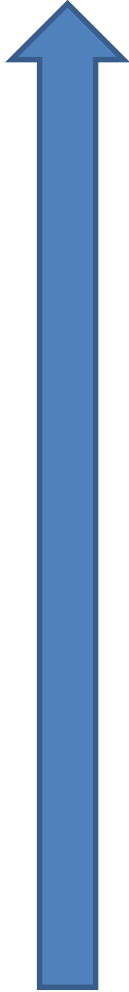


Vehicle Dynamic Testing and Design for Formula SAE

Sid Attravanam, Cooper Tire & Rubber Company



About Me



2014-Present



2013-2014



2008-2012



Ex-FSAE



Vehicle Dynamic Testing

Vehicle Dynamic Testing

Vehicle Testing – Why?



Reliability?



Handling

Image Credits –

1. http://e1.985dm.com/16/10/16-3/20/F1-carbon-fiber-hamilton-conclusions-headphones_3799985.jpg?20161003071813
2. <https://1.wimg.com/vi/SMTkT110dZ7max/default.jpg>

What is Handling?

A brief history of Handling.....

20th Century



21st Century

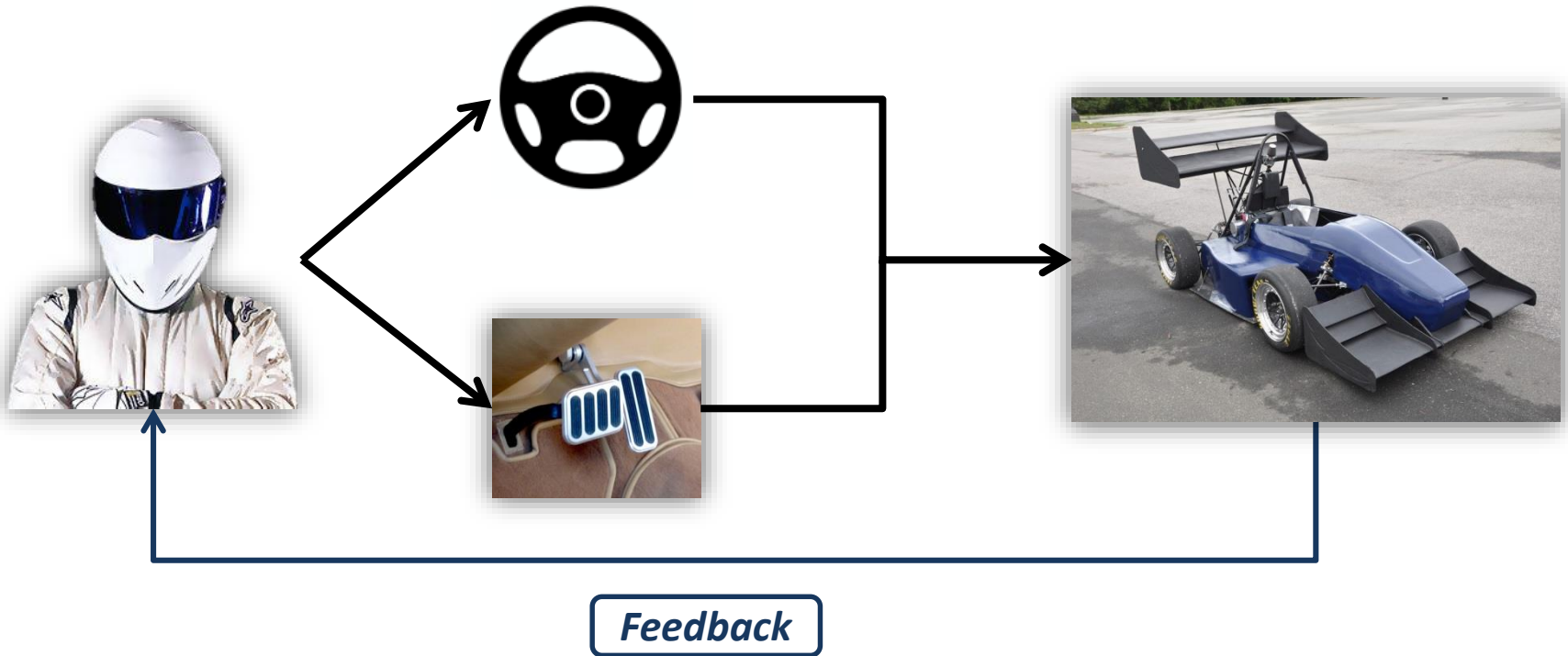


With decades of development, driver still operates vehicle with steering wheel, brake and throttle pedal

Image Credits –

1. <http://www.poptons.com/wp-content/uploads/2013/11/1954-Mercedes-Formula-1-Race-Car1.jpg>
2. http://1.bp.blogspot.com/_35u6T0R1CW/TA8HmouDUUAAAAAAAAAAM089DcwhGACw/s1600/DSC_0002.JPG

What is Handling?



Handling – Interaction between driver and vehicle

Image Credits –

1. <https://www.avtoforum.net/wp-content/uploads/2014/11/steering-180-81784x.jpg>
2. http://A.bp.blogspot.com/_3DnA10K1T0U/TA8vKnu1D6I/AAAAAAAAAM0/B3DhwGACw/s1600/DSC_0002.JPG

Vehicle Evaluation - Subjective



“This car doesn’t
turn **properly**”

“Doesn’t **feel right**”

“I like **this** one”

“Shakes **too much**”

Hard to make engineering decisions



Image Credits –

1. http://www.cosplayland.co.uk/files/costumes/1468/47213/tumblr_lh4wpr571gdtsfeo1_500_thumb.jpg
2. http://4.bp.blogspot.com/_3DnM0x1T0k/1s6v1evLD6I/AAAAAAAAAM0/B31DhwGACw/s1600/DSC_0002.JPG

