The Connection Between ‘Understanding Loadcase Physics’ and Structural Mass & Cost Efficiency; a BEV Side-Pole Case Study

Mark Dingman – Daphnis Structural Solutions

GREAT DESIGNS IN STEEL™

Daphnis Structural Solutions

Automotive Structural Consulting

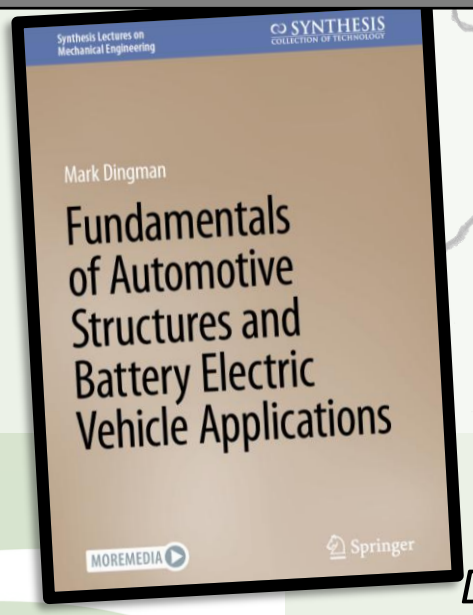
Headquarters:
Detroit area, US

Employees:
One

Global Support Capability:
Yes

Services:
Many

Springer: Fundamentals of Automotive Structures and Battery Electric Vehicle Applications



daphnis.co

Solutions Development

Architectural Development

Reverse Engineering

Seminars & Training

Let's Discuss Others

Introduction: Presentation Look-Ahead

- Breakdown the physics of the Side-Pole loadcase; pulling three important insights.

- Use the Tesla Model-3 to show how these insights can enable an efficient PBH design.

Introduction: Side-Pole Loadcase Refresher

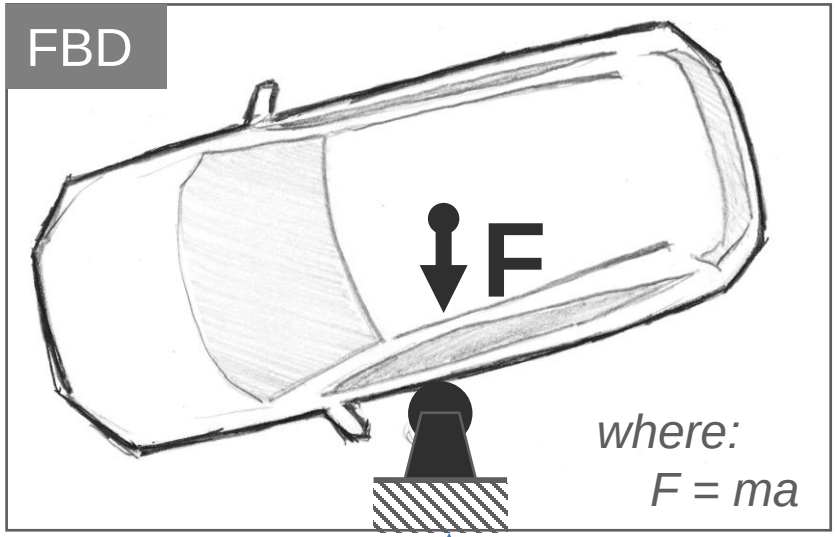
- Vehicle strikes a ‘rigid’ pole at 32 kph.
- Strikes at a fixed angle based on test protocol.
- Different protocols specify different impact locations along the rocker.
- Typically, a moving testbed is used to facilitate.
- EVs with a full-width underfloor propulsion battery have less intrusion, in order to protect the HV components.

