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

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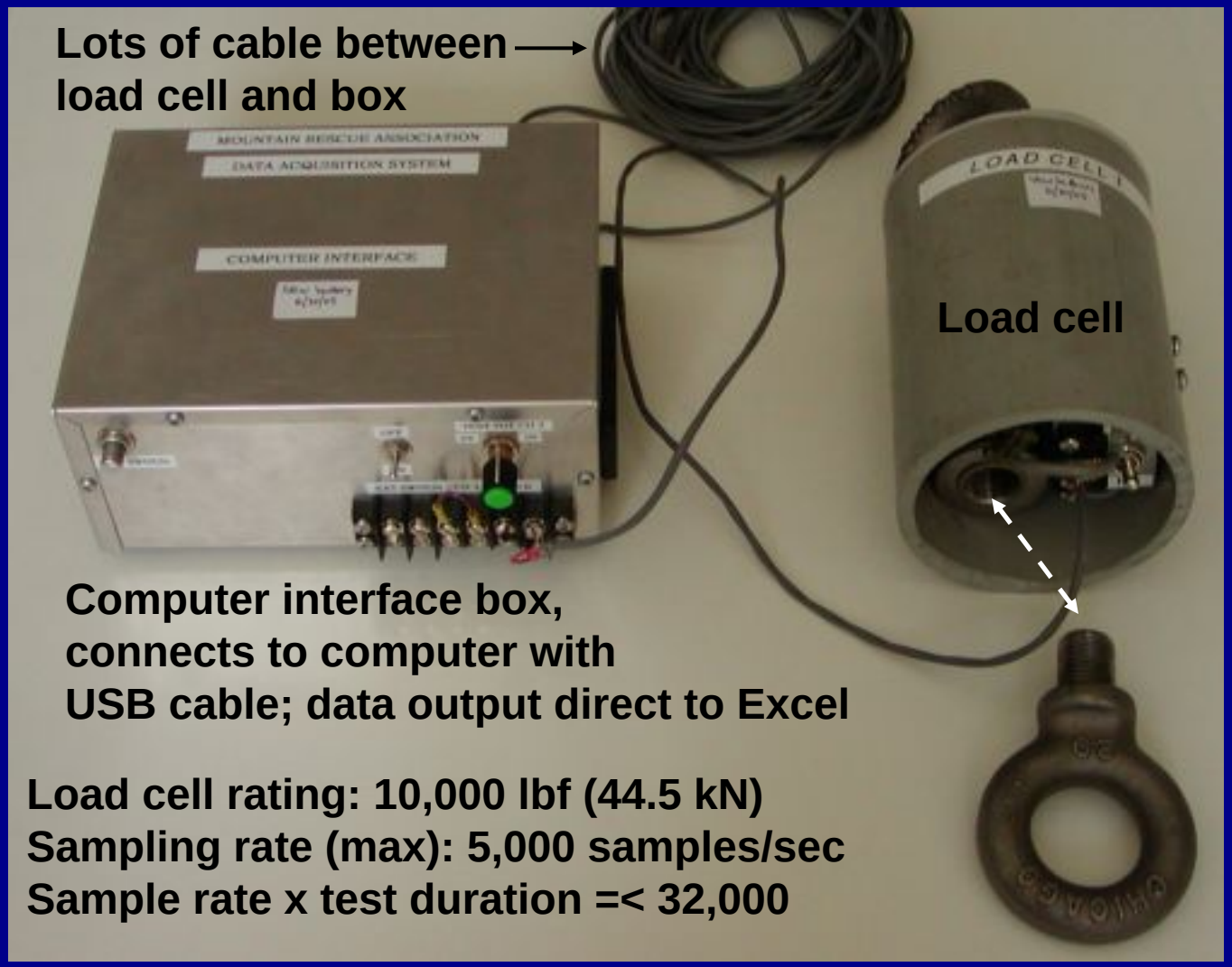
Backyard Testing: Pitfalls, etc. - Background

- 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

Backyard Testing: Pitfalls, etc. - Background (con't.)

- 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 x test duration =< 32,000

