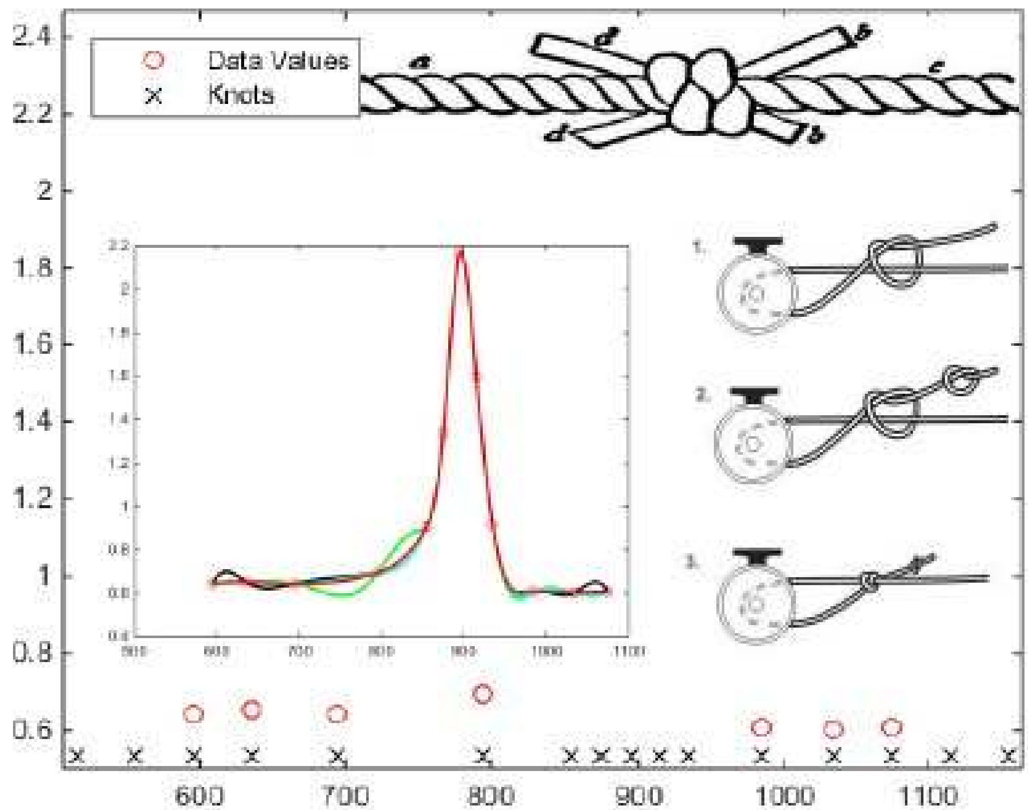
Nylon Highway

Issue #59



... especially for the Vertical Caver

#59

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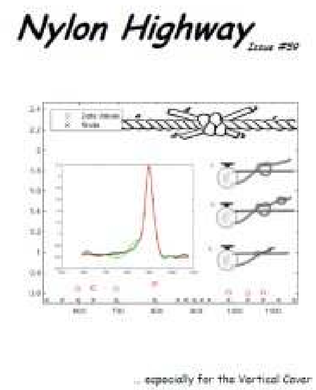

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The *Nylon Highway* is published by the Vertical Section of the National Speleological Society on a regular basis pending sufficient material. Material is posted on the Vertical Section's web site soon after being received by the Editor. A volume of all material is printed and distributed to those not having access to the electronic version on an annual basis.

It is the intent of this publication to provide a vehicle for papers on vertical work. All submitted articles containing unsafe practices will be returned to the author. Opinions expressed herein are credited to the author and do not necessarily agree with those of the Editor, the Vertical Section, its members or its Executive Committee. The reader should understand that some material presented in the *Nylon Highway* may be of an experimental nature and is presented herein for peer review. The reader should exercise good judgment and use common sense when attempting new vertical techniques or using new equipment.

WARNING: The reader must acknowledge that caving, climbing, mountaineering, rappelling, rescue work and other rope activities expressed in the *Nylon Highway* are inherently dangerous activities and serious injury or death could result from use and/or misuse of techniques and equipment described in this publication.

An Analysis of Bowlines

By Mark Gommers

This article was removed by request of the author.

The updated PDF is available on his website at:

http://www.paci.com.au/knots.php (at #2 in the table).

Original article was 32 pages.

Rescue Knot Efficiency Revisited

By John McKently

From the 2014 International Technical Rescue Symposium (ITRS)

John McKently has been the Director of the CMC Rescue School since 1995 and is a long time ITRS attendee and presenter. In addition to his teaching duties, his practical rescue experience comes from 40 years as a member of the Los Angeles County Sheriff's Montrose Search and Rescue Team.

<u>OCCUPATION / AGENCIES</u>

1. Senior Instructor: California State Fire Training
   • *Confined Space Technician*
2. Instructor: California Peace Officer Standards and Training (POST)
   • *Search Management* and *Winter Search Management*
3. Instructor: US Mine Safety and Health Administration (MSHA)
4. Member: Montrose (CA) Search and Rescue Team, Los Angeles County Sheriff's Department
5. Member: California State Fire Training
   • *Rope Rescue Technician Curriculum Development Working Group*
   • *Confined Space Technician Working Group*

Rescue Knot Efficiency Revisited

In 1987 personnel from CMC Rescue performed tests on a variety of knots commonly used in rescue systems to determine their efficiency. The purpose of testing was as preparation for the First Edition of the CMC Rope Rescue Manual and for presentations at various industry events. Prior to this time there had been similar testing on climbing knots, but the rope used was three-strand laid rope (Goldline) and there were no details of the testing conditions or methods used, so the results were not considered repeatable or of unknown value to rescuers using low stretch ropes.

Our testing was done at Wellington Puritan, a large rope manufacturer in Georgia, but no details were given about their test machine. There wasn't any Cordage Institute #1801 standard for test methodology at the time, though the report does state that Federal Test 191A Method 6016 was used. In the cases where there was a loop created by the knot, it was attached to the test apparatus with a ½" steel carabiner which had an MBS ±15,000 lbf, well above that of the sample rope or the test knot.

Tests were performed on 18 knots in rope and eight in webbing. Some were the same knot but purposely tied incorrectly. For example: a bowline with the tail on both the inside and outside of the loop. Five samples were tested of each knot and the point of break was noted. Most tests show breaking at the jaws of the test machine or in the knot. Our experience with the 2014 tests was that in most cases the rope broke at the first turn where it entered or exited the knot.

1987 Tests ½" Rhino Rescue Rope (100% Nylon)

Double Fisherman	21%	strength loss	equals	79% Efficiency
Figure 8 Bend	19%			81%
Figure 8 Loop	20%			80%
Double Figure 8 Loop	18%			82%
Bowline	33%			67%

1" Tubular Webbing (100% Nylon)

Water Knot	36%			64%
Overhand Loop	35%			65%

These and similar test results are referred to or copied directly in On Rope (Smith and Padgett), Confined Space and Structural Rope Rescue (Roop, Wright and Vines), and many other state and local fire training manuals.

From a quick glance at those test results, many of us determined that you could expect about a 20% strength loss. In the "Figure 8 family of knots," and those were much stronger than the more traditional Bowline, with the added advantage of the Figure 8's being an inherently safe knots.

In High Angle Rescue Techniques 3rd Edition (Hudson and Vines) four samples each were tested with the following results:

Bowline in 7/16"	74%	Bowline in ½"	73%
Figure 8	78%	Figure 8	80%

In this case no information was given as to the test methodology, environmental conditions or rope used for the test. While the results are not exactly the same, they are close enough to show a pattern confirming our earlier work. In that manual they also include the following caveat, "***Test results may vary, depending on a number of factors such as the design of the rope, the manufacturer and the test conditions.***" Truer words were never written and that statement is applicable to all of the tests described in this report.

During the process of revising the CMC Rope Rescue Manual in 2008 we thought it would be interesting to revisit the tests, and if possible repeat them to see how the results compared. For those tests we used CMC Lifeline, a 100% nylon product, which is similar in construction to the Wellington Puritan Rhino except that it is manufactured by New England Rope. The list of knots tested was reduced, but the other significant difference was the test machine. For the first time the force measuring was done by an electronic load cell and not a mechanical dynamometer so the readings were more precise.

As time went on 100% polyester rope was introduced. Polyester has a higher chemical resistance than nylon, but the main reason for its acceptance by the technical rescue community is that it has less elongation than nylon. Another property of polyester is that it is has less surface friction or is "slipperier" than nylon sheathed ropes. We wondered if that characteristic would allow the rope fibers within the knot to better adjust to the compression and tensioning that occurs during loading and maybe even be more efficient.

For consistency we tested the same knots used during our 2008 testing. We followed the Cordage Institute standard test method but there were some differences. The person tying the knots was different than the earlier tests. The test machine was different. Even with the longer pull distance(60" vs. 48") we had to pretension the samples beyond hand- tight for the series of tests using Rescue Lifeline. We assume that was done during the earlier tests but the notes did not indicate that. The testing was also done on a vertical axis where the previous testing was done horizontally. We do not think that would have a bearing on the results, but it should be noted. In the case of the loop knots- Alpine Butterfly, Figure 8 on a Bight, Double Figure 8 Loop and Inline Figure 8, there was no load in the loop during the end-to-end tests. We wanted to do that, and plan to do so in the future, but logistically it became very complicated and was compounded by the constant need to adjust the load as the sample elongates during the testing.