Breaking Down the Side-Pole Loadcase

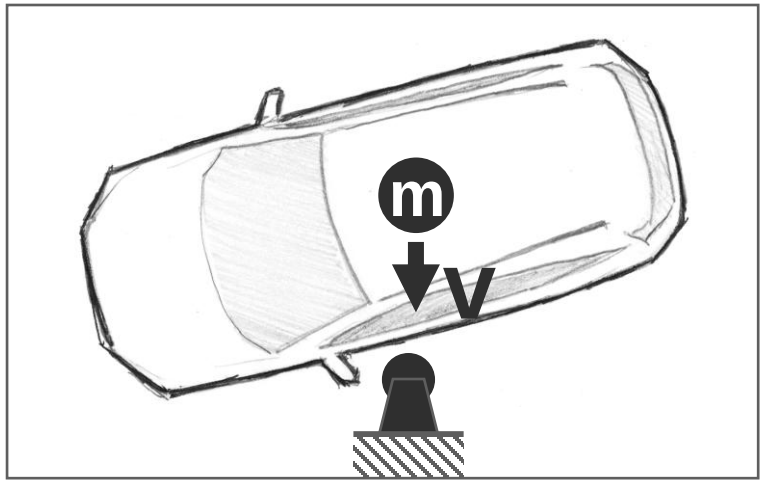
…three important insights

Side-Pole Physics: Breaking it Down

The first step is to develop the Free Body Diagram (FBD)…



=

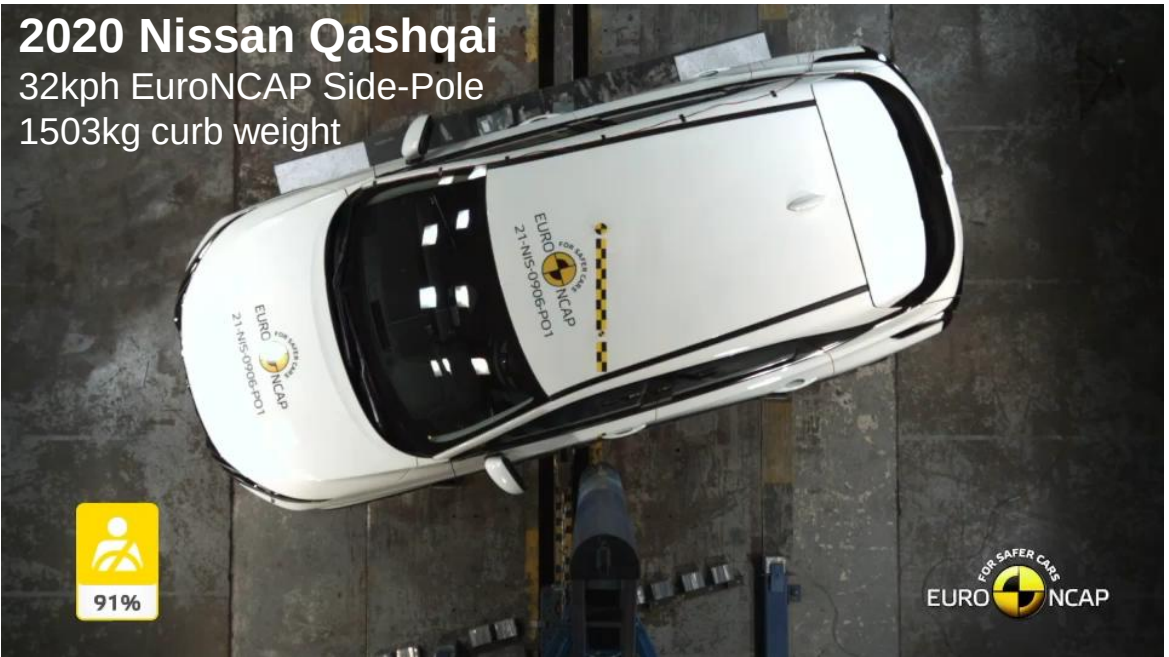


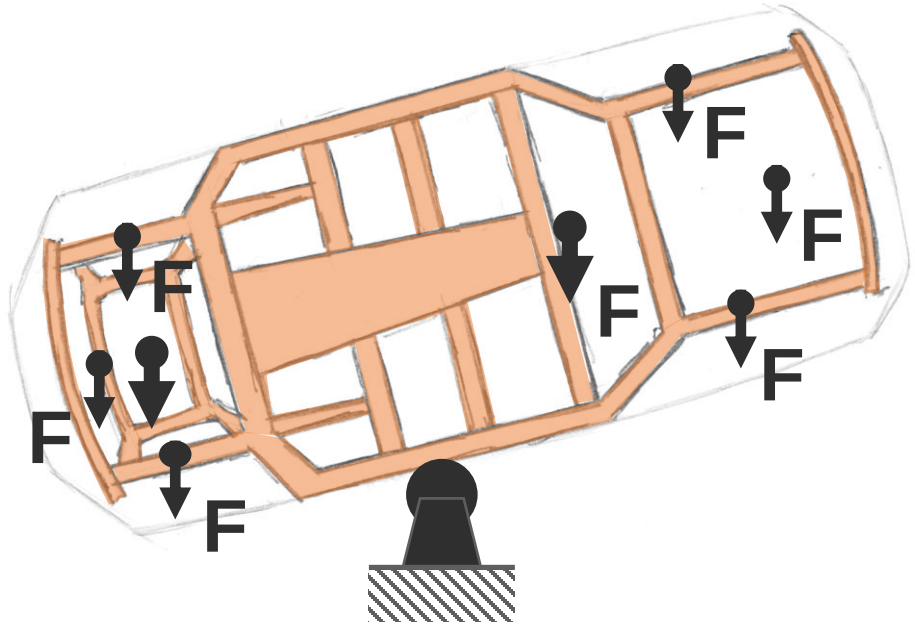
Side-Pole Physics: Insight #1: Ride-Down Loadpath

The structure performs an ‘energy ride-down’ function.
…and an appropriate structural topology should be applied.

Recognize that the vehicle mass is not lumped at the *cg* and that ‘objects in motion tend to stay in motion’.

Component masses will stress the vehicle structure that exists between them and the pole. The structural loadpath topology strategy and its strength must comprehend this.

