FIA Institute for Motor Sport Safety and Sustainability

Understanding the Factors Governing Motorsport Safety Fence Design Through DOE Techniques

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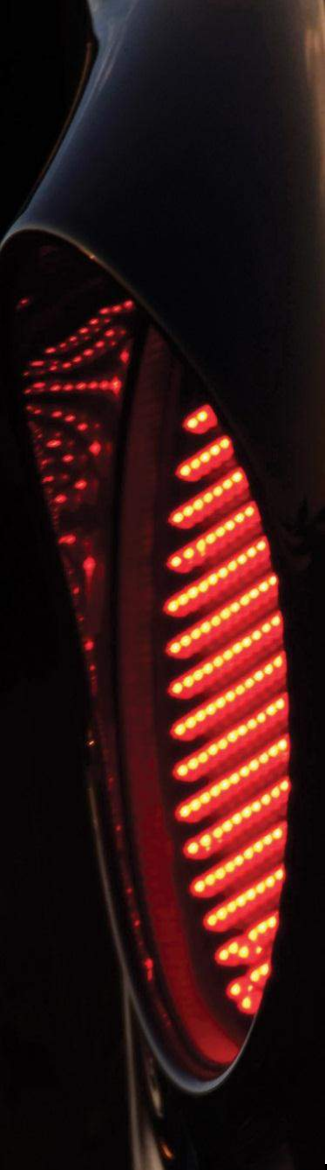


Introduction

- In recent years huge advances have been made in racing car design to improve safety

- Significant improvements have also been made in circuit design, one such improvement is the catch fence

- Catch fence design has significantly improved both driver and spectator safety

Project Drive

- Over the last few years there have been a number of incidents involving safety fencing that have led the FIA Institute to carryout extensive research into improving their design

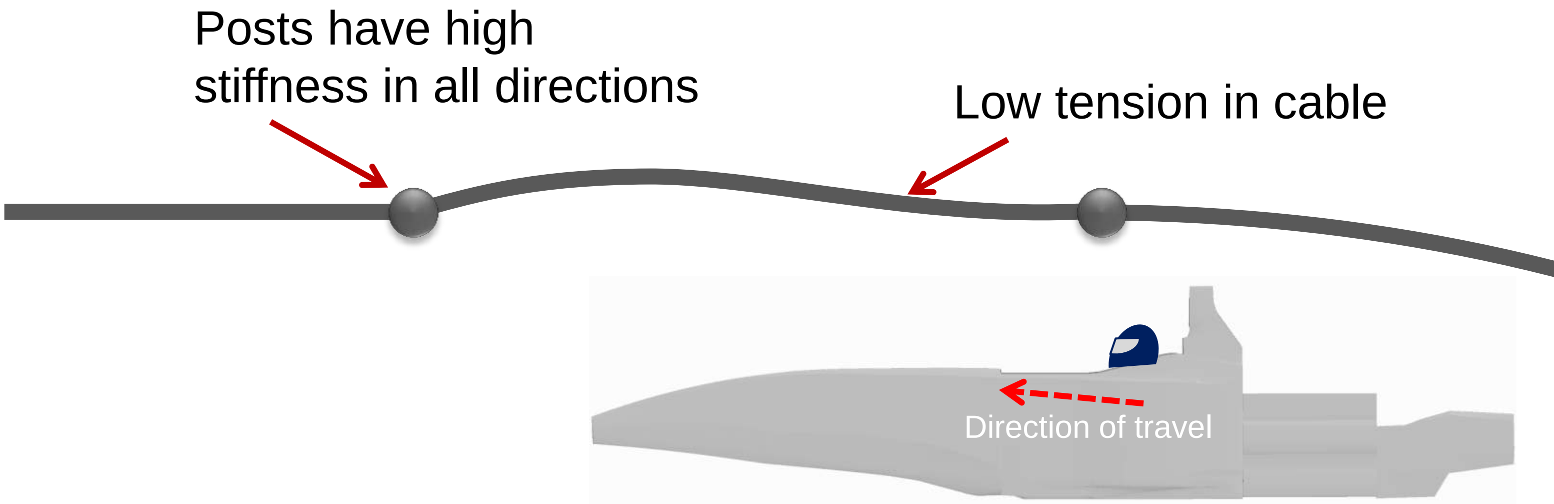
- Nascar – Daytona 2013, 33 spectators injured

- Dan Wheldon’s fatal crash at the IndyCar World Championships at Las Vegas Motor Speedway was one of the main focuses of this study