CMC Tests:

3/2008 ½" CMC Rescue Lifeline (100% Nylon)

9/2014 ½" Static Pro (100% Polyester)

	CMC Lifeline			CMC Static-Pro Lifeline		
	kN	Lbf	Efficiency	kN	Lbf	Efficiency
Control A	**42.7949**	9620		40.8792	**9190** (10 samples)	
Control B	**46.97152**	10,559				
Average	**44.8832**	10,090				
Alpine Butterfly						
End to End	**29.5851**	6651	66%	24.1894	**5438**	60%
Loop to End	**34.342**	7720	77%	24.7944	**5574**	61%
Bowline	**30.4932**	6855	75%	23.3621	**5252**	58%
Figure 8 Loop						
End to End*	33.0147	**7422**	74%	22.1877	**4988**	54%
Loop to End	**33.5487**	7542	77%	28.4108	**6387**	70%
Double Loop Figure 8	**32.8681**	7389	75%	27.0363	**6078**	66%
Figure 8 Bend	**25.47428**	5727	57%	27.0363	**6078**	66%
Double Fisherman	**35.5987**	8003	79%	32.8234	**7379**	80%
Inline figure 8						
End to End	**23.0918**	5191	51%	19.6834	**4425**	49%
Loop to End	**32.7848**	7370	73%	25.5639	**5747**	63%
Scaffold Knot	**36.5106**	8208	81%	28.0149	**6298**	69%

*Tests conducted 10/15/13 on samples from the same spools of rope as other tests

Values in **BOLD** type are as originally recorded. The other values are calculated from those.

Same samples as above submerged in Goleta, CA tap water for 1 hour

	CMC Rescue Lifeline (3/2008)			CMC Static Pro (9/2014)		
	kN	lbf	% Efficiency	kN	lbf	% Efficiency
Control	44.0107	**9894**	98	42.7608	**9613**	105
Bowline	28.1261	**6623**	67	23.7268	**5334**	58
Figure 8 Loop	37.9789	**8538**	91	27.7213	**6232**	68

Comparison of selected knot efficiency

Knot	Rhino Rescue-1987	Nylon Lifeline-2008	Polyester Lifeline-2014
Bowline	67%	75%	58%
Butterfly		77%	61%
Figure 8 on a Bight	80%	77%	70%
Double Loop Figure 8	82%	75%	66%
Figure 8 Bend	81%	57%	66%
Double Fisherman	79%	79%	80%
In line Figure 8		73%	63%
Scaffold Knot		81%	69%

These tests provide an estimate of what you can expect. There are numerous variables that can affect the efficiency of the knot.

John McKently
CMC Rescue
ITRS 2014

Slow Pull Testing of Progress Capture Devices

By DJ Walker & Russell McCullar

From the 2014 International Technical Rescue Symposium (ITRS)

Abstract:
For years, rope rescuers and students have calculated the safety margin of systems by comparing the greatest expected load and the weakest engineered component of a rope system. This ratio is often referred to as a Static System Safety Factor (SSSF). It allows for a safety margin or buffer to account for unidentified forces caused by friction and other "noise" within a system. The breaking strengths used to calculate the SSSF are often published by equipment manufactures and even stamped on products that are tested by third parties. The problem is that devices used in haul systems, acting as Progress Capture Devices or Ratchet Cams, do not have consistent published rates of failure. The purpose of this research is to identify the failure strengths and conditions of common PCDs and publish the information using conservative 3-sigma values in a format of SSSF ratios.

This allows rescuers and students to more readily perform field calculations of the SSSF of their haul systems and choose the most appropriate devices for a given application. The following research questions were answered using empirical testing and observation.

A. *What is the 3-Sigma MBS of a single Prusik, double Prusik, Rescuescender,Grip, Munter Hitch, I'D, and MPD when used on **12.5mm** PMI EZ-Bend?*
B. *What is the 3-Sigma MBS of a single Prusik, double Prusik, Rescuescender,Grip, Munter Hitch, I'D, and MPD when used on **11mm** PMI EZ-Bend?*
C. *What constitutes a failure of a PCD?*
D. *What constitutes a loss of confidence of a PCD?*

Bios: This will be a joint presentation by Russell MuCullar and DJ Walker.

DJ Walker: DJ is currently a Lieutenant in the Austin Texas Fire Department (AFD), serving as the Special Operations Training Officer. His responsibilities include the development and management of the Special Operations Training program for the 140 member AFD Special Operations Team. DJ is the Chair and founding member of a technical rescue committee called Regional Standardization of Equipment and Training (ReSET) who created and delivers a technical rescue training program that serves agencies in Central Texas. DJ is a member of Texas Task Force One, serving the State of Texas as a Helicopter Search and Rescue Technician (HSART), deploying with Texas Military Forces Blackhawk helicopters in time of disaster. He has been the South Central Regional Coordinator for the National Cave Rescue Commission (NCRC) since 2004 and facilitates cave rescue training and provides cave rescue resources in five states. DJ served as the Technical Rescue Track Leader for five consecutive NASAR conferences in the mid 2000's. When not working, DJ enjoys caving, climbing, hiking and doing anything outdoors. He has been a student of Technical Rescue since 1998 and regularly teaches rescue for a number of organizations. This will be his 12^{th} ITRS to attend.

James Russell McCullar II: Mr. McCullar is a Senior Instructor with the Mississippi State Fire Academy. His responsibilities include the management of NFPA 1006 Rescue Programs. Russell is a Rescue Specialist and Technical Search Specialist with FEMA Tennessee Task Force 1. His firefighting and rescue career began with the Lafayette County Fire Department in Oxford, MS, as a volunteer firefighter, where he ascended to the rank of Station Captain. As a career firefighter with the Batesville Fire Department, he rose to the rank of Station Lieutenant before his departure in 2010. In 2009, he earned his Master's Degree in Homeland Security at the University of Mississippi where he also received a Bachelor of Business Administration in Management in 2005. Over a fourteen-year career, he maintains certificate training in excess of 3000 hours and over 2000 hours of instruction in technical rescue.
Mr. McCullar spends his time instructing other rescuers around the state of Mississippi and the country. He resides in Brandon, Mississippi with his wife, Sydney.

Slow Pull Testing of Progress Capture Devices

2014 International Technical Rescue Symposium

DJ Walker & Russell McCullar

Rescue technicians strive to evaluate the integrity and behavior of their system components, and give consideration to those characteristics as they relate to safety. One of the more common analyses done of a rescue system is a **Static System Safety Factor (SSSF)** analysis. This **SSSF** is essentially the ratio of system or component strength compared to anticipated force. The **SSSF** becomes difficult to assess when the strength of a component, or the interaction of that component within the system, is unknown. Most of the engineered equipment and software common in rope rescue have a published and labeled Minimum Breaking Strengths (MBS) provided by the manufacturer and often validated by Underwriters Laboratories.

The problem is that devices used in haul systems, acting as **Progress Capture Devices (PCDs)** or ratchets, do not have consistent published rates of failure. There is no widely proliferated information outlining how these **PCDs** interact with the host rope at the point of failure. As a consequence of this information-gap, field practitioners cannot accurately calculate the **SSSF** in their systems. The researchers feel this likely leads to an over-estimation of system integrity and **SSSFs**. The purpose of this research is to identify the failure strengths and conditions of common **PCDs** and publish the information detailing high, low, and average rates of failure as well as the conditions in which this occurs.

The results of this research will allow rescuers and students to more readily perform field calculations of the SSSF of their haul systems and choose the most appropriate devices for a given application. The following research questions are the goal of this project. They will be explored using empirical testing and observation.

1. What is the strength of a single Prusik, tandem Prusik, Rescucender, Grip, Munter Hitch, I'D, and MPD when used on both new and old 12.5mm PMI EZ-Bend Kernmantle Rope?
2. What is the strength of a single Prusik, tandem Prusik, Rescucender, Grip, Munter Hitch, I'D, Basic, and MPD when used on both new and old 11mm PMI EZ-Bend Kernmantle Rope?
3. What constitutes a failure of a PCD?
4. What constitutes a loss of confidence of a PCD?

Background

SSSF

It is important that "Safety Factor," in the context of rescue and this research is clearly defined. There are two types of Safety Factors relevant to Technical Rescue:

1. <u>Component to Force Ratio</u>- the ratio between the MBS of a component compared to the force applied to it.
2. <u>Static System Safety Factor (SSSF)-</u> the Component to Force Ratio of the weakest link in the whole system.

Technicians must be capable of assessing forces applied to components. They must also be familiar with the Minimum Breaking Strength (MBS) of devices in the manner of which they are being used. There are a lot of myths about Safety Factors. The most prevalent of these incorrectly states that the National Fire Protection Association (NFPA) requires a 15:1 safety factor. NFPA has not published a minimum "Safety

Factor" in their technical rescue standards. It is up to teams, or Authorities Having Jurisdictions (AHJs) to decide how they implement Safety Factors into their programs or Standard Operating Guidelines.

