Backyard Testing: Pitfalls, Pratfalls and Things That Go Bump In the Night

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Backyard Testing: Pitfalls, etc. - Background

• Douglas County Search and Rescue Team (DCSAR) is a relatively new team, founded in 1998
• The team passed its testing to become a fully accredited Mountain Rescue Association (MRA) team in Spring 2005
• In preparing for the tests, team members were subjected to a lot of information on breaking strengths, forces, factors of safety, etc.
• Like most teams, DCSAR has its share of members who aren’t interested in the technical aspects of rescue, but also has many tech geeks, engineers, climbers, wackos and others who want to break things or are paranoid about equipment failure
  – Accreditation got these members thinking about testing
Opportunity knocked on the door of the Alaskan Embassy at the 2005 MRA summer conference in Vail

- The Alaska Mountain Rescue Group (AMRG) brought the MRA load cell and data acquisition system (DAS) to the meeting and said they weren’t hauling it back to Alaska

DCSAR members offered to take the load cell and DAS with them

The load cell is under the control of the MRA grants committee

- The chairman of the grants committee stated that no applications for the equipment had been received, but that at least one was expected

- DCSAR could use the load cell and DAS until an application was received

Team members took the equipment home with them

Lesson Learned #1 - Things taken home from late hour social gatherings involving alcohol can be a problem later
Backyard Testing: Pitfalls, etc. - MRA Load Cell and DAS

Load cell rating: 10,000 lbf (44.5 kN)
Sampling rate (max): 5,000 samples/sec
Sample rate \times \text{test duration} \leq 32,000

Lots of cable between load cell and box

Computer interface box, connects to computer with USB cable; data output direct to Excel
Backyard Testing: Pitfalls, etc. - Test Planning

• Step 1 - Poll the members interested in testing to determine what testing was desired
  – Specific suggestions were received from 3 engineers (civil, aerospace structures, aerospace mechanical) and a firefighter
  – A few other members just said that breaking anything would be OK

• Step 2 - Remind those making suggestions that there are no budget, no materials to test and no test facility

• Step 3 - Find budget and material
  – DCSAR had just begun replacing ropes, a limited supply of other softgoods was available, and there were “extra” carabiners in the team cache
  – No team money would be allocated to testing
Backyard Testing: Pitfalls, etc. - Test Planning (con’t.)

• **Step 4** - Find a place or places for conducting tests
  – AMRG had used a bridge for drop testing
    • Survey of bridges in the county found none usable
  – Buildings under construction, members’ garages, water towers and the last remaining fire lookout tower on the Colorado Front Range were considered
    • Only feasible location (i.e. the place tests could be conducted without fear of arrest) was a fire station

• **Step 5** - Determine mechanism for slow pull testing
  – Throw of available hydraulic rams was too short
  – Vehicle winches were the only method found

• **Step 6** - Reevaluate scope of testing once issues had been identified and resolved
Backyard Testing: Pitfalls, etc. - Test Planning (con’t.)

Night reconnoiter of Devils Head
Backyard Testing: Pitfalls, etc. - Test Planning (con’t.)

• **Step 7 - Test selection criteria**
  – Can be performed safely
  – Easy to perform
    • Limited time, materials, test apparatus and facility
  – Expendable hard and soft goods available
  – Technique or system used by the team
    • Especially those that are debated within the team and/or with outsiders
  – Little or no testing by others
  – Expected forces are within capabilities of test apparatus

• **Factors considered but not main drivers**
  – Advancing the art and science of rope rescue
  – Repeatability with sufficient runs for statistical analysis
Backyard Testing: Pitfalls, etc. - Test Planning (con’t.)