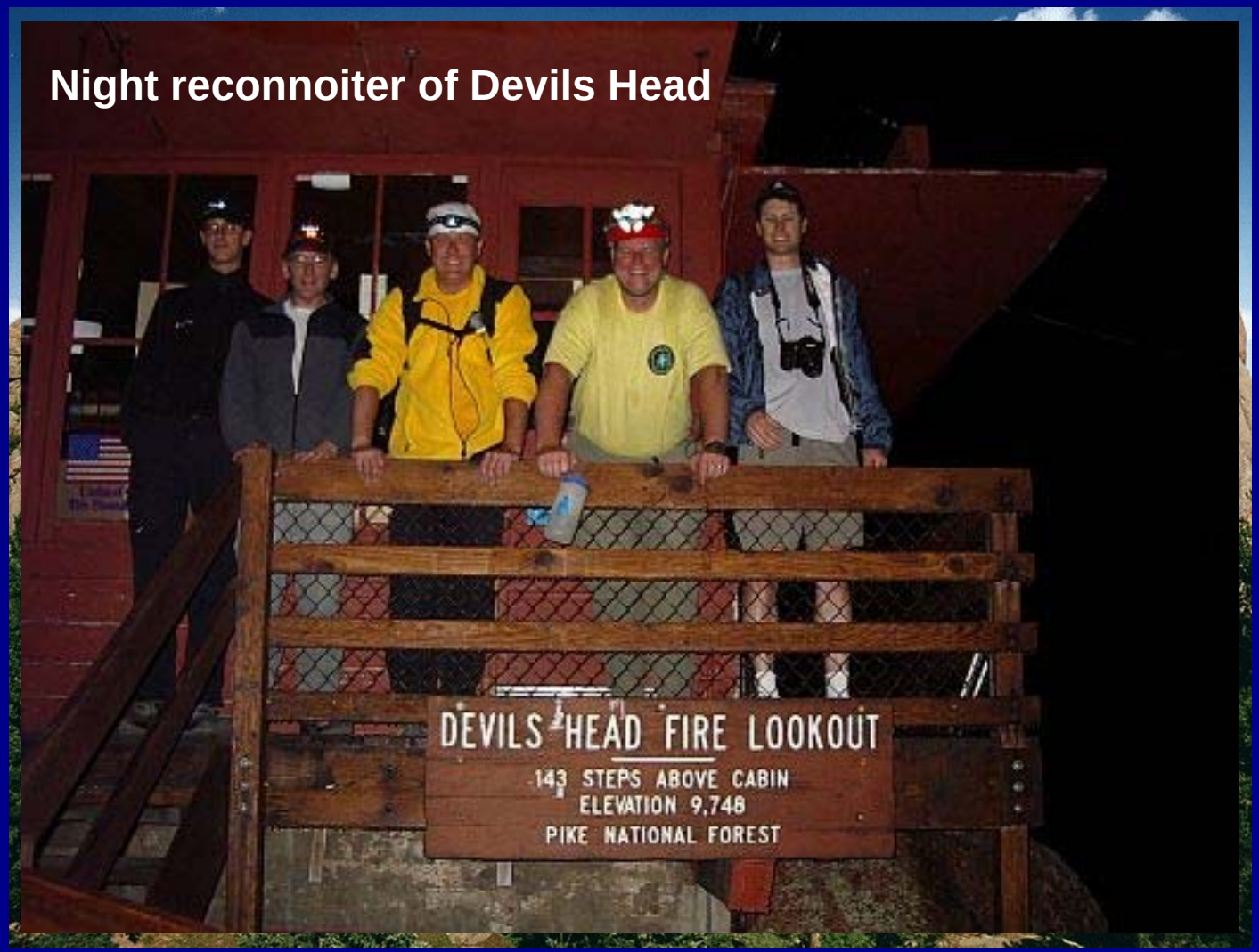
Backyard Testing: Pitfalls, etc. - Test Planning

- **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.)



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
- Coefficients of friction
- Failure testing of ropes
- Brake tube braking (wraps vs. load)
- Tandem vs. single Prusik
- Inline forces on uphaul/lowering system
- 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
- Snow picket tensioning system
- A member's rope and climbing rack that survived a condo fire (exposed to smoke only), and other old rope and softgoods

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
  - ASTM F2266 "Specification for Test Masses Used in Testing Rescue Systems and Components"
- 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.)

Backyard Testing: Pitfalls, etc. - Garage Drop Tests (con't.)

- 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***

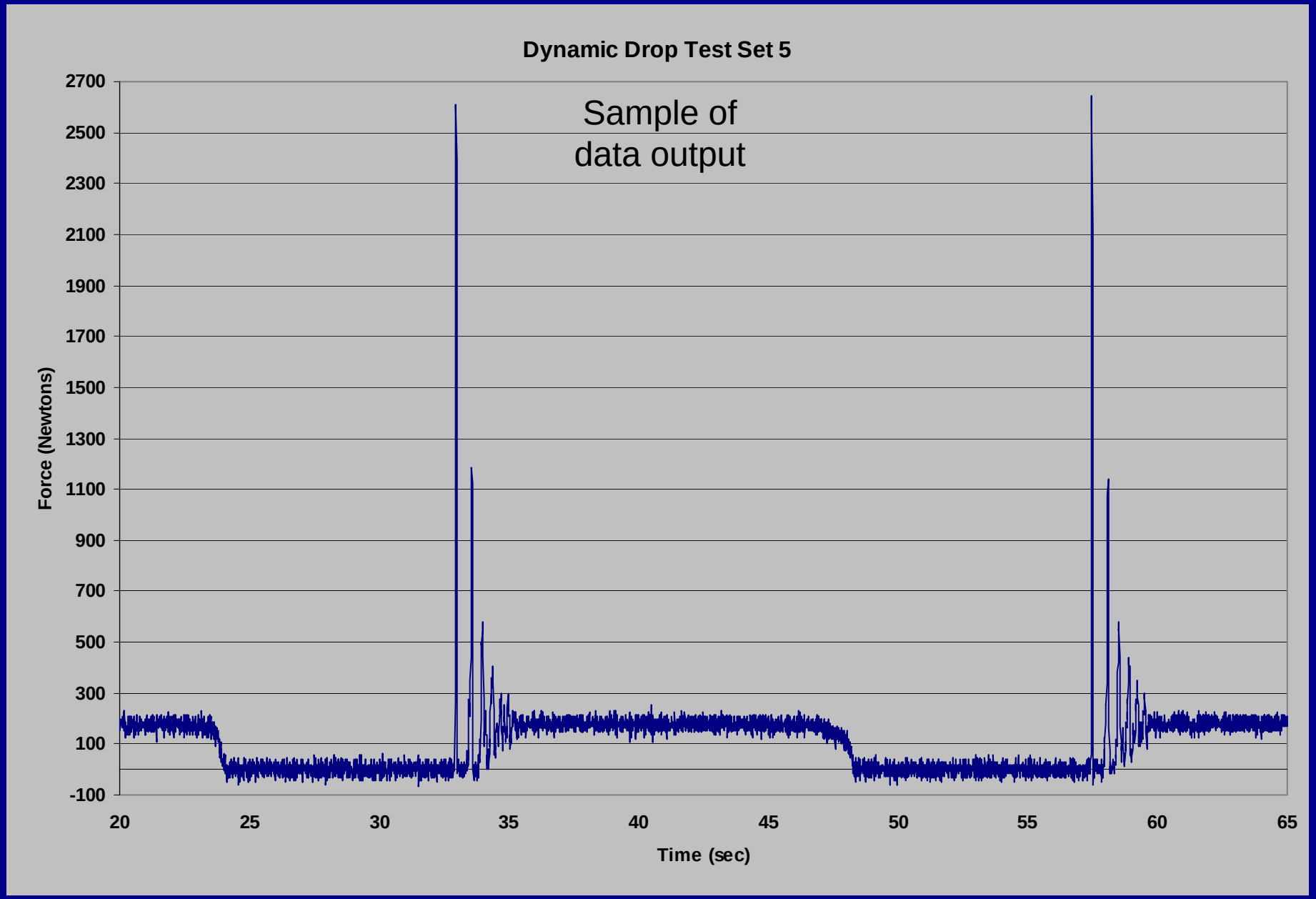
Backyard Testing: Pitfalls, etc. - Garage Drop Tests (con't.)

