SPM B-Net Study - 2013

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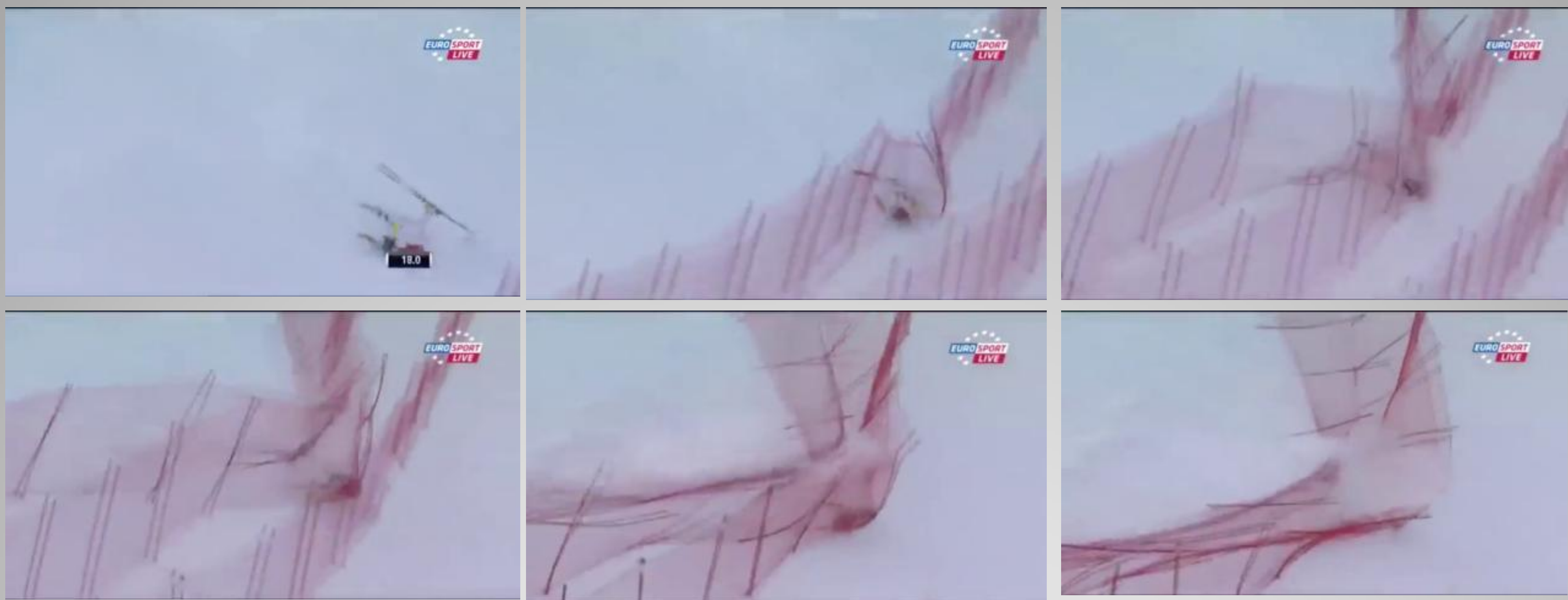
Introduction

- SPM B-Nets are "dynamic" systems which help to reduce the speed created during a fall by absorbing and dissipating the energy generated by the athlete.
- B-Net systems were introduced on the World Cup Ski circuit in 1985.
- The SPM B-Net system has been used for over 20 years at the most demanding alpine racing venues and has proved to be effective in helping to reduce serious injury resulting from high speed crashes.
- The goal of the 2013 study is to compliment and validate over 20 years of on-hill experience with scientific calculations, computer simulations and controlled testing.
- This document provides a clear explanation of how SPM B-Net systems work during an impact and how the energy involved is dissipated, as well as useful information regarding their correct use.

SPM B-Net Systems are Dynamic

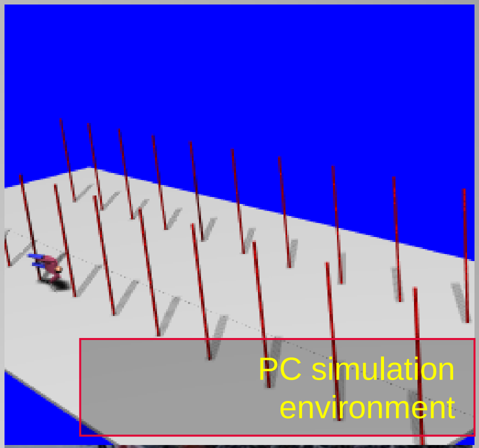


- This sequence from a crash shows a real impact where 3 rows of SPM B-Nets were involved and illustrates the dynamic nature of the system.
- A large portion of the system is involved and activated during the impact.
- The 2013 study provides an analysis of the energy involved in this kind of impact.