Central to determining a Safety Factor is identifying the MBS of a component. Without this, half of the ratio does not exist. For some devices MBS is simple to define. Take a carabiner for example: apply force to it until it fails; do this with several samples; perform some statistical mathematics, and you have a fairly reliable MBS. For other devices defining MBS is not so easy. In some cases it just may not be possible. How can rescuers quantify the Safety Factor of these devices in their intended application?

The PCD

Progress Capture Devices (PCDs) are used to "capture the progress" made while operating a hauling system. They are often used to support the load so that a mechanical advantage system can be reset. In this application, the PCD sees an initial application of force as the load is transferred, from the haul team, onto the PCD. Once the load is fully supported by the PCD it holds the load static until the system operator(s) take further action. There are many devices that can be used as a PCD. For the purposes of our study we focused on the following:

- Munter Hitch
- Single Prusik (8mm)
- Tandem Prusik (8mm)
- Petzl Rescucender
- Petzl Basic
- Petzl I'D
- PMI/SMC Grip
- CMC MPD (Multi-Purpose Device)

It is important to note that the PCDs are loaded in a controlled fashion. It is not the intent of this study to examine similar devices in a dynamic setting or a belay configuration. The results of this study should not be applied to belays.

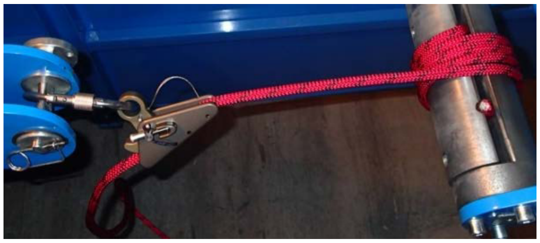
Literature Review

The following sources of information and literature were evaluated and considered in the context of the research: *Manual of U.S. Cave Rescue Techniques 3rd Ed.*, *Engineering Practical Rope Rescue Systems*, *High Angle Rescue Techniques 3rd Ed.*, *Technical Rescuer: Rope Levels 1 & 2, On Rope*, *CMC Rope Rescue Manual 3rd Ed.*, *Is Slow-Pull Testing of Equipment Realistic?*, *1-in. Webbing Anchor Tests* (2000), *NASAR Fundamentals of Search and Rescue*, User documents for various pieces of hardware. Consulting with Engineers & Trainers at PMI, CMC Recue, and Petzl.

Procedures & Experimental Design

All tests were conducted using a SKV Model TTL-10 horizontal test bed with 25,000 pound capacity at the PMI factory in LaFayette Georgia. The machine is in a large warehouse and conditions were a fairly consistent 72 degrees and 72% humidity. Each PCD was connected to the static end of the testing device with a SMC Light Steel Carabiner. Each rope section was 15 feet in length and was connected to a bollard on the end of a hydraulic ram. The ram had two speeds; the normal speed has a continuous pull rate of 6 inches per minute. The second speed, we called "Fast Forward", increased the rate of pull to 59 inches per minute. As each test began the "fast forward" was pressed until 1 Kilo-newton (kN) of force was exerted on the PCD, this was to simulate the initial loading of a PCD when the haul team is transitioning the load onto the PCD. A minimum of five samples of each combination of rope type and PCD type were tested. For a few combinations the sample size was increased due to unexpected anomalies or wide standard deviations. Each pull was continued until failure occurred, or five minutes elapsed time passed. During the tests, the following information was obtained: (a.) peak force value upon failure, (b.) graphic representation of the escalation and reduction of forces for each test, (c.) real-time observation of each test, (d.) video documentation of relevant tests and findings, (e.) photographs of remarkable observations, (f.) samples retained of each test combination or result.

Two examples of the test set-up can be seen below:



The Rope and Prusiks

There are so many variations of rope construction both between different manufacturers and with different models from any one manufacturer. The researchers who initiated this study most commonly use PMI EZ-Bend rope. In the interest of focusing efforts and resources, the tests were performed on PMI EZ-Bend rope. Diameters tested were 11mm and 12.5mm rope. Both new rope and old rope was used. The new rope was cut directly off a spool that never left the PMI factory. The "old rope" came from three different training caches and was considered "in service" up until the day it was used for testing. The 11mm rope was about 10 years old and saw service about 15 days per year. The older 12.5mm rope was 7 years old and saw service about 50 days per year. The second "old" 12.5mm rope was manufactured in 2011, in service for 1 year, and saw 24 days of use.

In addition to the "standard construction ropes" we also included 11mm Extreme Pro rope in the testing. Extreme Pro is a new rope made by PMI. It is an all Polyester rope with a bonded core and sheath using what PMI calls "Unicore" technology. Only "new rope" was used for the Extreme Pro test series.

The cordage used for Prusiks also consisted of new and old, all manufactured by PMI. The new accessory cord was cut directly off a spool that never left the PMI factory. The "old Prusiks" came from the same respective training caches as the rope and varied in age from 2004-2010.

Failure vs System Operation Limit

As the tests were conducted, a distinct behavior pattern was observed. Some rope/PCD combinations would behave in a way that was considered a "Failure" while others reached what the researchers deemed the "System Operation Limit".

Failure- an outcome that would have allowed the load to release and fall to the ground, or those outcomes that severely damaged the rope or PCD to the point that there was a *loss of confidence* in the ability for the PCD/rope to support the load. The most common type of *loss of confidence* was desheathing the rope, exposing the core.

System Operation Limit- an outcome where the rope or PCD did not cause a release of the load but the combination achieved a force where it would not perform the intended job (Progress Capture). Most commonly this was when the rope continuously slipped through the PCD and would not hold the load or cause a loss of confidence in the system's ability to support the load.

Limitations of Research

Time and budgetary constraints prohibited all possible PCD and rope combinations from being tested. Relevant devices that could be tested might include ratcheting pulleys, Gibbs Ascenders, and other cam-actuated PCDs. These results may not necessarily be extrapolated to ropes with a differing number of sheath carriers or handling characteristics. The sample sizes were limited to 5 tests per combination in an initial attempt to gain 3-sigma values. Three-sigma reporting was later considered to be a poor fit for the scope of the study. As with all research, however, larger sample sizes would likely yield even more accurate averages and reduce standard deviations. Another limitation encountered was the variability of the loading of PCDs while the machine was in “fast forward.” The intent was to load each device to 1 kN, but was limited by the researchers’ and operators reaction time. Due to time constraints, an adjustment to the experimental design was made in the test lab. For time-saving purposes, devices clearly exhibiting what came to be known as a System Operation Limit (SOL) were given an arbitrary five minutes of testing once the rope began travelling through the device. This typically resulted in 30” of travel, but it cannot be absolutely concluded what may have occurred if pulled indefinitely. The Munter Hitch may have tested more favorably in a working position, rather than tied-off. This may not reflect true field values. The test machine cage and experimental design did not allow researchers to explore this avenue. Perhaps utilizing a hand or mechanical grip may have resulted in a potential SOL behavior.

Results

The pages that follow are the raw data and notes from 5 days of testing from June 30-July 3, 2014 and follow-up testing on August 15, 2014. Following the data are observations and some recommended action items the rescue community should consider based on empirical observations, discussions and deliberations, and statistical analysis as a result of the research and testing.

Single Prusik

8mm Single Prusik

New Rope,11mm	Peak KN	Peak Lbf	Comments
11mm #1	14.69	3302.31	Prusik broke in the strand under the bridge
11mm #2	13.74	3088.75	Desheathed the rope, Several incremental slips prior to failure, large slip just under 9kN, big slips @ 13 kN
11mm #3	13.88	3120.22	Desheathed the rope, Several incremental slips prior to failure, large slip just under ?, big slips @ ? kN
11mm #4	13.85	3113.48	Prusik broke at the hitch, under the bridge, but further into the wraps
11mm #5	14.47	3252.86	Prusik broke in the strand under the bridge
Average	14.13	3175.52	
StandDev	0.425	95.51	

8mm Single Prusik (Old)

Old Rope, 11mm- (Rope was put in service around 2004. Prusiks vary in age 2004-2008)

11mm #1	12.47	2803.26	very little slip(3-4"), desheathed the rope at 12.47kN (a short slip bonds and bights, followed by sheath strip at a slightly lower value)
11mm #2	12.08	2715.58	very little slip(3-4"), desheathed the rope at 12.08kN(slipped two times, second bonds and bights, followed by sheath strip at a slightly lower value)
11mm #3	11.61	2609.93	Slipped for several inches (6"-8"), then bit down and desheathed the rope at 11.61kN
11mm #4	9.41	2115.37	very little slip(2-3"), Prusik broke at the bridge at 9.41kN
11mm #5	8.12	1825.38	very little slip(2-3"), Prusik broke at the bridge at 8.12kN (prusik-2005)
11mm #6	11.35	2551.48	very little slip(2-3"), Prusik broke at the bridge at 11.35kN
11mm #7	10.67	2398.62	very little slip(2-3"), Prusik broke at the Carabiner bight at 10.67kN
11mm #8	10.88	2445.82	very little slip(2-3"), Slip at 10.2, then grabbed fast, Prusik broke at the Carabiner bight at 10.88kN
11mm #9	12.84	2886.43	Very little slip (2-3"), Slipped at 12.84, then bit down and desheathed the rope at 10.2kN
11mm #10	9.42	2117.62	very little slip(2-3"), Prusik broke at the Carabiner bight at 9.42kN
Average	10.89	2446.95	
StandDev	1.510	339.42	