Garage Drop Test Results

	Mammut		Bluewater		Ratio
	kN	lbf	kN	lbf	B/M
Peak force (average)	2.48	556.99	3.20	719.92	1.29
Standard deviation	0.16	35.02	0.21	46.74	1.33
Peak force (median)	2.55	572.58	3.23	726.21	1.27

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
Force (Newtons)
2700
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
300
100
-100
20
25
30
35
40
45
50
55
60
65
Time (sec)

Backyard Testing: Pitfalls, etc. - Slow Pull Testing

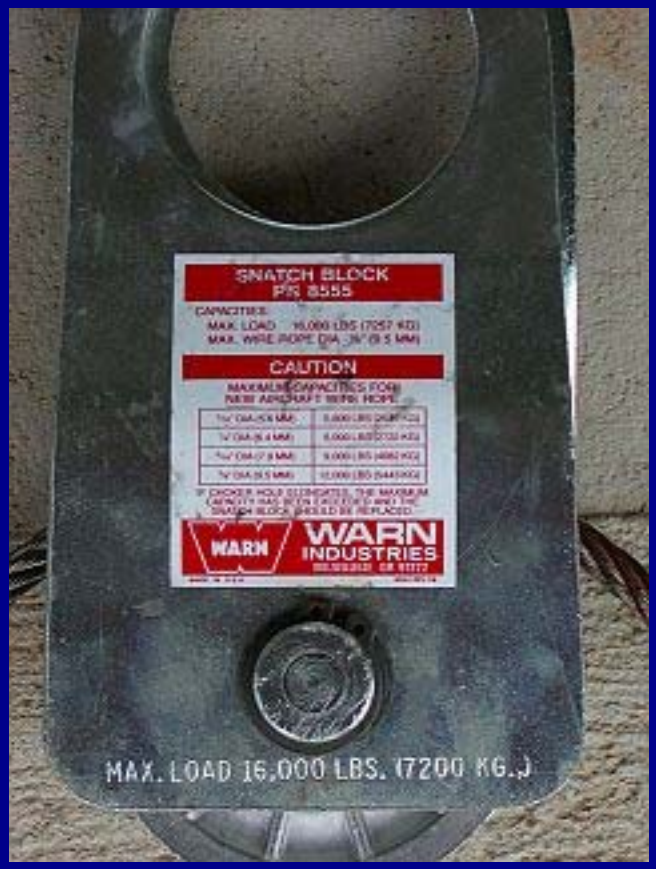
- **Step 13 - When the firefighter returned from his assignment, another attempt was made to set up a test date**
  - **Now others on the test team had out-of-town business trips**
- **Step 14 - A date was selected that the fire station and firefighter would be available (hopefully), and anyone interested 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)

Line Pull		Line Speed		Pull by layer		
lbm	kg	ft/min	m/min	layer	lbm	kg
0	0	30	9.1	1	10000	4536 inner
2000	907	14	4.3	2	9267	4203
4000	1814	9	2.7	3	8617	3909
6000	2722	7	2.1	4	8142	3693
8000	3629	6	1.8	5	7708	3496 outer
10000	4536	4	1.2	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

Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)

Slow Pull Test Summary

	Test	Broke at	Rope	Load Cell Results
1	Single Prusik	Prusik	New	None
2	Single Prusik	Rope	New	Yes
3	Single Prusik	Nothing	New	Yes
4	Single Prusik	Rope	New	None
5	Single Prusik	Rope	New	None
6	Single/double Figure 8 knots	Single 8	Old	None
7	Single/double Figure 8 knots	Single 8	Old	None
8	Snow picket tensioning device	Webbing	n/a	None

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"