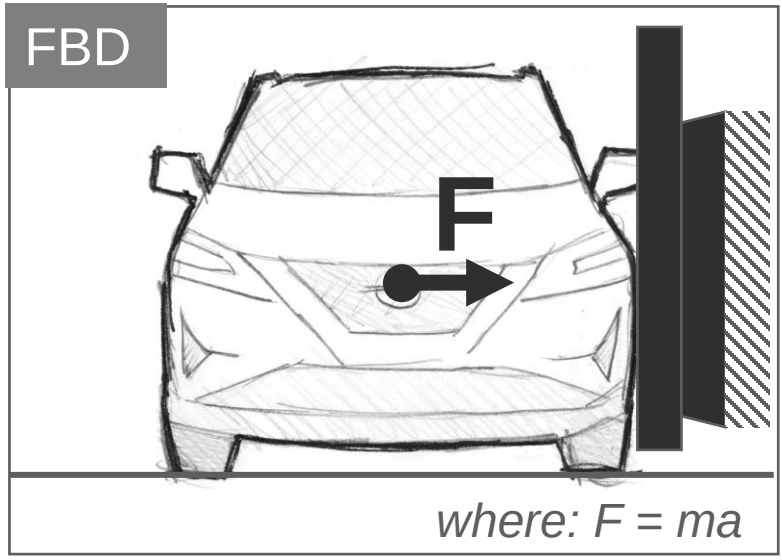




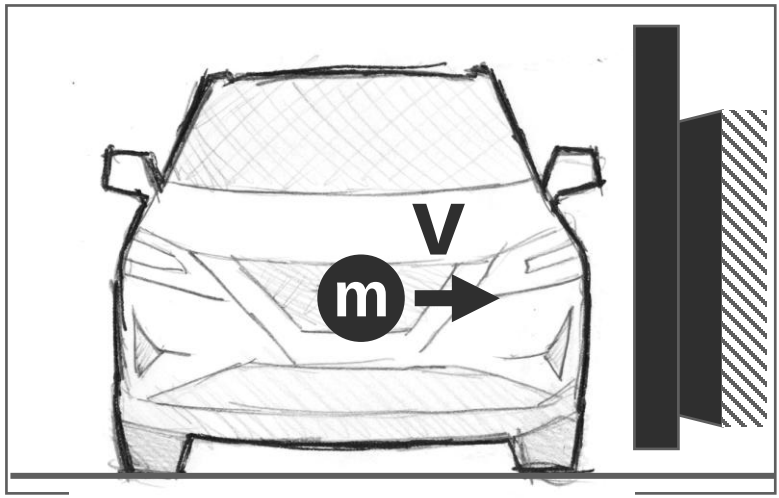
Side-Pole Physics: Breaking it Down

GDIS

To uncover the next insight, we must construct a FBD for the front view…



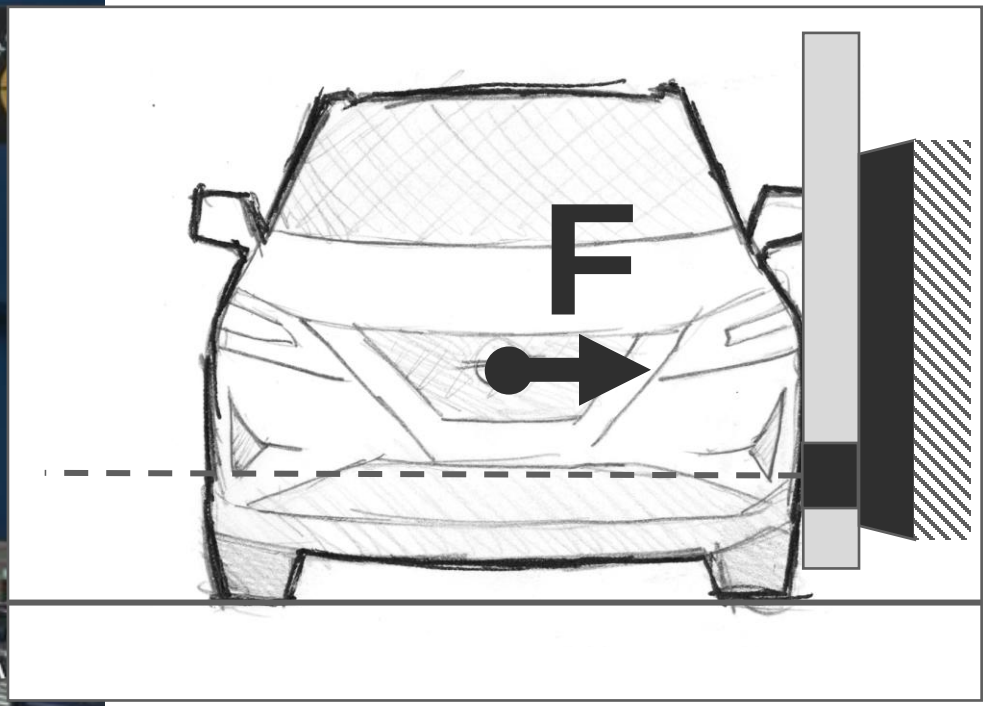
=



Side-Pole Physics: Breaking it Down

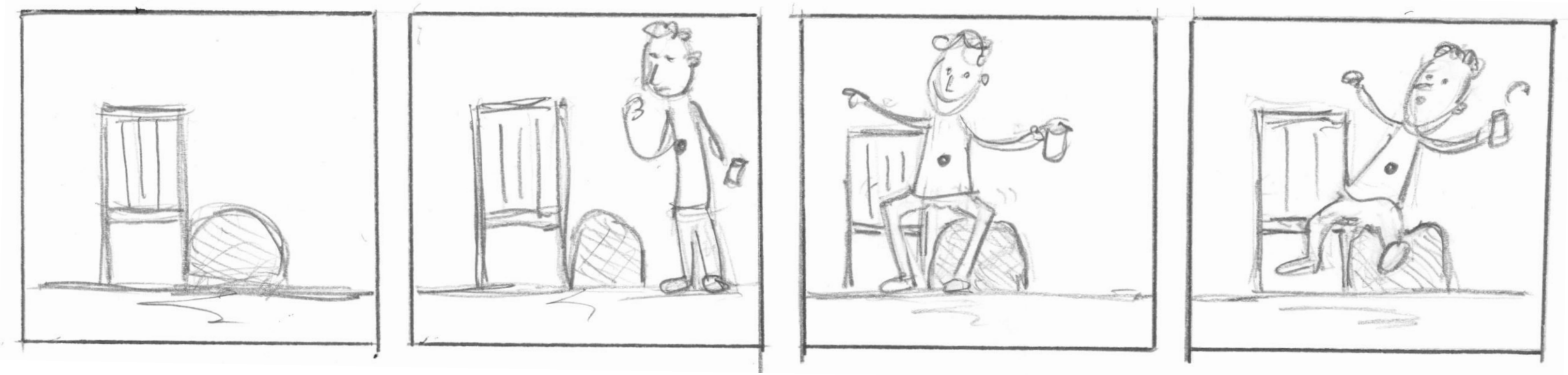
…note the vehicle's roll behavior…

5-star overall - 16/16 points for ‘Lateral Impact’



Side-Pole Physics: Breaking it Down

The effect of roll induced by a difference in contact strengths can be tricky to grasp, so consider the following analogy…