Flowchart

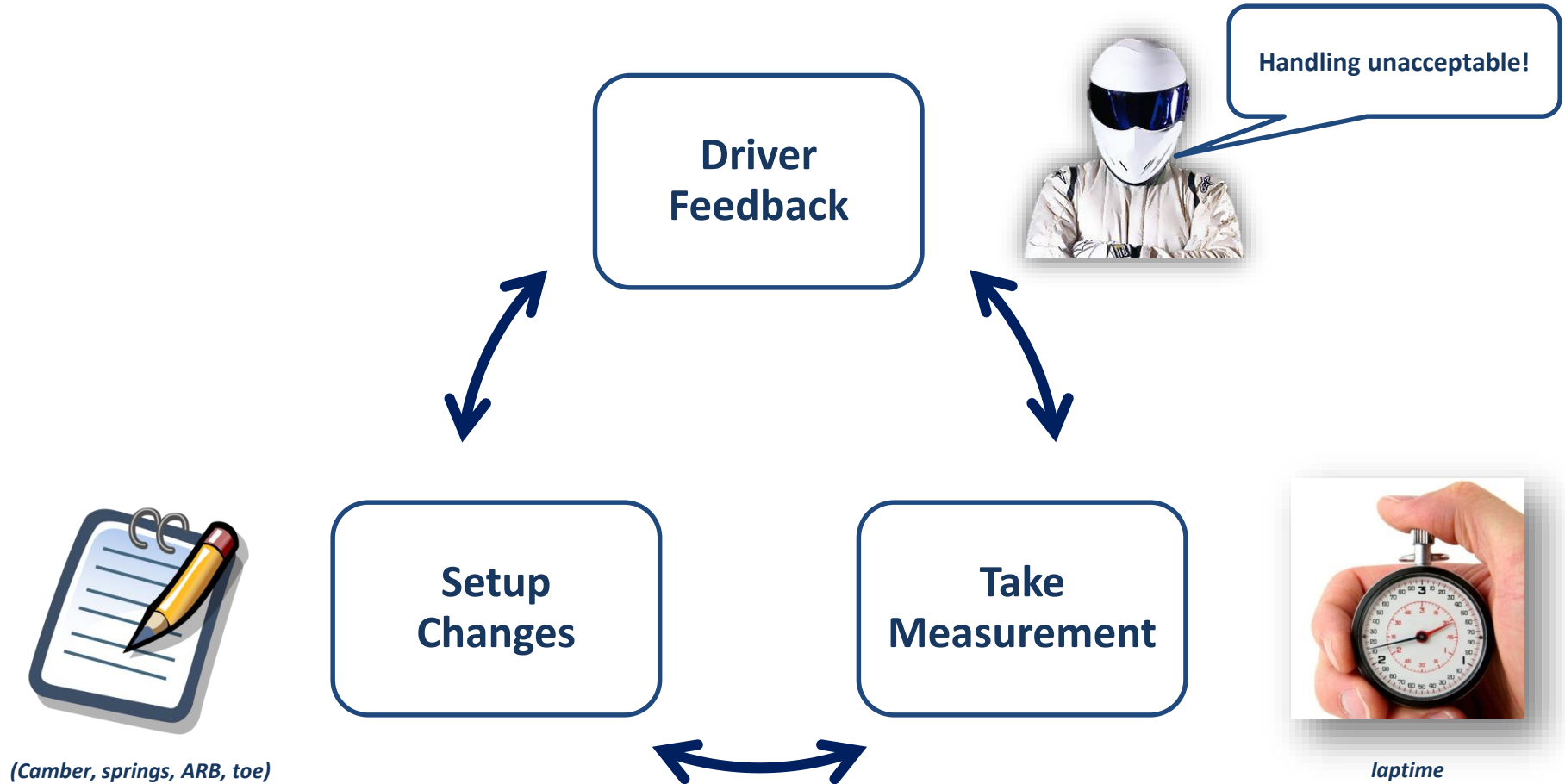
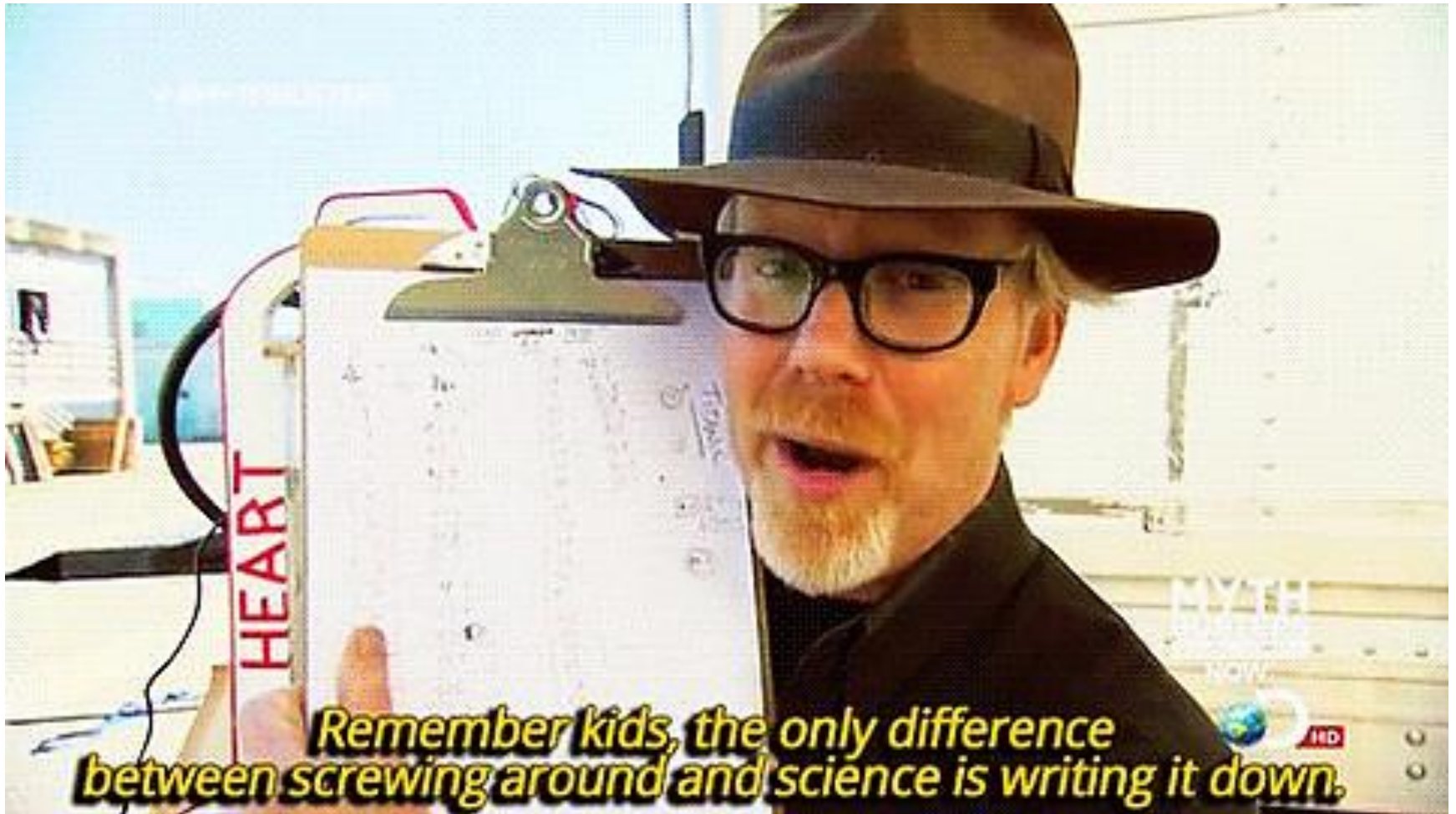


