Prevention II ,
Tuesday 13 March
14.50 – 15.10

Equipment engineering for injury reduction

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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

- Show how engineering design can be applied to reducing injuries
  - broad context
  - ski and snowboard bindings.

- Science
  - Looking at things as they are and asking why
  - Seek basic principles or axioms for scientific disciplines
    - Commonalities that can be applied to a wide variety of problems
  - Newton's laws of motion transformed mechanics from a natural philosophy to a scientific discipline

Objective

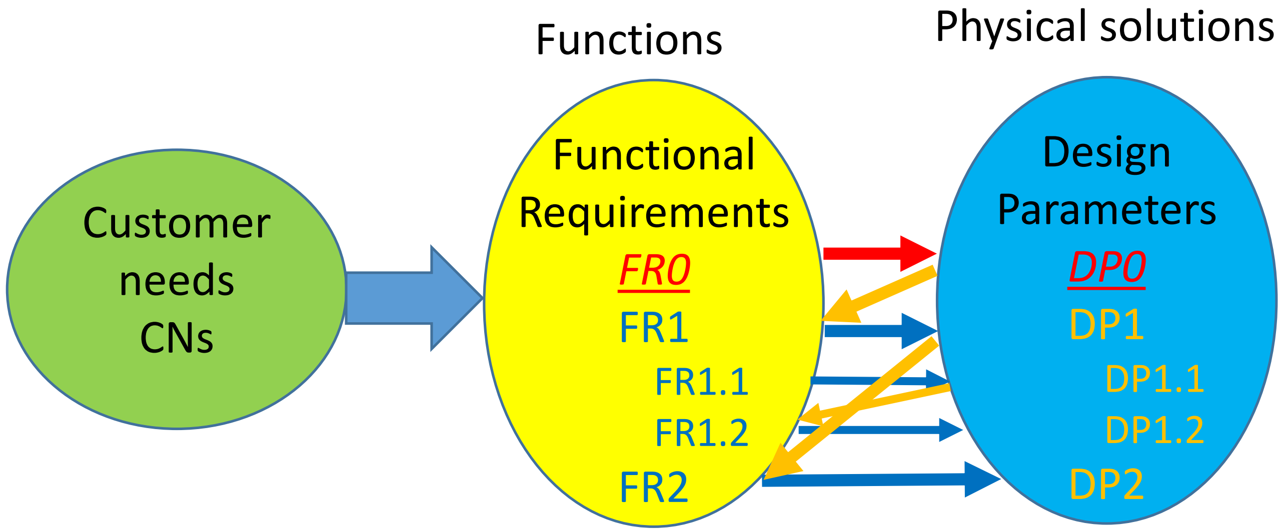
- Engineering
  - Dreaming of things that never were and asking why not?
  - Define desired functions independently of solutions

- Axiomatic design similarly transforms engineering design
  - Rigorous methods and criteria for development and assessment

- An engineering design solution can have similar scientific value to an experimental result
  - And maybe greater impact mitigating injuries

Principles of engineering design

- Engineering design thinking
  - Separate and decompose Functions and Physical solutions



Constraints: maintain enjoyment, performance, control cost

- *Decompositions must be collectively exhaustive*
- A design will be no better than its Functional Requirements – ***develop good functions first***

Design axioms

Principles of Design (Suh 1990)

1. Maintain the independence of the functions
   - Controllable, adjustable
   - Avoid unintended consequences

2. Minimize the information content
   - Avoid unnecessary complexity
   - Maximize the probability of success

Top level FRs for bindings

FR 1

transmit control loads with high fidelity for superior performance

FR 2

filter or absorb potentially injurious loads for protection

(avoiding inadvertent release (IR))

Currently…

- Systems lack independence and have unnecessarily high complexity
  - Same structures used for control, retention, and release

- Inadvertent release – a need that must be addressed
  - control linked with release
  - Adjustment to reduce the chance of inadvertent release
    - Increase load to release
    - Increase risk of injury

- Adjustment of bindings is based only on mass
  - strength and speed need to be considered for advanced, trained skiers
  - $F=ma$

Load based injury model

- Failure of a structure requires *sufficient*
  1. Force and torque combinations to initiate failure
  2. Work to propagate failure

Prevent injurious load transmission

Mechanisms to control load transmission

- Loading incidents in snow sports are transient
- Energy is limited ($\frac{1}{2}mv^2$)
- Loads can be adsorbed with mechanical work $v^2=2as$

