Trail design and potential for injury

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Prevention II , Tuesday 13 May, 15.10 – 15.30 :

Disclosure

- This presenter, an engineer, occasionally consults with and testifies for plaintiffs in civil suits on snow sport injuries and is remunerated for this

- First cannon of engineering ethics:

Hold paramount the safety, health, and welfare of the public

Objective

- Critically examine aspects of trail and barrier design that could be involved in injury
  - Hazards
  - Avoidance
  - Protection

State of the art

Many ski areas in the US

- Do not record location of injuries on the trails
- Do share injury data
- Lobby state legislatures to pass “Skier Safety Acts”
  - Pass liability to skier
- Have blatantly unsafe situations

Basic strategies with respect to hazards

- Identify
- Eliminate
- Control
- Avoid
- Deflect
- Absorb

Hazzard identification

Features reported as dangerous on a small web survey

• Drop-offs	12	• Intersection	1
• Moguls	10	• Objects In Trail	1
• Ice	5	• Abrupt Changes	1
• Sharp Corners	5	• Washboards	1
• Blind Spots	3	• Knolls	1
• Trail narrowness	2	• Unskilled skiers	1
• Other skiers	2	• Cut across trails	1

Paul Buchanan, *Joseph Giambarresi,* Steven Hennessey, Stuart Sundseth, and Andrew Tanner (2014) **Web Based Snow-Sport Injury Reduction**, WPI, IQP