Dan Wheldon Crash

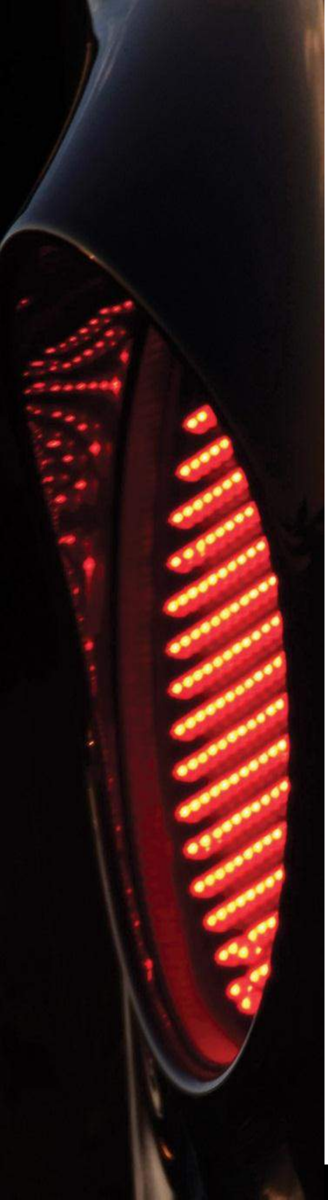
- 15 car incident at the Las Vegas Indy 500
- Wheldon impacted the rear of a car and launched into the air at 225mph
- Car flipped and impacted safety fence
- Wheldon’s helmet caught the fence pole, resulting in fatal head injuries

Dan Wheldon Crash



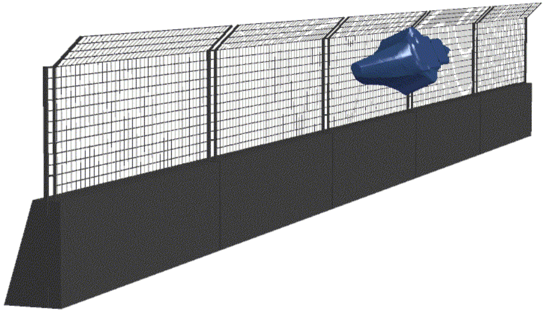
Study Purpose

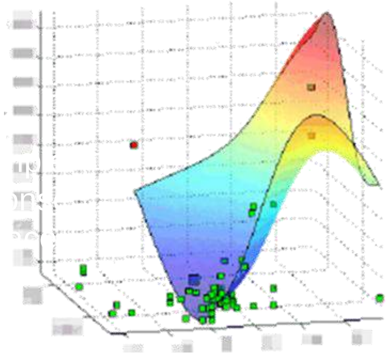
- Investigate the sensitivities involved in safety fence design
- What are the most important factors governing safety fence behaviour?
- Utilise design of experiment (DOE) techniques to gain a detailed understanding of fence design, with particular emphasis on cable installation



Understanding Fence Behaviour Through DOE

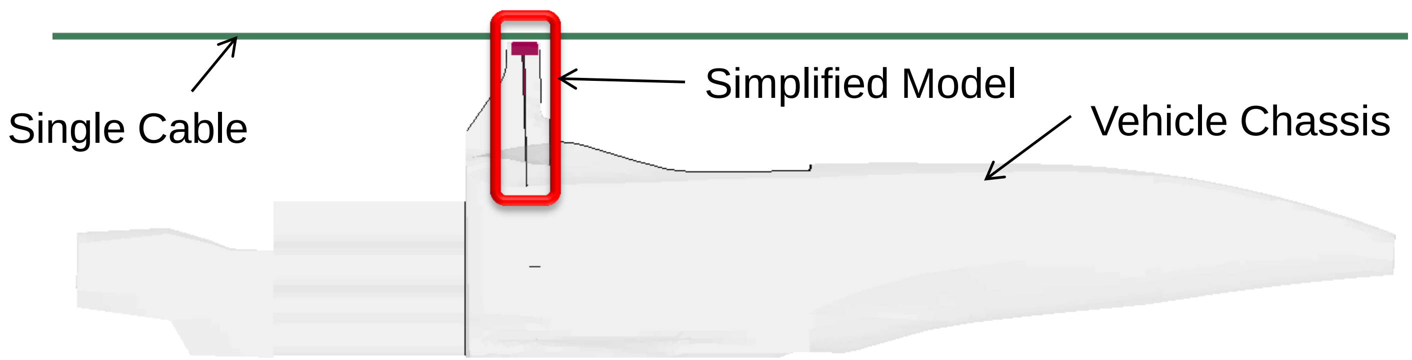
- A Design of Experiments (DOE) study allows assessment of the sensitivity of vehicle impact behaviour to various fence design parameters
- DOE can ‘quickly’ inform a user where to concentrate the majority of effort
- Given a number of input variables, a carefully distributed series of model analyses are carried out
- A mathematical model is built to describe the system’s entire response