General approach

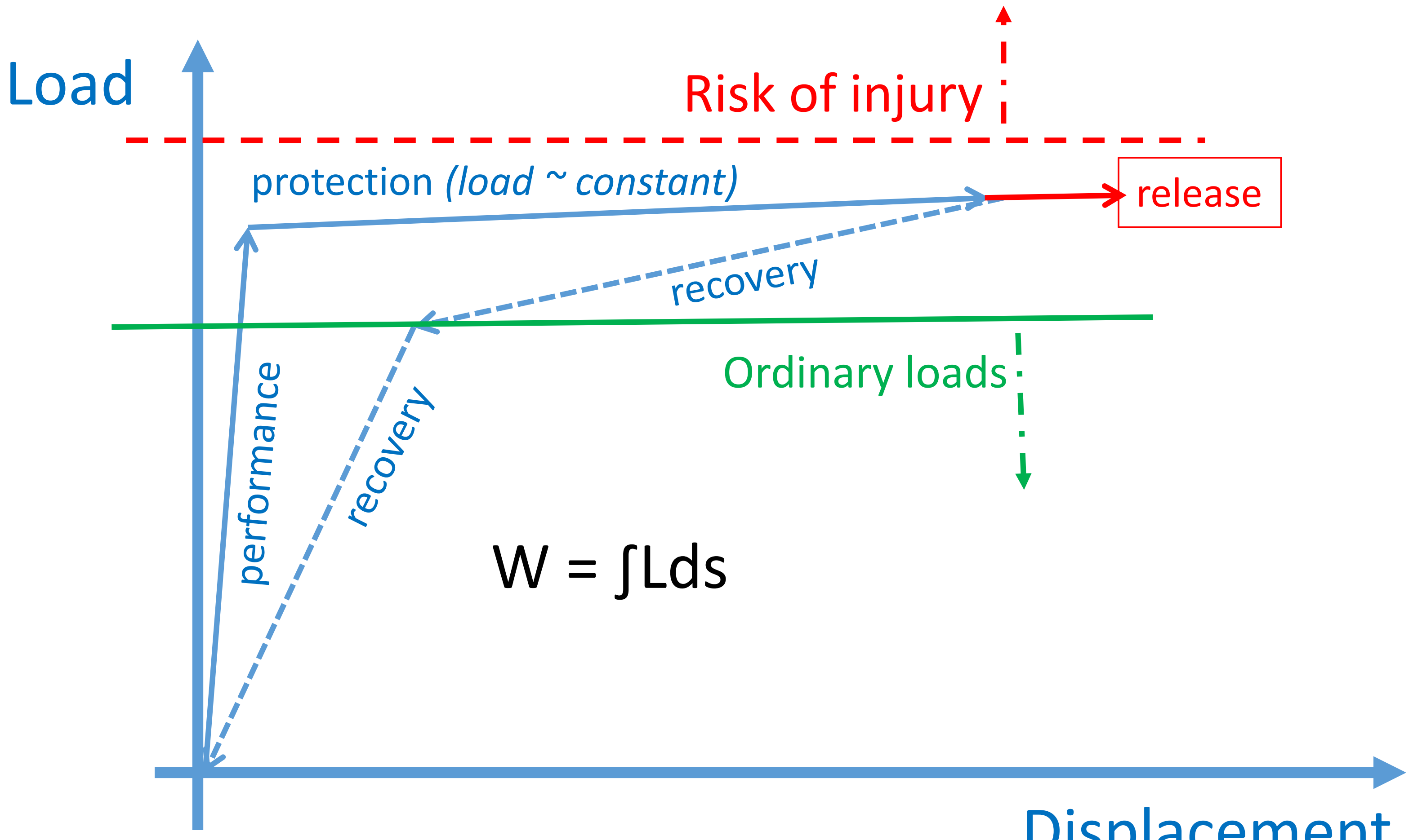
Customer (stakeholder) needs

- Eliminate inadvertent release (IR)
- Eliminate injuries where bindings transmit the injurious loads