Count incidences
e.g., near-misses, falls, and collisions

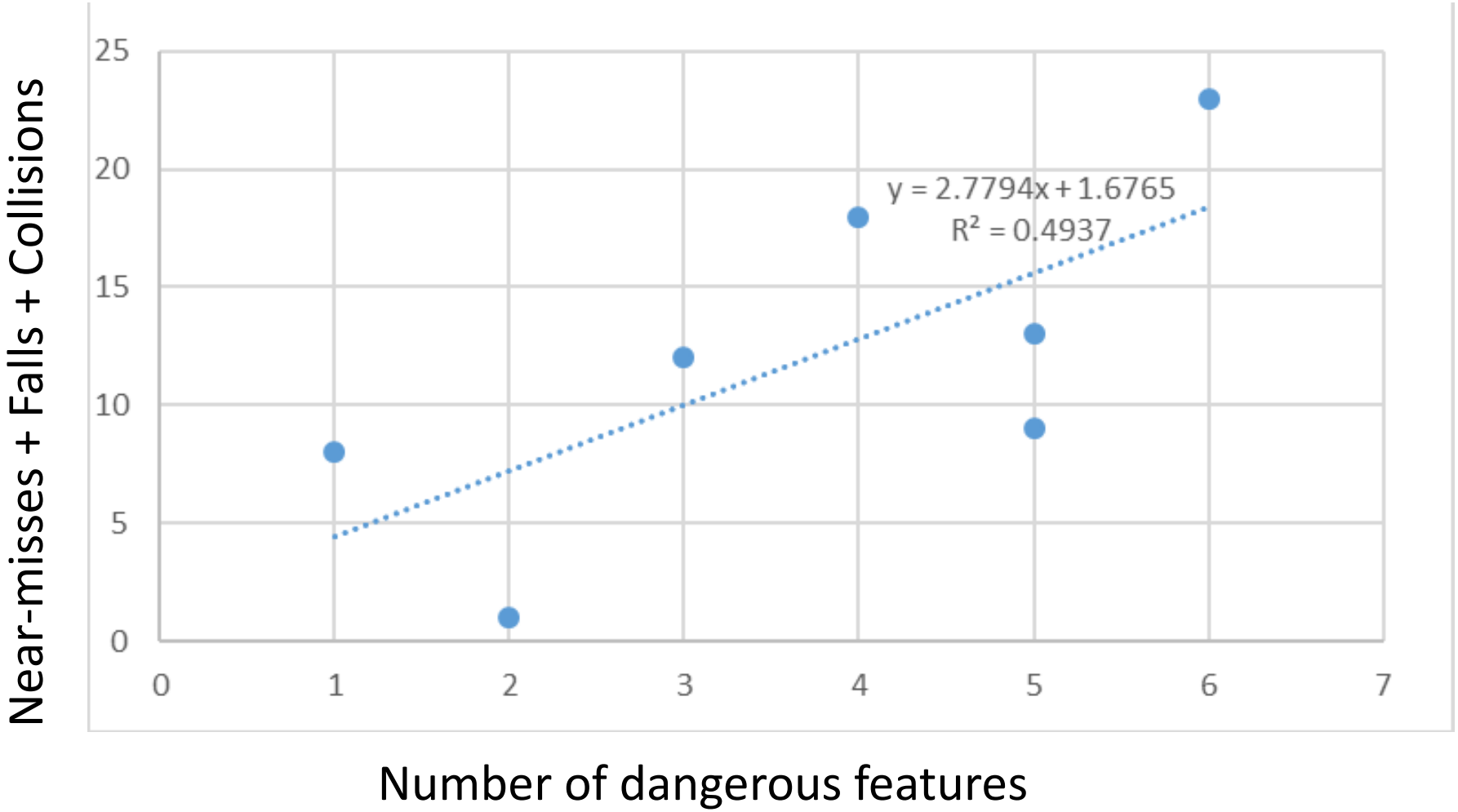
Selected intersections to observe

intersection between two trails of significantly differing nature

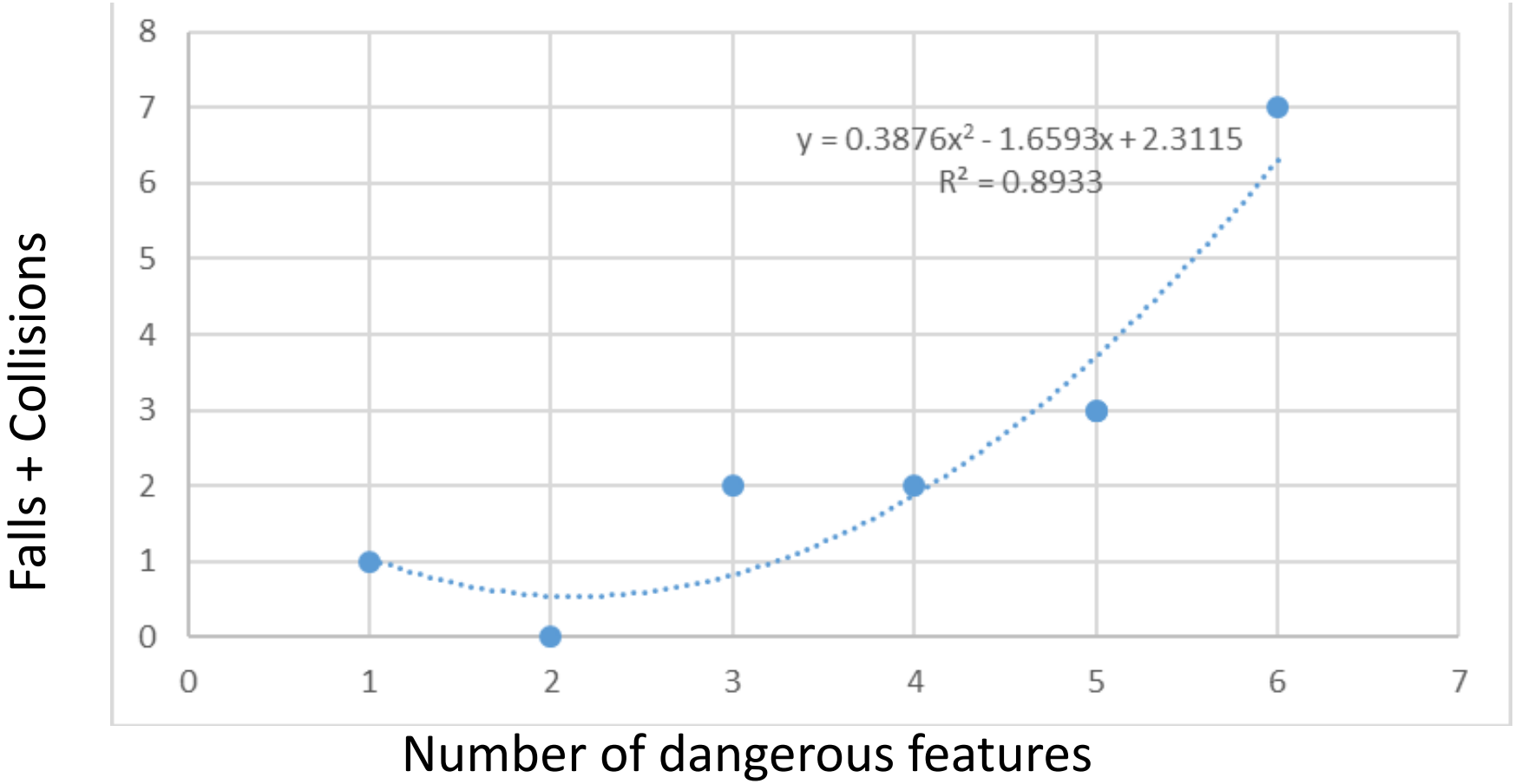
Direct Route	Hesitation (clean)	Near Miss	Collision	Fall
40	17	10	0	2