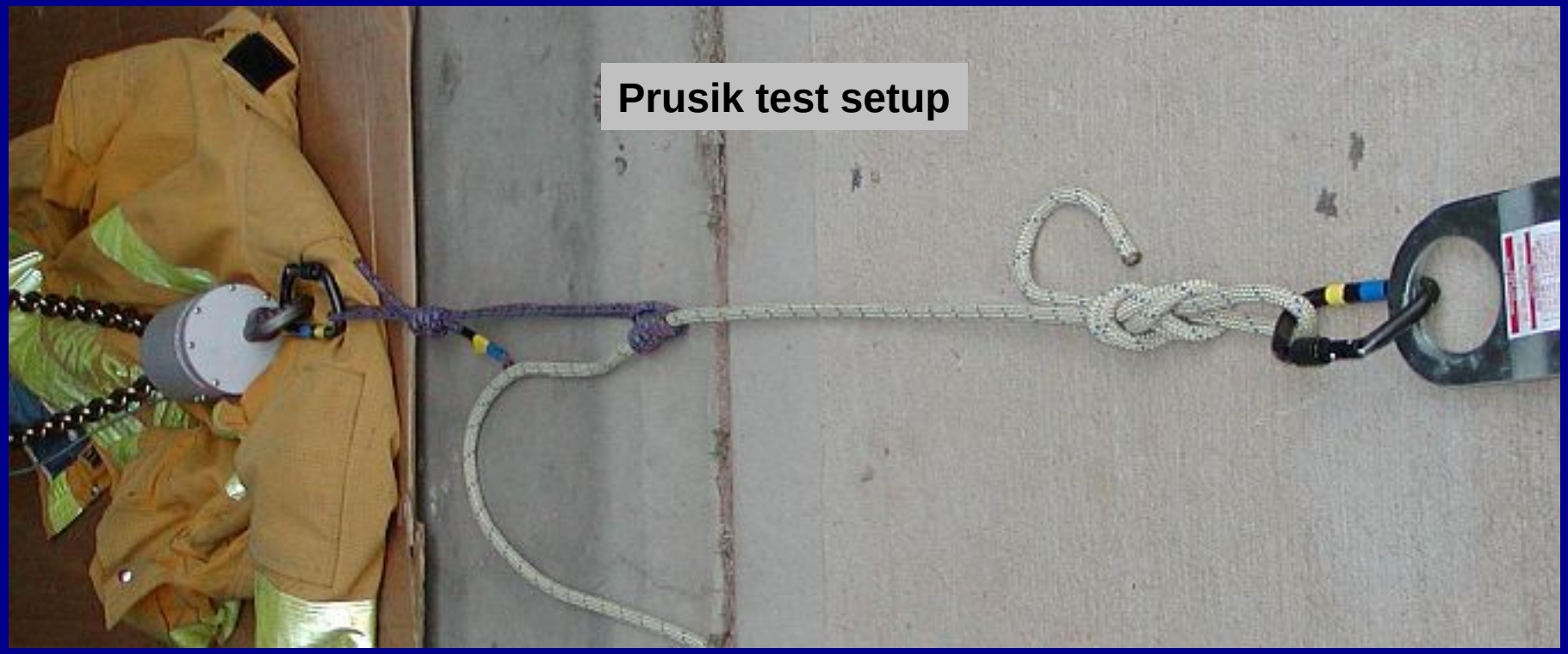
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)

- 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...

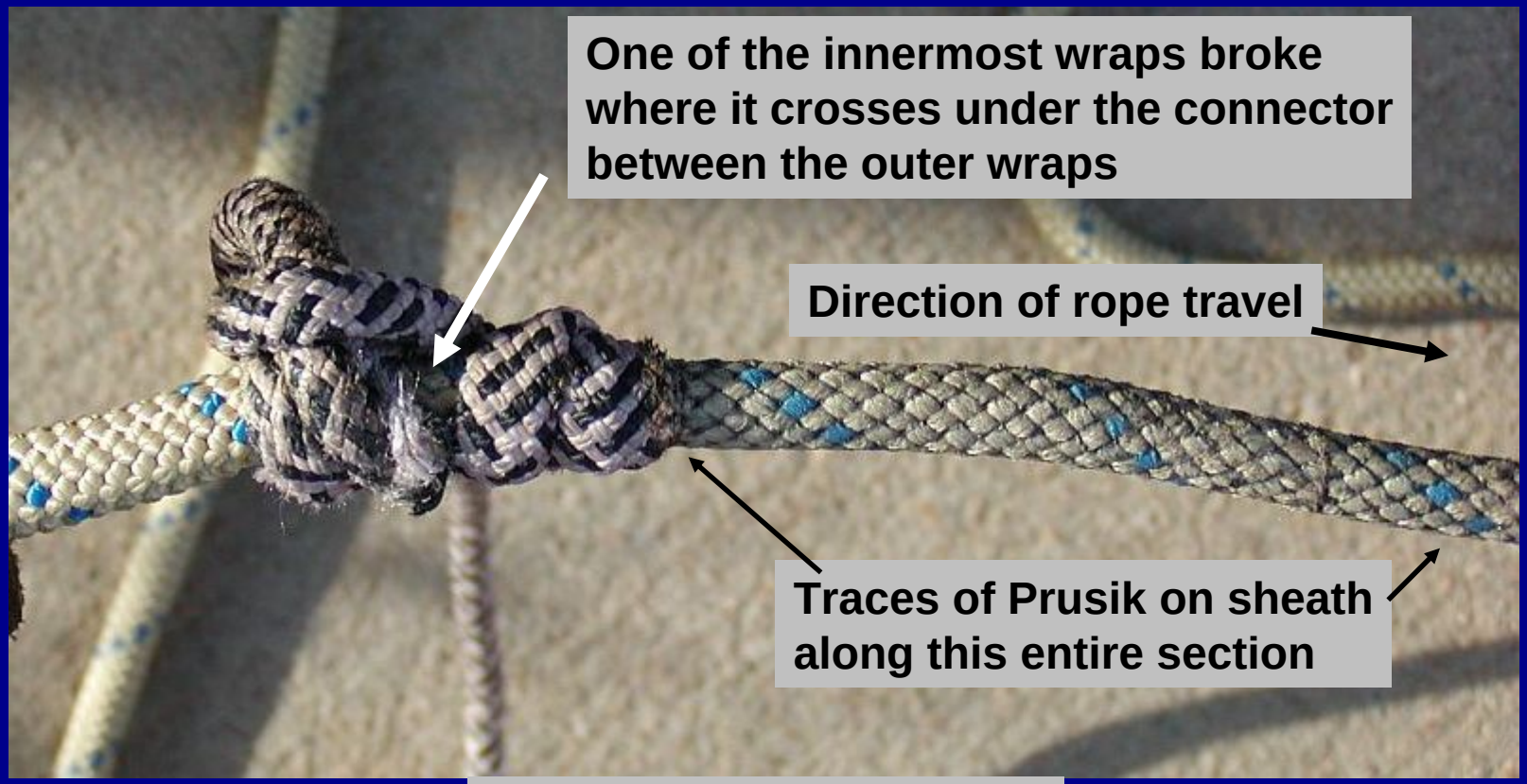
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)

