

# **Science as Applied to Technical Rescue Research**

Presented by:

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# Science as Applied to Rope Rescue

## By Thomas Evans

### Introduction:

Technical rescue necessarily involves the placing of human lives on rope systems with the expectation they will preserve and protect life. Unfortunately rope rescue systems are fallible since each component has a breaking strength which is a function of equipment age, wear, history, and system configuration and use. With so many variables and the stakes of failure so high, the loss of human life, it is prudent to attempt to learn as much as possible about the dynamics of rope rescue systems used routinely.

To learn more about equipment and entire systems, testing is performed and the results are, hopefully, disseminated to the community as a resource for others and future students. In becoming a student of the published literature, and in attending conferences and training of various types, it has become clear that the rope rescue community, as a whole, does not understand how the testing it performs is science, and what part of science it is. Consequently it is prudent to lay out the philosophical basis of rope rescue science, identify its strengths, honestly appraise the quality of the data generated, and lastly make suggestions for how to improve the science that is performed within rope rescue.

This article is not an indictment of small scale or back yard testing, which should be encouraged and the results made freely available. The intent is to honestly and frankly lay out the strengths and weaknesses of the science that is presently being performed related to rope rescue, so that the weaknesses can be identified, and solutions developed and implemented. Ultimately this is a call to action for more research and testing, just with improved methods, analysis, and greater collaboration.

This article will start with a description of the general philosophy of science, describe the method used to follow this philosophy, describe the state of rope rescue science, and then honestly assess the present state of science as applied to rope rescue. Finally suggestions are presented for improving testing, data analysis, and dissemination of information to the broader rope rescue community.

### What is Science?

Before a discussion of how science should be performed it is necessary to determine what is and is not science. It seems like a trite subject, however, some scientists disagree. The most universally accepted definition is that of Popper (1959). He suggested that science is defined by its ability to be falsified. In other words, explanations of how the world works are considered science if there is a way they can be proved wrong. This enables any person to test the validity of any explanation given to them since science is independent of reference frame (observer). As a necessary corollary, it is impossible to prove anything in science, since it is the fact that nothing can be proven that makes an endeavor science.

Falsification as the demarcation of what is and is not science dictates, in large part, how we perform science. What follows is a discussion of the method of performing science, which is not to be confused with what science is. The scientific method, itself, is not science, what the method produces is.

## The 'Scientific Method':

In grade, middle, and high school we teach 'The Scientific Method', which has some predetermined number of steps, somewhere between five, and fifteen. Different teachers emphasize different points, and teach a different 'method'. Since the scientific method is really in service to the demarcation of falsifiability, it is really a way of approaching a problem, not a rigid series of steps. While the method is not a series of discrete steps performed in sequence, the parts to the method will be presented here in logical order to facilitate understanding, even though in practice the steps are often accomplished simultaneously.

Science starts with an interest; interest in something a person has observed. There are two parts to this; first, initial observations, and second, interested parties. Without either, science does not move forward. Within rope rescue we have many practitioners with decades of experience (observations) and all of us are interested in the subject since we and our friends place our lives on the systems we build. Consequently there is an impetus for research, as demonstrated by the ITRS.

In an attempt to understand how part of the world functions, in this case rope rescue systems, hypotheses are developed by the interested observer to explain observations. All hypotheses have three parts; they are based on existing data (observations), they explain the data, and they are falsifiable (make predictions that can be tested). It is important to note that multiple hypotheses should be developed. When a person functions using multiple working hypotheses it becomes far more difficult to nurture a pet hypothesis that is favored above others and not adequately subjected to falsification (Chamberlin 1890).

Hypotheses are subjected to falsification through direct tests, which require producing antecedent conditions, which should produce a specific outcome given the explanation of the process under study. If the predicted outcomes are not observed, the hypothesis is rejected. Be aware false negatives and positives do exist so the use of analysis in all phases of experimental design, data collection, and analysis is essential (Johnson 1933). If the expected results are observed the hypothesis is supported, however, this does not mean the hypothesis is correct. It has only been supported, which is a logically much weaker outcome than direct falsification. Consequently supported hypotheses should be kept and tested further. With the next round of tests, additional hypotheses can be created and tested based on the observations accumulated during initial testing (for a detailed explanation of this method, see Gilbert 1886).