Near-misses + Falls + Collisions

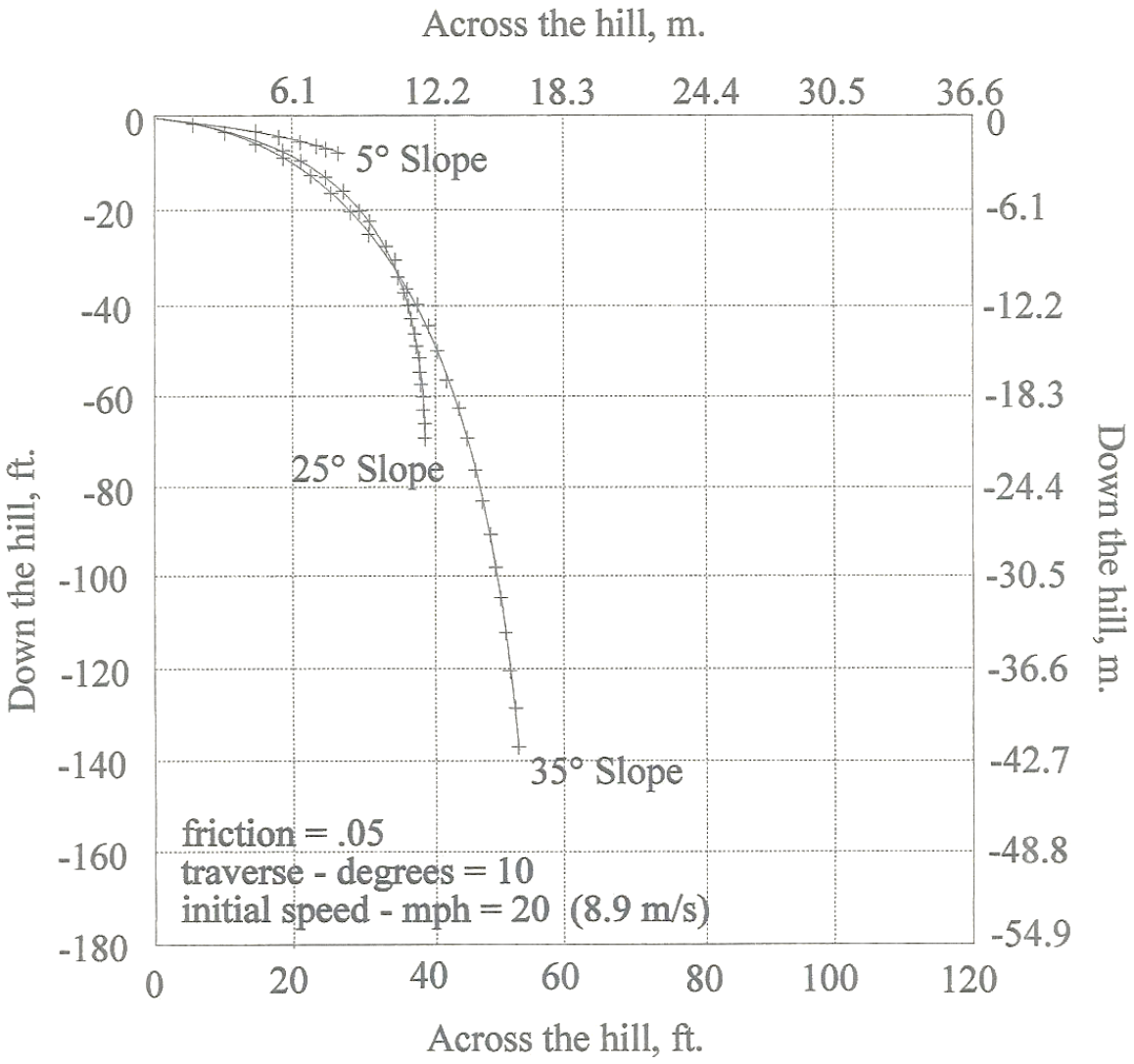
$R^2 = 0.5$



Falls + Collisions $R^2 = 0.9$

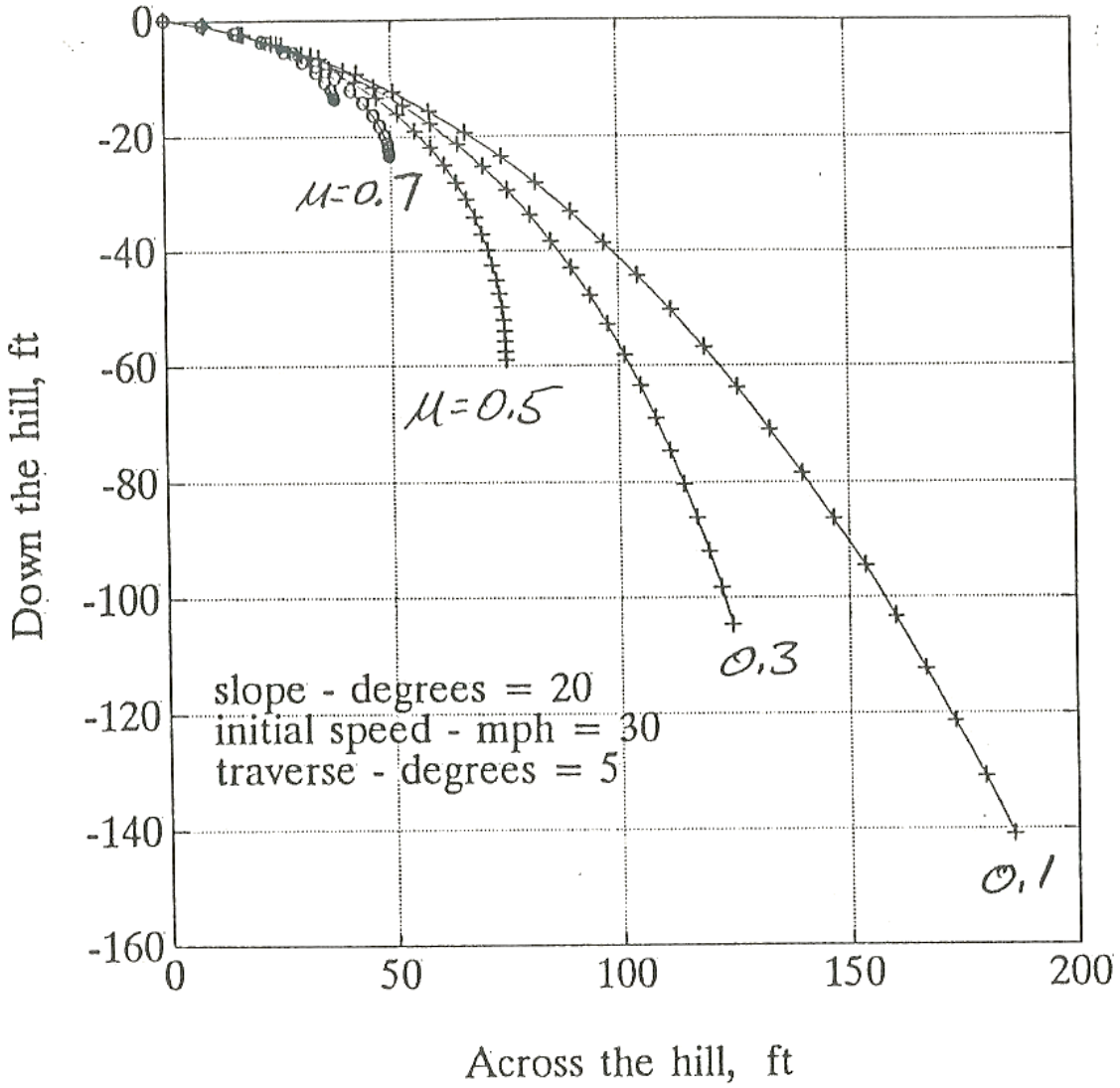


Trajectories & **slopes**



C.A. Brown, A.H. Hoffman, R.K. Heinzmann, "Loss of Control in Alpine Skiing and Subsequent