Image Credits –

1. https://www.avtoforum.net/wp-content/uploads/2014/11/eng-180_81784a.jpg
2. <https://blog.shareaholic.com/wp-content/uploads/2014/10/1000000000.jpg>

Savage Says!



Handling Testing

Handling Testing!

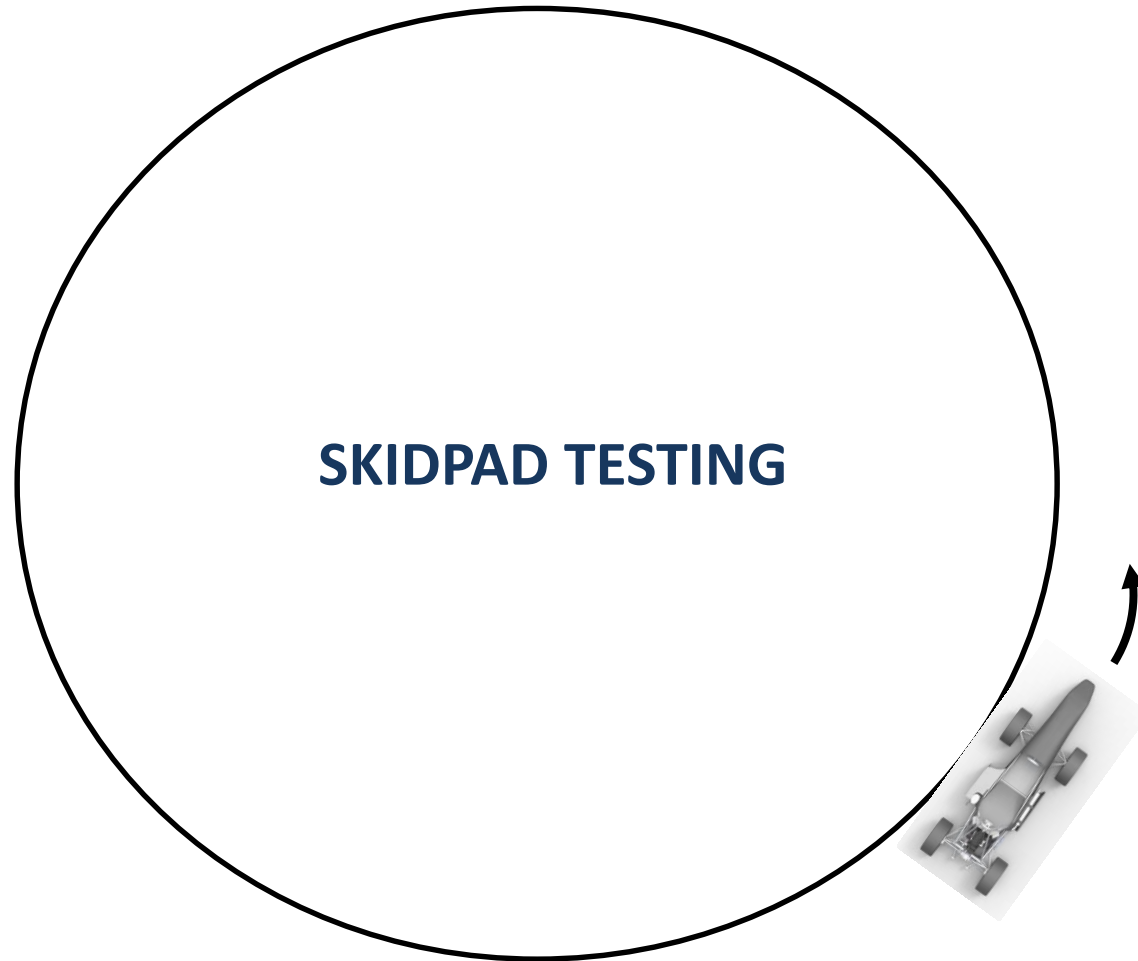


Image Credits –

1. <http://www.racecar-engineering.com/wp-content/uploads/2013/08/trac-view.jpg>

Handling Testing - Skidpad

SAE J266

(Steady-State Directional Control Tests)