8mm Single Prusik

New Rope, 12.5mm

12.5mm #1	13.87	3117.98	Prusik broke in the strand under the bridge
12.5mm #2	16.59	3729.43	Prusik broke in the strand under the bridge
12.5mm #3	14.72	3309.06	Prusik broke in the strand under the bridge
12.5mm #4	14.12	3174.18	Prusik broke in the strand under the bridge
12.5mm #5	14.82	3331.54	Prusik broke in the strand under the bridge
Average	14.82	3332.44	
StandDev	1.065	239.37	

8mm Single Prusik (Old)

Old Rope, 12.5mm- (Rope was put in service around 2007. Prusiks vary in age 2006-2013)

12.5mm #1	13.35	3001.08	very little slip (mainly as prusik tightened down), Prusik broke at the carabiner bight at 13.35kN
12.5mm #2	14.09	3167.43	very little slip (mainly as prusik tightened down), Prusik broke at the carabiner bight at 14.09kN
12.5mm #3	8.94	2009.71	very little slip (mainly as prusik tightened down), Prusik broke at the bridge at 8.94kN (prusik 2007)
12.5mm #4	8.34	1874.83	very little slip (mainly as prusik tightend down), Prusik broke at the carabiner bight at 8.34kN
12.5mm #5	11.19	2515.51	Slipped 3.5", prusik broke ar the carabiner bight at 11.19kN (prusik 2006)
Average	11.18	2513.71	
StandDev	2.562	575.99	

Single Prusik

New Rope, 11mm ExPro

11mm ExPro #1	10.73	2412.10	Desheathed the rope at 10.73. Rope desheathed 4.5" from starting point
11mm ExPro #2	9.7	2180.56	Continuiously "skipped" down the rope, would build to 9.5-9.7 and "skip". 21" of slip from the starting point
11mm ExPro #3	10.95	2461.56	Desheathed the rope at 10.95. Rope desheathed 3.5" from starting point
11mm ExPro #4	10.2	2292.96	Continiuious smooth slide between 6-7kN for five minutes. Peaked at 10.2 kN, then began slip for 21"
11mm ExPro #5	11.49	2582.95	Detheathed the rope at about 8kN, peak force was 11.49, 4.25" from the starting point
Average	10.61	2386.03	
StandDev	0.689	154.95	

XX	XXXX	Grey cells represent a "Fail"
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XX	**XXXX**	**Bold text represent an abnormal result**

Tandem Prusiks

8mm Tandem Prusik (New)

New Rope, 11mm	Peak KN	Peak Lbf	Comments
11mm #1	25.88	5817.82	desheathed rope in front of short prusik at 25.88 kN- 6.5" of slip from starting point (long prusik)
11mm #2	23.47	5276.06	desheathed rope in front of short prusik at 23.47 kN- 7.5" of slip from starting point (long prusik)
11mm #3	23.89	5370.47	desheathed rope in front of short prusik at 23.89 kN- continued to pull, desheathed in front of long prusik at 20.5ish
11mm #4	24.18	5435.66	Short prusik broke at 24.18 under the bridge, continued the pull, long prusik broke at 14.72
11mm #5	23.86	5363.73	Short prusik broke at 23.86 under the bridge, continued the pull, Long prusik desheathed the rope at 12.88
Average	24.26	5452.75	
StandDev	0.942	211.83	
11mm Anom1	26.290		Machine started pulling at a much faster rate unexpectedly. Pulled fast with desheathing in front of short prusik at 26.29

8mm Tandem Prusik (Old)

Old Rope, 11mm- (Rope was put in service around 2004. Prusiks vary in age 2004-2008)

11mm #1	18.43	4143.06	Some slipping (3.5"), Large slip around 18 kN, then Short prusik desheathed the rope at 18.43kN
11mm #2	15.87	3567.58	13-14" of slippage, then bit down and desheathed the rope at 15.87kN
11mm #3	19.65	4417.32	Some slipping (3.5"), Large slip at 19.65 kN, reducing loading, then Short prusik bit down and desheathed the rope at 15.8kN
11mm #4	16.35	3675.48	10-12" of slippage of slip, 16.34 kN Short prusik broke at the bridge, Continued pull, long prusik slipped an additional 2-3" and then desheathed the rope at about 10kN
11mm #5	15.85	3563.08	12-13" of slippage, short prusik desheathed the rope at 15.85kN
Average	17.23	3873.30	
StandDev	1.719	386.51	

8mm Tandem Prusik (New)

New Rope, 12.5mm

12.5mm #1	26.02	5849.30	desheathed rope in front of long prusik at 26.02
12.5mm #2	27.75	6238.20	desheathed rope in front of long prusik at 27.75
12.5mm #3	25.14	5651.47	Short Prusik Broke at 25.14 under the bridge; continued pull and long prusik broke at an unknown value
12.5mm #4	27.66	6217.97	Both prusiks broke at the same time under the bridges (4.5" of slippage from start to stopping point in front of the long prusik
12.5mm #5	28.32	6366.34	Short Prusik Broke at 28.32 under the bridge; continued pull and long prusik desheathed the rope at 14.24
Average	26.978	6064.65	
StandDev	1.338	300.72	

8mm Tandem Prusik (Old)

Old Rope, 12.5mm- (Rope was put in service around 2007. Prusiks vary in age 2006-2013)

12.5mm #1	24.96	5611.01	3-4" of slippage, desheathed the rope in front of long prusik at 24.96kN
12.5mm #2	18.45	4147.56	2-3" of slip, short prusik broke at the bridge 18.45kN, continued pull, long prusik broke at the bridge 12.8kN
12.5mm #3	16.67	3747.42	3-4" of slip, short prusik broke at the carabiner 16.67kN, continued pull, long prusik broke at bridge 8.59kN
12.5mm #4	21.4	4810.72	4-5" of slippage, desheathed the rope in front of the long prusik at 21.4kN
12.5mm #5	19.21	4318.41	5.5" of slippage, short prusik broke at carabiner 19.21kN, continued pull, long prusik broke at bridge 11.5kN
12.5mm#6	16.35	3675.48	2-3" of slip, short prusik broke at the bridge 16.35kN, continued pull, long prusik broke at the carabiner bight 10.2kN
12.5mm#7	17.69	3976.71	Short Prusik broke @ 17.69 kN, then long slipped and bites down and broke @ 14.1, Slipped 3"
12.5mm#8	24.8	5575.04	Short Prusik broke @ 24.80 kN, then long slipped and bites down and desheathed @ 15.9, Slipped 4-6"
Average	19.941	4482.79	
StandDev	3.430	771.03	

Tandem Prusik (New)

New Rope, 11mm Ex Pro

11mm ExPro #1	10.4	2337.92	Short prusik elongated and bumped against the long prusik, both continuously slipped down the rope at about 6.1 kN for five minutes
11mm ExPro #2	10.1	2270.48	Short prusik elongated and bumped against the long prusik, both continuously slipped down the rope at about 6.1 kN for five minutes
11mm ExPro #3	10.2	2292.96	Short prusik elongated and bumped against the long prusik, both continuously slipped down the rope at about 5.9-6.1 kN for five minutes
11mm ExPro #4	14.28	3210.14	Desheathed rope in front of Short prusik at 14.28kN
11mm ExPro #5	11.28	2535.74	Short prusik elongated and bumped against the long prusik, both continuously slipped down the rope at about 6.5-7 kN for five minutes
Average	11.25	2529.45	
StandDev	1.756	394.67	

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Petzl Rescucender

Rescucender

New Rope, 11mm

	Peak KN	Peak Lbf	Comments
11mm #1	4.57	1027.34	Continuous slip, very smooth, Some sheath bunching
11mm #2	3.91	878.97	Continuous slip, very smooth, Some sheath bunching
11mm #3	4.08	917.18	Continuous slip, very smooth, Some sheath bunching
11mm #4	3.46	777.81	Continuous slip, very smooth, Some sheath bunching
11mm #5	3.42	768.82	Continuous slip, very smooth, Some sheath bunching
Average	3.888	874.02	
StandDev	0.476	106.91	

Rescucender

Old Rope, 11mm- (Rope was put in service around 2004)

11mm #1	3.12	701.38	Continuous slip, very smooth, Some sheath bunching
11mm #2	3.30	741.84	Continuous slip, very smooth, Some sheath bunching
11mm #3	4.07	914.94	Continuous slip, very smooth, Some sheath bunching
11mm #4	4.85	1090.28	Continuous slip, very smooth, Some sheath bunching
11mm #5	3.01	676.65	Continuous slip, very smooth, Some sheath bunching
Average	3.670	825.02	
StandDev	0.779	175.12	

