plate

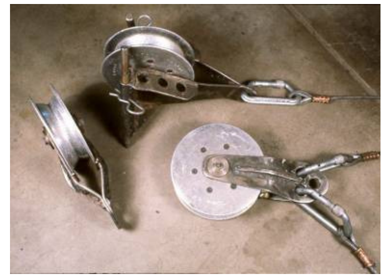
Over the years RMRG has tested many ropes, built new braking devices, cable raising and lowering devices (cable is necessary for mountain rescue in very long evacuations and fire zones), designed tough patient litters, patient helmets and many unique rescue systems (see photo montage below). Some are in use nationally and internationally, others are in use with RMRG only.

Throughout the years, the test tower facility in its various forms has played a major role in this development, and will continue to do so.

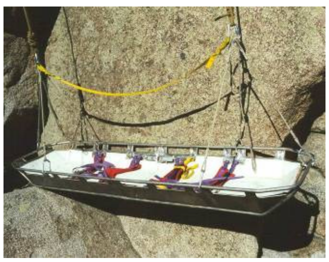
RMRG, with the help of National Instruments, has expanded its testing capabilities and hardware. With a new USB-6251 DAQ card and Labview 8.0, RMRG will add more advanced methods to its testing for greatly improved measurement. Fundamental quantitative high-speed or dynamic rescue rope properties including elongation have not been published, and, surprisingly, the rope manufacturers do not have this information. With the new NI high speed DAQ and LabView, RMRG is now in a position to acquire and analyze data from optical encoders and other sensors that will provide never-before-measured dynamic rope properties, leading to significantly better understanding of rescue systems.



RMRG Power Cable Winch (no longer in service)



RMRG Cable Pulleys



RMRG Super Litter

RMRG Super Litter Back-Packable

RMRG Super Litter Patient Helmet

RMRG Super Litter Wheel

RMRG Super Litter Ski Sled Attach-ments

A FINAL WORD ON RESCUE

RMRG operates on a budget of about $50,000 per year while expending, on average, 15,000 volunteer person-hours per year. Almost all of this investment is directed towards SAR missions (~ 130 / year), training, community safety education, the maintenance of rescue vehicles, purchase of new rescue equipment and the continuation of the long history of equipment design, testing and manufacture. The addition of ***Paraloc™*** rope to RMRG's rescue systems is one of the significant parts to this history.

The results of testing from RMRG's facility contribute towards increased safety for mountain rescuers and patients nationwide and even abroad. Development and testing help the Rocky Mountain Rescue Group to decide what is the most appropriate piece of equipment to use in its SAR operations, leading to safer and faster rescues, thus preventing injury and saving lives.

"We are in a constant pursuit to improve safety and find better methods to undertake rescue." Bill May. 38 year veteran of RMRG.

RMRG would like to recognize retired members Lewis Dahm and Dave Lewis for their pioneering efforts in mountain rescue equipment development and testing. The RMRG development and testing program would not be in existence without their dedication to the Rocky Mountain Rescue Group and the people we serve. We would also like to thank National Instruments for their support in upgrading our test tower data acquisition equipment.

This article was written with the assistance of Bill May.

Photos: Bill May, Jeff Sparhawk, Rich Farnham, Dave Christenson, Bijan Tuysserkani

Data: Bill May and Dan lack

Dan Lack, August 2007

RMRG member and participant in RMRG testing program

www.RockyMountainRescue.org

contact@RockyMountainRescue.org