Trajectories," Skiing Trauma and Safety: Tenth Volume, ASTM STP 1266, C.D. Mote, Jr., et al. eds., ASTM, Philadelphia (1996)186-195.

Trajectories & **friction**



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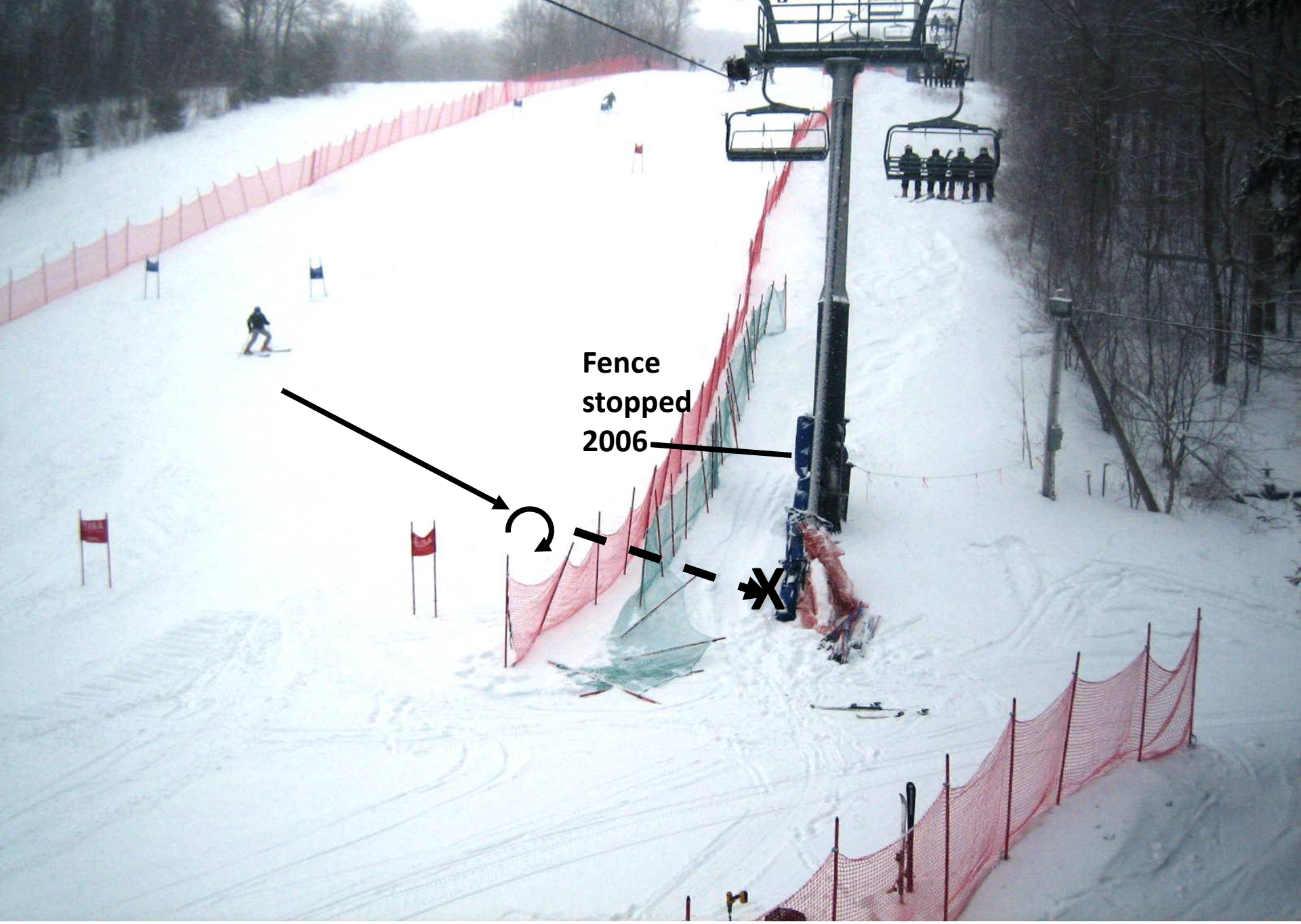
Equipment has improved