3

Constant Speed

Constant Steering Angle

Constant Radius

Max Lateral Acceleration

Understeer Gradient

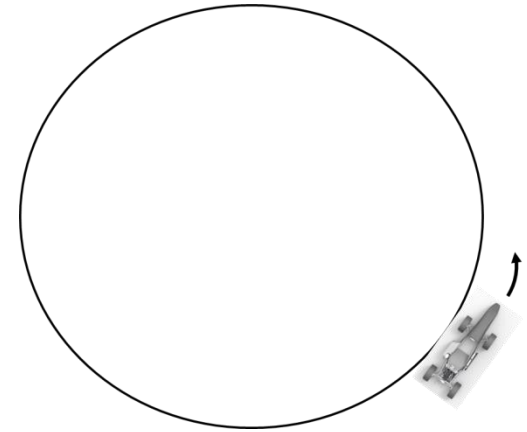
Skidpad Testing

Start at low speed

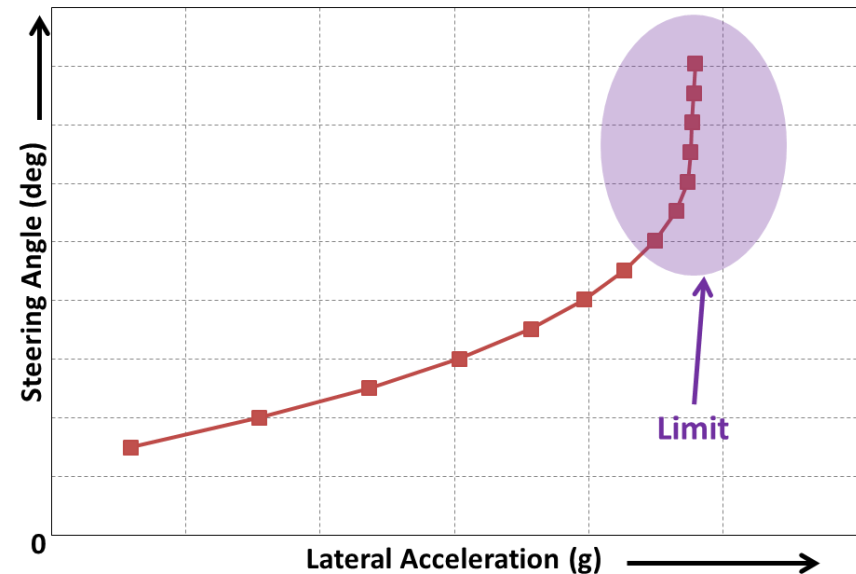
Slowly increasing speeds till
limit

Log steering angle (input)

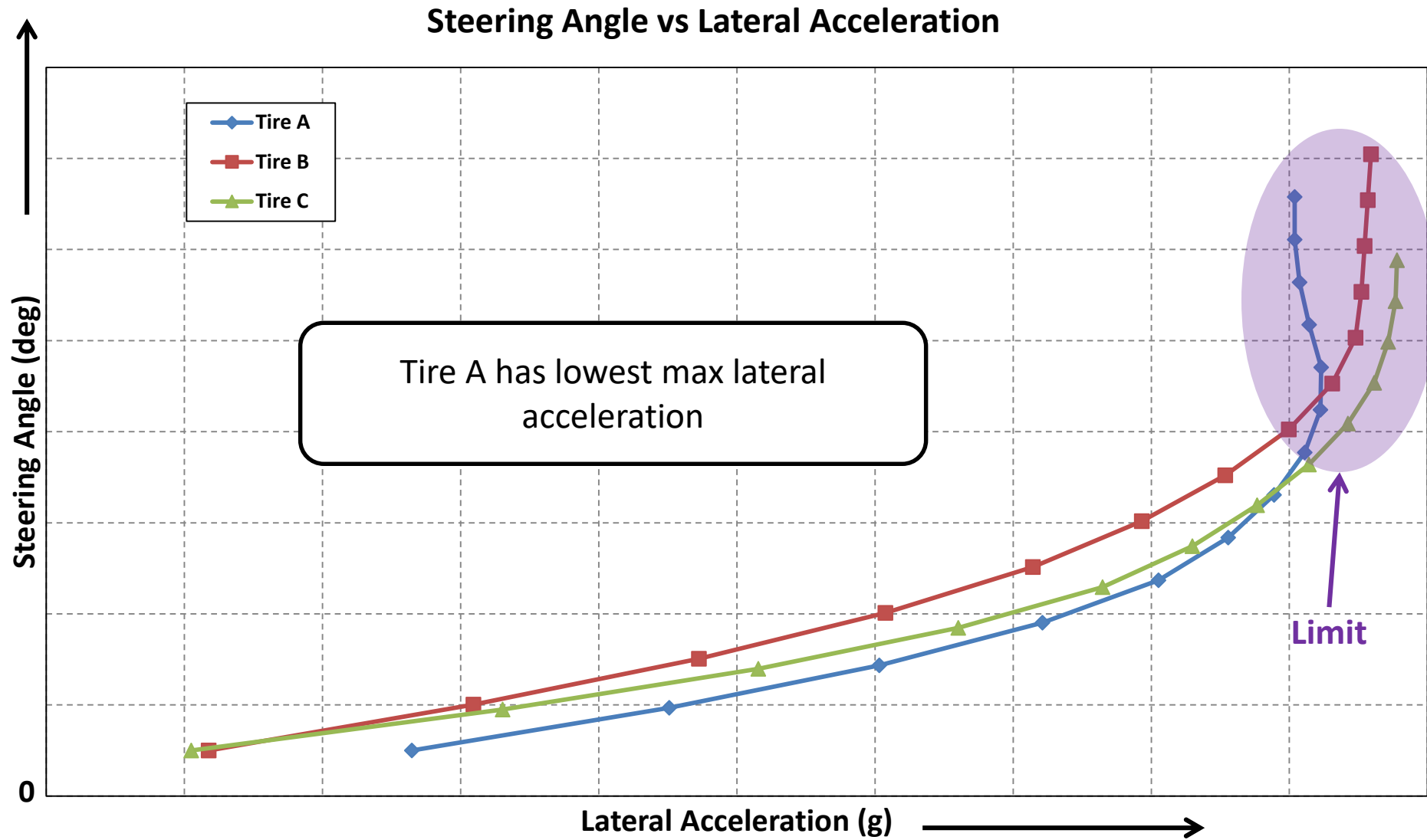
Log speed/yaw rate/lateral
acceleration (output)