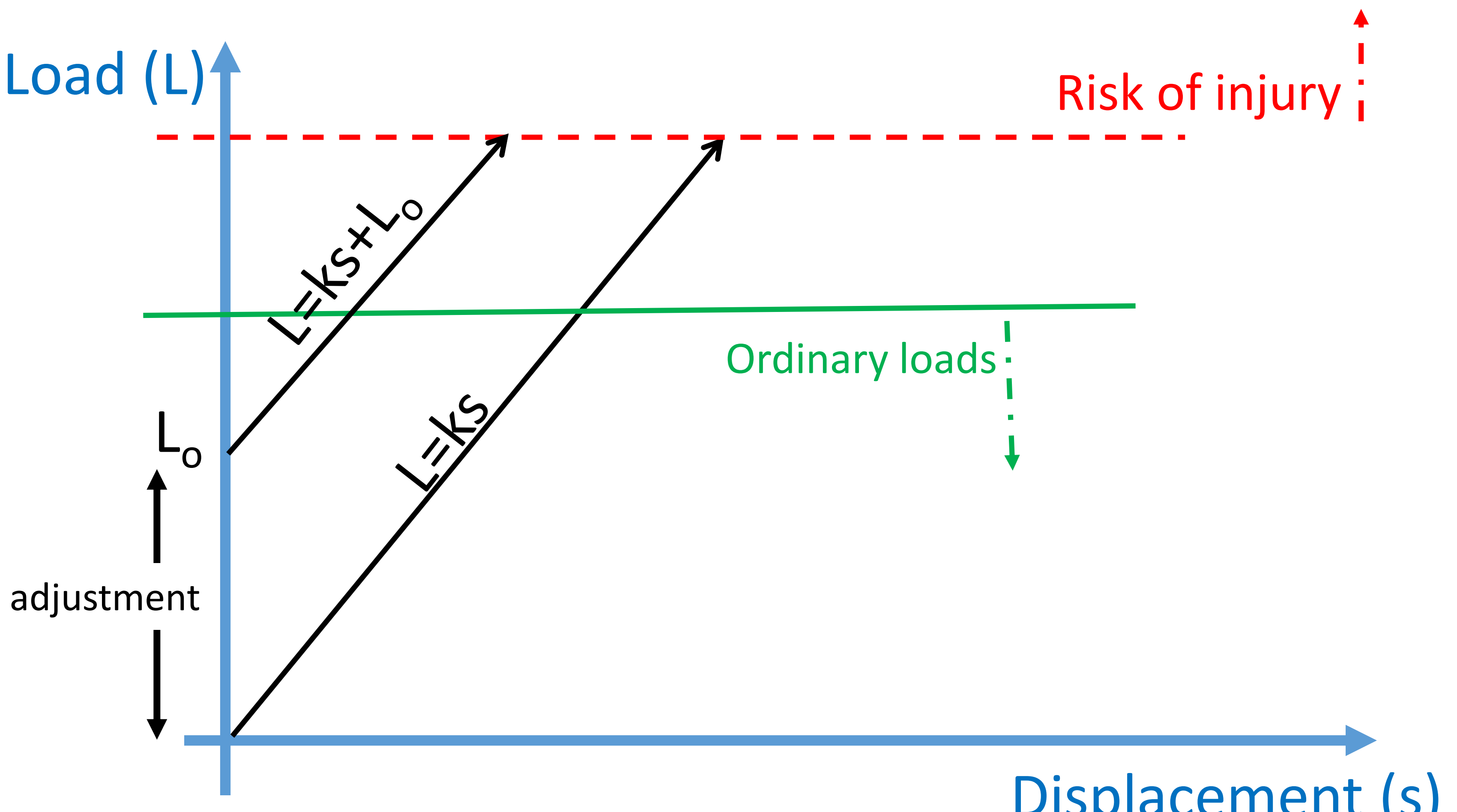
Load transmission

- Work and energy
  - $\int L ds = \frac{1}{2} m(v_2^2 - v_1^2)$
  - Do work on the equipment instead of the body
- Impulse and momentum
  - $\int F dt = m(v_2 - v_1)$
  - Reduce force and increase time to achieve the same result