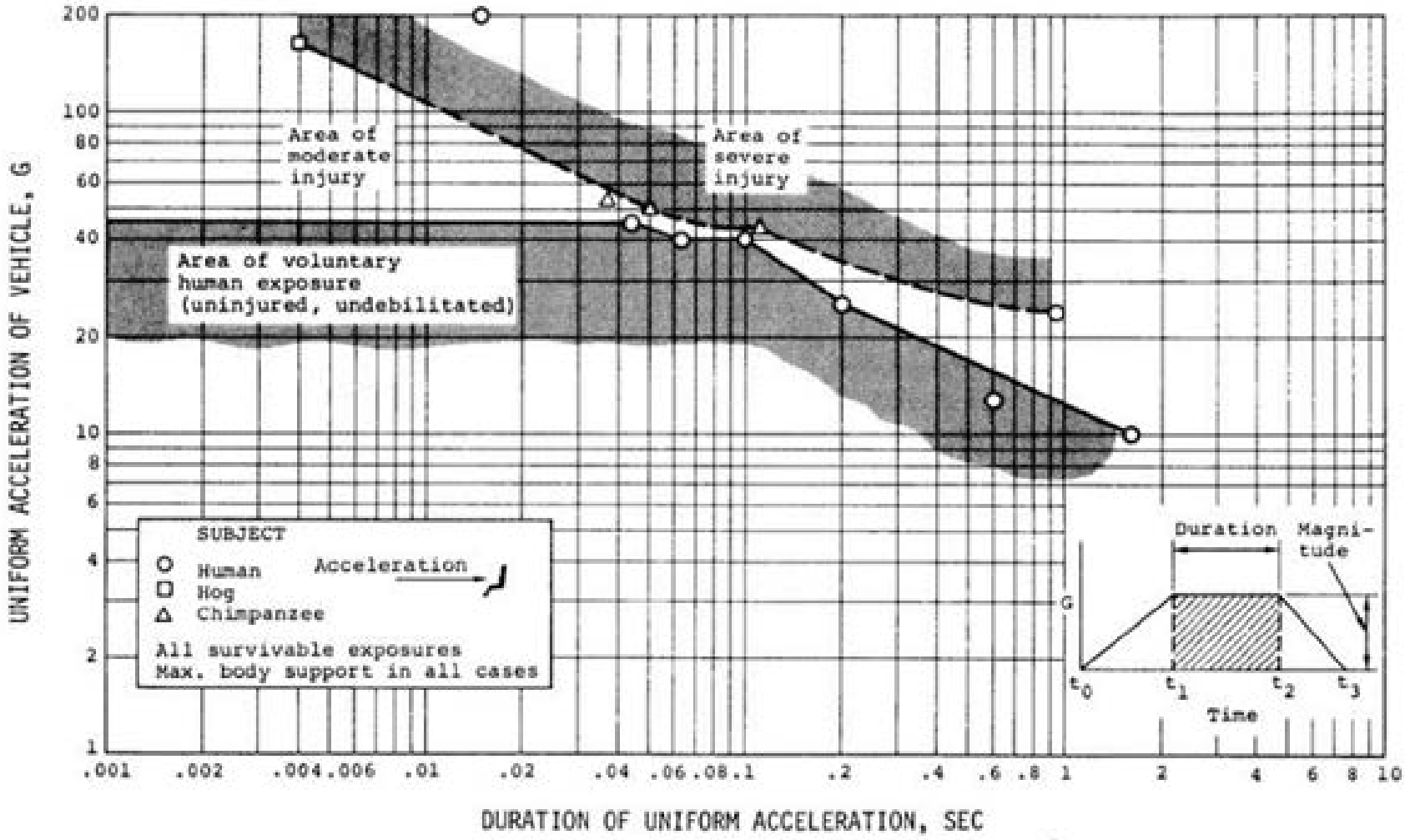
- Skis are better at transferring forces and turning
- Trajectories have changed
- Ballistic calculations are not enough