Steering Angle vs Lateral Acceleration



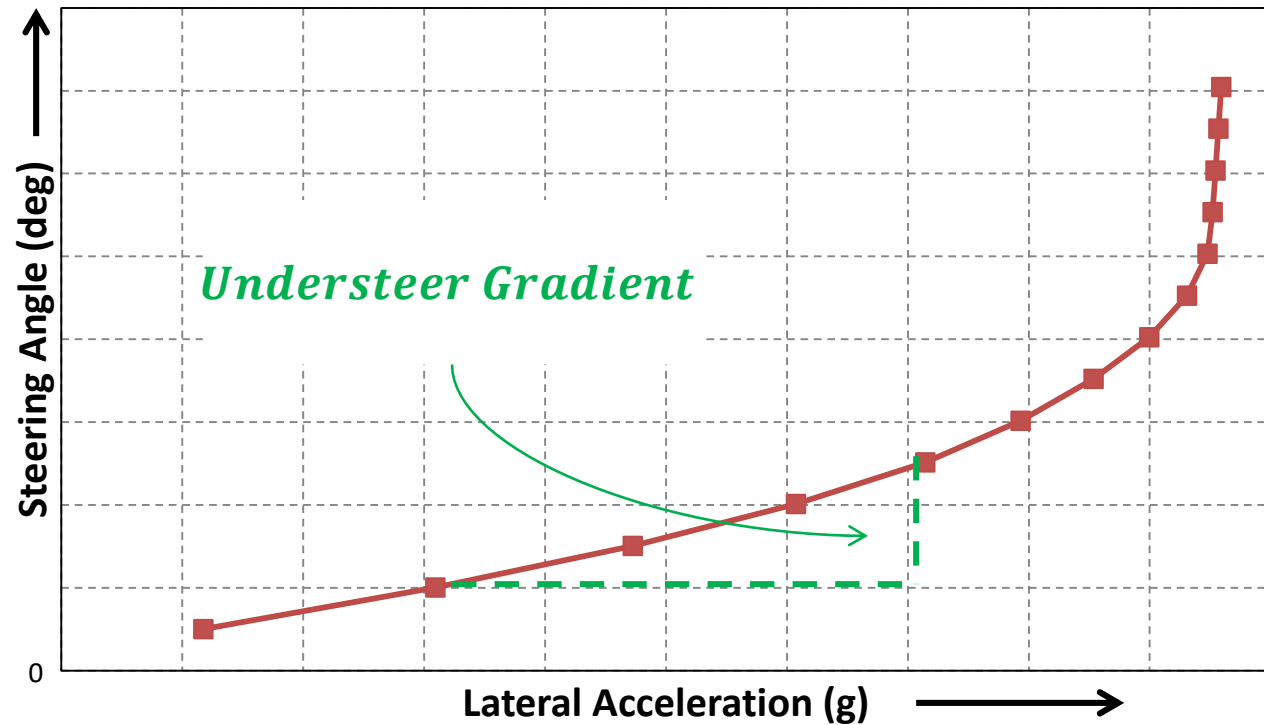
Skidpad Data



Understeer Gradient??

$$\text{Understeer Gradient} = \frac{d\delta}{da_y}$$

Steering Angle vs Lateral Acceleration

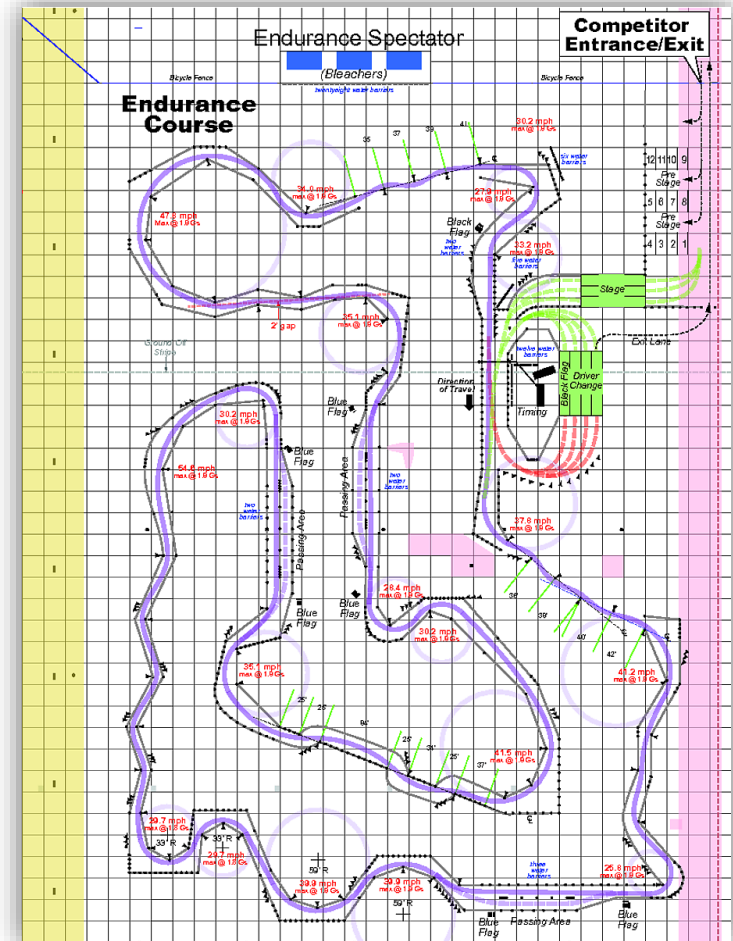


At the Limit?