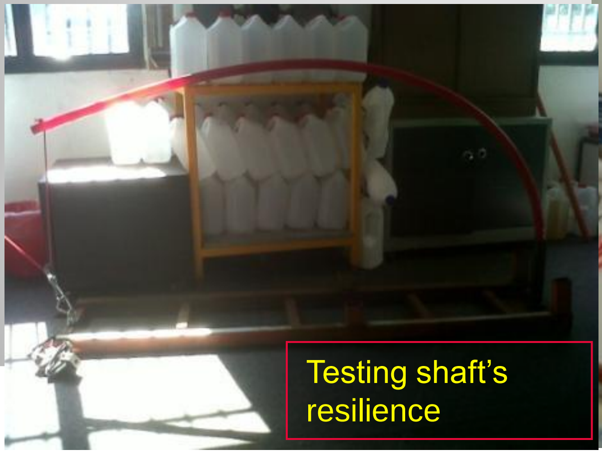
Scientific Approach

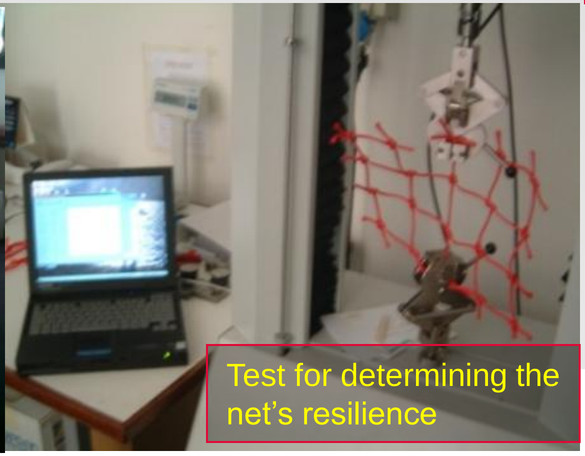
The 2013 study utilizes scientific knowledge gained through studies performed on other safety equipment like A-Nets systems and Air Pads, as well as the experience of more then 20 years in the field.

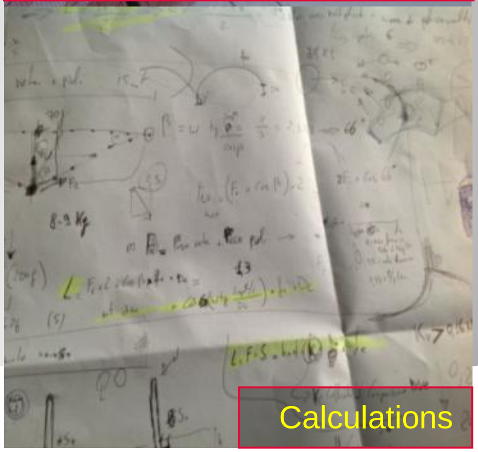
The hypothesis and theories developed were verified and confirmed through tests in the field, PC simulations, crash tests with dummies and by analyzing and comparing video footage of real crashes.


PC simulation environment


On hill test (Kitzbuhel Steilhang)


Testing shaft's resilience


Test for determining the net's resilience


Calculations

SPM B-Net System – Components/Performance/Modeling

SPM B-Net systems are composed of the following elements:

- Polycarbonate Support Poles
- Rectangular Net with Square, Knotted Mesh
- Attachment Clips

Important variables in B-Net performance include:

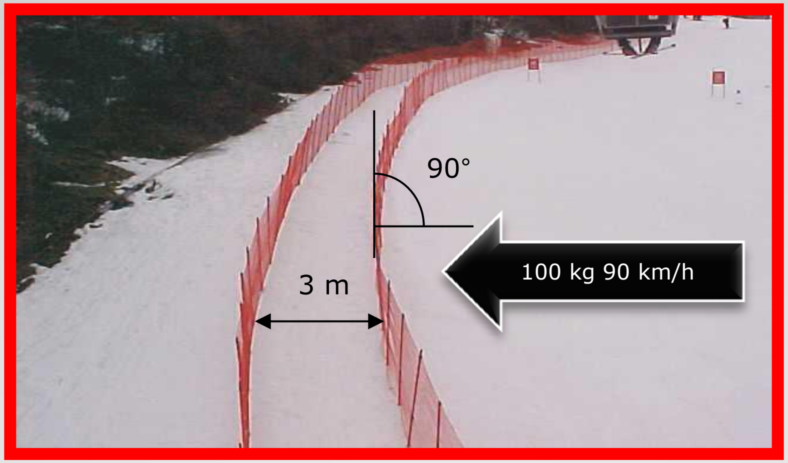
- Installation and positioning of the fence
- Condition/type of snow surface.

SPM created a mathematical model that considers all of the elements involved during a crash and simulates the crash on a PC. By using PC simulation it is possible to analyze different crash conditions and get important information regarding the behavior of B-Nets systems along with indications for their correct use.

Testing Assumptions and Variables

The analysis is based on the following input data, or variables:

- Weight of the skier (w/equipment): 85 Kg + 15 Kg = tot. 100 kg (220lbs)
- Impact speed = 90 Km/h (56mph)
- impact angle = 90 degrees
- Two rows of B-Net with 3m distance between the nets



The energy "carried" by the skier just before the crash is the "Kinetic Energy", described by the formula: $E_{cs}= \frac{1}{2} m*v^{2} = 31250$ J = 31,2 KJ

How SPM B-Nets Absorb Energy

The purpose of any B-Net system is "slow" the skier and dissipate the energy generated during the fall without inflicting significant injury.

