Friction Hitches for Technical Rescue - An Open-Ended Approach

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Introduction:

Redundant systems are standard practice for many Technical Rescue Teams in North America. Much discussion and debate has been conducted regarding appropriate methods for managing the two systems. Examples include, a Single (Tensioned) Mainline and a Separate (Un-tensioned) Belay or, two tensioned ropes supporting the load (TTRS). Regardless of the system of choice, a critical examination of key criteria must be considered. [1]Does the system have an acceptable *Static System Safety Factor*, pass the *Critical Point Test*, *Whistle Test*, and consider *Other Important Factors*? In addition, tremendous energy has been committed to the empirical study of devices associated with the various systems. Many studies have been conducted following the British Columbia Council of Technical Rescue (BCCTR) Belay Competence Drop Test Method (BCDTM). While minor differences exist, the BCDTM appears to be the basis for current Belay Testing Standards addressed in ASTM F-2436 and NFPA 1983. Historically, few devices have passed this rigorous examination meant to simulate a 'significant event' during the edge transition phase of a Technical Rope Rescue Mission. The Tandem Prusik Belay, 540 Rescue Belay Device, and MPD have all tested well on the drop tower and slow pull machine. As a result, these devices have been put into service by Teams with various Mission Profiles. It is important to recognize, operators of these devices primarily receive "non-event feedback" regarding their technique. This paper will explore limitations of popular rescue belay devices in use today as well as describe initial examinations conducted with the Blue Water VT Prusik to belay rescue loads.

Background:

The concept of redundant systems in rope rescue is nothing new. Despite more than 30 years of Rescue Belay System testing much debate still exists among Practitioners regarding the merits of this system or device versus that one. There are risks to mitigate during the edge transition. The astute practitioner will certainly consider force and stopping distance in their selection of devices. These components are fundamental to examinations using the BCDTM. In addition, one must recognize 'other potentially important factors'.

- Does the system 'self-actuate'?
- Can the operator defeat the 'reliable' fall arrest mechanism of the device?

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[1] Systems Analysis for Rope Rescue, 2006, Rigging for Rescue - Seminar Handout

- Is smooth movement of the load reliable so as to not **cause** some type of event during this phase?

As the operation moves beyond the edge transition risks morph due to increased rope in service. Force due to an abrupt stop on the rope is no longer of much concern. Mitigation efforts become focused on minimizing stopping distance should one of the rope systems become compromised. This is typically accomplished by sharing the total tension between both component systems. [2]In doing so, it is advisable to ensure both systems have a friction component and a 'hands free backup' component. In addition to 'stopping distance', the same 'other potentially important factors' from the edge transition phase must be evaluated.

Regardless of the phase of the operation and associated risks being mitigated, one must ask; what level of training and experience is required of the practitioner to perform these technical tasks with precision? Does the mountain of empirical data supporting the widespread acceptance of commonly used Rescue Belay Devices accurately translate to legitimate risk mitigation during Technical Rope Rescue Operations?

<u>Objectives:</u>

The objectives of this project were to examine:

1. limitations of strictly empirical study (BCDTM) as a means of evaluating rescue belay systems,

2. the capabilities and limitations of the BlueWater VT Prusik configured as an asymmetrical, 6 over 1, friction hitch used as a rescue belay device.

Test Method:

For decades the Technical Rescue Community has relied heavily upon empirical study of rescue belay devices and systems. [3]The foundation of this study has been the BCCTR Belay Competence Drop Test Method.

- 200 kg test mass (two persons + equipment) tied to
- 3 metres of rope, the belay system must be able to withstand a
- 1 metre drop of the load and stop it in
- 1 metre of additional travel with less than
- 15 kN of force

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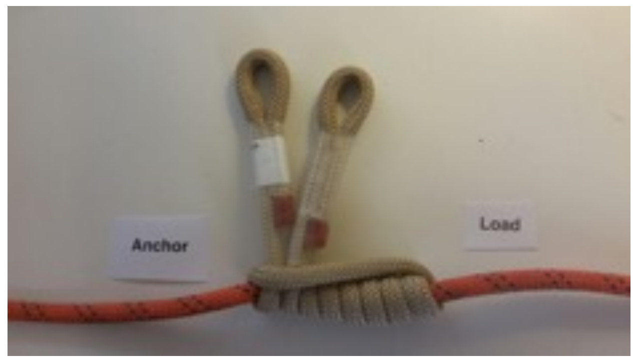
[2] Rescue Belays: Important Considerations for Long Lowers, ITRS 2007, Mike Gibbs, Rigging for Rescue