Rescucender

New Rope, 12.5mm

12.5mm #1	11.48	2580.70	As the sheath bunched, cam "skipped" several times
12.5mm #2	12.38	2783.02	Continuous slip, very smooth, Some sheath bunching, some "skips" after bunching
12.5mm #3	10.68	2400.86	Continuous slip, very smooth, Some sheath bunching, some "skips" after bunching
12.5mm #4	11.89	2672.87	Continuous slip, very smooth, Some sheath bunching, some "skips" after bunching
12.5mm #5	11.26	2531.25	Continuous slip, very smooth, Some sheath bunching, some "skips" after bunching
Average	11.54	2593.74	
StandDev	0.64	144.37	

Rescucender

Old Rope, 12.5mm- (Rope was put in service around 2007)

12.5mm #1	11.95	2686.36	Desheathed the rope
12.5mm #2	9.92	2230.02	Desheath the rope at 9.92, Continued pull until total failure 10.89
12.5mm #3	11.00	2472.80	Desheath the rope
12.5mm #4	9.79	2200.79	Desheath the rope
12.5mm #5	10.21	2295.21	Desheath the rope
Average	10.574	2377.04	
StandDev	0.901	202.62	

Rescucender

ExPro New Rope, 11mm

11mm ExPro #1	4.69	1054.31	Peaked at 4.69 and continuously slipped at about 4.3 for five minutes
11mm ExPro #2	4.73	1063.30	Started slipping at 2kN, continuously slipped at about 4.3 for five minutes
11mm ExPro #3	4.19	941.91	Peaked at 4.19 and continuously slipped at about 4 for five minute
11mm ExPro #4	4.08	917.18	Peaked at 4.08 and continuously slipped at about 4 for five minute
11mm ExPro #5	4.19	941.91	Peaked at 4.08 and continuously slipped at about 4 for five minute
Average	4.38	983.72	
StandDev	0.309	69.35	

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SMC Grip

PMI/SMC Grip

New Rope, 11mm	Peak KN	Peak Lbf	Comments
11mm #1	8.03	1805.14	little to no slip then desheathes rope at 8.03kN
11mm #2	8.99	2020.95	little to no slip then desheathes rope at 8.99kN
11mm #3	9.07	2038.94	little to no slip then desheathes rope at 9.07kN
11mm #4	7.67	1724.22	little to no slip then desheathes rope at 7.67kN
11mm #5	7.06	1587.09	little to no slip then desheathes rope at 7.06kN
Average	8.16	1835.27	
StandDev	0.864	194.16	

PMI/SMC Grip

New Rope, 12.5mm			
12.5mm #1	9.89	2223.27	little to no slip then desheathes rope at 9.89kN; bent the Grip axle (exposed to 5 pulls)
12.5mm #2	9.81	2205.29	little to no slip then desheathes rope at 9.81kN;
12.5mm #3	10.33	2322.18	little to no slip then desheathes rope at 10.33kN;
12.5mm #4	11.21	2520.01	little to no slip then desheathes rope at 11.21kN;
12.5mm #5	10.91	2452.57	little to no slip then desheathes rope at 10.91kN;
Average	10.43	2344.66	
StandDev	0.617	138.79	

PMI/SMC Grip

New Rope, 11mm ExPro			
11mm ExPro #1	6.72	1510.66	little to no slip then desheathes rope at 6.72kN
11mm ExPro #2	7.3	1641.04	little to no slip then desheathes rope at 7.3kN, continued pull, stayed steady about 3kN bunching the sheath up behind the Grip
11mm ExPro #3	7.4	1663.52	little to no slip then desheathes rope at 7.4kN
11mm ExPro #4	7.82	1757.94	little to no slip then desheathes rope at 7.82kN
11mm ExPro #5	6.88	1546.62	little to no slip then desheathes rope at 6.88kN
Average	7.22	1623.96	
StandDev	0.437	98.27	

Note: 2 of the 3 grips axel pins bent.

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Munter Hitch (Tied-off with a half hitch followed by an overhand)

Munter Hitch

New Rope, 11mm

	Peak KN	Peak Lbf	Comments
11mm #1	17.78	3996.94	Rope Broke where the loaded strand ran through the half hitch of the tieoff
11mm #2	17.28	3884.54	Rope Broke where the loaded strand ran through the half hitch of the tieoff
11mm #3	16.06	3610.29	Rope Broke where the loaded strand ran through the half hitch of the tieoff
11mm #4	15.72	3533.86	Major "Slip" through the hitch 15.72kN (likely the core breaking), then final break at about 6kN (likely the sheath breaking)
11mm #5	17.12	3848.58	Rope Broke where the loaded strand ran through the half hitch of the tieoff
Average	16.79	3774.84	
StandDev	0.867	194.91	

Munter Hitch

Old Rope, 11mm- (Rope was put in service around 2004)

11mm #1	12.44	2796.51	Rope Broke where the loaded strand ran through the half hitch of the tieoff
11mm #2	13.26	2980.85	Rope Broke where the loaded strand ran through the half hitch of the tieoff
11mm #3	13.29	2987.59	Rope Broke where the loaded strand ran through the half hitch of the tieoff
11mm #4	12.59	2830.23	Rope Broke where the loaded strand ran through the half hitch of the tieoff
11mm #5	14.41	3239.37	Rope Broke where the loaded strand ran through the half hitch of the tieoff
Average	13.20	2966.91	
StandDev	0.779	175.05	

Munter Hitch

New Rope, 12.5mm

12.5mm #1	21.44	4819.71	Rope Broke where the loaded strand ran through the half hitch of the tieoff
12.5mm #2	22.5	5058.00	Rope Broke where the loaded strand ran through the half hitch of the tieoff
12.5mm #3	21.97	4938.86	Rope Broke where the loaded strand ran through the half hitch of the tieoff
12.5mm #4	25.53	5739.14	Rope Broke where the loaded strand ran through the half hitch of the tieoff
12.5mm #5	22.75	5114.20	Rope Broke where the loaded strand ran through the half hitch of the tieoff
Average	22.838	5133.98	
StandDev	1.587	356.80	

Munter Hitch

Old Rope, 12.5mm- (Rope was put in service around 2007)

12.5mm #1	14.26	3205.65	Rope Broke where the loaded strand ran through the half hitch of the tieoff
12.5mm #2	14.53	3266.34	Major "Slip" through the hitch 14.5kN (likely the core breaking), then final break at about 5.5kN (likely the sheath breaking)
12.5mm #3	15.42	3466.42	Rope Broke where the loaded strand ran through the half hitch of the tieoff
12.5mm #4	16.19	3639.51	Rope Broke where the loaded strand ran through the half hitch of the tieoff
12.5mm #5	14.39	3234.87	Rope Broke where the loaded strand ran through the half hitch of the tieoff
Average	14.958	3362.56	
StandDev	0.825	185.52	

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XX	**XXXX**	**Bold text represent an abnormal result**

CMC MPD

MPD

New Rope, 11mm	Peak KN	Peak Lbf	Comments
11mm #1	4.15	932.92	continuous slippage at about 4kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
11mm #2	4.45	1000.36	continuous slippage at about 4.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
11mm #3	4.1	921.68	continuous slippage at about 3.9kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping (28" travel)
11mm #4	4.53	1018.34	continuous slippage at about 4.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping (30" travel)
11mm #5	4.33	973.38	continuous slippage at about 4kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
Average	4.31	969.34	
StandDev	0.186	41.77	
11mm #6A	4.61	1036.33	Parking break is set. Continuous slippage at about 4.2kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping

MPD

Old Rope, 11mm- (Rope was put in service around 2004)

11mm #1	7.16	1609.57	continuous slippage (w/ some "skipping") at about 6.7kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
11mm #2	7.24	1627.55	continuous slippage at about 6.25-7.2kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
11mm #3	7.52	1690.50	continuous slippage at about 6.25-7.2kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
11mm #4	7.9	1775.92	continuous slippage at about 7-7.9kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
11mm #5	7.99	1796.15	continuous slippage (w/ some "skipping") at about 7.6-7.9kN, then quit "skipping" and slipped about 6.5-7.4kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping
Average	7.56	1699.94	
StandDev	0.376	84.45	
11mm #6A	7.55	1697.24	Parking break is set. continuous slippage at about 6-7kNkN. Some bunching of the rope beyond the device. Rope still in good shape after slipping

MPD

New Rope, 12.5mm

12.5mm #1	9.4	2113.12	continuous slippage at about 8.5-8.75kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping (minor fuzzing)
12.5mm #2	8.67	1949.02	continuous slippage at about 8-8.4kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping (minor fuzzing) (30")
12.5mm #3	8.64	1942.27	continuous slippage at about 7.9-8.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping (minor fuzzing)
12.5mm #4	8.37	1881.58	continuous slippage at about 7.9-8.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping (minor fuzzing) (30.5")
12.5mm #5	8.44	1897.31	continuous slippage at about 7.7-8.5kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping (minor fuzzing)
Average	8.704	1956.66	
StandDev	0.410	92.07	