Test preparation

Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)

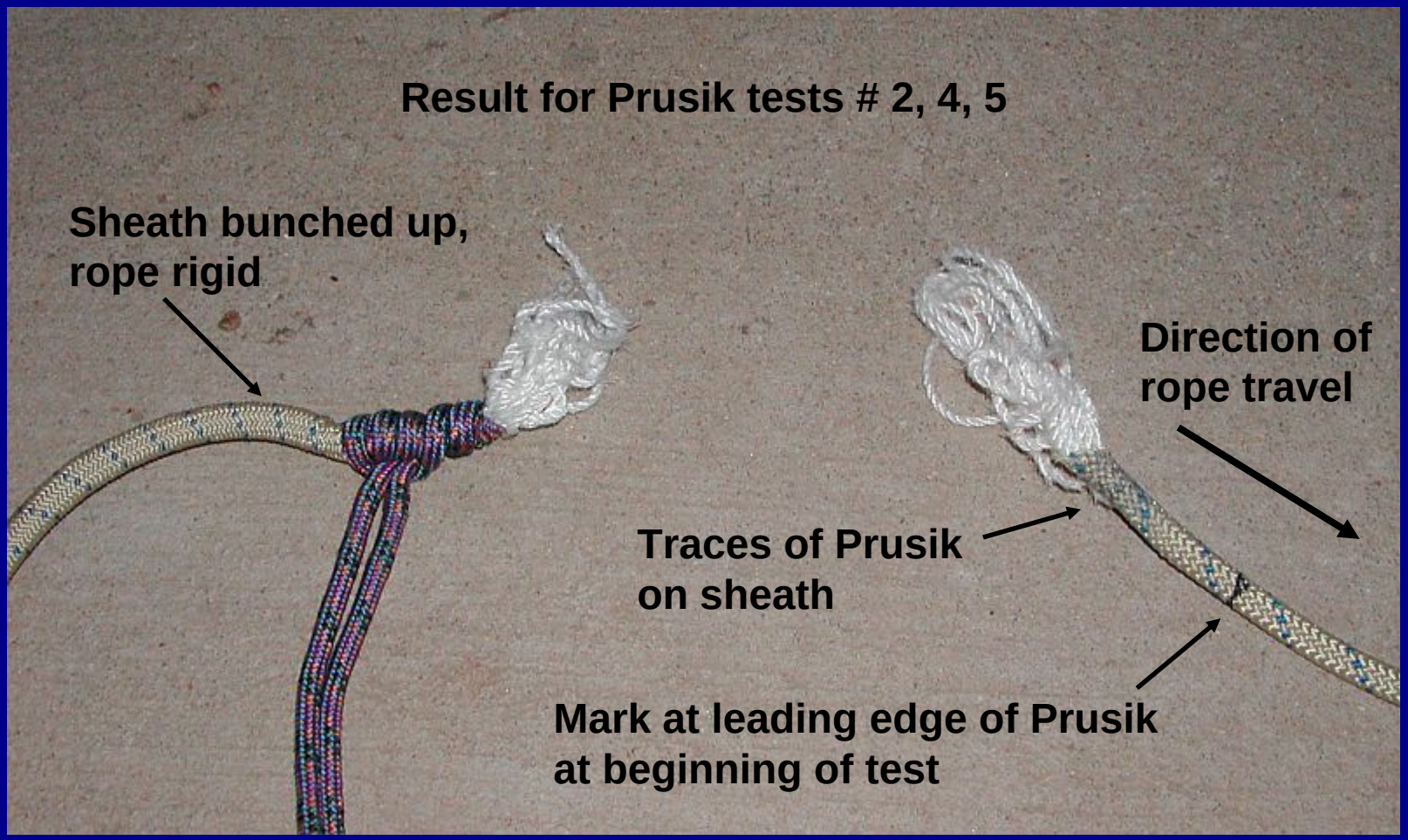


Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)