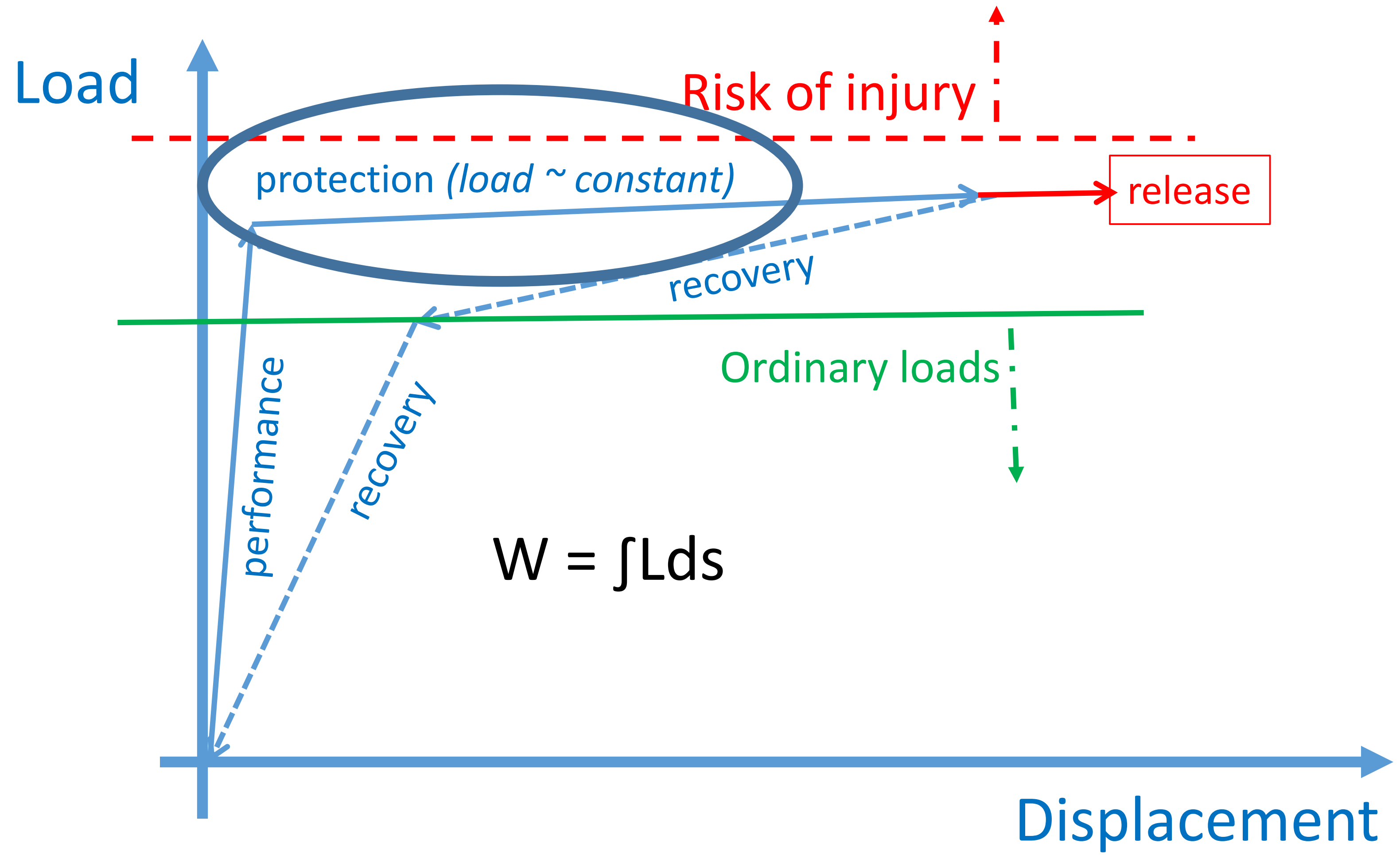
Do mechanical work on the equipment



Conventional proportional springs



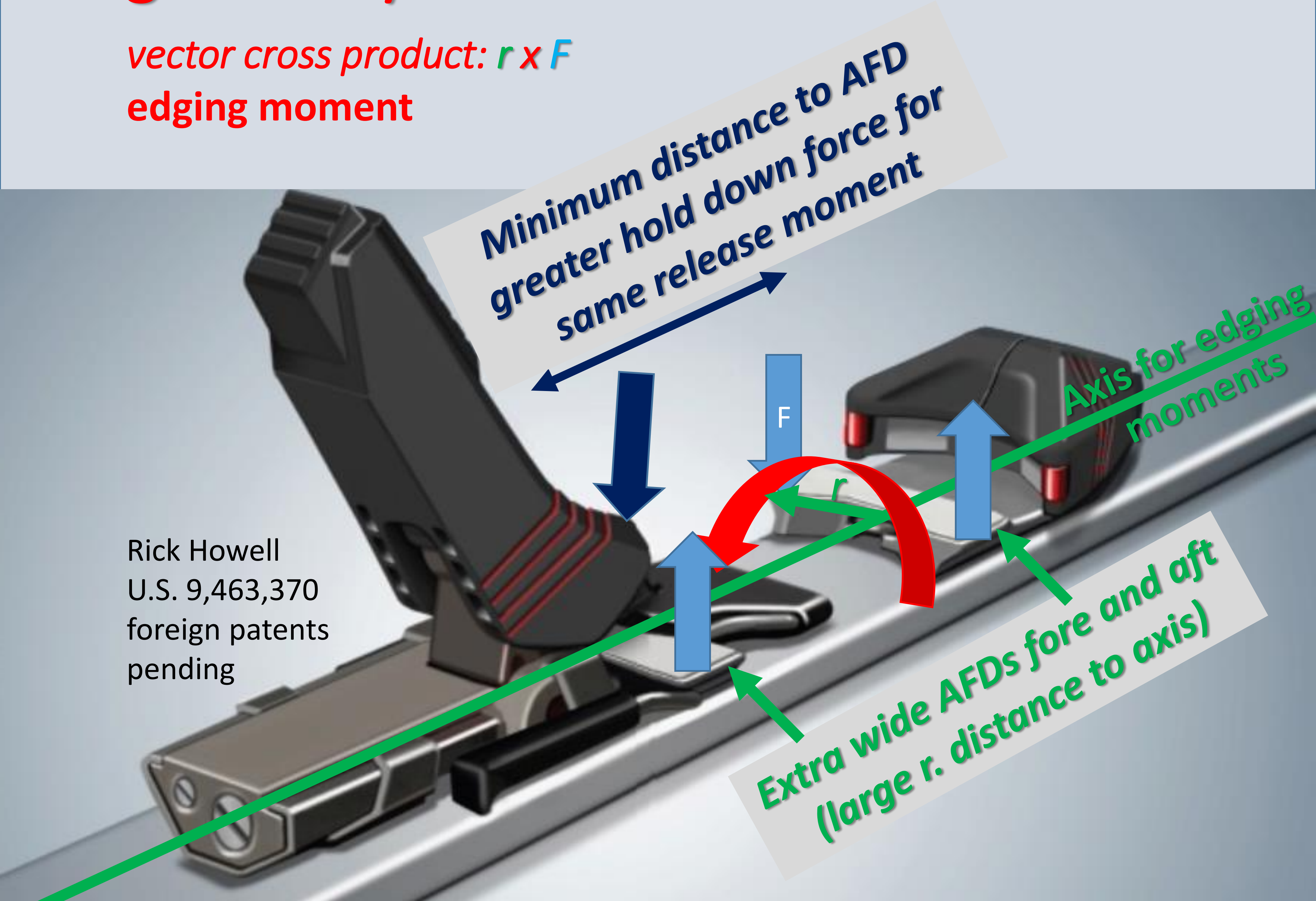
Another look at the constant force spring