[3] Rescue Systems Testing, BCCTR Research Section 1990, Arnor Larson

[4]The BlueWater VT Prusik was selected for further testing based upon initial results gathered during 2013 and 2014 Aramid Fiber Friction Hitch testing conducted by Rigging for Rescue in Ouray, Colorado. When configured as an asymmetrical, 6 over 1 friction hitch working on 11mm host rope, the VT Prusik appeared favorable as a rescue belay device. For teams operating with smaller diameter ropes, the VT was tested with an asymmetrical configuration, 7 over 1 working on 9 to 9.8mm host rope. In both cases this appeared to be the maximum number wraps achievable given the relationship between VT and host rope diameter. It became known as 'max over one'.

11mm host rope w/ Asymmetrical 6 over 1



9.5mm host rope w/ Asymmetrical 7 over 1

In addition the standard BCDTM drop testing and limited 'red-line' drop tests with larger Fall Factors, similar configurations were tested in slow-pull at a rate of approximately 25mm per second. The intent was to observe the interaction between friction hitch and host rope. Did the hitch 'slip' as expected with Nylon Prusiks and if so, at what force?

<u>Variables:</u>

- Fall Factor 1/3 to Fall Factor 1
- Slow-pull slip testing (approximate rate 25mm per second)
- BlueWater VT Prusik (various hitch configurations)
- Sterling RIT Eye to Eye (various hitch configurations)
- New England KMIII - 11mm new & used - Polyester sheath, Nylon core
- PMI EZ Bend - 11mm used - Nylon sheath, Nylon core
- CMC Static Pro - 11mm new - Polyester sheath, Polyester core
- Sterling SuperStatic - 11.5mm new - Nylon sheath, Nylon Core
- BlueWater ARMORTECH - 11mm new - Technora over Polyester double sheath, Nylon core
- BlueWater Canyon Line - 9mm new - Technora sheath, Nylon core
- BlueWater Canyon DS - 9.2mm new & used - Technora/Polyester blend sheath, Nylon core

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[4] High-modulus aramid fiber friction hitches in technical rope rescue systems, ITRS 2014, Mike Gibbs, Rigging for Rescue

A third phase of testing was conducted with a human operators on the belay. It was recommended operators use standard Tandem Prusik Belay (TPB) technique (Hitchhiker Grip). Operator experience and training with the TPB technique varied substantially. For those less familiar with rigging the VT Prusik in an asymmetrical 6 over 1 configuration or the TPB technique, a short instructional video was available. No additional instruction was given prior to the test.

The test mass was lowered approximately 150-200 cm via the mainline then released at one of two pre-determined release points. The intent was to lower far enough such that the belay operator technique could be captured on video for further analysis. The belay rope was routed through the high directional resulting in a Fall Factor 0 event. This set-up certainly produces less force than one with Fall Factor 1/3. This phase of testing focused on operator technique and relative stop distance. Measurements were taken to determine stopping distance. No force instrumentation was employed. Being a Fall Factor 0 event, forces were expected to be less than what was observed during the drop test phases of this project.

The tests were conducted using:
- 200 kg rigid test mass
- Fall Factor 0 (except for slack generated due to operator technique)
- Rope in Service at drop position - either 680 cm or 747 cm
- Human operators

<u>Variables:</u>
- BlueWater VT Prusik - new and used
- CMC 8mm Nylon Accessory Cord to create 2 triple wrapped Prusiks for TPB - new and used
- Sterling SuperStatic2 - 11mm new - Nylon sheath, Nylon core
- NE KMIII Max - 11mm new - Polyester sheath, Nylon core
- Lowering distance (pre-release) approximately 150-200 cm
- Human operator experience and training with TPB technique

A fourth phase of this project included personal correspondence and literature review. Practitioners and teams have shared stories related to concerns regarding rescue belay systems not performing as expected when a human operator is involved. All of the devices considered have performed favorably using standard BCDTM and slow-pull methodologies.

Results & Discussion:

<u>Drop Test:</u>
Between July, 2013 and present 62 drop tests using a single friction hitch constructed with a Technora sheath over Nylon core and sewn eyes on each end. Many more drops were conducted with various configurations of the BlueWater VT Prusik in combination with other devices. The intent was to gain a better understanding of the capabilities and

limitations of such devices. Irrelevant configurations have been removed from the data pool as it bears little influence on this study. Most data points reflect a BlueWater VT Prusik while the Sterling RIT Eye to Eye was used in a couple drops.