After many failed attempts at falsification, a hypothesis can be elevated to the level of theory, but this is a level of esteem only afforded a few ideas, like the Theory of Gravity, Electromagnetic Theory, Theory of Evolution, Germ Theory, etc. It should be noted that the word 'theory' has a distinct meaning in science that it does not have within the culture as a whole. The word 'theory' in popular culture denotes uncertainty, while in the scientific context, 'theory' denotes an idea that has been tested so rigorously that it is unlikely to be falsified.

Finally, results from tests and analyses should be disseminated to others in a format accessible to other contemporaries and later generations. If results are not communicated in some permanent way, it is equivalent to the tests never occurring. Without a permanent record of past events, other students and investigators have no way to learn the information gained from previous tests, and are often forced to repeat them to determine the validity and applicability of the information learned through secondary sources.

While practicing the method outlined above, it is possible to make many mistakes leading to unfounded and erroneous conclusions. Consequently there are data collection, analysis, and

reporting conventions that have become standard practice to facilitate producing reliable data and forming robust conclusions

### Data Collection, Analysis, and Reporting Conventions:

Data can be collected poorly, incorrectly, and analyzed inappropriately. To eliminate a myriad of problems with data analysis, conventions have been established for the collection of data. A complete treatment of these issues is outside the scope of this article, however, there are a few conventions that are important enough to mention explicitly.

Robust data is collected in well designed experiments, which are most easily designed in collaborative teams from the inception of an idea to publication of results. The strengths of each collaborator are utilized while each weakness is minimized by the presence of other's strengths. Having many perspectives improves and hones the thought process and produces a more elegant and physically meaningful product. For best results all experiments should be designed in collaborative groups.

Each research group should develop, and explicitly state, multiple working hypotheses. Having multiple hypotheses prevents investigators from preferentially treating hypotheses differently and yields more information generated per experiment.

Given that multiple hypotheses are being tested during an experiment, there should be multiple treatment groups. Having multiple treatments increases the amount of information gathered from each test, moving science forward faster and more efficiently.

For statistically significant results, large sample sizes should be used (>30) in each treatment. It is important to note that this means that there should be above thirty samples in each treatment, necessitating a substantial investment in raw materials, time, or both. If statistically significant samples are not used, it is difficult to obtain results that reflect the variability between treatment groups and variability in responses within a treatment. Distinguishing these differences can be subtle, so there is no substitute for large enough sample sizes.

Samples used in experiments should have known and common histories. Without a known history it is impossible to determine if the results obtained in a test were due to the experimental treatments or the history of the sample. In addition, all samples should have the same history so observed changes can be confidently assigned to variability in response to treatments and not the history of samples.

All treatments and trials should be performed identically so the observations made reflect experiment treatments, and not changes in experiment method, measurement, or observation.

Quantification of experimental results is, strictly speaking, not always necessary. Depending on the hypotheses subjected to falsification, quantification may not be needed since even categorical variables can be statistically analyzed. However, when quantification is employed, data should be collected consistently and with the desired degree of accuracy and precision.

Results of experiments should be analyzed using statistics. There are many methods for data analysis, and the appropriate method should be used given the experimental design and the type of data collected. Often a statistics professional is needed to analyze results, and should be consulted if needed.

Experiments and entire studies should be repeated. There is variability in experiment results, and this variability can only be observed and measured by replication. In addition, previous research has rarely been repeated, and the results and conclusions have not been validated or tested. Without repeating previous research, it is possible that the conclusions

reached were in error, and subsequent research is building on incorrect information. Also, many research projects have never had results published, leaving students wondering the genesis of the conclusions taught by previous generations, thus necessitating experiment replication and dissemination of new results.

Results and conclusions from tests should be disseminated to the greater scientific community. The format of communication should be one that can be archived as well as easily distributed, which is typically a publication of some sort. It is imperative that results be archived so that results are not lost, and research is needlessly repeated (replication of previous studies requires a record of previous research, so the replication I cite here would be to generate initial results anew). Peer review of articles can be helpful to bring additional ideas and points of view to bear on a problem, however, peer review can also lead to unpopular ideas being censored even if supported by data. Ultimately peer review should be considered and used when appropriate and beneficial.

#### State of Rope Rescue Science:

This assessment is based on a perusal of the ITRS proceedings papers available to the author (2000, 2009, ITRS archives online), combined with the handful of rope rescue related research reports that can be found on line with a few Google searches. The results are primarily observations, not backed with statistics; however, since a general picture of the state of rope rescue science was the goal, this approach was deemed adequate.