High fidelity transmission of control loads

vector cross product: r x F

edging moment



Rick Howell
U.S. 9,463,370
foreign patents
pending

IR is loss of control

Dynamic response *Chatter off*

Ski has a higher natural frequency than the binding

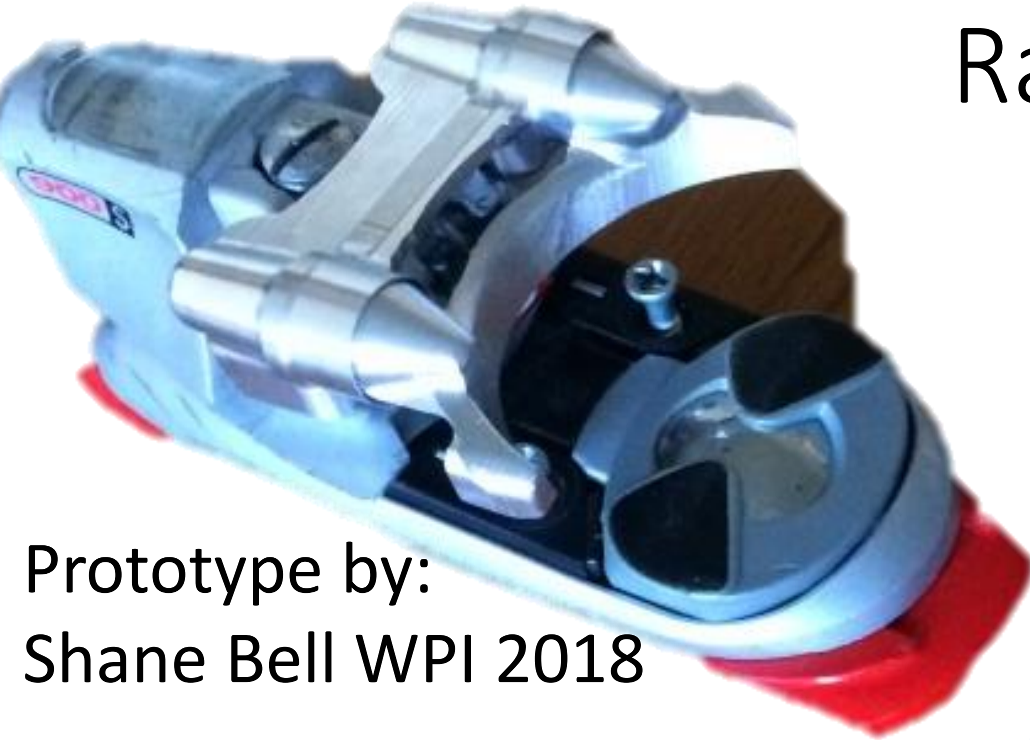
Ski goes into deep flex

Heel piece slides back on its track for accommodation


Ski goes into counter flex or hyper camber
Heel piece cannot recover fast enough to retain the boot


Ski is off
Race is over for this skier
Problem – frequency of ski flexing and counter flexing is faster than the binding response