Due to the preliminary nature of this testing, a wide spectrum of device configurations and host ropes were examined. Various combinations of the data set are summarized below. These combinations represent baseline scenarios (BCDTM) as well as 'red-line' tests. Fall Arrest System (FAS) extension considers initial rope in service (300 cm) plus rope stretch, knots tightening, & slide distance through belay device. To strictly pass the BCDTM criteria, a belay system must limit the FAS extension to less than 400 cm.

1) BCDTM friction hitch configured max over one (6 or 7 over 1) on 9-11mm rope

Sample Size - 29
Peak Force Range - 6.4 to 13.2 kN
Mean Peak Force - 8.5 kN
FAS extension Range - 27.5 to 135 cm
FAS extension Mean - 79 cm

4 data points in the above set exceeded a FAS extension of 100 cm. All 4 were using 9.8mm host rope. This is not surprising considering the rated elongation from the manufacturer is greater than that of the 11mm ropes.

2) BCDTM friction hitch configured six over one on 11mm rope

Sample Size - 14
Peak Force Range - 7.9 to 13.2 kN
Mean Peak Force - 9.9 kN
FAS extension Range - 27.5 to 108.5 cm
FAS extension Mean - 60.5 cm

3) 200 cm drop on 300 cm of rope, friction configured six over one

Sample Size - 6

<u>4 catches</u>
Peak Force Range - 7.4 to 9.4 kN
Mean Peak Force - 8.4 kN
FAS extension Range - 93.5 to 172 cm
FAS extension Mean - 123.5 cm

<u>2 fail</u>
- 1 excessive slide distance (FAS extension 320 cm)
- 1 friction hitch failed - Technora sheathed rope

The failure of the friction hitch on the rope with a Technora sheath is interesting. Previous slow-pull test series conducted at Rigging for Rescue also indicate Technora hitches on host ropes with a Technora sheath may produce highly variable results.

4) 300 cm drop on 300 cm of rope, friction hitch configured six over 1
Sample Size - 3

In 2013, during the initial phase of drop testing, the BlueWater VT Prusik configured 6 over 1 on 11mm host rope with a Polyester sheath over Polyester core produced a 'catch'. The Peak Force was 8.9 kN and the FAS extension, 151 cm. Both the host rope and the VT Prusik were new for this test.

In 2015 the Fall Factor 1 test was attempted again. This time with used VT Prusiks on very used 11mm PMI EZ Bend, a 100% Nylon rope. 2 tests were conducted and both failed the VT Prusik.

<u>Slow-pull Test:</u>
Twenty five slow-pull tests were conducted using the BlueWater VT Prusik. The Initial Slip Force range for slow-pull slip tests were **5-20 kN**. With the Mean being **12.2 kN**.

<u>Human Factor Drops with VT and TPB:</u>
34 human factor drops were conducted. 13 tests were with the VT configured six over one on 11mm rope. The FAS Extension Range was 62.5 to 205 cm with the FAS Extension Mean being 97.3 cm. 10 tests were with classic TPB on 11mm rope. The FAS Extension Range was 73.5 to 145 cm with the Mean being 100.5 cm. The remainder of the drops from this series were quick-look with many different techniques and configurations. Noteworthy comments from one operator during the VT drops include, "I know my hand was facing palm down when the drop occurred." This resulted in a 205 cm FAS Extension.

<u>Literature Review & Personal Correspondence:</u>
Through a non-exhaustive review of the literature and many personal correspondences, it appears strictly empirical examination of rescue belay devices and systems may not accurately represent the true capabilities and limitations of widely accepted devices and systems.

In 2014 the following anecdote was shared via email by John Lindsley-Thayer. It comes from a SAR Team consisting of both paid professionals and volunteers. The training time and call volume of this Team could be considered 'very high'.

> "…Like I said we had the scarab set up as our main and we had a dual prusik system set up for a two hand belay technique. Our mainline was a short segment of rope so it would run free through the scarab simulating a complete failure of the mainline system. One officer ran the main and the other ran the belay, both of us knowing the eventual outcome. I'd say we ran the lower for about 5-10 feet before the "failure," but running the belay the correct way had great results. I'd say the belay stopped the load within five to ten feet (all approximate here), and the prusiks never welded onto the line, but they were all trashed after the test. I will add, it was a very violent transition…we managed to completely crush the aluminum roller edge protectors.
>
> The following training we did the same set up with our volunteers, but did not tell them what the test was. The scary part of it, I'd say 75-80 percent of our volunteers either defeated the belay with improper grip (too tight of a grip on the prusiks), not having the proper belly in the line, not holding

> hands parallel, or not applying proper force against the anchor (allowing slack in the line between the hands and the anchor). Many of the folks natural instinct was to either hold on to the rope or chase it over the edge (fortunately they were all on personal anchors), and I want to say we had one or two loads actually hit the ground."