MPD

Old Rope, 12.5mm- (test 1-10 rope was put in service around 2007; test 11-12 rope was in service 1 year)

12.5mm #1	10.65	2394.12	continuous slippage at about 8.5-10.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. Some "skipping"
12.5mm #2	9.74	2189.55	continuous slippage at about 9-9.6kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. Some "skipping"
12.5mm #3	11.47	2578.46	continuous slippage at about 10-11.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. Some "skipping"
12.5mm #4	10.98	2468.30	continuous slippage at about 9.5-10.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. Some "skipping"
12.5mm #5	13.28	2985.34	Slipped for short distance (Approx. 12"), Desheathed the rope were the rope is "pinched" in the cam.
12.5mm #6	16.24	3650.75	Slipped for short distance (Approx. 12"), Desheathed the rope were the rope is "pinched" in the cam.
12.5mm #7	13.78	3097.74	continuous slippage at about 9.5-10.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. Some "skipping"
12.5mm #8	13.5	3034.80	Slipped for short distance (Approx. 8"), Desheathed the rope were the rope is "pinched" in the cam.
12.5mm #9	11.09	2493.03	continuous slippage at about 10-10.5kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. Some "skipping"
12.5mm #10	**10.95**	**2461.56**	**On application of force it bit down and caused some moderate sheath damage(core shot) and then began to slip. Continuous slippage at about 9-10.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. Some "skipping"**
12.5mm #11 * **	8.73	1962.504	continuous slippage at about 7.9-8.8kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. No Skipping
12.5mm #12 * **	8.31	1868.088	continuous slippage at about 7.5-8kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. No Skipping (30" slip)
12.5mm #13 * **	8.83	1984.984	continuous slippage at about 8-8.75kN. Small "pop" and then the slipping started. Some bunching of the rope beyond the device. Rope still in good shape after slipping. No Skipping (34" Slip)
12.5mm #14 * **	7.66	1721.968	continuous slippage at about 7-7.6kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. No Skipping (30" slip)
12.5mm #15 * **	8.40	1888.32	continuous slippage at about 8-8.4kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping. No Skipping
Average	10.907	2451.97	
StandDev	2.442	548.88	

*** Denotes that this is a different rope from previous tests. This rope was in service for 1 year.

MPD

New Rope, 11mm

11mm ExPro #1	6.24	1402.75	continuous slippage at about 6kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping.
11mm ExPro #2	6.82	1533.14	continuous slippage at about 6.5-6.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping.
11mm ExPro #3	6.24	1402.75	continuous slippage at about 6-5.8kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping.
11mm ExPro #4	6.42	1443.22	continuous slippage at about 6.25kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping.
11mm ExPro #5	6.07	1364.54	continuous slippage at about 6-5.8kN. Some bunching of the rope beyond the device. Rope still in good shape after slipping.
Average	6.36	1429.28	
StandDev	0.286	64.38	

Note: Tensioned end of rope exiting the device takes on flat shape at cam (inside), then V or (triangle) when running through deep pulley sheave upon exiting

XX	XXXX	Grey cells represent a "Fail"
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XX	**XXXX**	**Bold text represent an abnormal result**

Petzl I’D

Petzl ID

New Rope, 11mm	Peak KN	Peak Lbf	Comments
11mm #1	4.63	1040.82	Continuous slipping around 4-4.2kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping. (30")
11mm #2	4.47	1004.86	Continuous slipping around 3.8-4.2kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
11mm #3	4.86	1092.53	Continuous slipping around 4.25-4.75kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
11mm #4	4.65	1045.32	Continuous slipping around 4-4.25kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
11mm #5	4.78	1074.54	Continuous slipping around 4.25-4.75kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
Average	4.68	1051.61	
StandDev	0.150	33.70	

Petzl ID

Old Rope, 11mm- (Rope was put in service around 2004)

11mm #1	7.16	1609.57	Continuous slipping around 6-7kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
11mm #2	6.66	1497.17	Continuous slipping around 5-6.5kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
11mm #3	8.00	1798.40	Continuous slipping around 6-7kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
11mm #4	6.34	1425.23	Continuous slipping around 5.8-6.1kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
11mm #5	7.35	1652.28	Continuous slipping around 6.2-7kN. Some bunching of the rope sheath beyond the device. Rope still in fair shape after slipping.
Average	7.10	1596.53	
StandDev	0.642	144.26	

Petzl ID

New Rope, 12.5mm

12.5mm #1	5.6	1258.88	Continuous slipping around 5-5.25kN. Bunching of the rope sheath beyond the device. Rope still in fair shape after slipping. (31" of slip) No noticeable rope treatment in device
12.5mm #2	5.82	1308.34	Continuous slipping around 5-5.25kN. Bunching of the rope sheath beyond the device. Rope still in fair shape after slipping. No noticeable rope treatment in device
12.5mm #3	5.64	1267.87	Continuous slipping around 5.5-5.75kN. Bunching of the rope sheath beyond the device. Rope still in fair shape after slipping. No noticeable rope treatment in device
12.5mm #4	5.79	1301.59	Continuous slipping around 5-5.75kN. Bunching of the rope sheath beyond the device. Rope still in fair shape after slipping. No noticeable rope treatment in device
12.5mm #5	5.72	1285.86	Continuous slipping around 5-5.75kN. Bunching of the rope sheath beyond the device. Rope still in fair shape after slipping. No noticeable rope treatment in device
Average	5.714	1284.51	
StandDev	0.094	21.18	

Petzl ID

Old Rope, 12.5mm

12.5mm #1	8.11	1823.13	Desheathed the rope at 8.11kN where the rope is pinched by the cam. Little to no slipping
12.5mm #2	6.88	1546.62	Desheathed the rope at 6.88kN where the rope is pinched by the cam. Little to no slipping
12.5mm #3	6.70	1506.16	Desheathed the rope at 6.7kN where the rope is pinched by the cam. Little to no slipping. Continued pulling, and it continued to pop core bundles. Saw an additional peak of 8.05kN
12.5mm #4	8.01	1800.65	Desheathed the rope at 8.01kN where the rope is pinched by the cam. There was 4-6" inches of slip prior to biting down.
12.5mm #5	6.29	1413.99	Desheathed the rope at 6.29kN where the rope is pinched by the cam. There was 4-6" inches of slip prior to biting down.
12.5mm #6 * **	5.95	1337.56	continuous slippage at about 5.2-6kN. Some bunching of the rope beyond the device. Moderate amount of sheath picks after pull (coming from "V" of new cam). No Skipping
12.5mm #7 * **	6.25	1405	continuous slippage at about 5.5-6kN. Some bunching of the rope beyond the device. Moderate amount of sheath picks after pull (coming from "V" of new cam). No Skipping
12.5mm #8 * **	5.47	1229.656	continuous slippage at about 4.8-5.4kN. Some bunching of the rope beyond the device. Moderate amount of sheath picks after pull (coming from "V" of new cam). No Skipping
12.5mm #9 * **	5.71	1283.608	continuous slippage at about 5-5.6kN. Some bunching of the rope beyond the device. Moderate amount of sheath picks after pull (coming from "V" of new cam). No Skipping
12.5mm #10 * **	5.64	1267.872	continuous slippage at about 5-5.2kN. Some bunching of the rope beyond the device. Moderate amount of sheath picks after pull (coming from "V" of new cam). No Skipping
Average	7.198	1618.11	
StandDev	0.816	183.48	

*** Denotes that this is a different rope from previous tests. This rope was in service for 1 year.

Petzl ID

New Rope, 11mm ExPro

11mm ExPro #1	**7.15**	**1607.32**	**There was an initial peak that significantly damaged part of the sheath where the cam pinches the rope, then it continuously slipped 6-6.25kN with no further damage. Some bunching of the rope sheath beyond the device**
11mm ExPro #2	7.38	1659.02	Continuous slipping around 6kN. Some bunching of the rope sheath beyond the device. Some "lumps" in the rope where it traveled through the device.
11mm ExPro #3	7.04	1582.59	On the application of force the device bit down and significantly damaged the sheath where the cam pinches the rope, then continuously slipped 6-6.5kN with no further damage.
11mm ExPro #4	7.73	1737.70	On application of force the device bit down and damaged the sheath. Device then allowed rope to slide through (12-14") until 3 min into the slipping it bit down and desheathed the rope where the cam pinches the rope.
11mm ExPro #5	7.17	1611.82	Continuous slipping around 6kN. Some bunching of the rope sheath beyond the device. Some "lumps" in the rope where it traveled through the device. Noticeable glue on sheathe and device
Average	7.29	1639.69	
StandDev	0.273	61.37	

Note: Appears to be small specks of glue on the rope sheath and in the device after test.