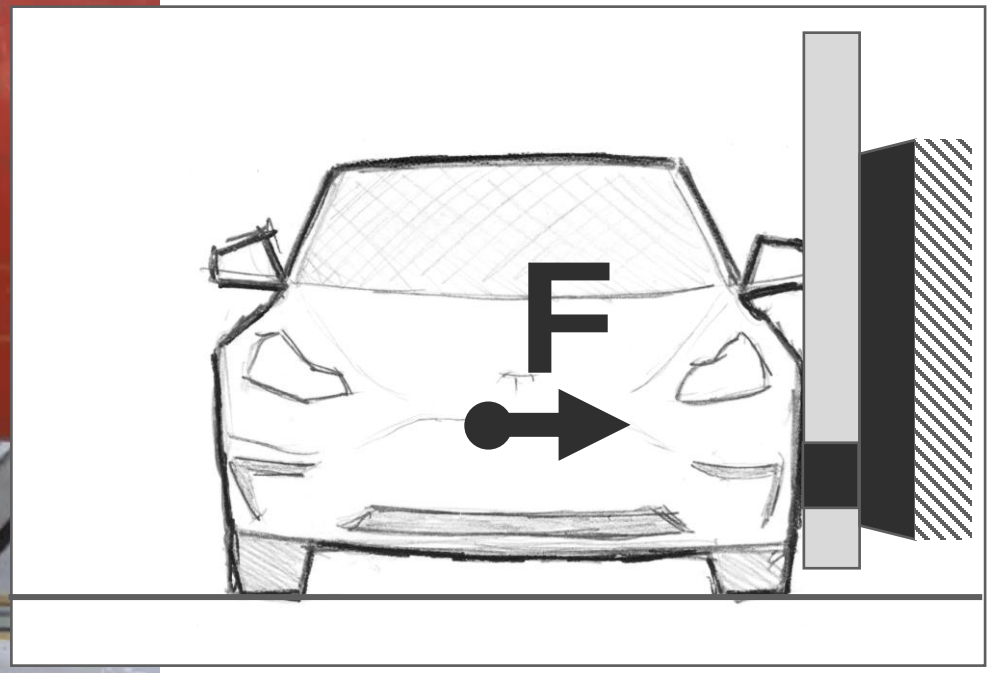


…a man, thankfully wearing a shirt that indicates his center of gravity, attempts to sit half on a wooden chair and half on a bean-bag chair. Roll will be induced.

Side-Pole Physics: Breaking it Down

EVs tend to have a lower *cg*, however it still tends to be above the rocker/sill. …EVs roll too.

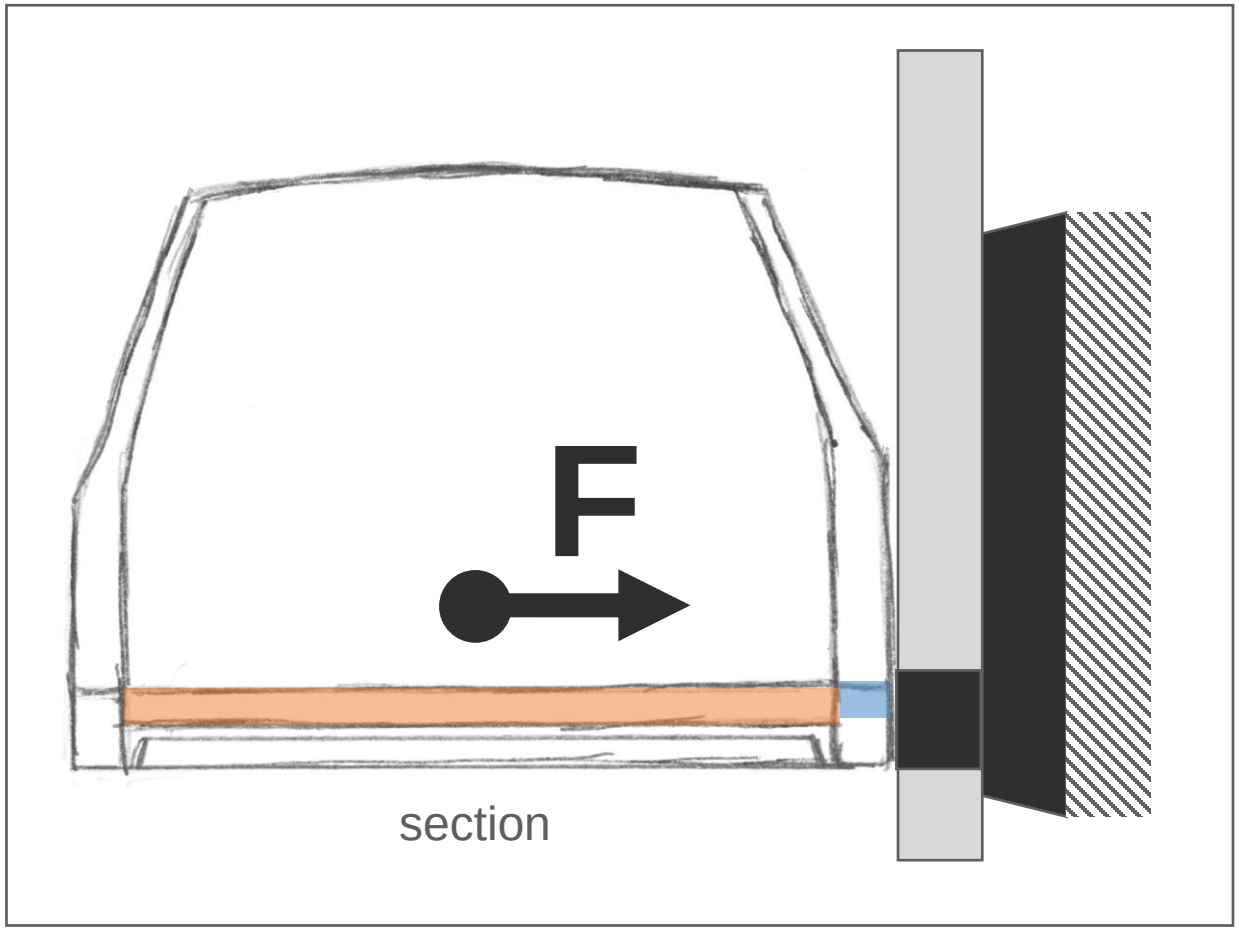
5-star overall - 15.3/16 points for ‘Lateral Impact’