The vast majority of experiments performed were conducted by research groups comprised of one or two people. The drawback to such small working groups is lack of input from others, leading to oversights in experimental design, data collection, and in data presentation. Research carried out in collaborative teams is often demonstrably better. There were exceptions where tests requiring small parties of participants between three and around a dozen personnel.

Most often experiments were designed to gather observations rather than test hypotheses. Since most testing solidly fell under the rubric of pilot experiment, usually tests failed to yield statistically significant results. When hypotheses were tested, rarely multiple hypotheses were used.

Samples used in tests usually had known histories (usually hypothesis tests), however, some samples had unknown histories, and were tested to determine their safety after extensive use.

Small sample sizes and few replicates are the rule, with no counterexample found in any publication.

In nearly all cases results were quantified, though the statistics used were not always appropriate, or correctly applied.

Studies were rarely repeated, though similar questions or hypotheses were often investigated, frequently with similar results.

Results are rarely published or made available to the community outside of ITRS proceedings, which are often incomplete. When results are freely available to the public, they are often difficult to find and access.

Given the present state of technical rescue science, what are the strengths exhibited by our combined research efforts?

### Strengths of Technical Rescue Science:

Past ITRS proceedings volumes, miscellaneous digital publications, and the personal accounts of rope rescue practitioners constitute a huge body of observations upon which hypotheses can be generated. This sea of experience is enormous, encompassing hundreds of years of combined observations, and should be organized into meaningful hypotheses. This mass of observations is far greater than in some fields of science, so this resource is substantial.

The sheer number of rope rescuers dwarfs many fields of professional science, and should not be discounted as a substantial advantage in rope rescue science. The massive group of interested and motivated observers involved in technical rescue had such great interest that they created their own conference (ITRS), which is an incredible achievement for the growth and development of science in any discipline. The potential for volunteers to carry out experiments is prodigious, simply because so many individuals are interested in the results.

With such an interested pool of motivated volunteers it comes as no surprise that there is a panoply of pilot experiments with published results upon which full scale testing can be based. Experimental sciences generally start with pilot experiments when investigating new phenomena, thus the existing published results from pilot experiments provide an ideal starting point for future research projects.

Practitioners of rope rescue techniques come from many trades and walks of life, creating a personnel pool with versatile expertise. Nearly any research project of interest to the technical rescue community could be investigated using the knowledge possessed by existing interested parties, so long as they were brought together to work in a group. Such diverse skill sets are difficult to find in a single discipline of science, necessitating the development and fostering of professional collaborations, which are easier to form in technical rescue since all parties are interested in, and have knowledge concerning the phenomena under study.

### General Deficiencies within Technical Rescue Science:

Most research conducted would benefit from greater collaboration, with greater numbers of investigators involved in designing and implementing experiments, and subsequent data analysis. Small research groups are capable of solid science, so the pursuit of a large research group is preferable but not necessary for robust results.

Experiment design has been lacking across most studies, and would be most improved by the clear statement of multiple hypotheses. With a clear statement of the hypotheses under study, the data necessary to falsify them can be determined and collected, thus directing the use and consumption of resources. Even employing the basic concept of a hypothesis test would be an improvement for most research.

Most research used small sample sizes which produced data too inadequate to analyze rigorously with statistics. Larger sample sizes are needed in addition to improved experiment design, which can be expensive. If a collaborative group is assembled more resources can be donated or purchased to facilitate experimentation, which yields increased statistical power and resolution when large samples are used.

Often there was a focus on quantifying results as a means of demonstrating legitimacy of the research. Quantification does not equate to well designed and performed research, so a readjustment of the expectation of quantification is needed. Categorical data can be analyzed statistically, and is a good alternative to time consuming and often expensive quantification procedures or equipment. During hypothesis generation and experiment design, the data required to falsify hypotheses should be determined. In some cases quantification of results is not

necessary, so the decision should be made whether or not to quantify results. If quantification is chosen, then the accuracy and precision of the measurements needed should be determined and the equipment with the required accuracy and precision should be obtained. It is important to design research based on the science and not the measurement device available, since measurement devices can be purchased, borrowed, or rented. In many cases local universities or companies are willing to loan out equipment or allow their use on site for research purposes, so even expensive equipment can be used for free with a little ingenuity and persistence.

Statistics were often not used, and when they were employed, they were often used incorrectly. Results of experiments should be analyzed using the appropriate statistics for the experiment design. If a researcher or research group does not know how to analyze results appropriately, seek professional assistance from a statistician (many can be found at local universities). As a rope rescue community we should be calculating and applying statistics correctly, or not at all, given that we alter systems and the safety of human lives, as a result of these statistics.