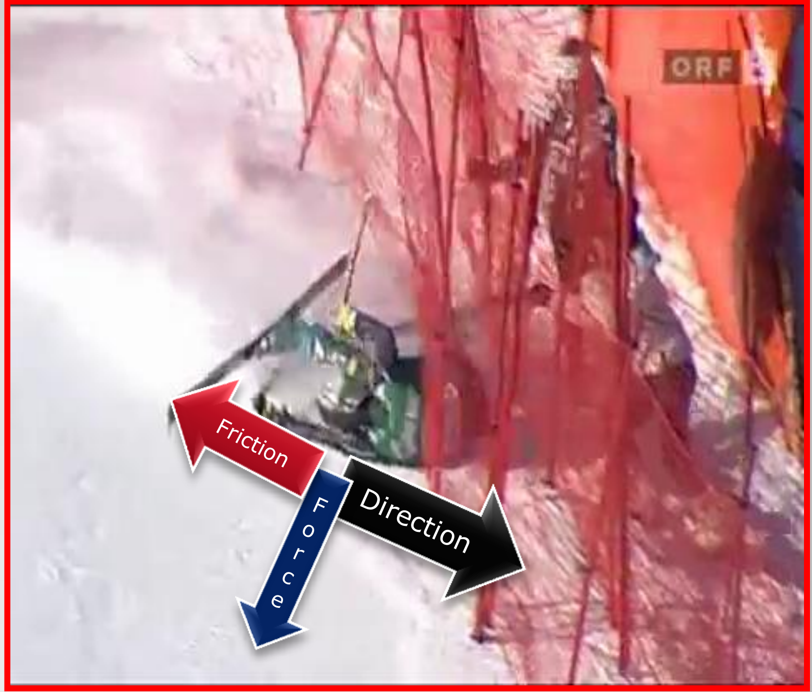
Energy related to a high speed crash is absorbed and dissipated in the following ways:

1) Speed is reduced as the athlete slides on the snow during the fall.
2) Speed is also reduced and energy absorbed as the skier slides, or drags along the net.
3) Energy is absorbed by the deformation of the poles upon impact.
4) Speed is reduced by dragging the system upon and after impact (poles and net).
5) Energy is absorbed as the poles are pulled out of the snow upon impact.
6) Energy is dissipated as the net deforms upon impact.
7) Energy is absorbed by the friction of the attachment clips sliding on the poles as the net deforms.

The Effect of Sliding Along the Snow

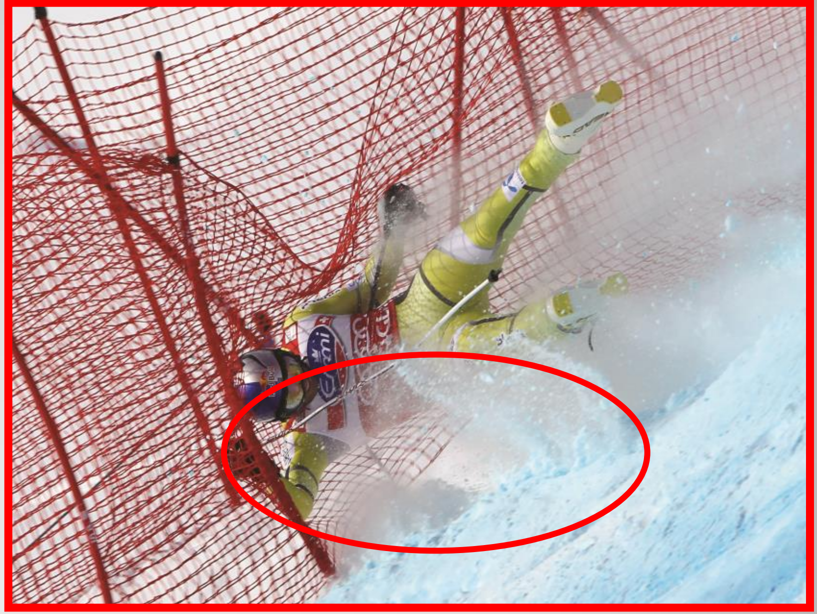
During the impact the skier's body slides on the snow.

The interaction of a body sliding across the snow generates friction which contributes to the reduction of speed.



The Effect of Sliding Along the Net

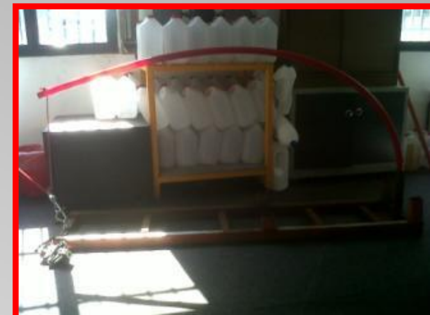
During the impact the skier's body slides along the front of the net. The duration of this is shorter than the time spent sliding on the snow, but the coefficient of energy absorption of a body sliding along a net is much higher.

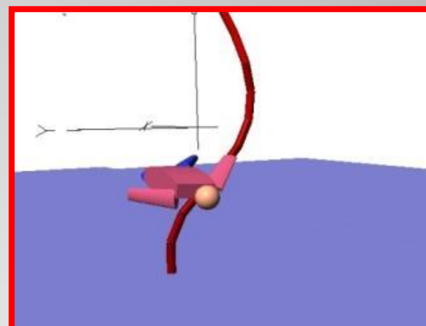


Deformation of B-Net Poles

The SPM polycarbonate B-Net poles are deformed during impact. This absorbs energy and reduces speed. The pole's height and the characteristics of polycarbonate contribute significantly to the absorption function of the SPM B-Net system.

Photos:
Top – Testing the strength and bend characteristics of the pole in the SPM laboratory.
Middle - Mathematical study of the pole using Finite Element Method and computer simulation of the impact.
Bottom – On site data collection of real impact that is used for comparison with simulated impact.