Tests suggested and selected

• Drop a loaded litter a couple of inches

• Failure testing of ropes

• Tandem vs. single Prusik

• Rope strength reduction caused by bend around carabiner
  (similar to testing presented at ITRS 2004 by McKently and Parker)

• Prusik/webbing tie-in to litter (tested by Marc Beverly, Spring 2005)

• Single vs. double figure 8 knot

• A member’s rope and climbing rack that survived a condo fire
  (exposed to smoke only), and other old rope and softgoods

• Coefficients of friction

• Brake tube braking (wraps vs. load)

• Inline forces on uphaul/lowering system

• Snow picket tensioning system
Backyard Testing: Pitfalls, etc. - Test Planning (con’t.)

• **Step 8** - Gather test standards and specifications
  - CI 1801 - Cordage Institute “Low Stretch and Static Kernmantle Life Safety Rope”
    - Includes test parameters for slow pull testing

• **Step 9** - Write test plan
  - On second thought, against better judgement, don’t write a plan, perform testing on the fly

• **Lesson Learned #2** - Write the test plan

• **Step 10** - Pick a day to start testing at the fire station
  - Then put testing on hold while the firefighter goes out of county on a wildland fire assignment
Backyard Testing: Pitfalls, etc. - Test Planning (con’t.)

• **Step 11** - While on hold, perform inline testing of DCSAR lowering system (which does not require FD resources)
  – Haul laptop computer, load cell and interface into field
  – Put load cell between anchor and brake tube on a low angle scree lowering (convince members it’s OK)
  – At conclusion of lowering find that the DAS has not recorded any data
  – Remove load cell from rescue system and continue training
  – Later discover broken wire between load cell and interface box

• **Step 12** - Perform tests to verify system is working properly and to become more familiar with it
  – Simple, lightweight drop tests
**Backyard Testing: Pitfalls, etc. - Garage Drop Tests**

- Simple test to get familiar with the DAS and load cell
- Needed to do something while waiting for the rest of the test team to become available
- Load cell anchored to roof joist in residential wood frame garage using 1 in. (25 mm) tubular webbing
  - Roof joist - double 2 x 8 inch (51 x 203 mm) nominal
- Test mass - 3 barbell weights tied together with webbing
  - 41.5 lbm (18.8 kg) including webbing and carabiner
  - Mass selected based on availability, ease in raising it (one person operation) and to limit forces on anchor
- Mass connected to load cell with rope and carabiners
  - Figure 8 at one end, bowline at other of rope
  - 32 to 34 in. (0.8 to 0.9 m) (pre-drop) from end of one loop to the other (used an existing piece of rope)
Backyard Testing: Pitfalls, etc. - Garage Drop Tests (con’t.)

Anchor

Pre-drop

Post drop

In line before drop

FF = 1

Test mass

41.5 lbm/18.8 kg
Tests conducted using two types of rope
  - 10.5 mm Mammut Duodess dynamic
    • Personal climbing rope, used mainly for top roping
    • Purchased about 1980, retired many years ago and cut into short sections for knot practice
  - 10.6 mm Bluewater II static
    • DCSAR team rope, used for variety of technical rescue systems in all seasons
    • Purchased 1999, retired in 2005
    • Stored in a rope bag in team trucks parked outside

Drops were made with an approximate fall factor of 1
  - Test mass was lifted to the level of the anchored end of the rope (eyeball measurement), and then released

Tests were repeated multiple times on the same section of rope
### Backyard Testing: Pitfalls, etc. - Garage Drop Tests (con’t.)

#### Garage Drop Test Results

<table>
<thead>
<tr>
<th></th>
<th>Mammut</th>
<th>Bluewater</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak force (average)</td>
<td>2.48 kN</td>
<td>3.20 kN</td>
<td>1.29</td>
</tr>
<tr>
<td></td>
<td>556.99 lbf</td>
<td>719.92 lbf</td>
<td></td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.16 kN</td>
<td>0.21 kN</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>35.02 lbf</td>
<td>46.74 lbf</td>
<td></td>
</tr>
<tr>
<td>Peak force (median)</td>
<td>2.55 kN</td>
<td>3.23 kN</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td>572.58 lbf</td>
<td>726.21 lbf</td>
<td></td>
</tr>
</tbody>
</table>