>70% Turning Maneuver

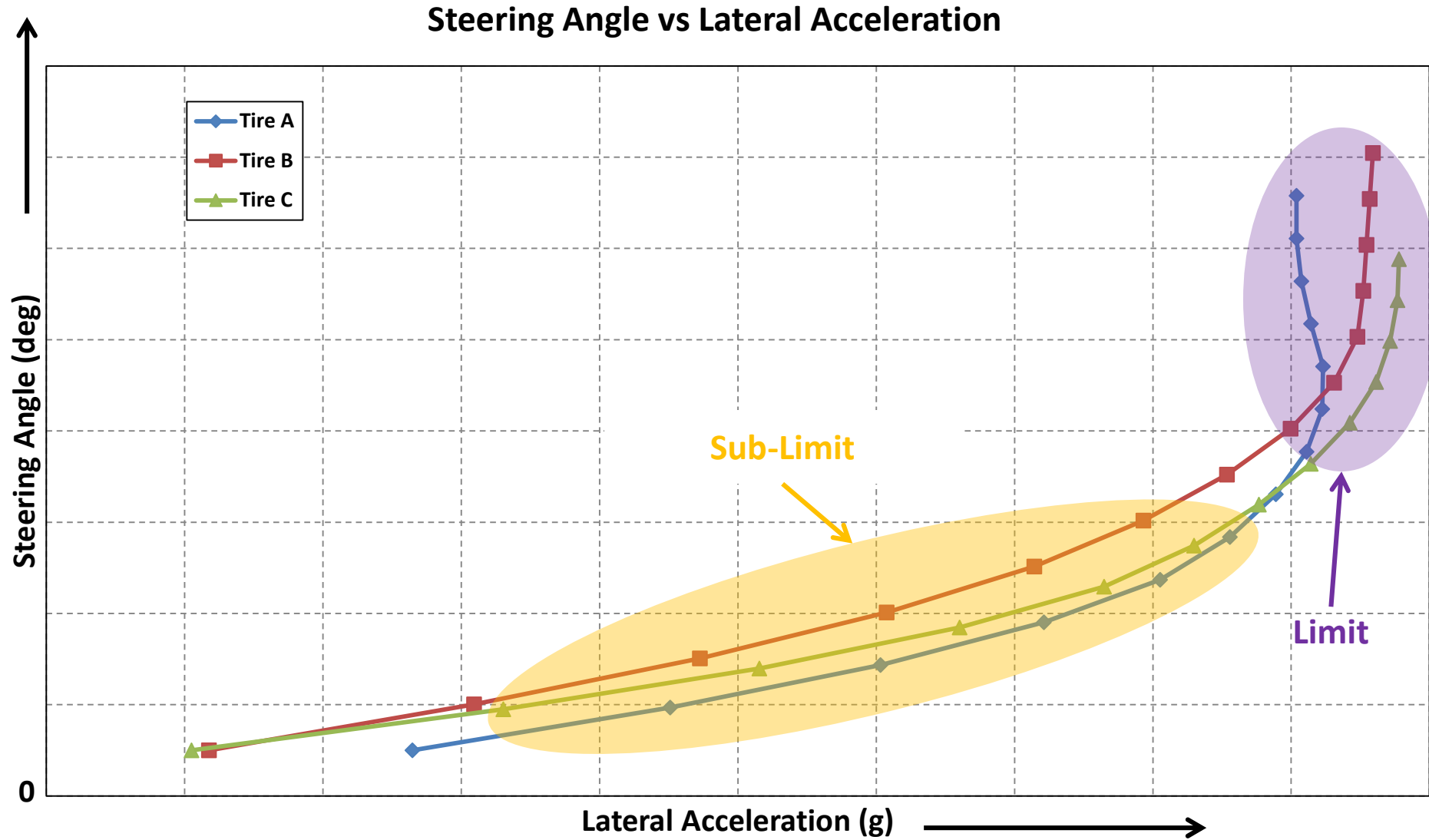
Max Lateral G – How fast can you go?

Understeer Gradient – How do you get to Max Lateral G?