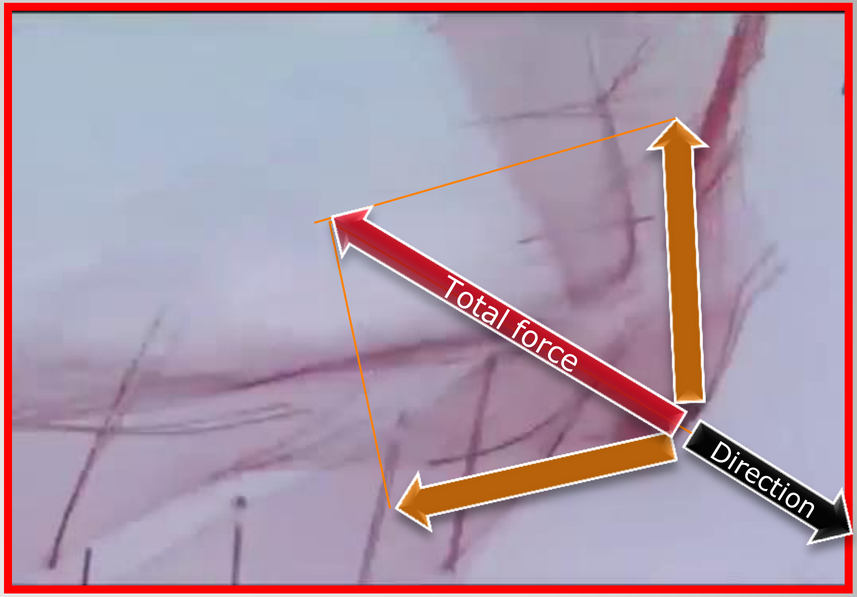




SPM S.P.A.

Dragging the Entire System

A major part of the energy absorption and deceleration is achieved as a result of the "braking force" generated when the poles and net which is deformed and dragged during the impact.



Friction of the Poles in the Snow

When SPM B-Net poles are flexed during an impact, they absorb and dissipate energy by pressing the snow around the installation hole.

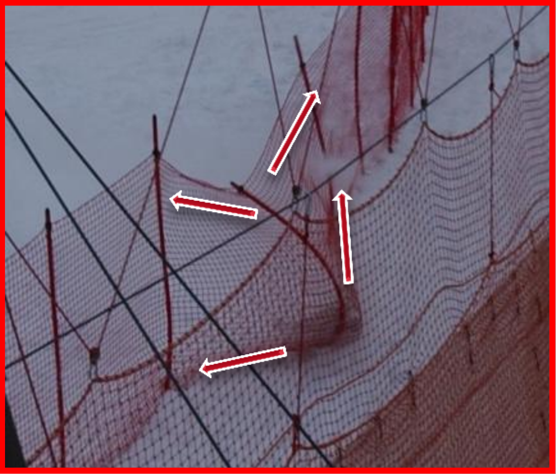
In addition the pressure of the pole against the snow increases the friction between the poles and the snow when the pressure (impact) is high enough to remove the poles from the snow.

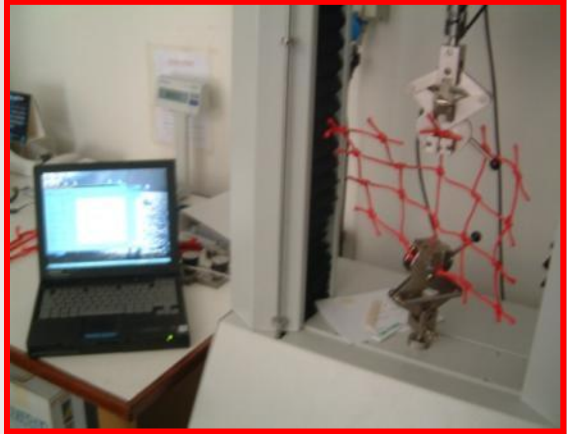
Net Deformation

The most important characteristic of B-Net is its elasticity.

SPM's nets are made of High Density Polyethylene extrusion (HDPE) Polycarbonate, which is ideal for absorbing energy in a crash. In fact, in the case of high speed crashes (high impact energy) the maximum tension on the plait, or twine averages 40-50% below the breaking limit, or tensile strength of the twine.

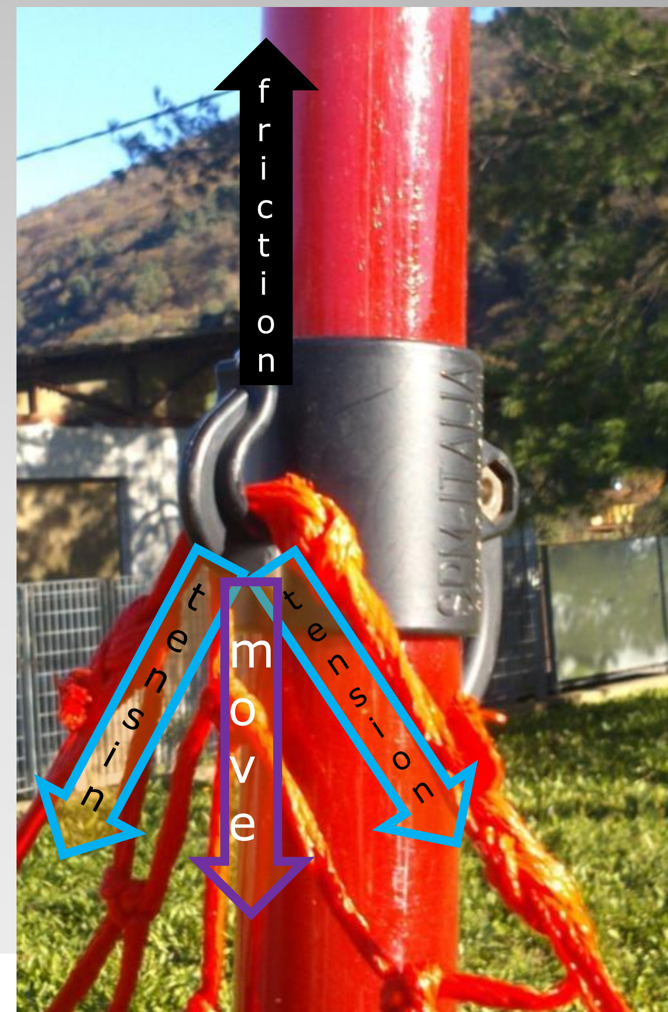
Over 20 years of experience with real crashes confirm this important technical consideration.