- *n = 27 drops on each rope, fall factor approx. 1*
- *DAS sampling rate was 100 samples per second*

- **Notes**
  - Tests were conducted in sets, not one continuous series. Average peak force of last set was about 10% higher than first set.
Dynamic Drop Test Set 5

Sample of data output

Time (sec)

Force (Newtons)
Backyard Testing: Pitfalls, etc. - Slow Pull Testing

• **Step 13** - When the firefighter returned from his assignment, another attempt was made to set up a test date
  – Now others on the test team had out-of-town business trips
• **Step 14** - A date was selected that the fire station and firefighter would be available (hopefully), and anyone interested was told just to show up
  – Only two people showed up and the one with the keys to the building was an hour late
• **Step 15** - Slow pull testing begins!
  – Testing was interrupted once while the firefighter helped with the deployment of other FD personnel to a fire
  – Testing went smoothly, more or less
    • Data collection was another matter
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

- Slow pull mechanism
  - Fixed anchor - Type I water tender (fire engine)
    - Estimated vehicle mass almost 80,000 lbm (36,287 kg)
  - Warn MX10000 winch mounted on Type VI fire engine
    - Cable routed through a snatch block (pulley) rated at 16,000 lbm (7200 kg) for 2:1 mechanical advantage
    - Estimated vehicle mass: 10k to 12k lbm (4536 to 5443 kg)
  - Winch specifications (estimated, based on other Warn winches)

<table>
<thead>
<tr>
<th>Line Pull (lbm)</th>
<th>Line Speed (ft/min)</th>
<th>Line Speed (m/min)</th>
<th>Pull by layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>30</td>
<td>9.1</td>
</tr>
<tr>
<td>2000</td>
<td>907</td>
<td>14</td>
<td>4.3</td>
</tr>
<tr>
<td>4000</td>
<td>1814</td>
<td>9</td>
<td>2.7</td>
</tr>
<tr>
<td>6000</td>
<td>2722</td>
<td>7</td>
<td>2.1</td>
</tr>
<tr>
<td>8000</td>
<td>3629</td>
<td>6</td>
<td>1.8</td>
</tr>
<tr>
<td>10000</td>
<td>4536</td>
<td>4</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Tests used layers 4 and 5.
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Larkspur Fire Dept. Brush 162
Warn MX10000 winch with snatch block
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Larkspur Fire Dept. Tender 165

Load cell attached to tender with choker chain
### Slow Pull Test Summary

<table>
<thead>
<tr>
<th>Test</th>
<th>Broke at</th>
<th>Rope</th>
<th>Load Cell</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Prusik test</td>
<td>Prusik</td>
<td>New</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Single Prusik</td>
<td>Rope</td>
<td>New</td>
<td>Yes</td>
<td></td>
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<tr>
<td>2</td>
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<tr>
<td>Single Prusik</td>
<td>Nothing</td>
<td>New</td>
<td>Yes</td>
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</tr>
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<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Single Prusik</td>
<td>Rope</td>
<td>New</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Prusik</td>
<td>Rope</td>
<td>New</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Single/double Figure 8 knots</td>
<td>Single 8</td>
<td>Old</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single/double Figure 8 knots</td>
<td>Single 8</td>
<td>Old</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
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<tr>
<td>Snow picket tensioning device</td>
<td>Webbing</td>
<td>n/a</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Single Prusik test** - 3 wrap 8 mm Prusik on 11 mm Bluewater II
**New rope** - 10.6 mm Bluewater II less than 2 years old
**Old rope** - 10.6 mm Bluewater II over 5 years old
**Single/double Figure 8 knots** - single Figure 8 one end, double at other
**Snow picket tensioning device** - called by some a “cargo tie-down strap”
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

• Comments on testing
  – Test 1 - interface box switch ON, but load cell switch was OFF
    • Lesson Learned #3 - Switch ON - data flows; Switch OFF - no data; Switch ON - data, Switch OFF - no data, etc.
    • This same observation was made at the beginning of the drop tests
  – Test 2 - Hmm
  – Test 3 - Hmmmm
  – Test 4 - Check switches - both ON, check wires - connected; proceed on in the name of science
  – Test 5 - Could we have broken the load cell? Proceed on in the name of time
  – Test 6 - Must have broken the load cell; proceed on in the name of fun...
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Note proper use of PPE

Test preparation
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Prusik test setup
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Result from Prusik test #1

One of the innermost wraps broke where it crosses under the connector between the outer wraps.