The observations of this practitioner are noteworthy. They will become a common theme among other anecdotes collected. “Improper grip” of the friction hitch, “not holding palms of hands parallel”, and “not applying force against the anchor” all promote the operator’s ability to hang on to the device during an event. This appears to increase the probability of the operator defeating the system.

Another anecdote shared by Nicholas Le Maiter of the Mountain Club of South Africa illustrates significant variation in technique being demonstrated by Club Members.

> “…Some time after adopting the TPB we noticed a great degree of variance in how people were applying the technique with respect to hand position (on one prusik, both prusiks, angle between hand position and belay line); bight size; bight position (bight in front of prusiks, bight between prusiks). We put it down to us failing to train it properly and tried again with much the same results. This made it clear that we were not able to get people to apply the technique properly and the fault lay with us as trainers. We then decided to test it out and see if it could cope with the variation that we were seeing in the applied technique.”

Upon reviewing video provided by the Mountain Club of South Africa, three distinct causes and effects appear.
1) When the operator’s anchor side hand holding the Prusiks turns palm down with the thumb toward the load and the pinky toward the anchor, it appears easier for the operator to defeat the system. This results in a significantly longer stopping distance or no catch at all.
2) When the operator’s anchor side hand holding the Prusiks remained in a position with the palm toward the load and pulling hard against the anchor (toward the load) the TPB appears to ‘self-actuate’ with little or no opportunity for the operator to defeat the system. This results in a relatively short stopping distance.
3) When the operator’s anchor side hand slides back toward the anchor slack is created between the anchor and the Prusiks. If the event occurs at this moment, it appears the operator is able to ‘ride’ the Prusiks forward to a palm down position, similar to situation #1. This results in a significantly longer stopping distance or no catch at all.

[5],[6]In 2000 and 2005 Jerome Stiller presented to the ITRS audience raising questions about methodology used to evaluate the effectiveness of Prusiks.

[7]In 2007, Reed Thorne presented “Again…Are you really on belay?” Thorne questions the reliability of Prusiks configured for raising applications.

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[5] When Prusiks Go Bad, or Are You Sure That Thing’s Gonna Hold?, ITRS 2000, Jerome Stiller

[6] Tandem Prussiks: Is no news good news?, ITRS 2005, Jerome Stiller

[7] Again…Are you really on belay?, ITRS 2007, Reed Thorne

> "The Prusik-minding-pulley influences the performance of the TPB **negatively** during a raising when using a standard hands-free maintenance of the tandem Prusiks."

Cause for concern in this case is likely due to either one or both of the following:
1) capturing rope through the PMP on the belay during a raise creates some slack in the Prusik. This slack has potential to migrate into the hitch itself decreasing the friction between the Prusik and the host rope.
2) the Prusiks are hitched to a rope that is now feeding straight into the PMP. [8]"Tandem Prusiks appear to be less reliable at initially grabbing a straight rope rather than a bent one."

[9]In 2007, Billy Masterson, Casey Cloud, & Herb Dorn presented "One way I'd rather not take to get off the top of a building and the device that saved us…despite it's misuse." This case study clearly indicates the MPD performed effectively and arrested the fall **after** the operator stopped misusing it.

With the 540 Rescue Belay Device, 2 initial actions are frequently observed following improper operator technique.
1) The device is promptly returned to the gear shelf in favor of another device because it is too difficult to achieve a smooth operation with the 540.
2) The operator 'rides' the release handle in favor of achieving a 'smooth' feed of the rope through their system.

From the Patient's perspective, neither of these actions are desirable. When operated well, the 540, arguably produces the one of the most reliable fall arrest Belay System available to practitioners.

<u>Discussion:</u>
Drop Testing and Slow-pull examination serve well as initial indicators regarding the suitability of Rescue Belay Devices. Widely accepted standards such as the BCDTM generate a reference point from which further consideration of 'other factors' may begin. The practitioner and organization must critically analyze what factors most appropriately mitigate risks associated with their specific mission profile. More 'red-line' tests will help clearly define the upper boundary capabilities of the BlueWater VT Prusik configured 'max over one'.