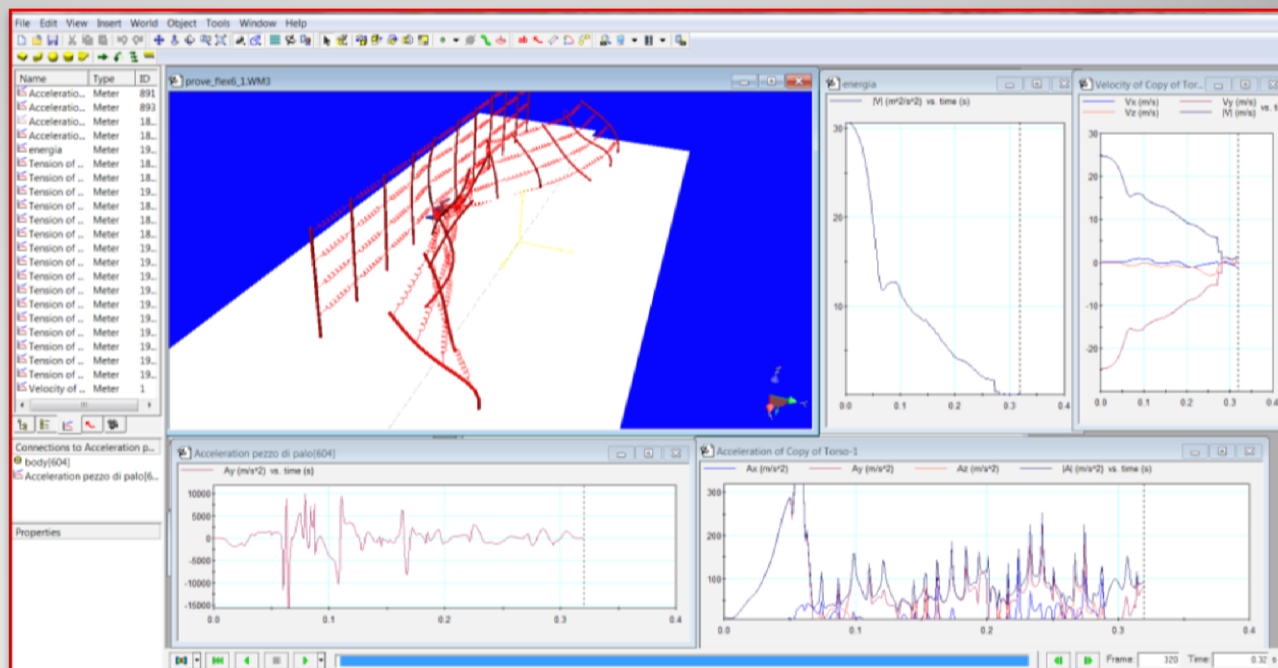
The Role of Attachment Clips

The net attachment clips used on SPM B-Net poles are designed to slide on the pole when the tension on the net is greater than the tension when the clips are in a static state.
Upon impact the upper clip will slide down and the lower clip will slide up.
This action helps with net deformation and also creates friction which contributes to the energy absorption capabilities of the system.