Fence
stopped
2006

Protection

- Controlled deceleration $a = \frac{1}{2} v^2/s$

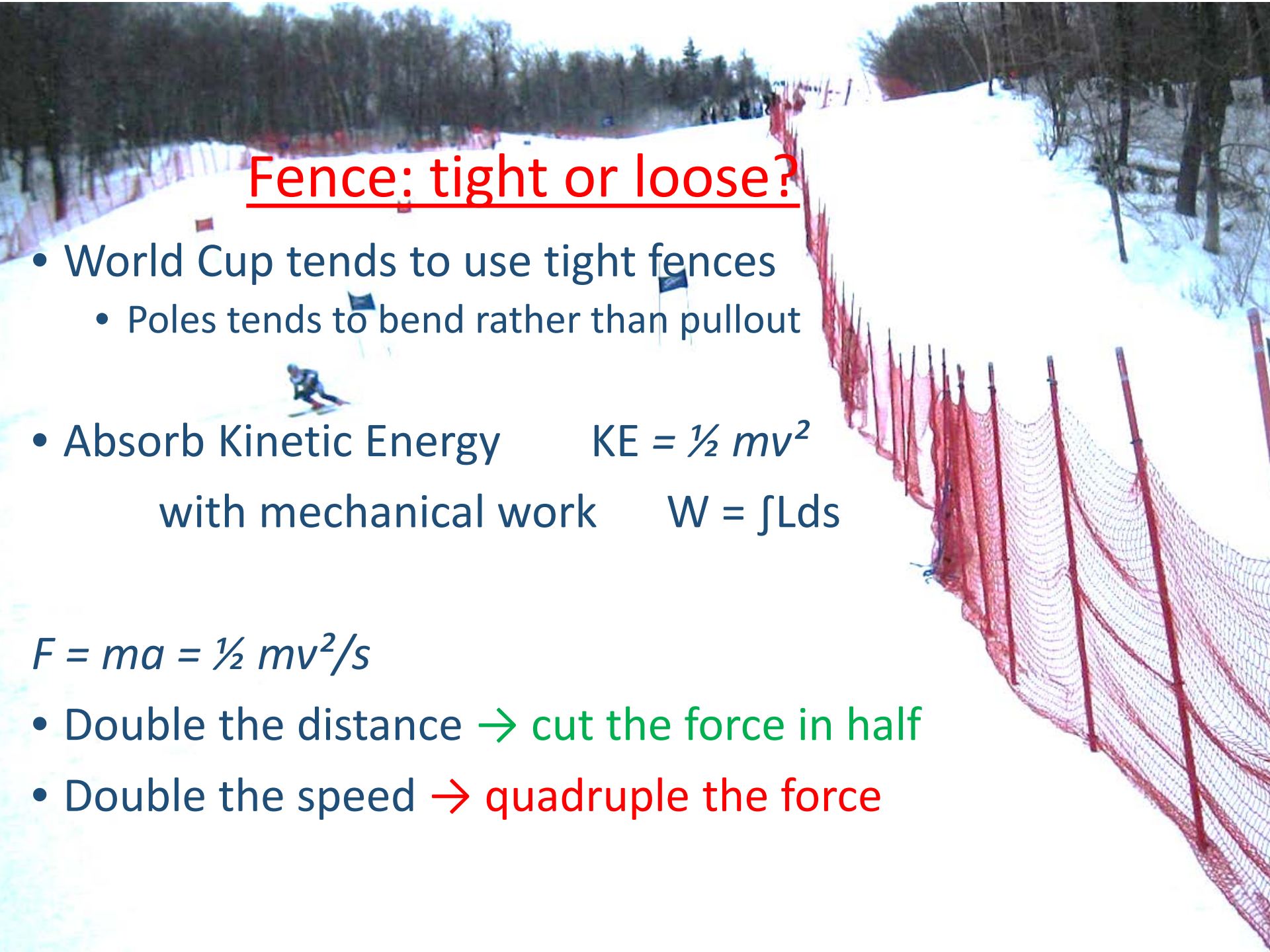
Absorb energy over the stopping distance, s



How is the energy adsorbed?

- Poles bending
- Pole pullout
- Fence stretch

Spacing between fences is insufficient



Fence: tight or loose?

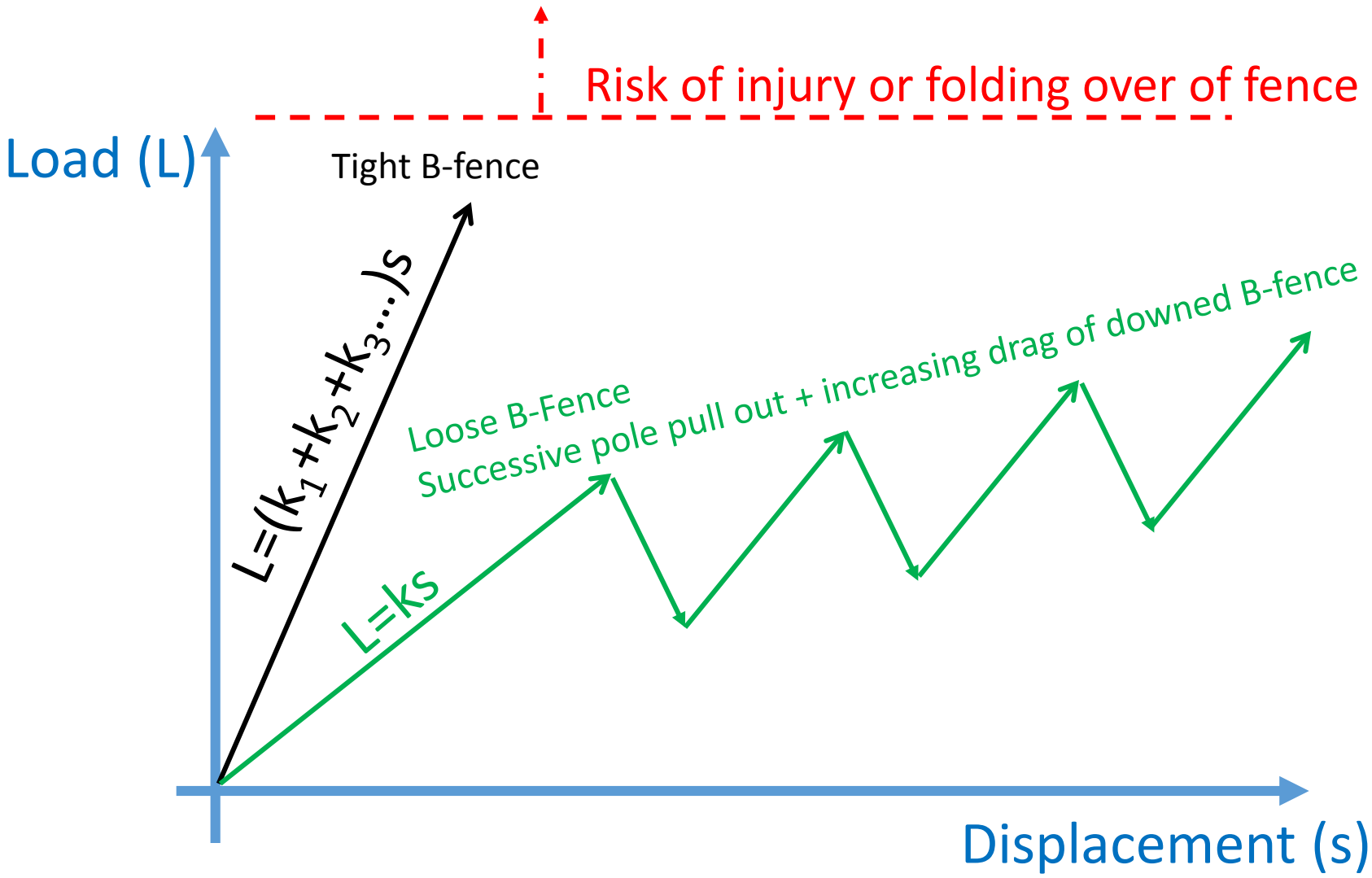
- World Cup tends to use tight fences
  - Poles tends to bend rather than pullout
- Absorb Kinetic Energy $KE = \frac{1}{2} mv^2$