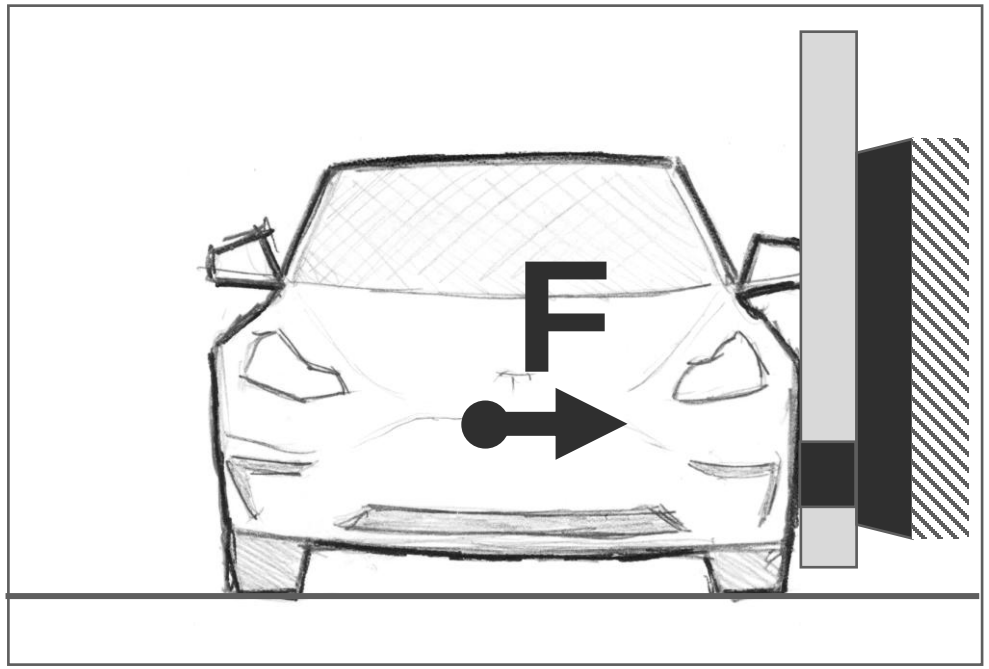
Side-Pole Physics: Insight #2: Vertical Alignment of EA

Minimize the vertical distance between the EA & its back-up structure and the *cg*.

This can be a paradigm shift from initial concepts of propulsion battery protection.



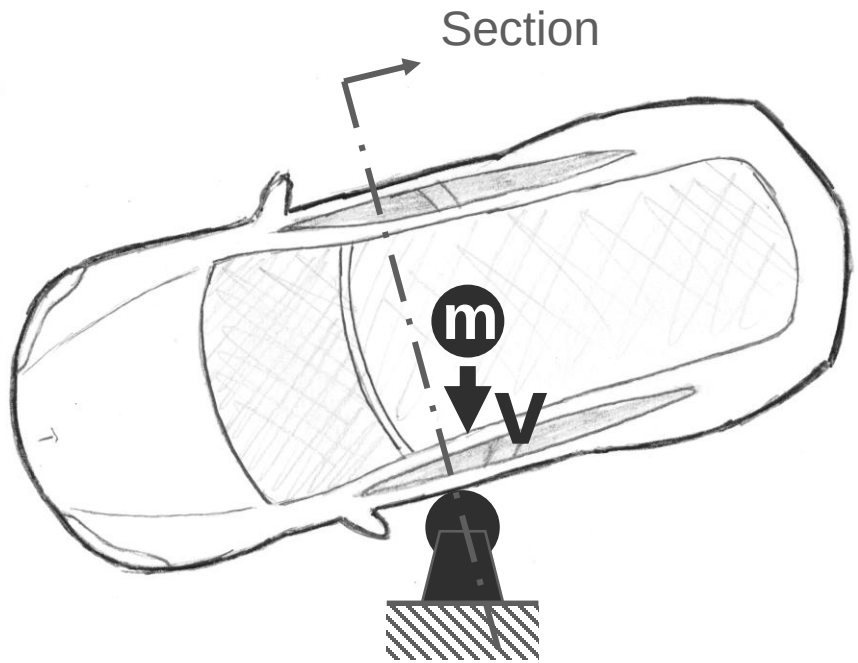
…remember, it is the vehicle that experiences the crash event, not the propulsion battery.



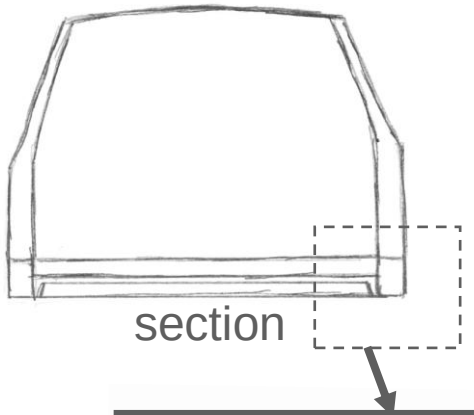
Side-Pole Physics: Insight #3: EA Allocation

Allocate an appropriate amount of energy absorption (EA).

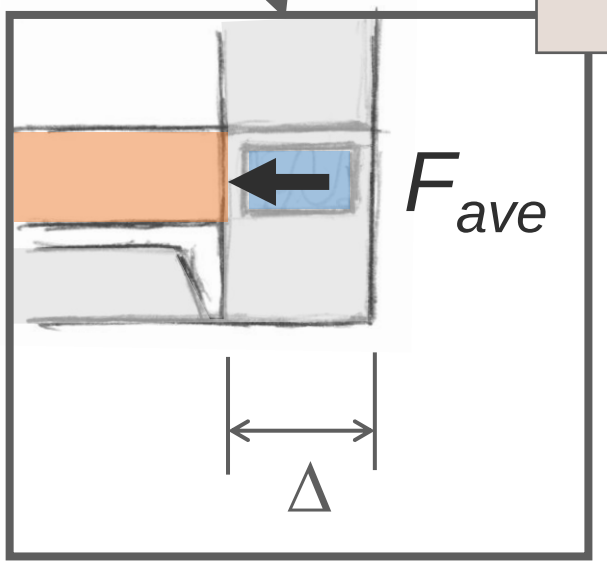
To keep the force seen by the undeformed back-up structure to a reasonable level, an appropriate amount of EA must be allocated.



from the equation for Work:



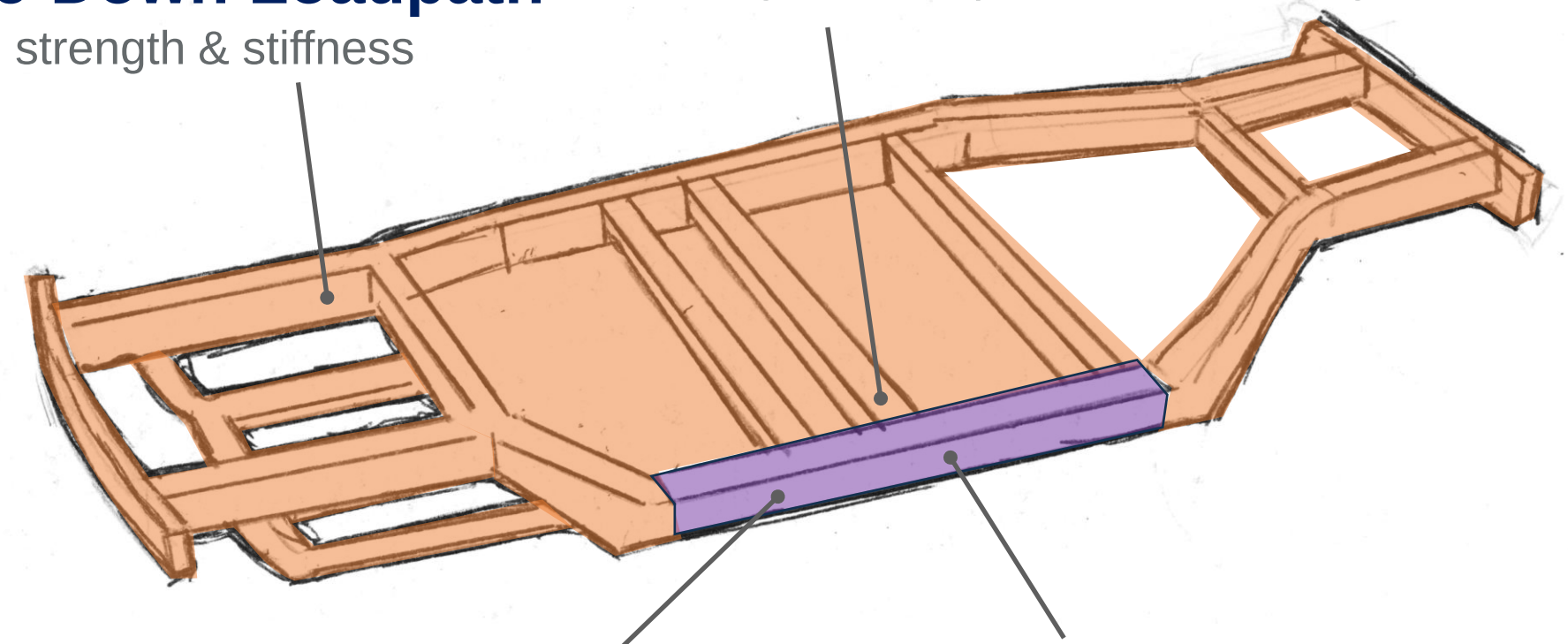
$$F_{ave} = \frac{mv^2}{2\Delta}$$



Side-Pole Physics: Summary of Insights

High EA & Backup Structure
geometric position and strength

Ride-Down Loadpath
strength & stiffness



Adequate EA
spatial allocation

Ride-Down Loadpath &/or EA*
stiffness & engineered strength

This learning might seem like something relevant only to OEMs; not the case.

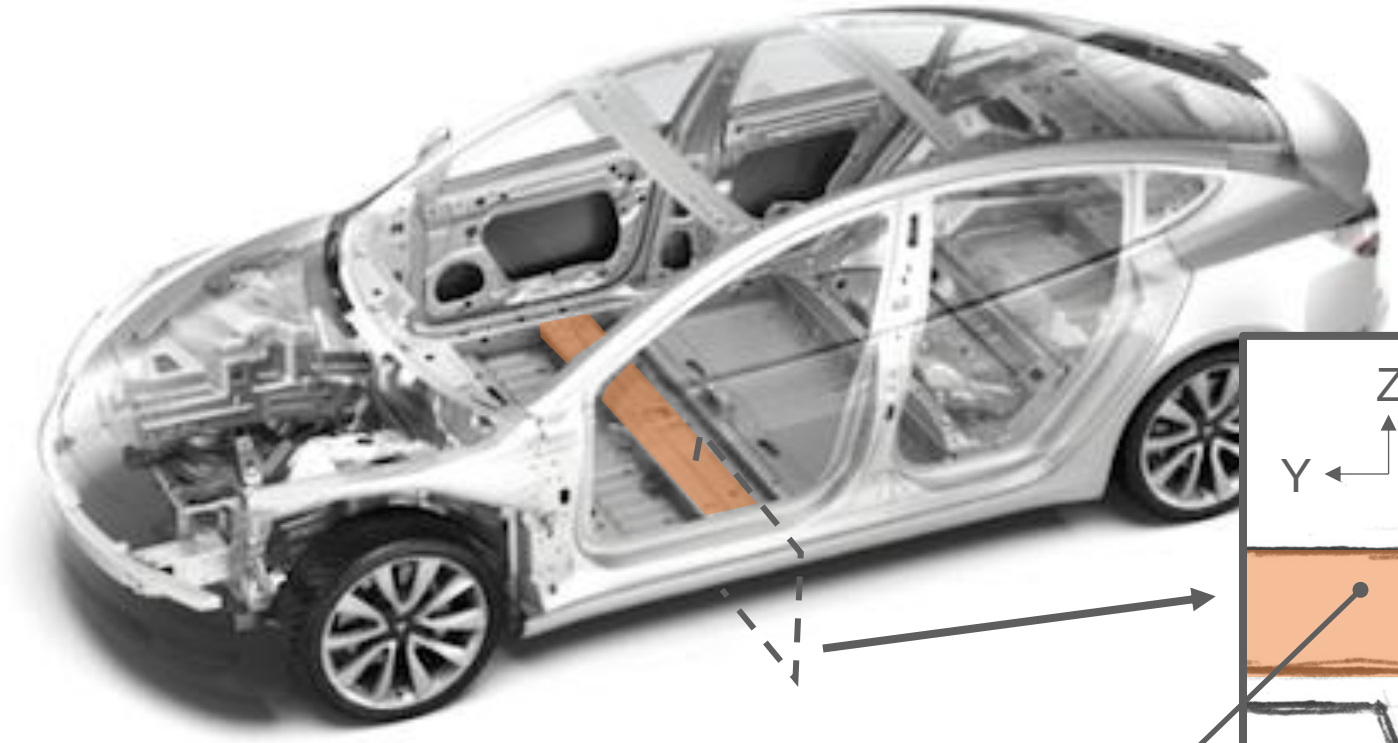
Understanding the structure's participation in the event is important to suppliers too.