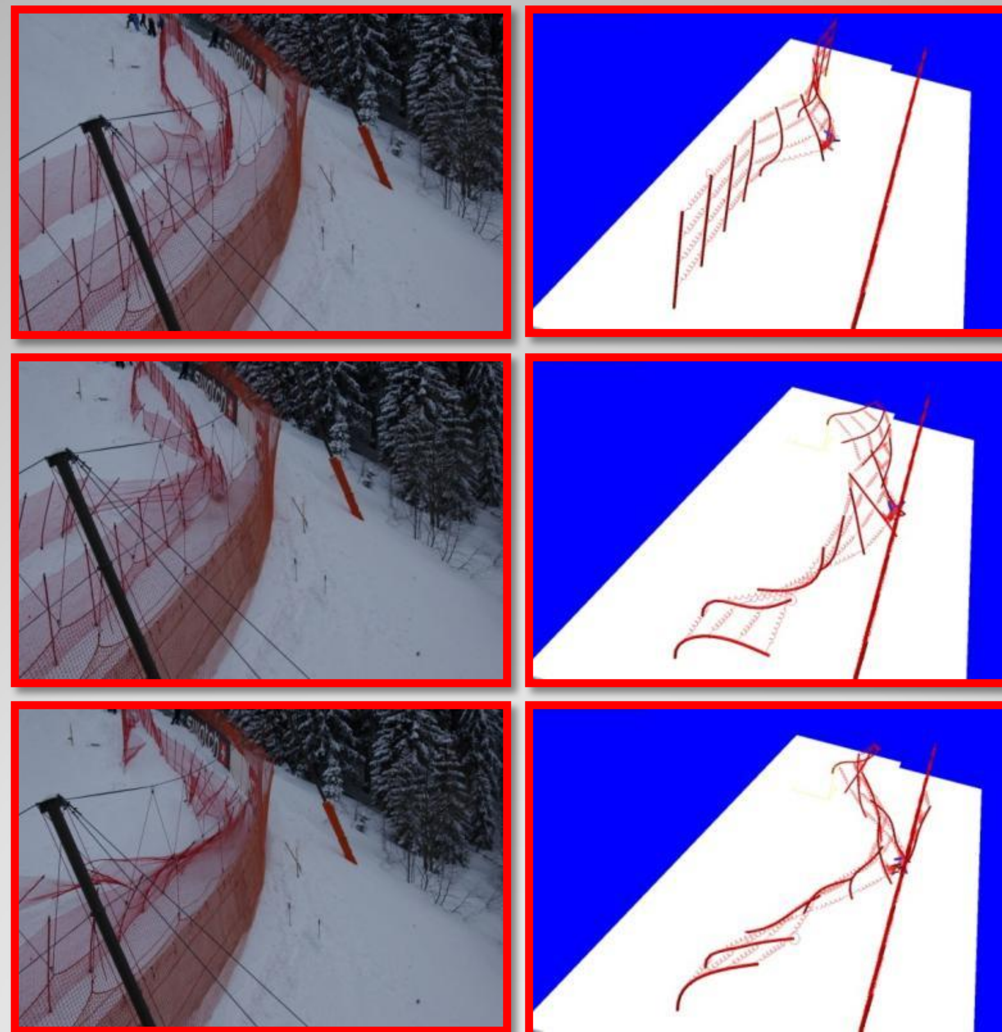


Mathematical Modeling

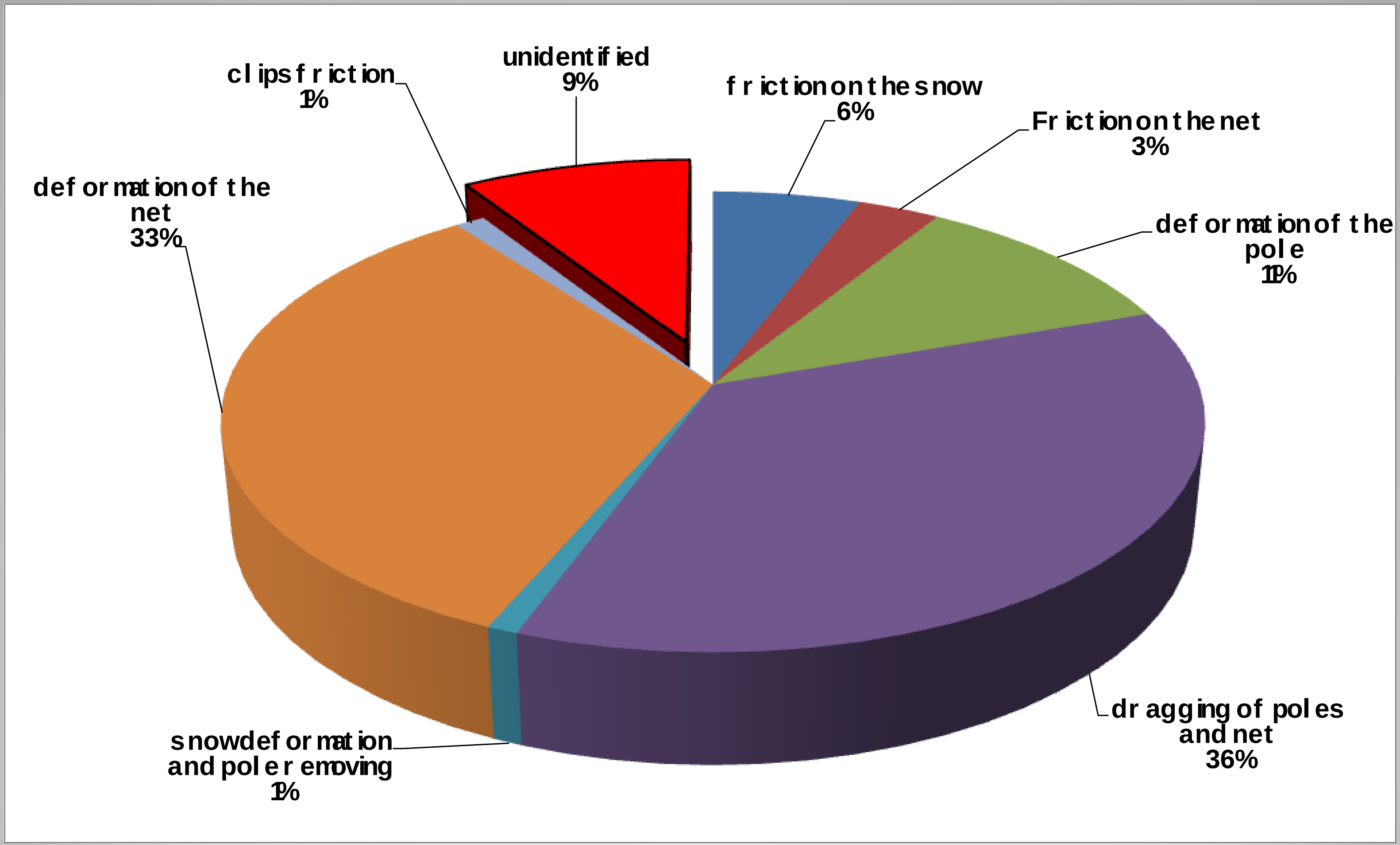
All the afore mentioned energy related variables were considered when creating the mathematical simulation model for SPM B-Net systems.
All of the theoretical calculations were validated by comparison with practical testing data obtained from in house and field testing.
The following page illustrates a comparison between a simulated crash using the SPM computer model and a real crash filmed during tests at Kitzbuhel and proves the validity of the model.