Direction of rope travel

Traces of Prusik on sheath along this entire section
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Result for Prusik tests # 2, 4, 5

Sheath bunched up, rope rigid

Direction of rope travel

Traces of Prusik on sheath

Mark at leading edge of Prusik at beginning of test
Result of Prusik test #3
Part A

Fusing of Prusik and rope

Direction of travel of rope

Mark at leading edge of Prusik at beginning of test
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Result of Prusik test #3
Part B

Brush 162
Prusik Pull Tests 2 and 3

Test 2
Rope broke

Test 3
Nothing broke, truck moved
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Single Figure 8

Double Figure 8

Snow picket tensioning device
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con’t.)

Figure 8 failure

Free end of rope

To double Figure 8

Tensioning device failure

Free end

To load cell

To winch
Backyard Testing: Pitfalls, etc. - Lessons Learned

- Bet against the firefighter, and bet heavy
- Make sure the interest in testing is really there
- Have defined goal(s) or objective(s)
- Have enough time to do the tests properly
- Be familiar with the test equipment
  - Hardware and software
  - During pre-test of garage drop tests, only every other test was recorded
    - Compensated for it during subsequent testing
- Document everything
  - In writing, photos and video
    - Pre- and post-test
    - Needed for post-test analysis
Backyard Testing: Pitfalls, etc. - Lessons Learned (con’t.)

• Have a written plan - a checklist at a minimum
  – For consistency, repeatability and so nothing is missed
• Test plan - checklist items
  – Safety
    • Where are things going to go when they break
  – What hardware and soft goods were used on each test
  – Procedure for tying knots
    • Record who tied them
      – Ideally the same person each time
    • Check that they are tied per the procedure, and tied consistently
  – Mark the starting location or leading edge of components that may slip, slide or move
Backyard Testing: Pitfalls, etc. - Lessons Learned (con’t.)

• Test plan - checklist items (con’t.)
  – Soft goods tensioned or slack at start of test
    • Distance between end connections
  – Winching procedure and amount of cable unspooled
  – Make sure batteries are OK
  – Check all electrical connections
  – Make sure items which need to be turned on are ON
  – Recheck all mechanical and electrical connections after every dynamic test run

• For more ideas and recommendations see “Testing on a Shoestring” presented by Loui McCurley at ITRS 2004
Backyard Testing: Pitfalls, etc. - Conclusions

• What did we really learn from the tests?
  – Even “insignificant” loads (the weight of just a rescue pack) can create significant forces in a shock load situation
    • But how valid are the results - is dropping a 41.5 lb mass on a 10,000 lbf load cell in the “noise level” response of the cell?
  – In the Prusik tests in which the rope broke, there was a loud, gunshot-like sound before any obvious, visible signs of failure
    • The sound is not a warning that something bad is going to happen, it’s a too late warning that something bad has already happened
    • Subsequent failure continued in steps, as the winch continued to pull the rope
Backyard Testing: Pitfalls, etc. - Conclusions (con’t.)

• What else did we learn from the tests? Not much...
  – Not enough tests of any one configuration to draw any conclusions
  – Too many variables
    • Knots, materials, line slack, winch operation
  – Insufficient documentation before each test run to help with analysis of results
  – Lack of load cell data
• BUT…
  – No one got hurt or killed
  – We met the minimum amazement factor (Attaway/Thorne ITRS 0?)
  – We had fun