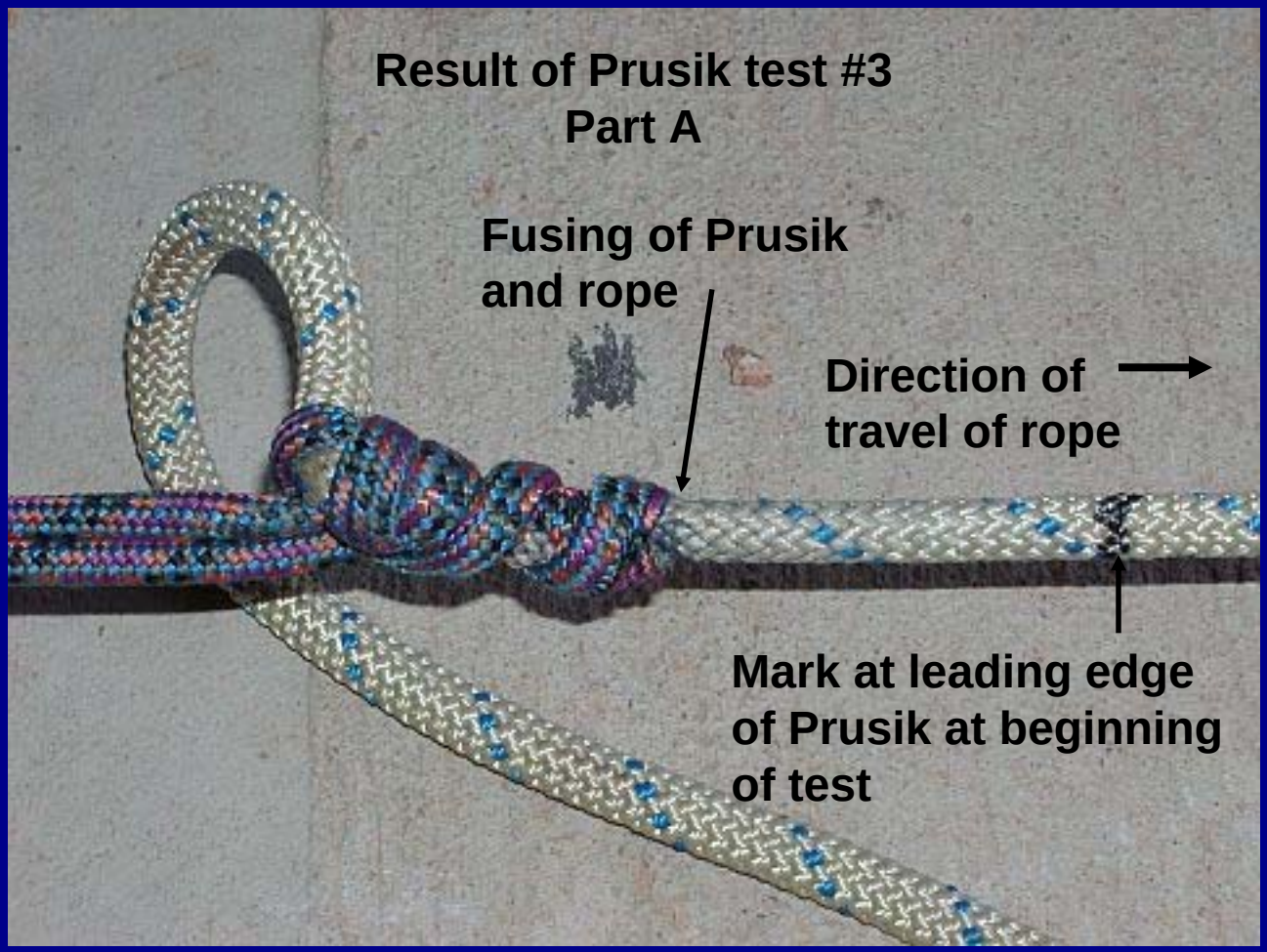


Result from Prusik test #1

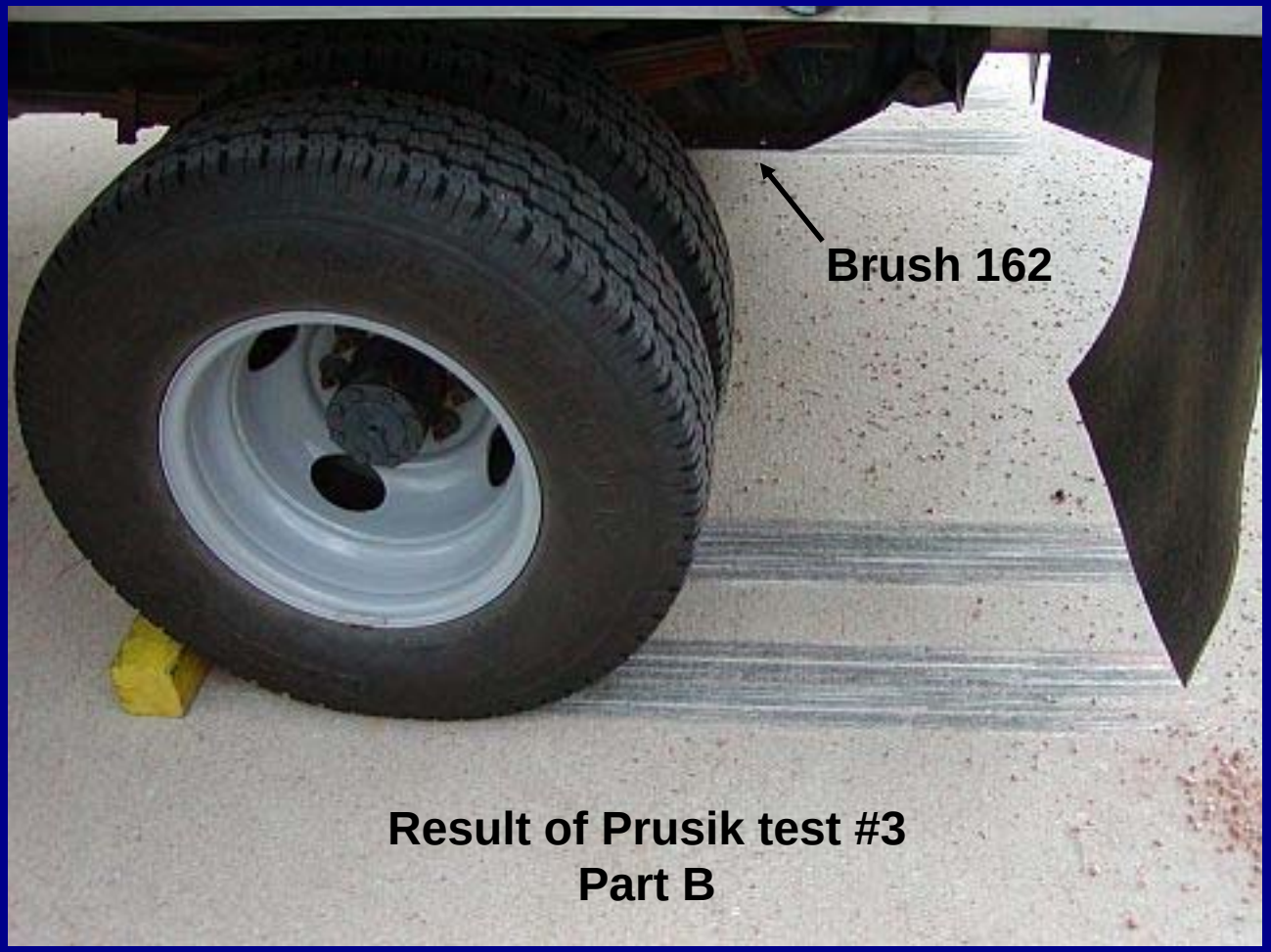
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)