Input FE Model

- A cut down model was created to replicate the effect of a full vehicle impacting a single cable of a fencing system
  - The reduced model provided much faster solve times, allowing a large DOE study to be carried out
  - Still provided detailed cable to roll-hoop contact and correct vehicle inertia



DOE Parameters

- For the purpose of this project the following parameters were variable in the DOE study:
  - Cable Diameter
  - Cable Pre-tension
  - Velocity normal to fence
  - Post position

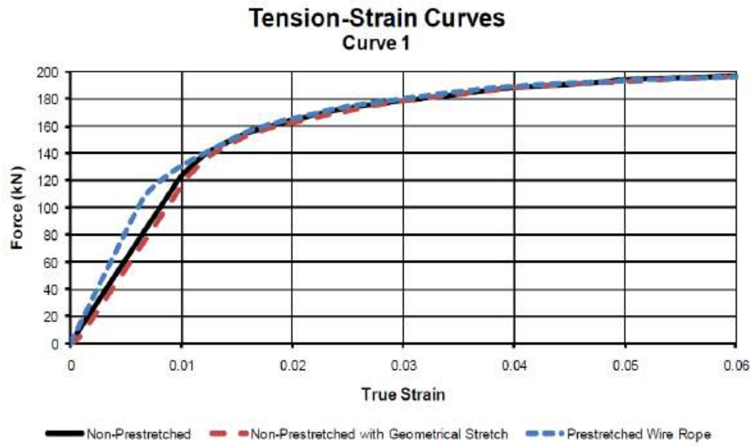
TENSILE GRADE 1770N/MM2
7 x 19 Wire Strand Core
A similar rope to 6x19 but the Fibre Core is replaced by a wire strand
resulting in less flexibility but a slightly higher breaking strain and better resisance to crushing

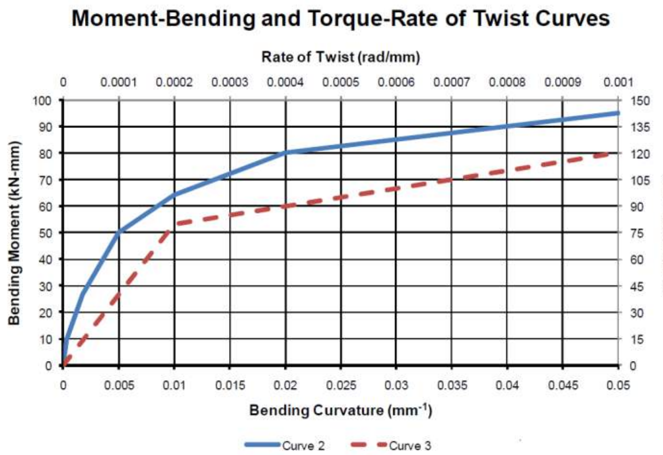
Size Diameter	Approximate Mass	Minimum Breaking Load	Approximate SWL
mm	kg/100M (Weight)	Tonnes	kgs FOS 5:1
2	1.49	0.24	48
2.5	2.4	0.37	74
3	3.43	0.54	108
4	6.1	0.96	192
5	9.53	1.50	300
6	13.7	2.16	432
7	19.5	3.15	630
8	25.5	4.11	822
9	32.2	5.2	1.0
10	39.8	6.42	1.2
11	48.2	7.77	1.5
12	57.3	9.25	1.85
13	67.3	10.8	2.16
14	78	12.6	2.5
16	102	16.4	3.2
18	129	20.8	4.1
19	144	23.1	4.6
20	159	25.7	5.1
22	193	31.1	6.2
24	229	37	7.4
26	269	43.4	8.6
28	312	50.4	10.00
32	408	65.7	13.1

- The following parameters were fixed:
  - Velocity parallel to fence
  - Roll-hoop shape
  - Cable material