  with mechanical work $W = \int L ds$

$F = ma = \frac{1}{2} mv^2/s$

- Double the distance → cut the force in half
- Double the speed → quadruple the force

Tight v Loose Fence




ROSSIGNOL
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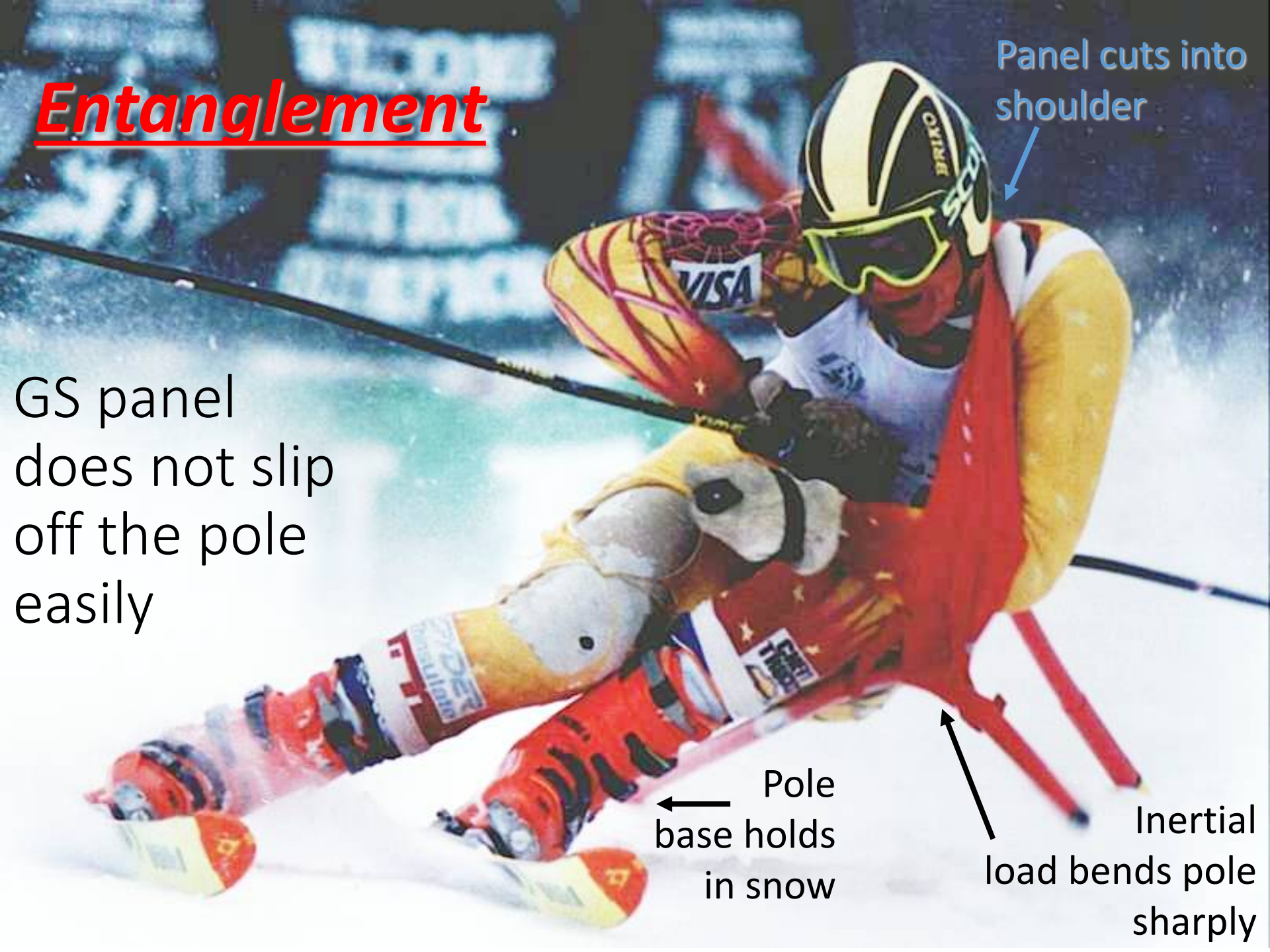
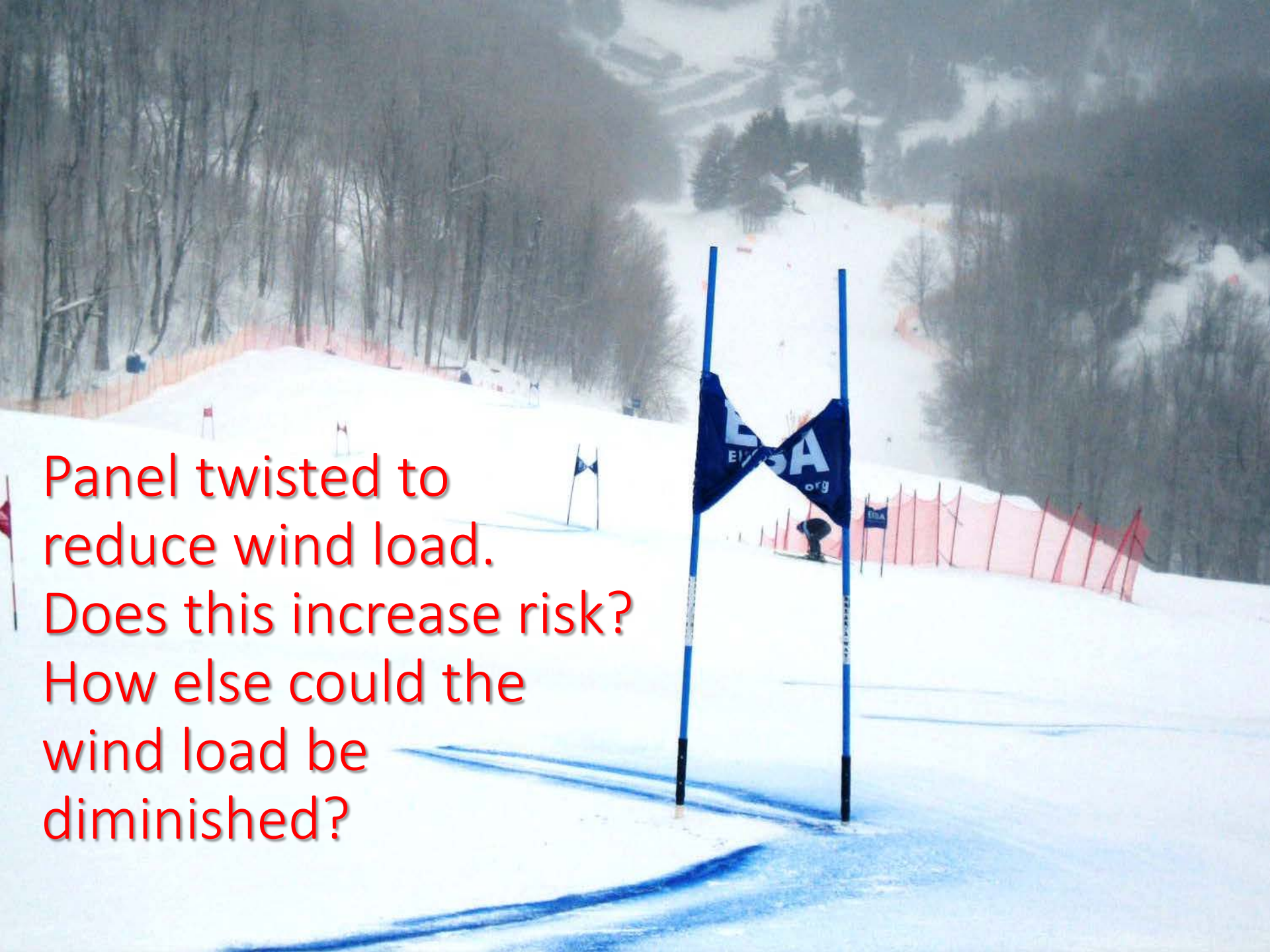
Standoff is too small. How many poles could pull out before contact with the lift tower?


Entanglement
Panel cuts into shoulder
GS panel does not slip off the pole easily
Pole base holds in snow
Inertial load bends pole sharply


Panel twisted to reduce wind load. Does this increase risk? How else could the wind load be diminished?

Concluding remarks

- Practices and barrier equipment appear to be improving (Kelly Brush Foundation)
- Safe practices and reporting are improving (Snowsport Safety Foundation)
- Serious, preventable accidents continue
- More research is needed – modeling, observation, and epidemiology
- What kinds of functionality should we expect to see in ten years?

Thank you for your kind attention