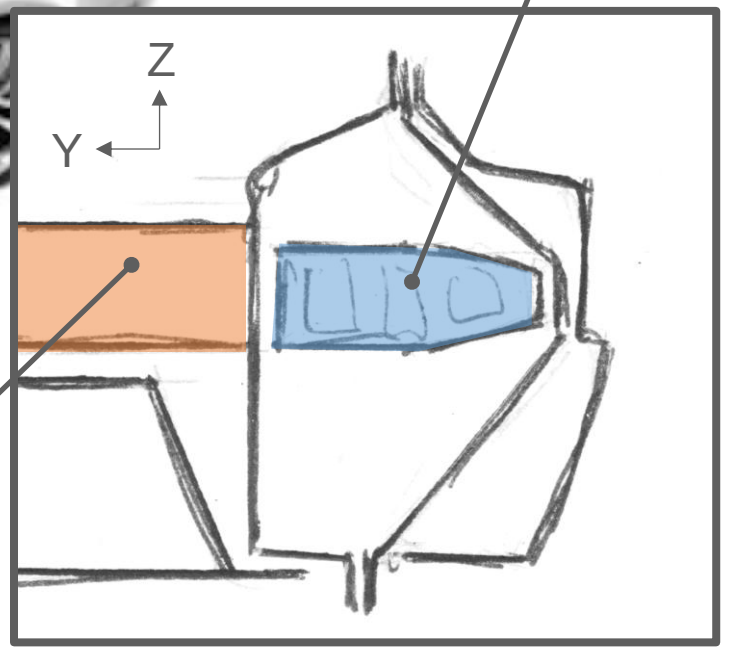
…important for; component designs, solution development, physical testing, etc.

*function is dependent on the loadpath topology strategy of the vehicle in question

Case Study: Tesla Model-3 PBH

Tesla Model-3 Case Study: Vertical Alignment of EA





High EA Position

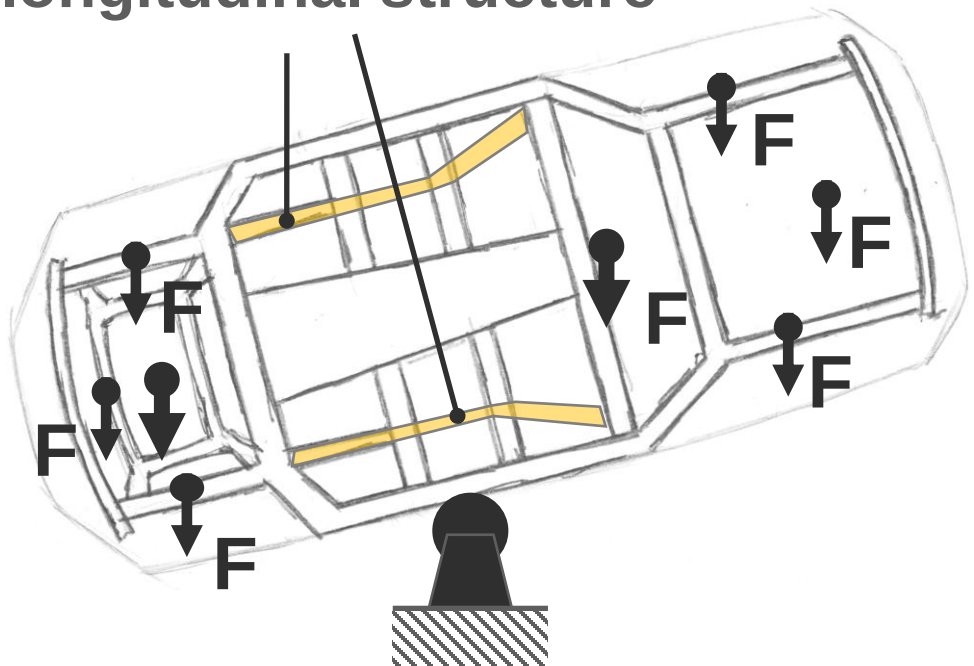
Strong EA Engagement Backup Structure

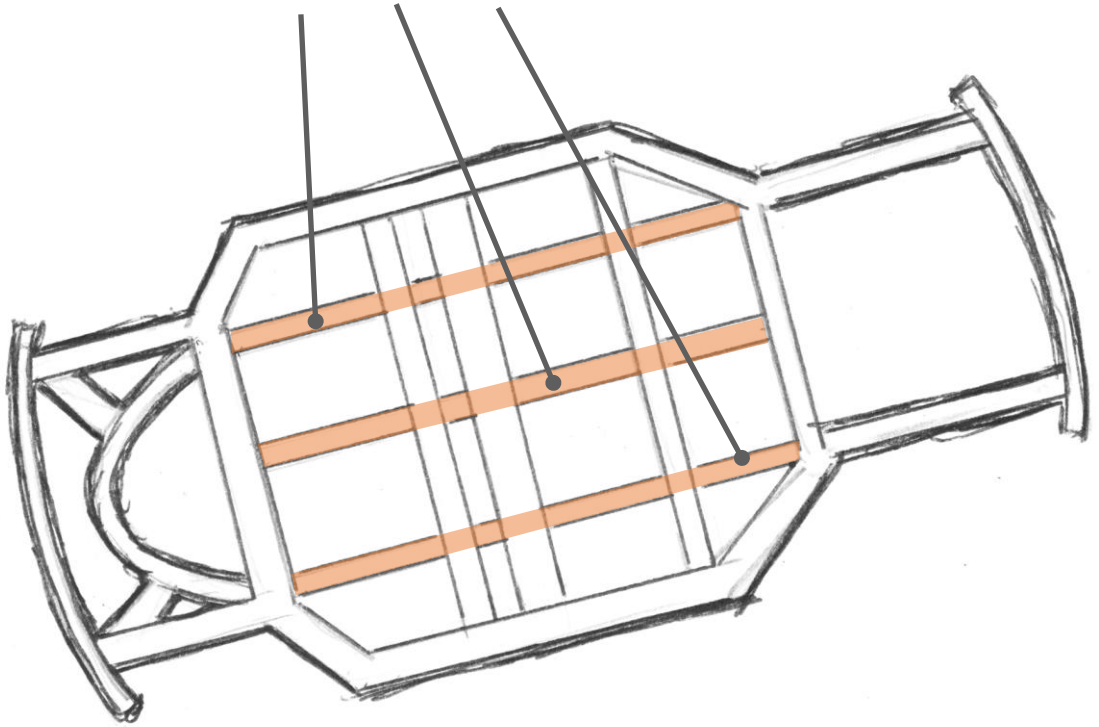
Note that, with this strategy, lateral members within the PBH are not required for EA backup structure.