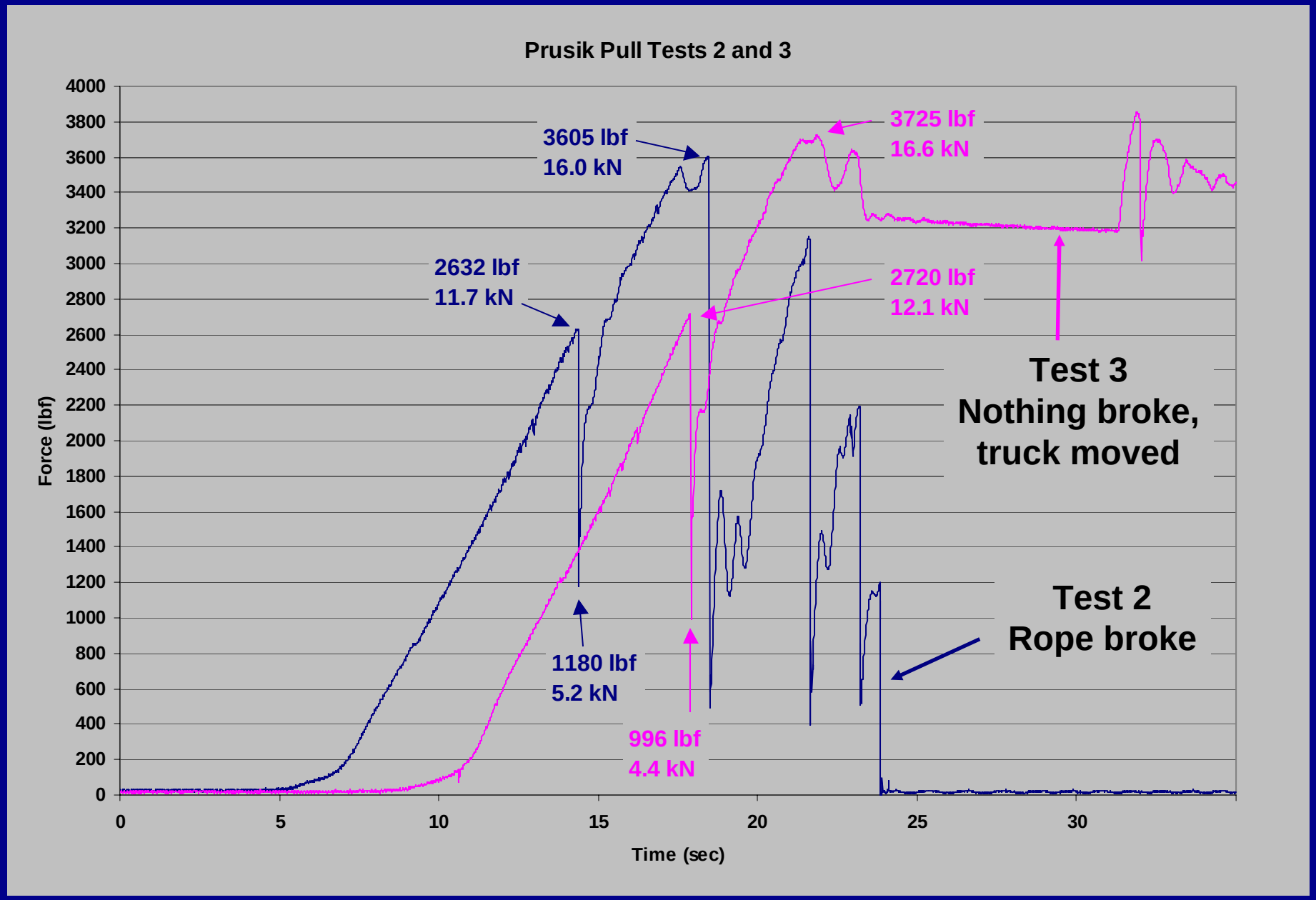
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)