XX	XXXX	Grey cells represent a "Fail"
XX	XXXX	White cells represent "System Operation Limit"
XX	**XXXX**	**Bold text represent an abnormal result**

Petzl Basic

Petzl Basic

New Rope, 11mm	Peak KN	Peak Lbf	Comments
11mm #1	5.67	1274.62	Desheathed the rope at 5.67kN
11mm #2	5.35	1202.68	Desheathed the rope at 5.35kN
11mm #3	5.66	1272.37	Desheathed the rope at 5.66kN
11mm #4	5.85	1315.08	Desheathed the rope at 5.85kN
11mm #5	5.45	1225.16	Desheathed the rope at 5.45kN
Average	5.60	1257.98	
StandDev	0.197	44.38	

Petzl Basic

Old Rope, 11mm- (Rope was put in service around 2004)

11mm #1	5.66	1272.37	Desheathed the rope at 5.66kN
11mm #2	5.97	1342.06	Desheathed the rope at 5.97kN
11mm #3	5.52	1240.90	Desheathed the rope at 5.52kN
11mm #4	5.26	1182.45	Desheathed the rope at 5.26kN
11mm #5	5.68	1276.86	Desheathed the rope at 5.68kN
Average	5.62	1262.93	
StandDev	0.258	58.11	

Note: Same device for all above tests. After last test, device was still usable but cam was binding slightly.

Petzl Basic

New Rope, 11mm

11mm ExPro #1	**5.37**	**1207.18**	**Basic broke at 5.37kN. Rope has little to no sheath damage. (This was the 11th test with this device).**
11mm ExPro #2	6.16	1384.77	Desheathed rope @6.16kN (Device 2)
11mm ExPro #3	**5.98**	**1344.30**	**Basic broke at 5.98kN. Rope has little to no sheath damage. (Device 2, 2nd pull).**
11mm ExPro #4	6.43	1445.46	Desheathed the rope at 6.43kN (Device 3).
11mm ExPro #5	6.19	1391.51	Desheathed the rope at 6.19kN. (Device 4).
11mm ExPro #6	6.26	1407.25	Desheathed the rope at 6.26kN. (Device 6).
11mm ExPro #7	5.81	1306.09	Desheathed the rope at 5.81kN. (Device 6). Continued pull until Rope sheath bunched and jammed in the device. Basic Broke at 9.10kN after 5.5 feet of slipping
11mm ExPro #8	**5.61**	**1261.13**	**Basic broke at 5.61kN. Rope has little to no sheath damage. (Device 4, 2nd pull.**
11mm ExPro #9	**5.6**	**1258.88**	**Basic broke at 5.37kN. Rope has little to no sheath damage. (Device 3, 2nd pull).**
11mm ExPro #10	**5.25**	**1180.20**	**Basic broke at 5.37kN. Rope has little to no sheath damage. (Device 5, 2nd pull).**
Average	5.87	1318.68	
StandDev	0.400	90.00	

XX	XXXX	Grey cells represent a "Fail"
XX	XXXX	White cells represent "System Operation Limit"
XX	**XXXX**	**Bold text represent an abnormal result**

Observations/Points of Consideration

No Perfect PCD Observed

1. There was not a single device that in some combination did not cause a failure. Though it is clear that some have a propensity to fail whereas others have a propensity to reach a System Operation Limit.

   Devices that typically reached a System Operation Limit:
   - Petzl Rescucender (except 7 year old 12.5mm well used rope)
   - Petzl ID (except 7 year old 12.5mm well used rope)
   - CMC MPD (except 7 year old 12.5mm well used rope)

   Devices that typically Failed or caused a loss of confidence:
   - Single Prusik
   - Tandem Prusik
   - SMC/PMI Grip
   - Petzl Basic
   - Munter (tied off w/ half-hitch and overhand finish- acted similar to a knot)

   There are clear advantages to a PCD that reach a System Operation Limit and do not have a tendency to fail. These devices will just not operate as intended when subjected to higher forces. On the other hand those PCDs that fail include PCDs that have served the rescue community well for years. Suspending their use is not recommended, but instead realizing their expected behaviors and either choosing to accept them or not.
2. Tandem Prusiks have a considerable higher holding capacity over singe Prusiks. Some text books and studies cite single triple-wrap Prusik's holding power ranging from 7.0-9.5 kN and Tandems from 7.5-10.5 kN. This research indicates to the contrary. Our study did not substantiate claims of little difference between singles and tandems.
3. Older Ropes and Prusiks trended toward much lower strengths. Additionally, the 7 year old 12.5mm rope that had been well used had a tendency to fail in those devices that typically otherwise would have reached a System Operation Limit.
4. Researchers early-on, and later a consulting statistician, noted an unusual trend of PCDs performing more safely and reliably on an 11mm host rope. These observations were not only confined to one-size-fits-all devices, but to Prusiks and devices engineered specifically for certain size host rope.
5. The bonded core and sheath of the Extreme Pro did not necessarily prevent desheathing of the rope. PCDs that typically caused desheathing on EZ-Bend rope also caused desheathing of the Extreme Pro in at least some of the tests.
6. The Extreme Pro rope behaved considerably different from the EZ-Bend rope. It is unclear if this is an artifact of the bonded core and sheath or that the rope is made of Polyester and not Nylon like the other ropes tested. The different behavior patterns were especially true with the Prusik tests:
   - Two of the five single Prusiks did slip continuously on Extreme Pro (as opposed to the norm of failing with EZ-Bend). The other three desheathed the rope (as opposed to the more normal breaking of the prusik).
   - Tandem Prusiks on Extreme Pro had considerable lower SOL or Fail values, almost equivalent to single Prusiks. Four of the five tandem Prusiks on Extreme Pro did slip continuously with one desheathing the rope.
   - All Prusik SOL or Fail values on Extreme Pro were markedly lower than the tests on EZ-Bend.

Conclusions and Recommendations

1. This research strongly indicates that Prusiks cannot be predictably or reliably counted upon to slip and re-grab- thus acting as "clutch." In some test sets, samples may have behaved as such, while other samples gave little warning before failing. Instructors and users relying on Prusiks to "clutch or force limit" should use extreme caution and consider suspending the use of this theory. Slipping Prusiks appear to be an indicator of impending failure more so than a "clutch or force limiter".
2. When using PCDs that have a tendency to fail, it is recommended that users employ a Safety Factor of 5:1 or greater. It may be prudent to engineer other parts of the system to a higher Safety Factor, but for most applications the PCD may be allowed to have a lower Safety Factor due to the nature of its tasking -being that it is temporarily supporting a static load.
3. For those PCDs that have a tendency to reach a System Operation Limit, it is recommended that the System Operation Limit be at least 1.5 to 2 times the anticipated static load. This will account for some dynamic loading and other factors that could cause small increases in force.
4. Older Prusiks had a notably lower breaking strength than new prusiks. It is recommended that Prusiks be changed out regularly depending on use patterns. Annual or Bi-annual replacement cycles are recommended if the Prusiks see more than just a few days of service per year.
5. One of the most significant lessons of the research was in the degradation of nylon software. The oldest 12.5mm rope in our testing was 7 years old and saw significant service every year. This rope did not perform well in many PCDs. We followed up and performed tests on a more moderately used rope with only 1 year of service and found that it performed much better. It is essential that organizations implement proactive gear management systems and protocols. It is recommended that ropes seeing significant service be replaced on shorter service intervals. It quite possibly may be that a good starting point is five years for ropes that see significant use.

Recommendations for Future Research

1. Expand testing to include ratcheting pulleys, Gibb Ascenders, and other common devices.
2. Expand and duplicate testing on similarly sized ropes with higher carrier sheaths from different manufacturers.
3. Look more deeply into software use, degradation of nylon, and product life-cycle of rope, accessory cord, and webbing. This should especially be done with high-volume training organizations.
4. Examine the behavior of PCDs on ropes made with different material (e.g. polyester).

2014 Vertical Section Business Meeting

July 16, 2014

Choral Room, Lee High School, Huntsville, AL

1. Call to Order: VS Chairman Terry Mitchell called the meeting to order at 10:06 am. There were 26 members in attendance.

2. Approval of minutes from last year's meeting, Aug 7, 2013; Approved as published.

3. Officer Reports.

A. Chairman's Report: Terry Mitchell said there were errors in the Convention Program concerning times for the week's vertical events, and that schedule changes had been published in the Daily Bulletin.

B. Treasurer's Report: Ray Sira reported the VS has three bank accounts with a total balance right now of $11,588.51. He discussed several items of income and expense during the past year. Treasurer's Report copies will be available soon.

C. Secretary's Report: Ray said we have approximately 300 registered members.

D. Editor's Report: Tim White said there are few technical articles in the "Que", that will be sent to Gary Bush for upload to the Nylon Highway in the following weeks. Tim said he is also the online editor of the Cave Chat forum, titled "On Rope", and in both jobs he is continuously monitoring for safety protocols.

4. Committee Reports.

A. Climbing Contest Coordinator: Bill Cuddington;

Bill expressed thanks for rope donations from PMI, climbers, and for the gym facilities. He does not yet have the exact number of climbing participants Monday & Tuesday, but will send that information later via email. The approximate number ranges between 50-60, and 6 or 7 records were broken.

The Awards Ceremony will be Friday Noon in Room 150. Prizes will have to be claimed in person. If you cannot come please remember to have someone come pick it up for you. Miriam Cuddington said she needs to order new award certificates.

B. Rebelay Workshop: Gary Bush said there were not a significant number of participants Tuesday, and the majority of time was spent "redialing" equipment. A good time was had by all.