A significant drawback to classic tandem Prusiks is the material itself. Gripping ability is largely dependent upon how supple the cord is. Cordage available to consumers appears to vary dramatically with regard to how supple it is. Another potential pitfall of classic tandem Prusiks is their ability to loosen up once initially hitched on the host rope. As movement occurs, material can flow into the hitch, decreasing its gripping ability on the host rope. A final pitfall for consideration is the fact two Prusiks must be used for

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[8] Are you really on belay, 1990, John Dill

[9] One way I'd rather not take to get off the top of a building and the device that saved us… despite its misuse, ITRS 2007, Masterson, Cloud, & Dorn

heat dissipation during the severe BCDTM event. For many operators, effectively managing two triple wrapped 8mm Nylon Prusiks proves to be quite a challenge.

The BlueWater VT Prusik is constructed using a Technora sheath and Nylon core with sewn eyes on each end. The device measures 80 cm in length with an MBS of 16 kN pulled end to end. [10]Teijin, the maker of Technora, suggests it is an abrasive fiber, with a very high resistance to heat, and significantly greater resistance to flexural fatigue than other Aramid Fibers. The finished product from BlueWater results in a device that is consistently very supple with many configuration options for the rope work practitioner. Gripping ability on the host rope is favorable due to the abrasive nature of the Technora and how supple the device is. Rigged 'max over one', the VT exhibits very little ability to become too loose on the host rope like its classic Prusik counter-part. Due to the heat resistant nature of the VT, initial tests indicate a single 'max over one' friction hitch tolerates the heat generated from standard BCDTM drops.

All devices have potential downsides. Due to the abrasive nature of Technora and it's high resistance to heat, more glazing of the host rope has been observed in BCDTM and larger drops. Human factor drops with the VT have not produced any glazing. In 2013, both the VT and host rope samples were slow-pull tested following the BCDTM drops. All tests indicated no significant loss of strength in spite of moderate glazing of the host rope. Teijin suggests a potential pitfall of Technora being a low resistance to UV light. "The strength of Technora can be lowered to half when exposed to sunlight for about 3 months." It is unclear how this specifically impacts the performance of the BlueWater VT Prusik in rope rescue applications.

Video analysis of human factor testing and comments gathered during personal correspondence have yielded many excellent insights regarding the true capabilities and limitations of the devices and systems widely accepted by practitioners today.

Recommendations:

- Continue to vet all potential rescue belay devices and systems through standardized drop testing and slow-pull methodologies. Recognize the limitations of such examinations.
- Develop standardized test methodologies and performance guidelines for human factor testing and evaluation of rescue belay systems.
- Continue to test the BlueWater VT Prusik using BCDTM, 'red-line', and human factor methodologies for appropriateness as a rescue belay device. Initial examinations suggest it could be a viable alternative to the classic TPB with many additional benefits due to properties, construction, & consistency.

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[10] Technora - The Power of Aramid, Technical Brochure, Teijin Corporation

- When employing the 'Hitchhiker Grip' to belay the lower of rescue loads with a friction hitch system (TPB or VT 'max over 1') strictly adhere to these key points for system optimization at or near the edge transition phase of the mission:
    1. **Snug** friction hitch must be gripped firmly in the anchor side hand with the thumb **perpendicular** to potential loading direction at all times.
    2. Anchor side hand will pull **hard** against the **anchor** while maintaining a hand position with thumb **perpendicular** to potential loading direction.
    3. When advancing host rope through the friction hitch, use the load side hand to pull rope through the anchor side hand, maintaining an anchor side hand position with thumb **perpendicular** to potential loading direction.
- When belaying the raise of rescue loads with a friction hitch system and Prusik Minding Pulley (PMP) it is imperative the hitch not be able to 'loosen up' while riding against the PMP. This can occur as a result of the hitch being too long for the associated PMP and/ or the hitch material being too stiff. Consider using the BlueWater VT Prusik configured 'max over one' to mitigate the risk of 'loosening up'.
- Develop realistic belay training scenarios and exercises (i.e. dropping 200kg mass onto belay systems with human operators). This will elicit legitimate operator responses to a failure event. Combined with video analysis, practitioners will receive accurate feedback regarding their operational technique. The importance of this training methodology cannot be overlooked. Without it, practitioners primarily receive "non-event feedback".
- Critically analyze the device and technique choices being made within your Technical Rope Rescue Team. Do they accurately match your mission profile? What biases and heuristics are active within your Team or Organization regarding device and system choices?

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