Cable modelling

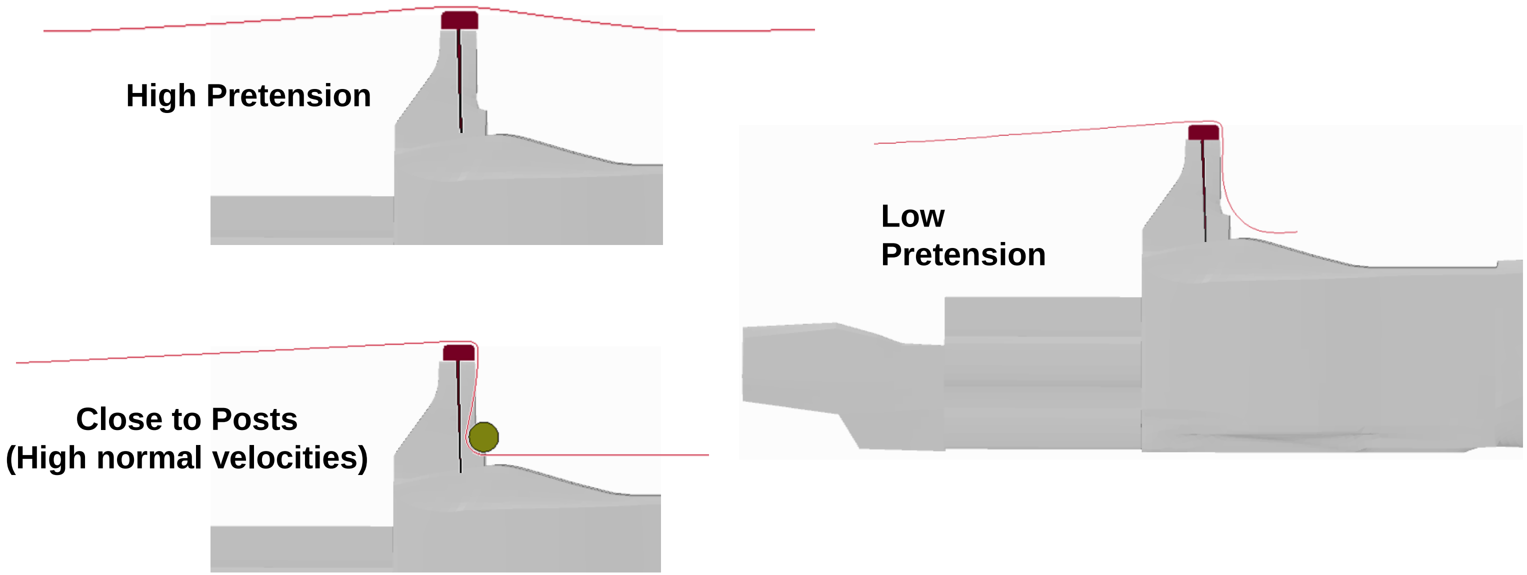
- Accurate material data for cable modelling was very limited
- A correlated cable model was found published at the 11th International LS-Dyna Users Conference (2010) by Cody S. Stolle and John D. Reid
  - The below material curves were correlated in cable impact testing:





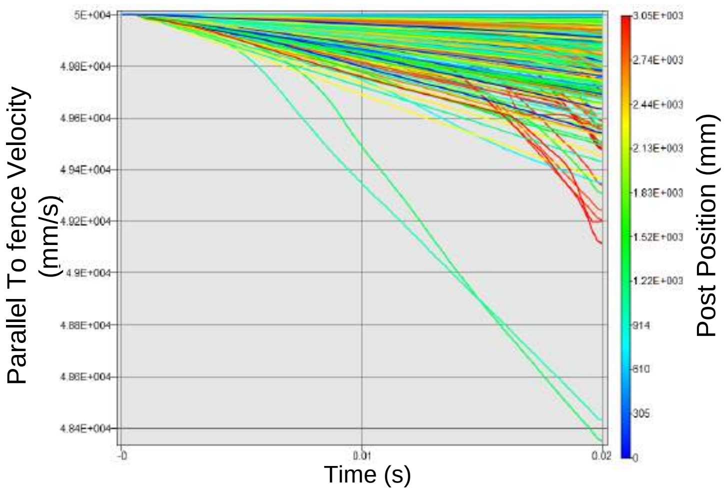
Possible Behaviours

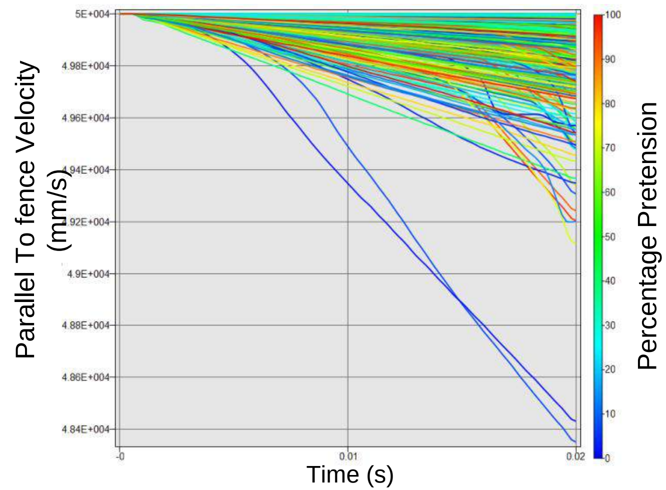
- Initial studies showed some of the possible behaviours that could occur during an impact