Tesla Model-3 Case Study: Ride-Down Loadpath

Longitudinal PBH structure is introduced to offset some of the ride-down loadpath that is inherently lost in a full-width, underfloor EV configuration.

Typical ICE under-floor longitudinal structure



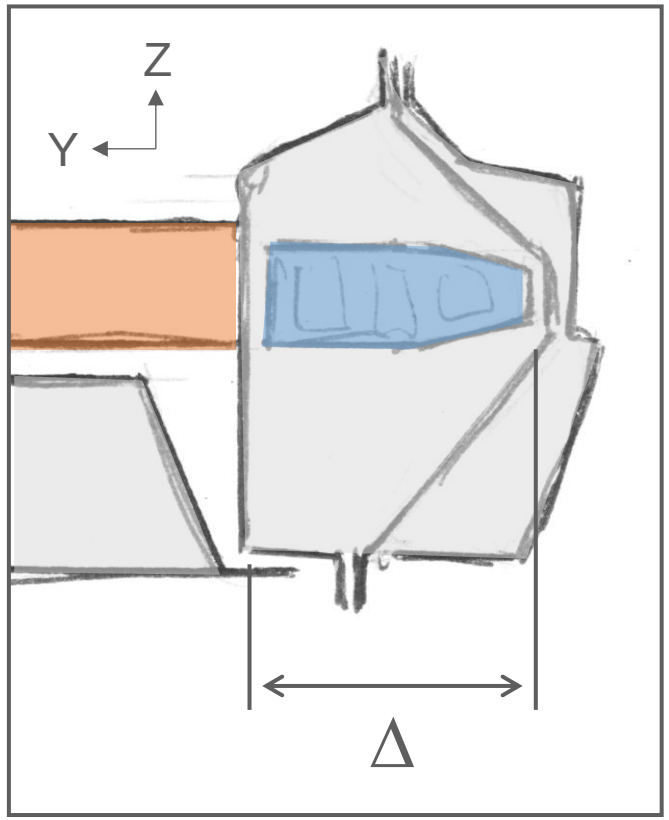


Tesla Model-3

Tesla Model-3 Case Study: Appropriate EA Allocation

Tesla allocates appropriate EA space.

Furthermore, this is a consistent EA strategy; The allocated EA space in other Tesla architectures increases as mass increases.



$$\Delta = \frac{m\ v^2}{2\ F_{ave}}$$

Mass

Reasonable force applied to the backup structure

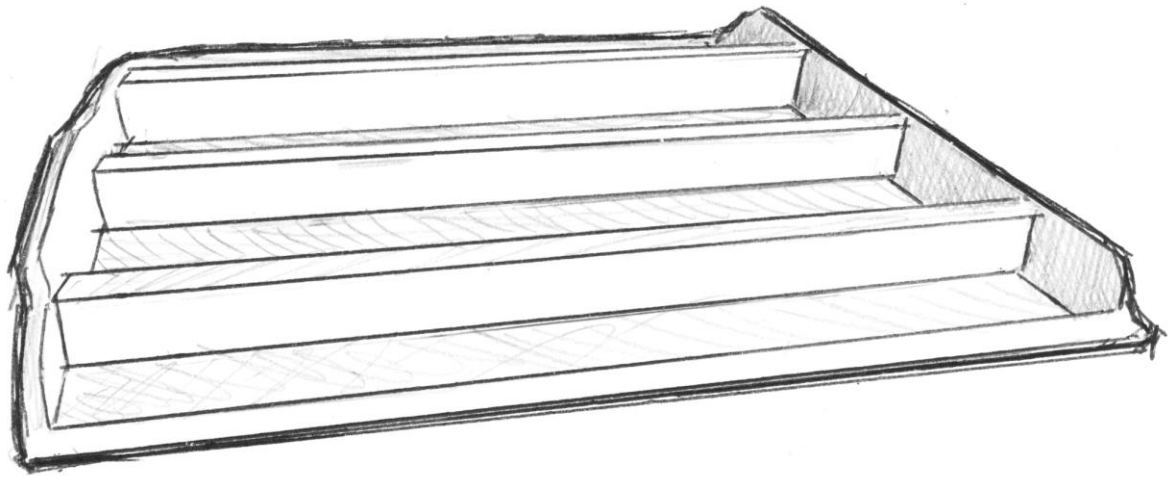
(from the work equation)

Tesla Model-3 Case Study: Summary

Tesla's Physics-Driven (or highly, influenced) Design Utilizes:

- **Adequate EA Allocation**
- **Comprehension of the Ride-down Loadpath**
- **High EA Positioning**

…to achieve an industry benchmark for efficiency, in steel.



Wrap-up:

- Broke-down the Side-Pole loadcase physics & extracted some insights that enable great design.

- Illustrated how these insights are used by Tesla to achieve design efficiency.

…hoping this presentation inspires you to take a few minutes to think about the physics of your next stubborn engineering problem and draw a FBD.