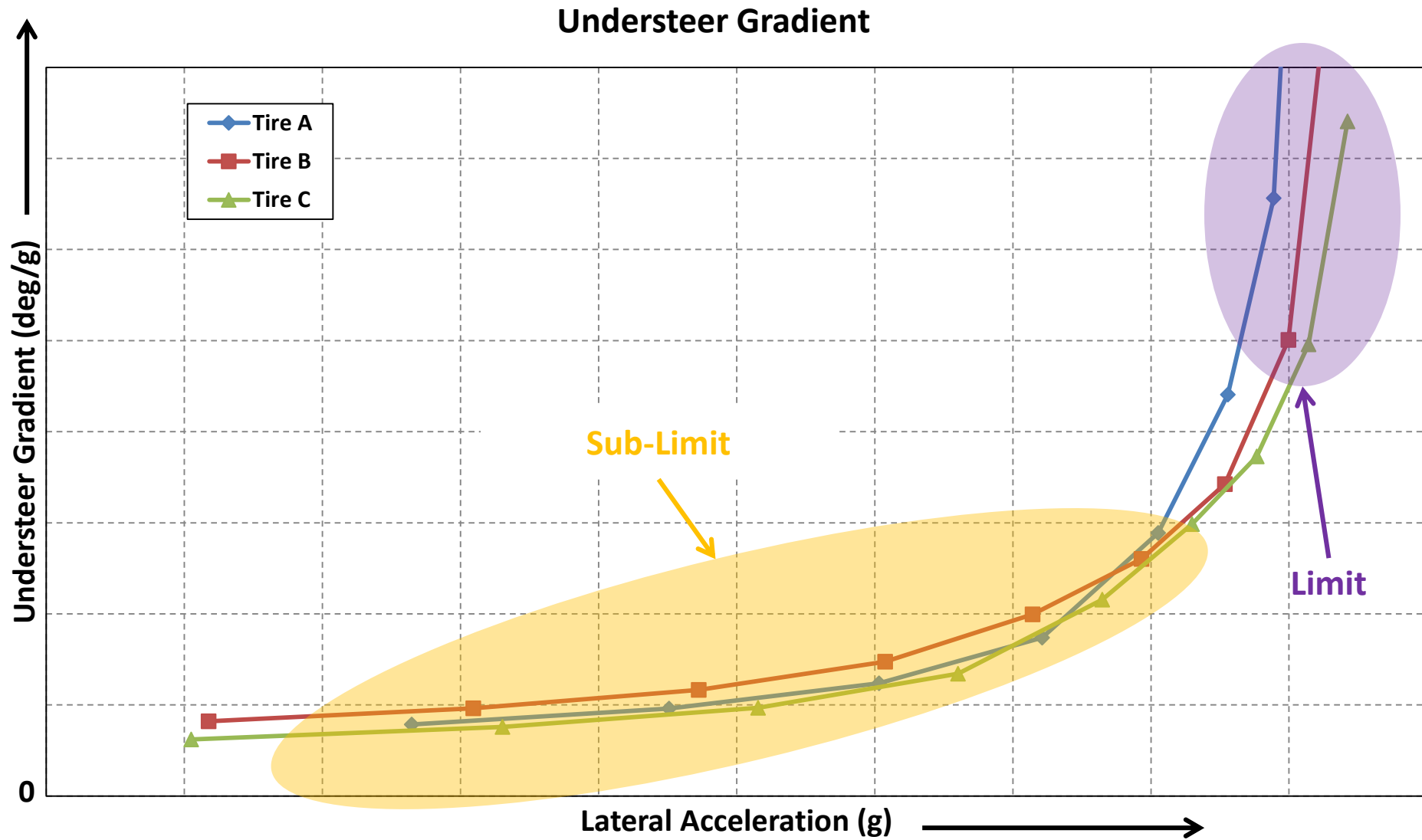


2013 FSAE Lincoln Endurance

Skidpad Data



Understeer Gradient

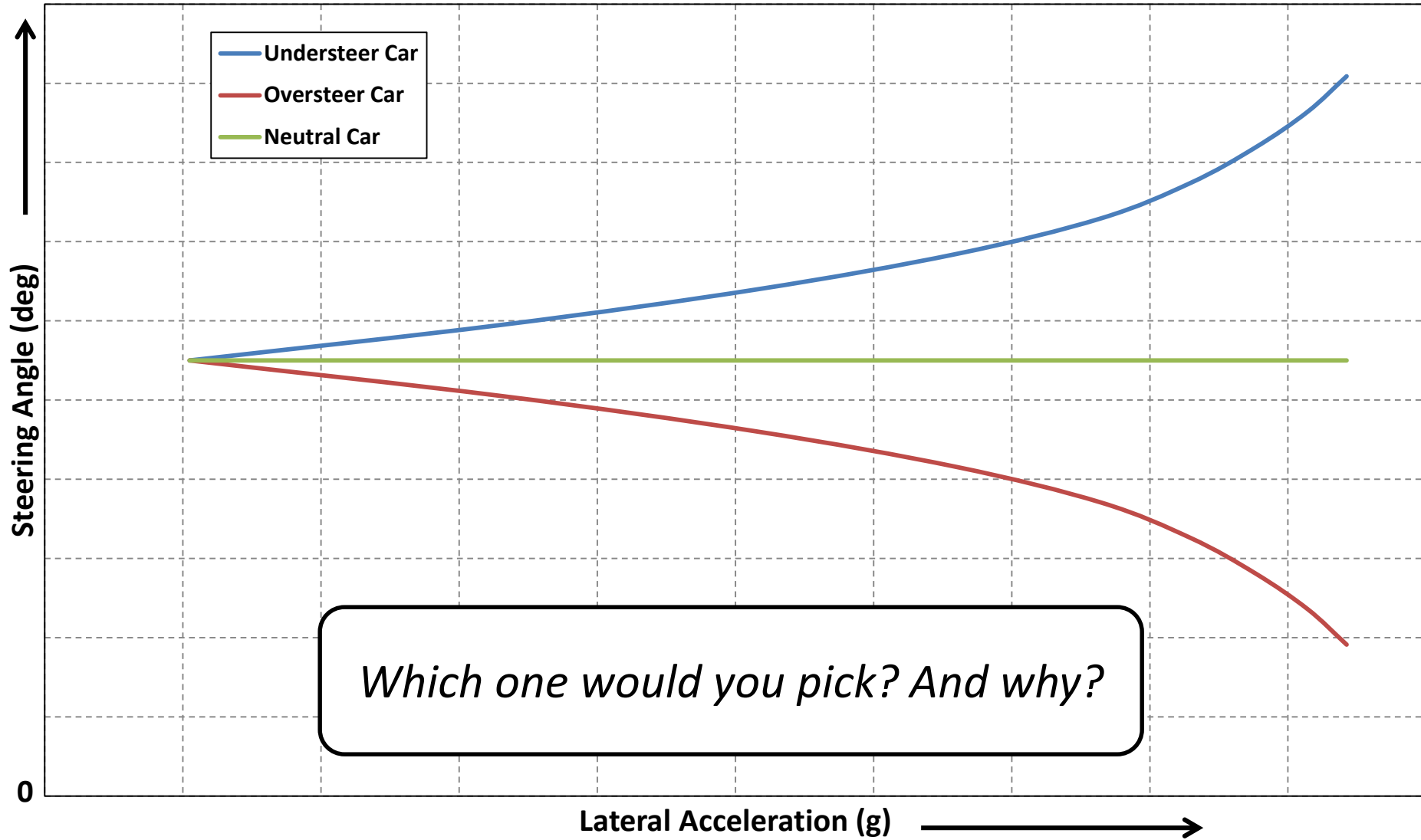




LIFE'S A ROAD TRIP. COME ON, LET'S GO.™

QUIZ TIME!