Technical rescue experiments should be replicated to provide observations of the variability in phenomena, as well as to validate previous research. There is a vast amount of testing data that is not available to the serious student, so it is impossible to determine what the best technique is without accepting the recommendations of senior riggers. This creates a dire need to replicate previous research and publish the results so informed decisions can be made by serious students. An excellent example is the testing data used to develop recommendations for tensioning of highlines. Without access to the experimental design and raw data it is unclear if these recommendations should change with different equipment, etc. The only way to know is to replicate the research.

Lastly, there is an urgent need for communication of testing data and results. Standards should be developed for the reporting of test conditions and results, the dissemination of information, and archiving these reports. Technical rescue science should be held to a higher standard than other sciences because lives literally hang in the balance on the conclusions we derive. Consequently we urgently need reporting standards that will improve information access for all parties interested in rope rescue.

#### Suggestions for Improvement:

Research should be performed in collaborative groups where ideas, talents, and resources can be pooled. As science has become ever more specialized, a collaborative framework has become essential, and is now the standard means of operating. Rope rescue science should adopt this collaborative research model for most research. Moreover, as a community we should choose a few important questions and pool our resources to answer these questions. This is equivalent to the high energy physics community pooling resources to build and operate ever larger particle accelerators, or biochemists forming cancer research centers. Large collaborations facilitate answering bigger questions more efficiently.

A considerable time should be spent in experimental design, preferably involving a group of investigators. Investigators should consider reading one of many books on experimental design and analysis, which would give them ideas to improve their research. All research groups should also consider peer review by asking external personnel to review their ideas. This is an excellent way to receive outside suggestions, and this process often greatly improves the final product. University or government laboratory scientists are good resources to contact for external review, as are other rope rescue technicians and researchers.

Rope rescue experimentation has been performed on a limited budget, which has forced small sample sizes, and lack of replication. This can be solved by applying for federal grants through the National Science Foundation and the Department of Homeland Security. Large sums of money have been made available for 'security' related research, and rope rescue solidly falls under this rubric. Since small sums of money could be used to perform large scale experiments that would dramatically alter our understanding of rope rescue systems and their function, such a proposal would have a high probability of success. Probability of success would increase with a consortium of nonprofit organizations pooling their resources and facilities, like the National Speleological Society, the American Alpine Club, the Mountain Rescue Association, and the National Association for Search and Rescue, etc. It is time for rope rescue science to take the next step to performing larger scale experiments by forming larger working groups, across organizations, and applying for federal support for research.

Research groups should request help from outside parties for equipment and analytical support. Universities are underutilized by the public, particularly public universities that have a mandate to perform research that benefits the society as a whole. Avail yourselves of their greatest resources, their professors and graduate students, who can then make physical resources, like testing equipment, available. In addition, if math and statistics are not strengths within a research group, approach a statistician about helping with data collection and analysis.

Lastly, we need a technical rescue research journal. Results from backyard and larger scale tests go unreported commonly. This creates pockets of local knowledge that others have a hard time evaluating. It is time we, as a community, supported the development of a peer reviewed, open access, journal that will publish rope rescue related research articles. This single step will facilitate the dissemination of rope rescue knowledge, improve safety for all, and contribute to improving the quality and quantity of the science published in the field.

The preceding is not meant as an indictment of rope rescue research, but a call to action. Presently the research performed is not of the quality we are capable, since there are many intelligent and motivated rope technicians that could improve the science. As a community we should organize, make a list of priorities, pool our resources, seek out funding, and carry out a series of large scale experiments on commonly used systems. This effort would unify the technical rescue community, identify and then investigate the most pressing questions, and ultimately lead to increased safety for rescuers and subjects alike.

### Bibliography:

Note: For a copy of any of the citations send an e-mail to: [cavertevans@gmail.com](mailto:cavertevans@gmail.com)

Chamberlin, T.C., 1890, The method of multiple working hypotheses, *Science* (old series) 15:92-96

Gilbert, G.K., 1886, The inculcation of the scientific method by example, with an illustration drawn from the Quaternary geology of Utah, *American Journal of Science* 31:284-299

Johnson, D., 1933 The role of analysis in scientific investigation, *Science* 77(2007):569-576

Popper, K., 1959, *The logic of scientific discovery*, Basic Books, New York