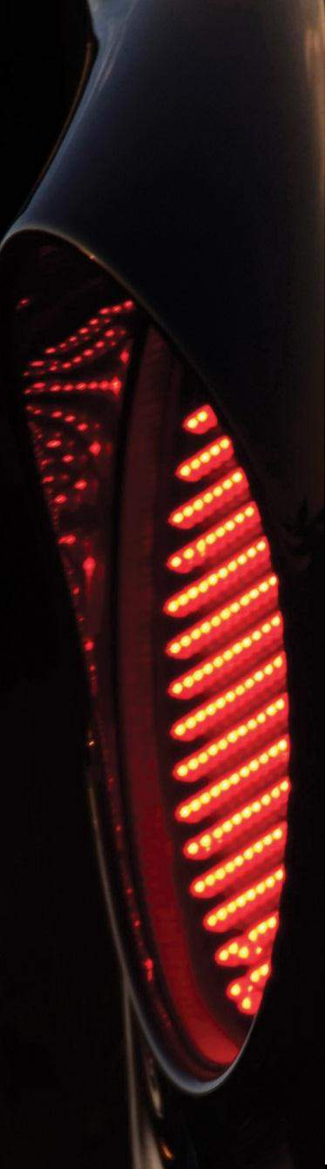


Simulation Plots

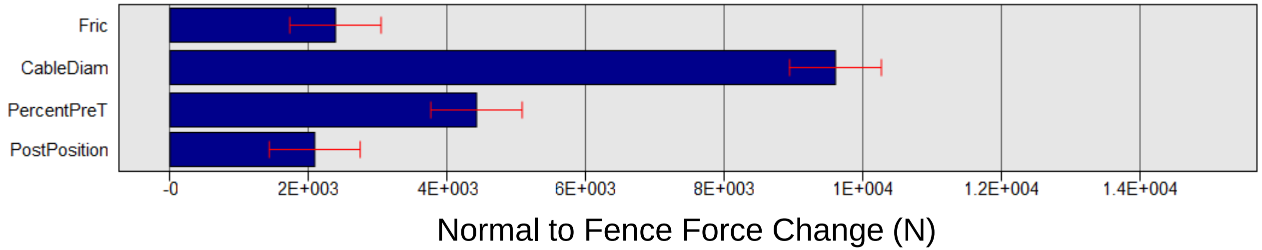
- Over 600 simulation runs were included in the DOE, below are the velocity/time graphs for each run
- The gradient change is due to one of two situations:
  - The posts cause a rapid deceleration when approaching the post
  - Low pretension values causing a ‘ruffling’ effect