C. Vertical Techniques Workshop: Interim Workshop Coordinator John Woods was not present, but he sent word that Instructors and other Helpers should meet at 10am Thursday in the Gym, with the participants arriving at 11am.

D. Education Coordinator: Bruce Smith said he has been working on improvements to the Basic and Intermediate vertical course. He said he has not received a significant amount of feedback, or participation. He feels there is not a lot of involvement or acceptance of the vertical section teaching skills, rules, and or regulations, and that grottos are modifying our courses. He said we may need to leave pushing of adherence to these published techniques to the NSS leadership.

Several suggestions were offered to Bruce from the membership:

- ❖ Idea from Bill (??): Perhaps have a vertical training session during conventions for grotto educators to ensure they are qualified.
- ❖ Suggestion from Tim White: May need to do this on a more regional level because not all NSS members participate in the NSS conventions.
- ❖ Suggestion from audience member: Agreeing that actual NSS convention may not be the best location for education training for instructors, and would be more successful on a more regional scale.

E. Awards Committee Chairman: Bruce Smith presented service awards to former Secretary-Treasurer Bill Boehle for his service 2004-2013, and to Jenny Clark, widow of former Vertical Techniques Workshop Coordinator Terry Clark, for Terry's service in that position 2000-2013.

Chairman Terry Mitchell announced that the VS had donated a brick at the new NSS Headquarters building in memory of Terry Clark, and he presented Jenny with the letter and certificate from the NSS acknowledging that donation. It will be brick number 251.

F. Bylaws Committee: Terry Mitchell reported that the Bylaws Committee (he and Bill Boehle) had prepared an amendment to Bylaw 4.(E) Vacancies, to address the inadequacies that had come to light upon the untimely death of Terry Clark last October.

The proposed amendment provides detailed procedures for filling Officer and other EC vacancies that may occur during the year between section meetings without having to wait until the next annual election. This bylaw amendment was approved by the Executive Committee July 13, 2014.

G. Symbolic Items: Bill Boehle reported that he restocked in late 2013 and had to raise most of the retail prices. The big selling items are T-shirts and sweatshirts. The pins he ordered in 2013 were a significant expense but the return should eventually equalize regarding profit margin. Sweatshirts are on sale for S and M sizes.

H. Web Page: Gary Bush reported that the VS web page is up to date now. However, more pictures are always needed and welcome. The price changes for symbolic items will be listed on the Web page and be kept as up to date as possible.

I. Out Reach Committee: Jon Schow was not present, so Terry Mitchell read Jon's emailed report: "***Currently there are 266 people who have liked the vertical section Facebook page. I'd like to start sharing interesting stories about vertical trips, learning, teaching, and so forth."***

Terry added that his personal opinion is that *"Public outreach is going but it is not going fast."* He suggested publications on the webpage, in the Nylon Highway, and the NSS news.

5. Old Business: NONE.

6. New Business:

A. Volunteer needed to be the new Vertical Techniques Workshop Coordinator. Peter Hertl suggested Terry Zornes, a "top flight vertical guy," or Kurt Waldron, who is interested but wants more information about the job. Terry Mitchell and Peter agreed to talk to Kurt later this afternoon. **NOTE:** ***Later that day Terry and Peter did talk to Kurt Waldron about the position and Kurt agreed to accept it.***

B. Transportation and Storage of the Vertical Workshop equipment. Jenny Clark had brought the equipment to Huntsville this year, but in the absence of a new Workshop Coordinator, we aren't sure what to do with it following the workshop on Thursday.

Tim White comments: Terry Clark always transported the equipment, but now we need to figure out how we are going to coordinate the equipment transportation in the future.

Suggestions From the Crowd: Store the equipment at the NSS headquarters and have it transferred up.

Chairmen Terry Mitchell suggested that we wait and see who will be the next Vertical Techniques Workshop Coordinator, and if we do not have one by the end of the week, the issue will be addressed by the executive committee on Friday. **NOTE:** ***On Friday July 18, Kurt Waldron assumed custody of the equipment and took it home with him.***

Jane Mitchell said we need to reimburse Jenny Clark for equipment transportation. It was pointed out that we have been doing this for the past few years, and the issue was referred to the Secretary-Treasurer.

C. A suggestion from the crowd was made to increase the participant fee for the Vertical Techniques Workshop: Former Treasurer Bill Boehle said that there would not be a significant need for a price increase right now.

7. Elections:

A. Secretary-Treasurer (1-year term): Ray Sira was nominated for another term. There were no other nominations. A motion was made and carried to suspend the rules, and Ray Sira was elected by unanimous consent.

B. Two "At-Large" Executive Committee Members (2-year terms): Terry Mitchell and Mike Rusin were nominated for the two positions. Peter Hertl was nominated but declined. The rules were again suspended, then Mike and Terry were re-elected by Unanimous Consent.

8. The Business Meeting was Adjourned at 11:24am. The Chairman asked everyone to reconvene in 10 minutes for the **Vertical Session.**

The Vertical Session began at 11:35, 7/16/2014, in the Choral Room

1. **Opening Remarks**. Chairman Terry Mitchell reported that during the break the elected members of the Executive Committee, consisting of himself, Mike Rusin, Bill Boehle, Miriam Cuddington, and Ray Sira, had met briefly to elect the coming year's Chairman, Vice Chairman, and the Appointed Positions on the EC. These are all 1-year terms of office.

Terry said that he has been re-elected to another term as Chairman, and Miriam Cuddington has been re-elected as Vice Chairman. Bill Cuddington was re-appointed as Contest Coordinator, Bruce Smith was re-appointed as Education Coordinator, and Tim White was re-appointed as Editor. The position of Vertical Techniques Workshop Coordinator was still temporarily vacant.

NOTE: ***A very short VSEC meeting was conducted Friday, July 18, 2014, to formally appoint Kurt Waldron as the Vertical Techniques Workshop Coordinator.***

2. The Vertical Session was chaired by Bill Cuddington:

A. Bruce Smith - Demonstration of the OR1 Goliath seat harness and how to shorten the waist band beyond its apparent limit. Bruce said this adjustment is little understood.

B. Bill Cuddington- Discussions on heat training and preventing over-heating during rope ascending.

C. John McCrary - John is the owner of PANGAEA Vertical Caving Systems in Vinemont, AL; email rocjoc8@yahoo.com. John demonstrated an improved Double Bungee Ropewalking System that he has developed from a specialized racing system. It is tuned for efficient rope racing and he claims it is a better system for vertical caving as well. Among other refinements, the system includes a hydration bladder in a small Camelback pouch attached to the back of the chest harness.

3. The Vertical Session Adjourned at 12:01pm.

Minutes respectfully submitted by Ray Sira, Vertical Section Secretary-Treasurer

June 16, 2015

NSS Vertical Section

Secretary's Report

December 2014

By Raymond Sira

Number of Members as of 2014.. 264

Number of Subscribers as of 2014.. 16

Number of Expired Memberships 2013... 105

Number of Memberships due to Expire 2014.................................... 93

Number of Annual Volumes Paid for 2014…...................................... 3

Number of Complementary Subscriptions... 2

Member Exp Date	Members	Subscribers	Annual Volume
Comps			2
2013	102	3	1
2014	85	8	3
2015	33	2	2
2016	15	0	1
2017	24	2	0
2018	51	1	0
2019	56	3	0

NSS VERTICAL SECTION
TREASURER"S REPORT (through 7/9/2014)

By Ray Sira

INCOME:	
Nylon Highway Annual Volume Sales	$40.00
Vertical Training Course Sales	$0.00
2013 Convention Workshop Registration	$550.00
Symbolic Item Sales	$460.00
Nylon Highway Back Issue Sales	$14.00
Shipping Postage Charges	$7.11
Donations	$0.00
Bank Interest (Ally) July 2013 – May 2014	$115.60
TOTAL INCOME:	**$1,186.71**

Expenses:	
Shipping Costs	$2.99
NSS – website hosting fees (2012 & 2013)	$24.00
2012 Vertical Workshop Transportation Expense Subsidy (Terry Clark)	$199.00
2013 Climbing Contest Prizes	$117.50
Vertical Workshop & Rebelay Course Supplies/Expenses	$0.00
Nylon Highway Annual Volume Production & Mailing Costs	$1.82
Symbolic Items Restocking (T-Shirts, Sweats, etc.)	$1,168.50
Symbolic Items Restocking (VS Pins)	$568.65
Symbolic Items Restocking (VWS Instructor T-Shirts)	$0.00
VS Recognition Awards	$87.40
Climbing Contest Record Boards (2012 update)	$32.10
Printing/Photocopying – Climbing Contest	$0.00
Photocopying/Supplies for 2013 NSS Convention Administration	$28.87
Petty Cash for postage	$0.00
Training/Education Costs	$0.00
TOTAL EXPENSES:	**$2,248.83**

ACCOUNT BALLANCES:	
TD Bank (NJ) (Bill's account as of 6/30/2014)	$1,839.37
Well Fargo (Ray's account as of 7/9/2014)	$2,040.00
ALLY Demand Notes (est. as of 6/15/2014	$7,709.14
TOTAL:	**$11,588.51**