Kitzbuhel Testing and Computer Modeling



Contributors to Energy Dissipation in SPM B-Net Systems



Importance of Each Contributing Factor

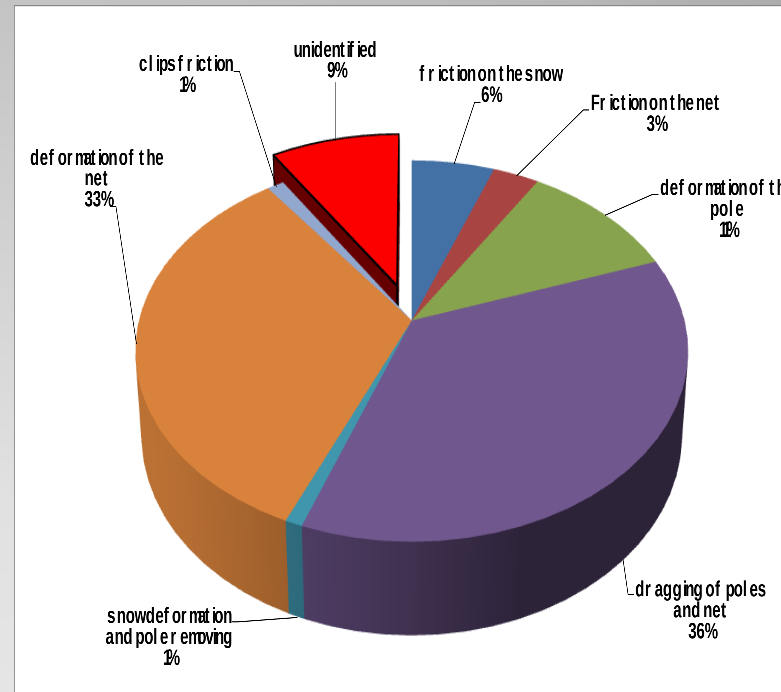
Our analysis shows the main factors that contribute to the dissipation of the energy are:

- dragging of poles and net 36%
- deformation of the net 33%
- deformation of the poles (a) 11%

Other contributing factors are:

- friction on the snow 6%
- friction on the net 3%
- friction of the clips 1%
- friction in the hole (b) 1%

9% is "undefined"



Note: the poles along with the friction generated by the poles in the holes (a+b) contribute 12% to the dissipation of the energy. ***In comparison, poles with a breaking point at snow level (scored) contribute 0% to energy absorption related to pole movement in the snow and the "dragging effect" is significantly reduced due to the fact that scored poles break upon impact.***

Test Results/Notes

Moreover, the analysis shows that for the SPM Modeled crash considered (100 kg mass at 90 km/h speed):
A B-Net system with 2 rows is sufficient to dissipate the energy generated during the crash.

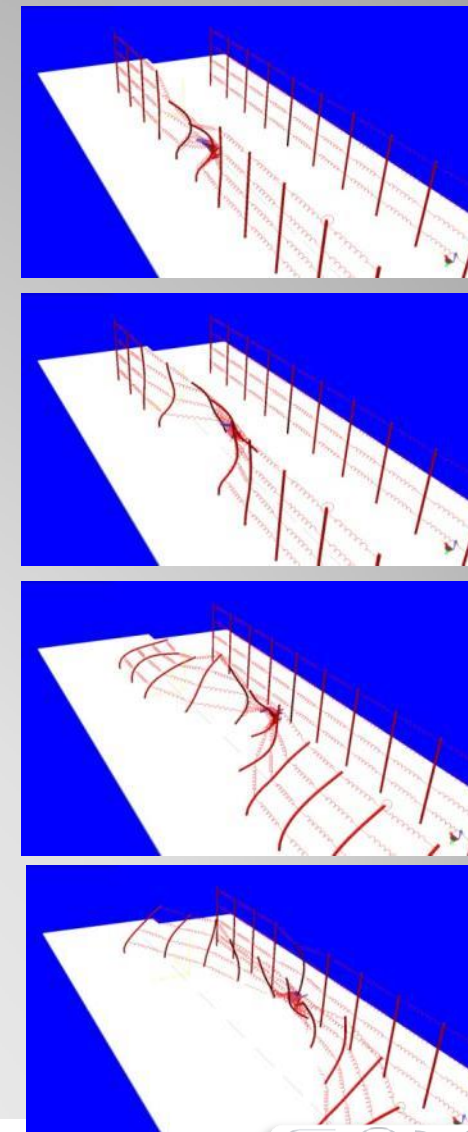
Notes:

a. As external variables not considered in the present simulation can influence the dynamic of the crash (e.g. the skier goes under one of the nets) a 3rd row is suggested for speed events.

b. The assumption is that no poles or nets fail during the crash (see additional comments and data regarding net tensile strength on page 22).