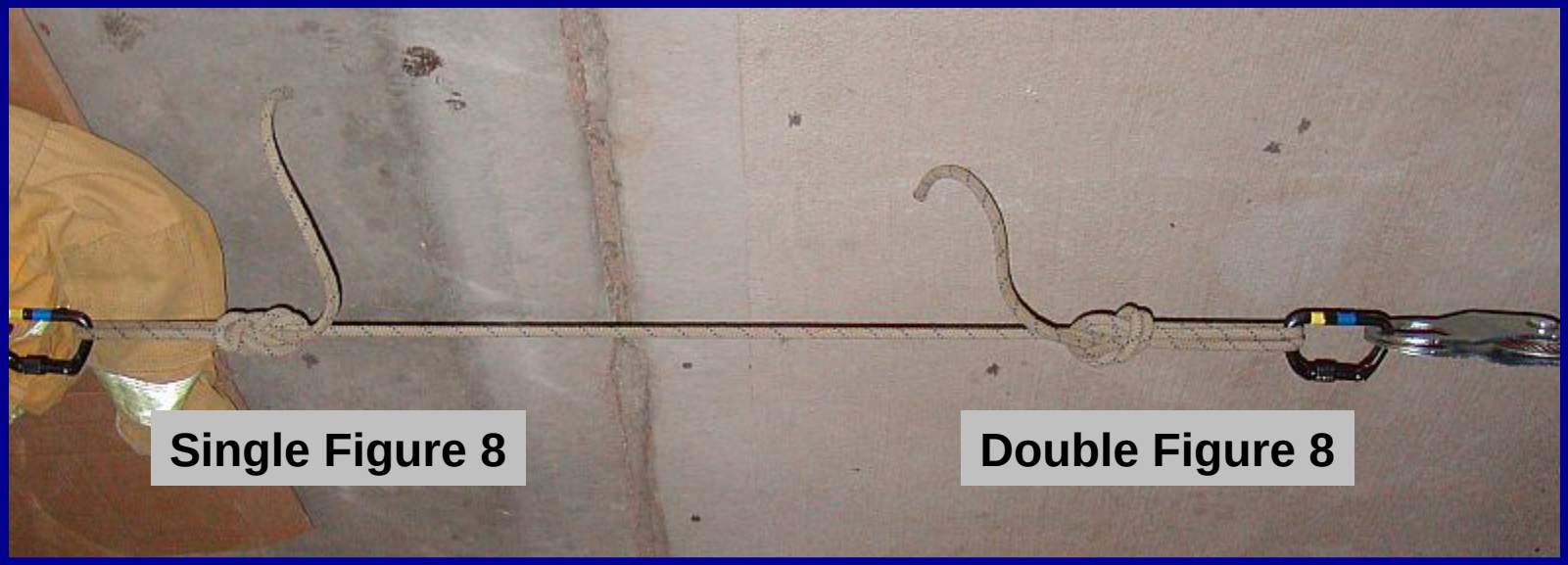
Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)



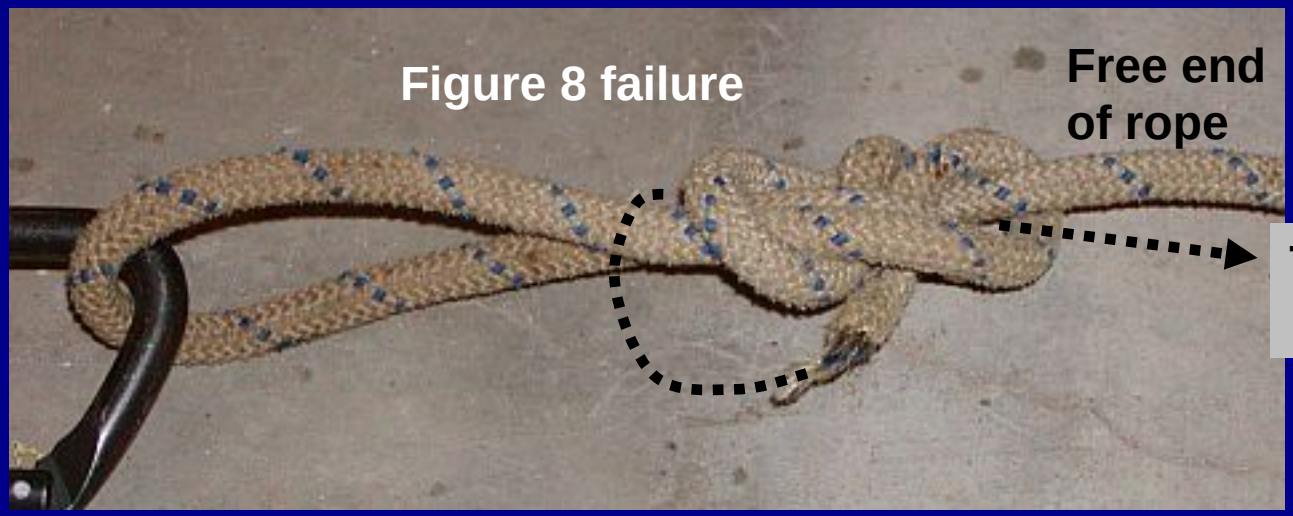
Result of Prusik test #3
Part B


Prusik Pull Tests 2 and 3
Force (lbf)
Time (sec)
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
3605 lbf
16.0 kN
3725 lbf
16.6 kN
2632 lbf
11.7 kN
2720 lbf
12.1 kN
Test 3
Nothing broke,
truck moved
Test 2
Rope broke
1180 lbf
5.2 kN
996 lbf
4.4 kN

Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)



Backyard Testing: Pitfalls, etc. - Slow Pull Testing (con't.)



Tensioning device failure

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