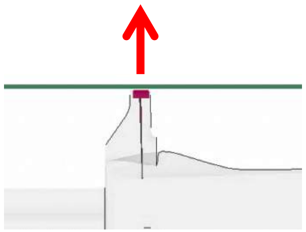


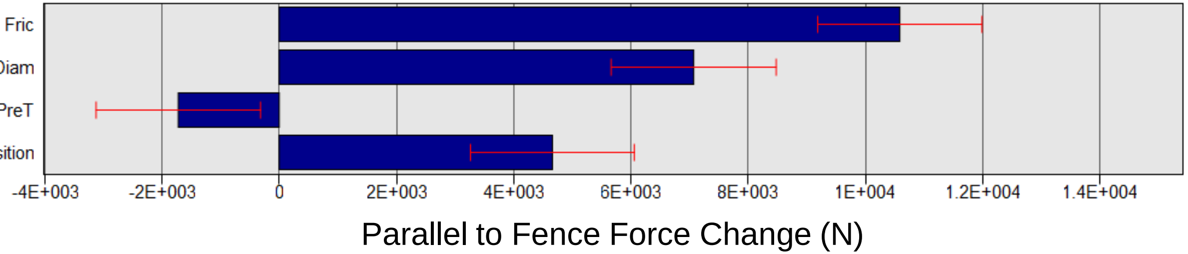


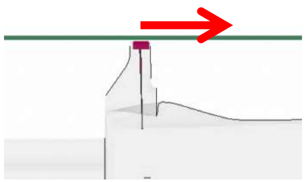


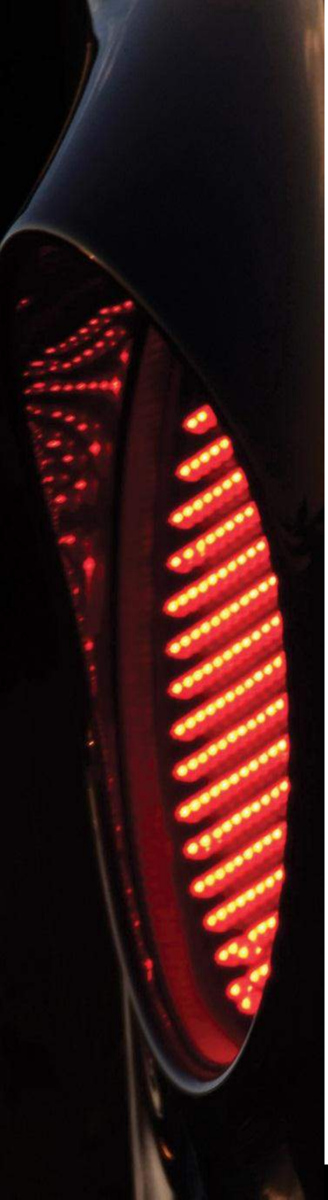
Sensitivity Results





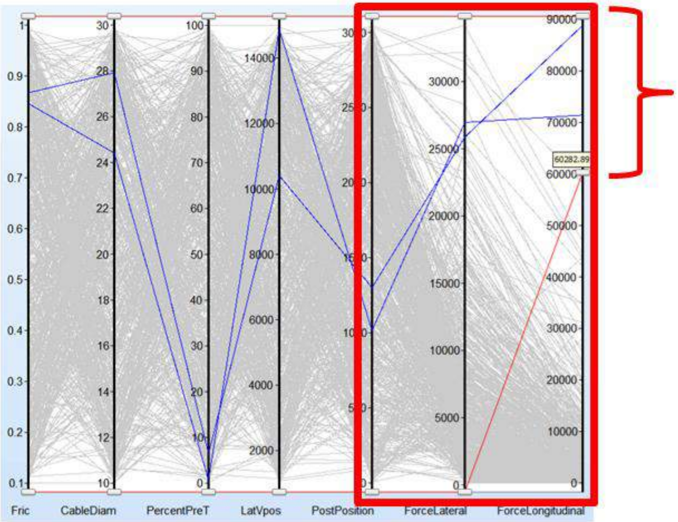






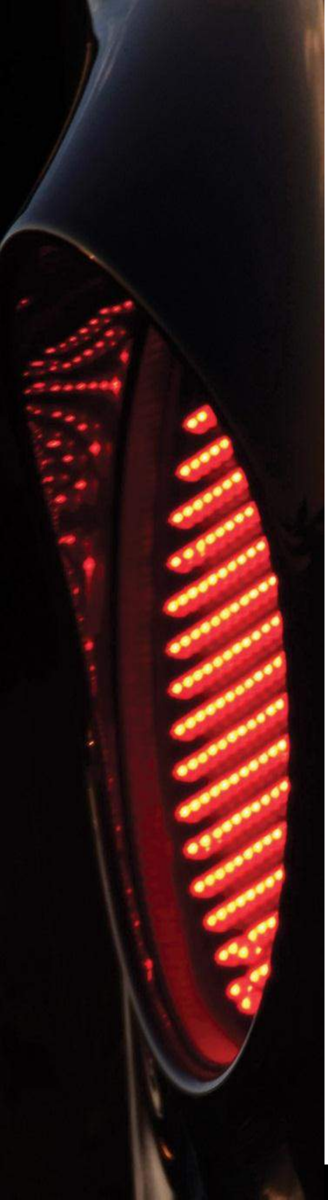
Force Ranges

- Plot shows force ranges possible within allowable cable properties
  - When compared with the FIA regulations (max. longitudinal 60kN, roll hoop vertical 90kN), there are a small number of combinations that will exceed the longitudinal limit
  - High friction/cable diameter, low pretension, at high lateral velocities