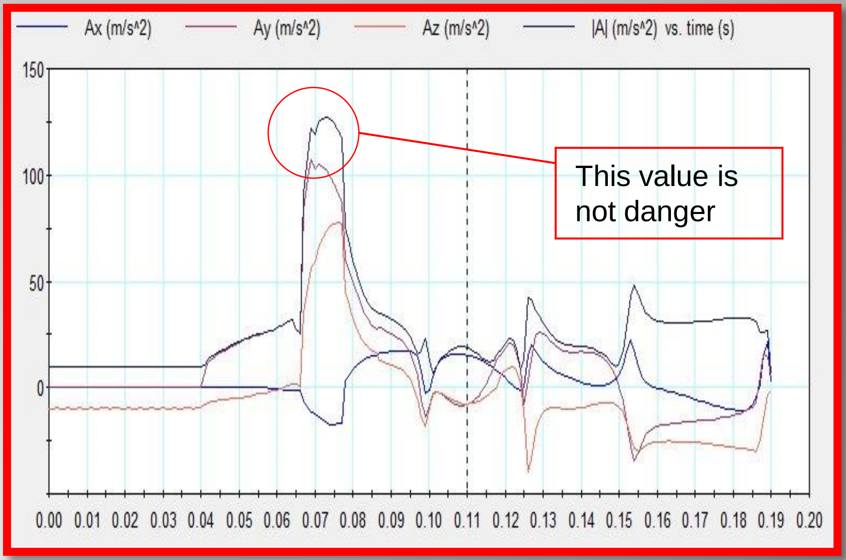
c. On average the skier is stopped within 6 meters. Therefore it is extremely important that there is enough space between the last row of fence and the obstacle or hazard

d. The dragging of the system plays a very important role in dissipating the energy (36%). Therefore it is extremely important that a minimum of one 20m section of net is above AND below the section of net directly in form of the obstacle.



Test Results/Notes

The peak of deceleration absorbed by the body of the skier when impacting a properly installed and maintained SPM B-Net System is always below the maximum value scientific research defines as the limit the human body can withstand without catastrophic injury.



The results of our simulation are confirmed by the wide variety of crashes that have occurred over the 20 years that SPM B-Net systems have been used in World Cup Races

General Findings of the Study

The analysis shows that:

A. The deformation of the net contributes approximately 33% to the dissipation of the energy generated during the crash.

B. The tensile strength on the SPM B-Net plaits/twine was always in excess of the impact values observed in both laboratory and field testing

Note: The tensile strength was calculated using the plaits/twine of 16 mesh squares around the center of gravity of the impact. For a 5 cm mesh net, a radius of 80 cm from the center of the impact was measured.

SPM B-Net Tensile Strength

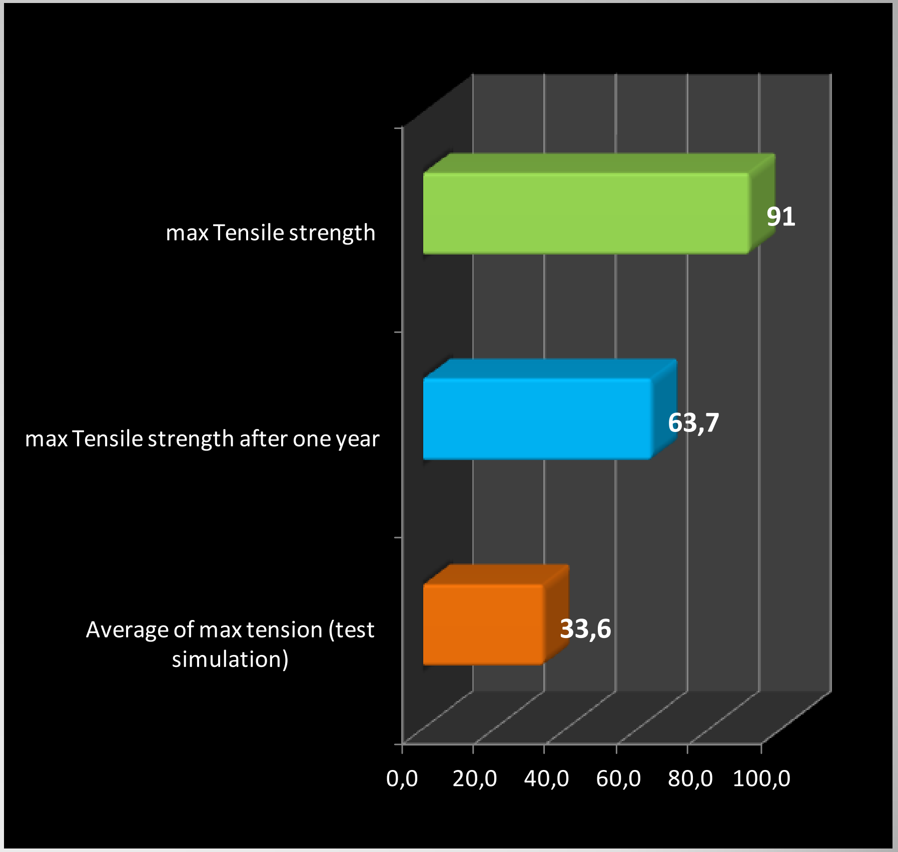
The green bar represents the maximum tensile strength of a new net (108kg/sq.cm)

The blue bar represents the maximum tensile strength of a used net:

a. 'Used' defined and replicated through controlled laboratory environmental testing with 8,760 hours of constant UV exposure which is equal to 4 years of normal use.

b. The decadence of tensile strength for SPM B-nets is about 25- 27% in the first year with gradual additional degradation over subsequent years.

The orange bar indicates the Average of the maximum tensile strength generated on each filament of the net.
In this case we have considered 16 filaments for this simulation.



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DISCLAIMER

NOTE: The result of the simulation does not guarantee that no mesh will break during the crash. However, it is evidence that a B-Net system, when correctly assembled and installed, is able to resist to the impact generated during a typical alpine ski racing crash

Please, always remember that:

- nets characteristics decrease in case of a previous impact, accident, improper installation and/or storage, contacts with solvents, salts or corrosive products
- the cord material is not resistant against cutting with ski edges or other sharp objects