Rapid response ski binding



Prototype by:
Shane Bell WPI 2018

Brown and Madura
US Patent 9,358,447

Rapid response ski binding

Brown and Madura
US Patent 9,358,447

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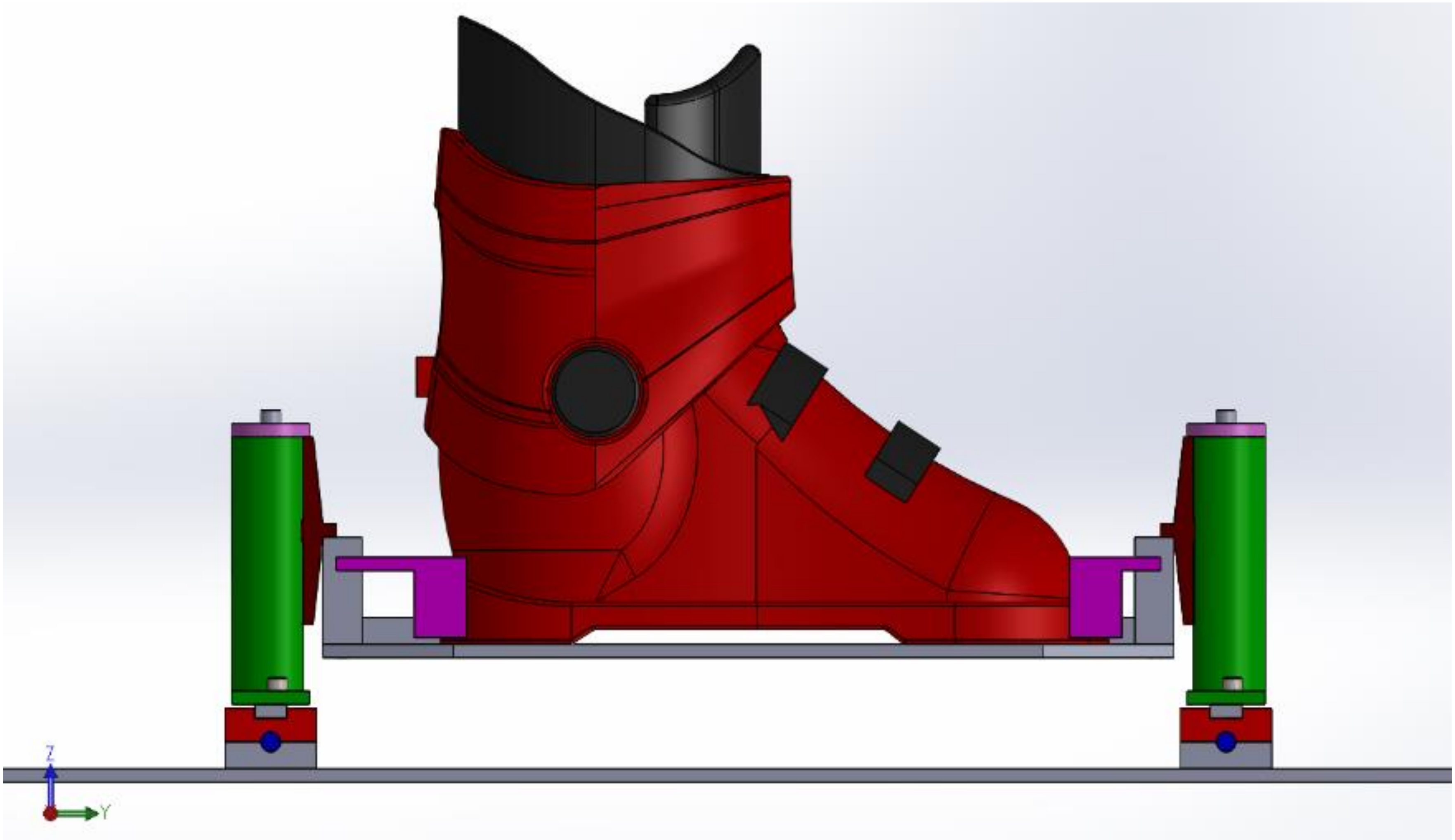
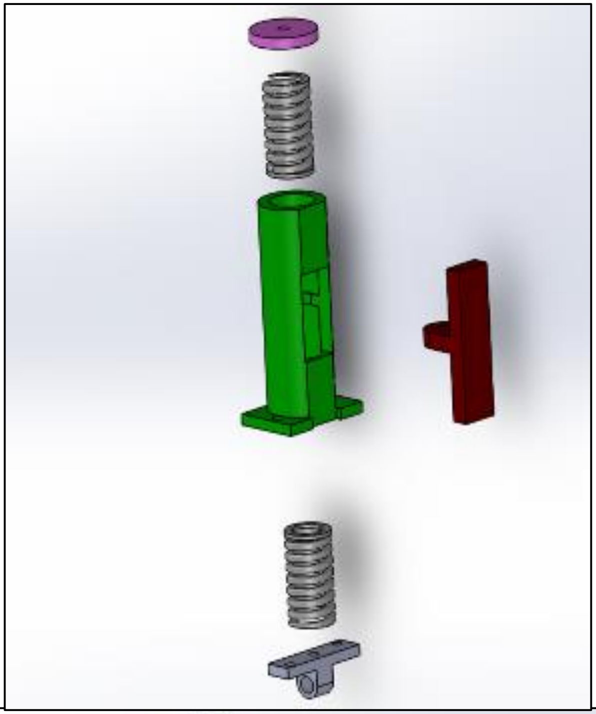
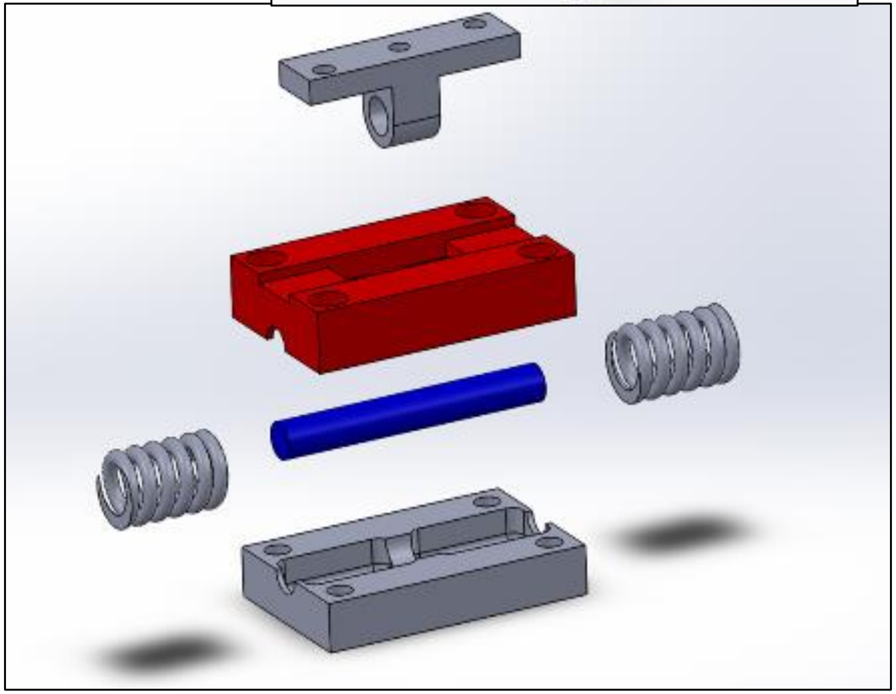