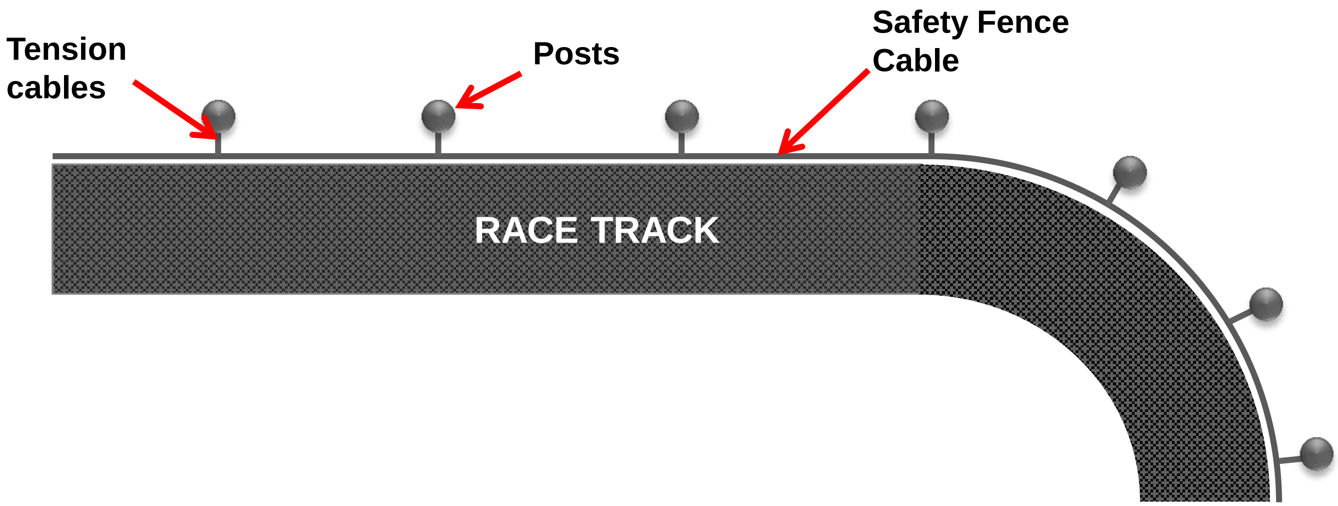
Optimum Parameters

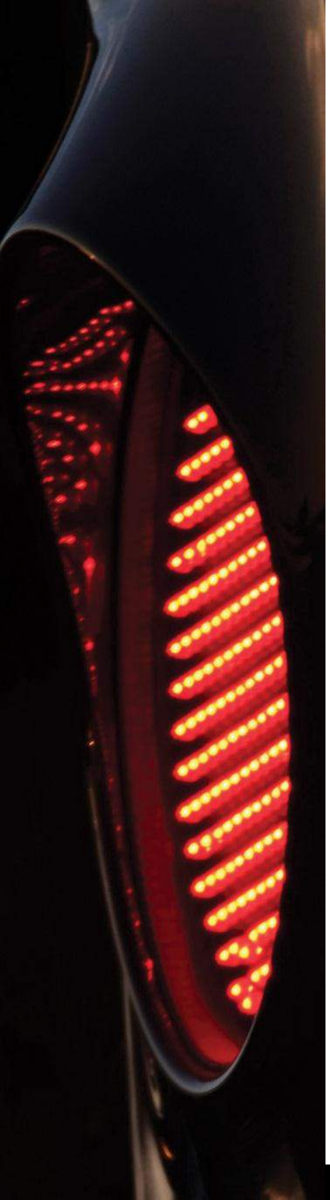
- Safety Fence Objective
  - Return vehicle to track as quickly as possible
  - Reduce parallel to fence force and therefore likelihood of ‘ruffling’
  - Reduce intrusion into fence and therefore interaction with posts
- Optimising the DOE results to maximise normal to fence (restoring driver to track) force and minimise parallel to fence (likelihood of tumbling) force provides:
  - Friction Coefficient – 0.15
  - Cable Diameter – 27.7mm
  - Cable Pretension – 99.3%



Potential Future Design Solutions

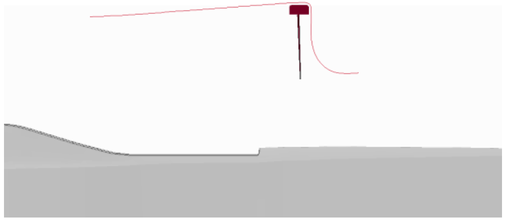
- Offset the posts away from the fence to reduce likelihood of vehicle impacting them
- Tension cables maintain shape of the safety fence

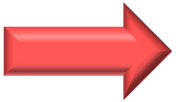


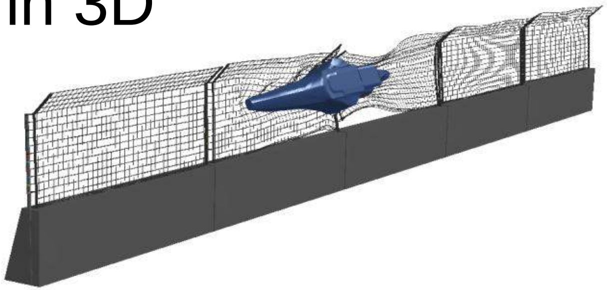


Future Studies

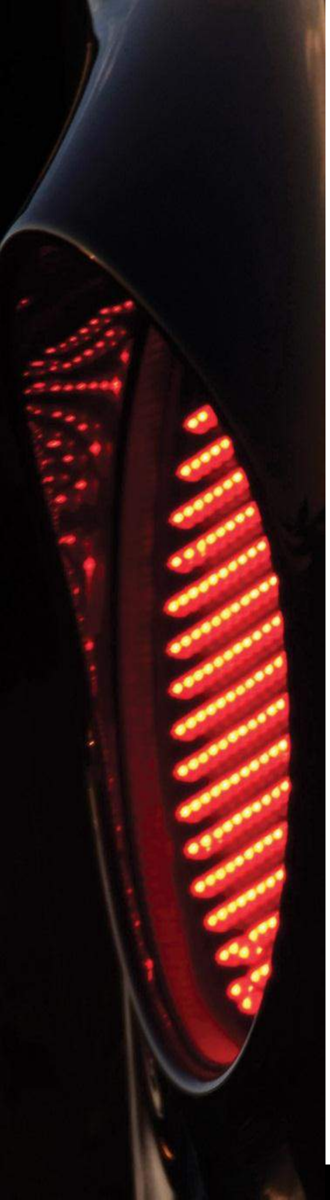
- Investigate impact effect in 3D







- Further investigations into post positions/designs
  - Offset posts
  - Collapsible posts