Patent pending

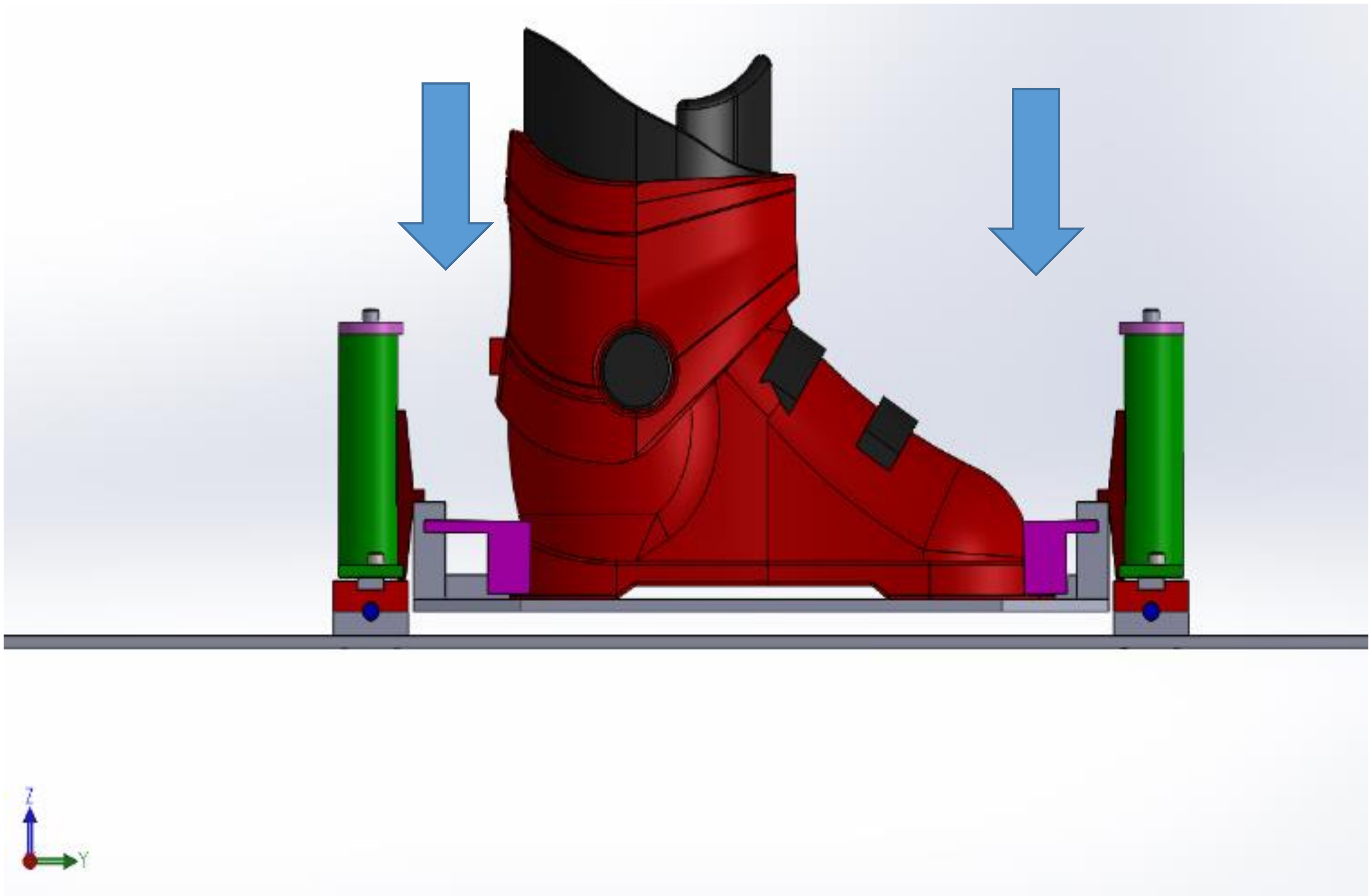
Preloaded spring configuration





Patent pending

Absorbing position – Tibial Plateau



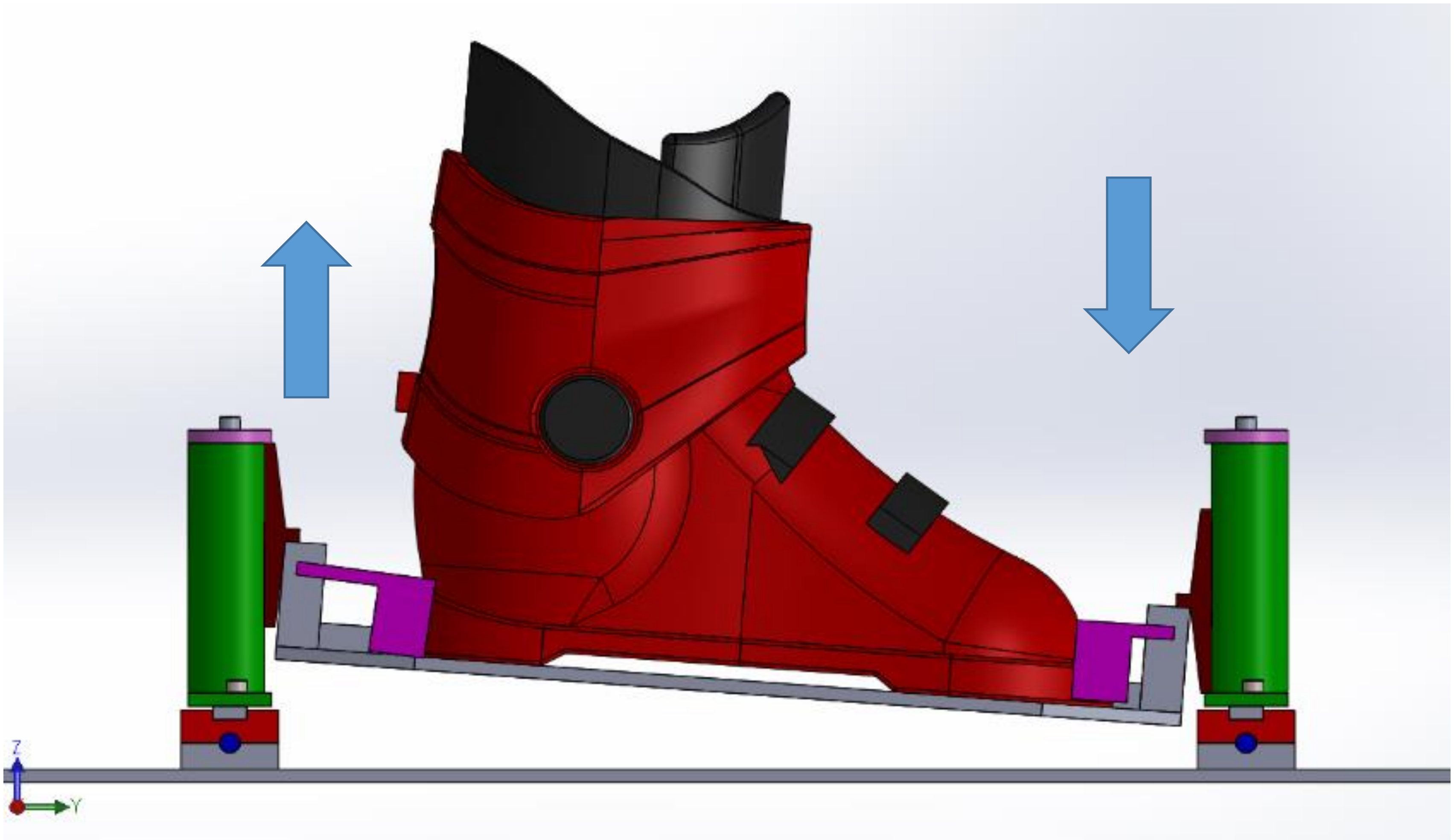
Patent pending

Absorbing positions – twist and valgus

Center of rotation can be anywhere

Patent pending

Absorbing position – Forward bending



Patent pending

Absorbing displacement - BIAD

Patent pending

Release position at end of travel

Patent pending

Thank you for your attention!