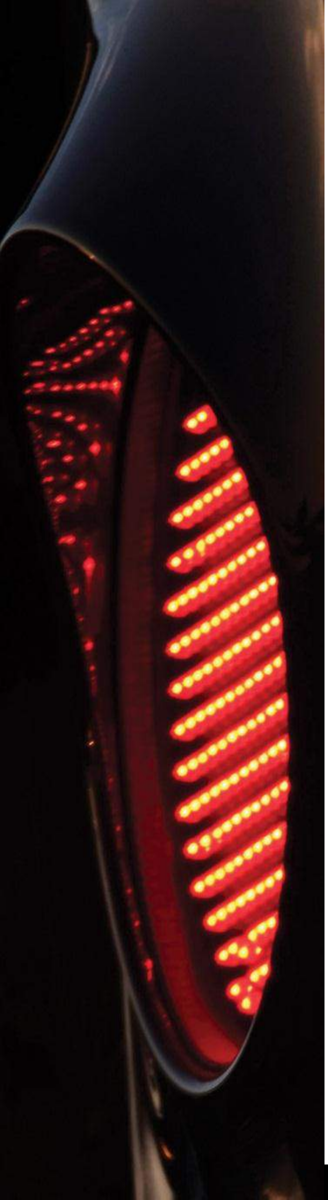


Conclusions

- Current safety fence designs have significantly reduced both spectator and driver injuries, however further improvements can be made

- The DOE techniques used provided a clear insight into the sensitivities involved in fence design

- Further studies are required to implement new designs to continue the improvement in safety



Any Questions?

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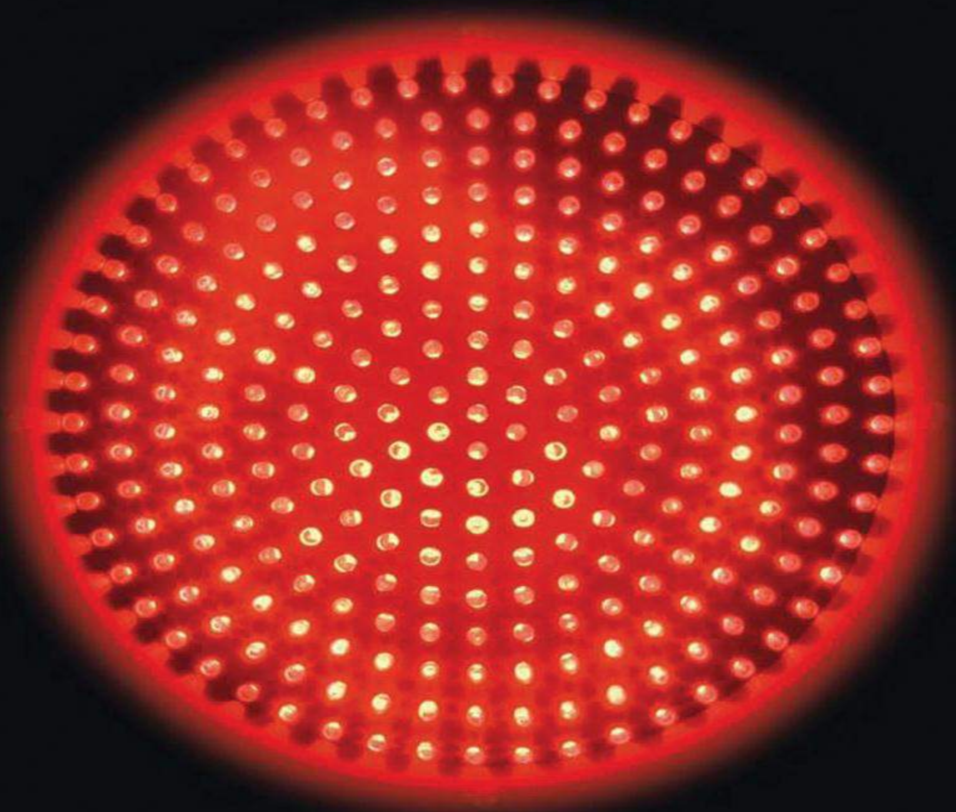

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