Choose your Steer



Feedback for Handling

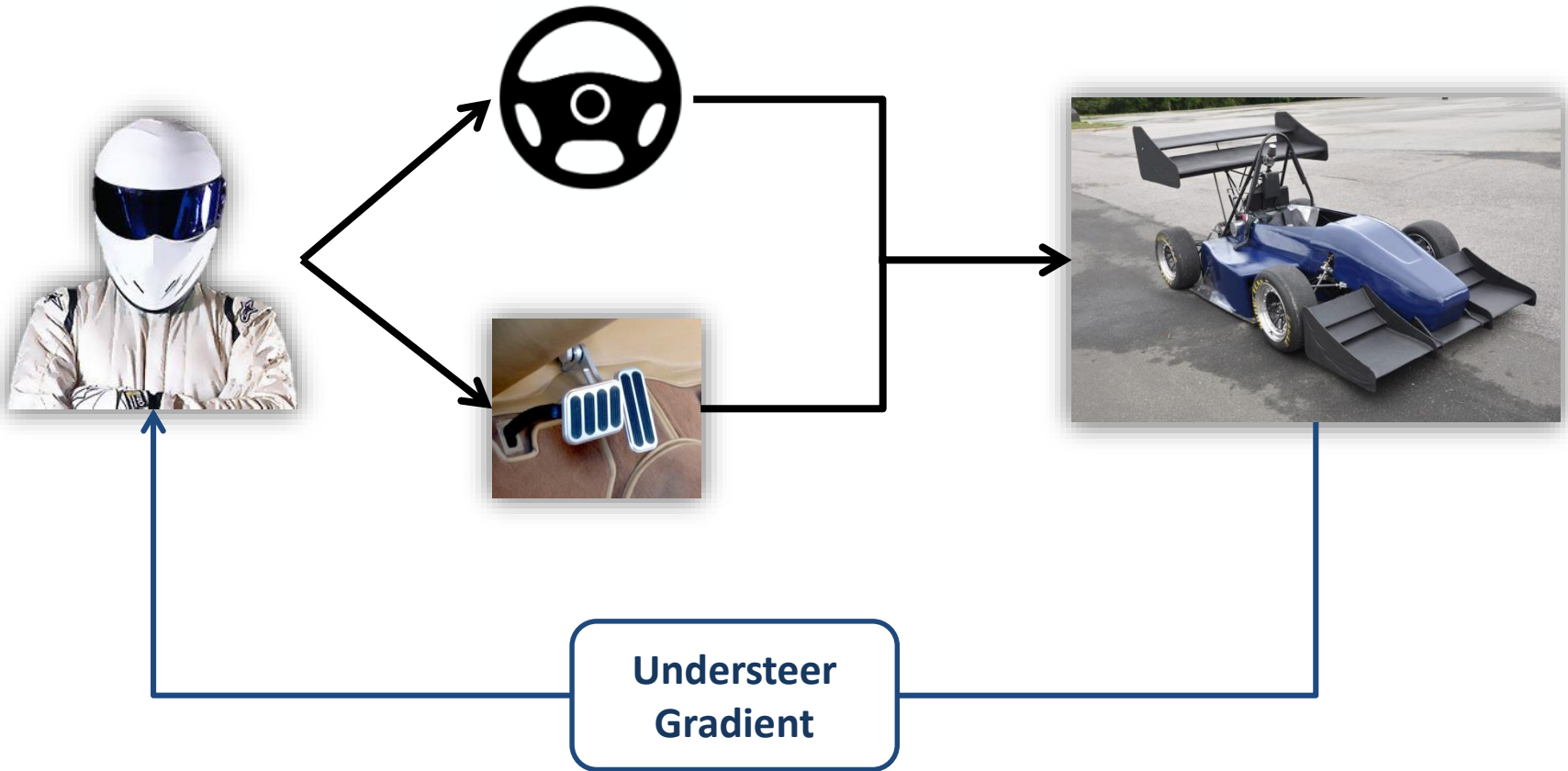
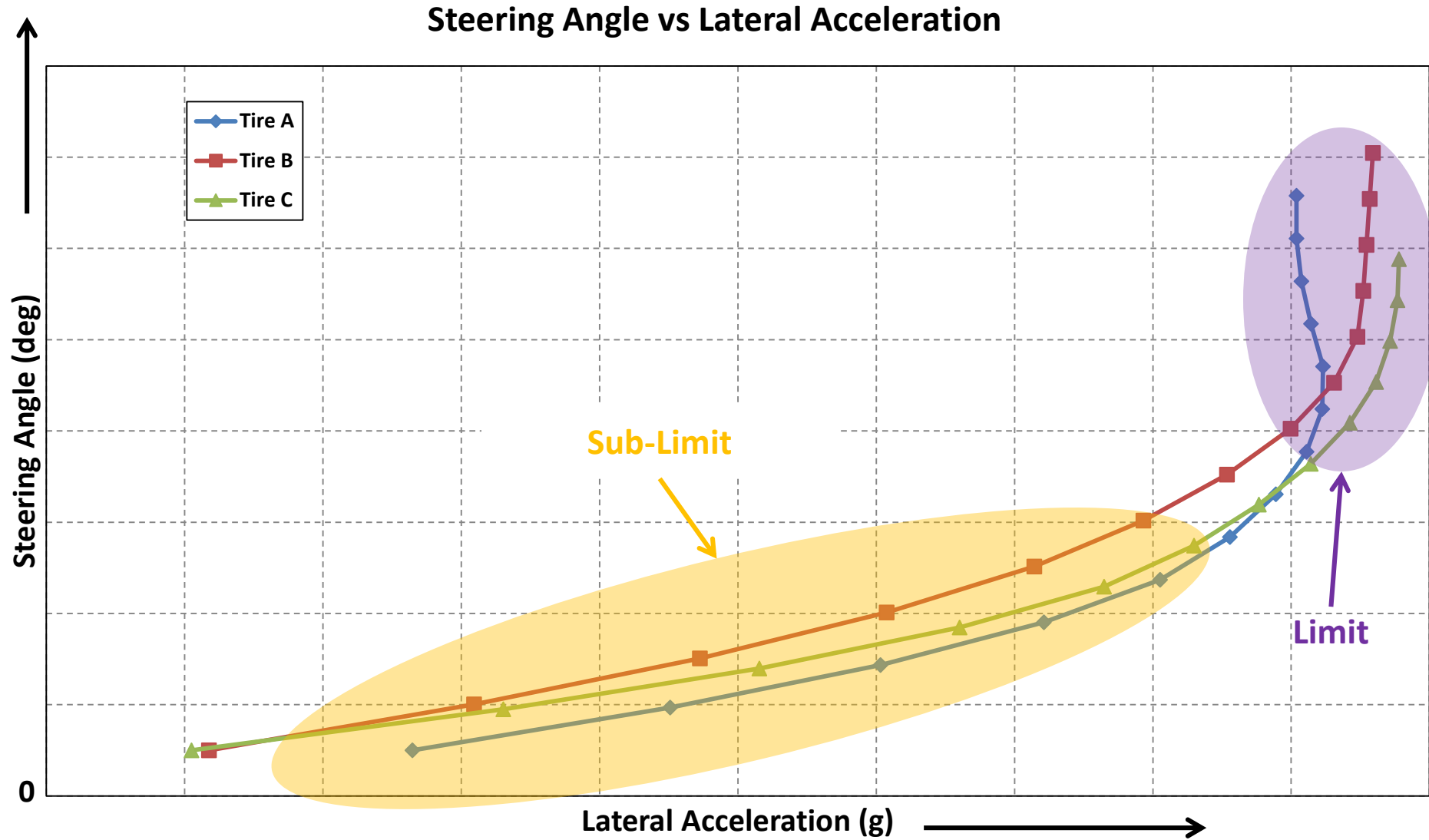


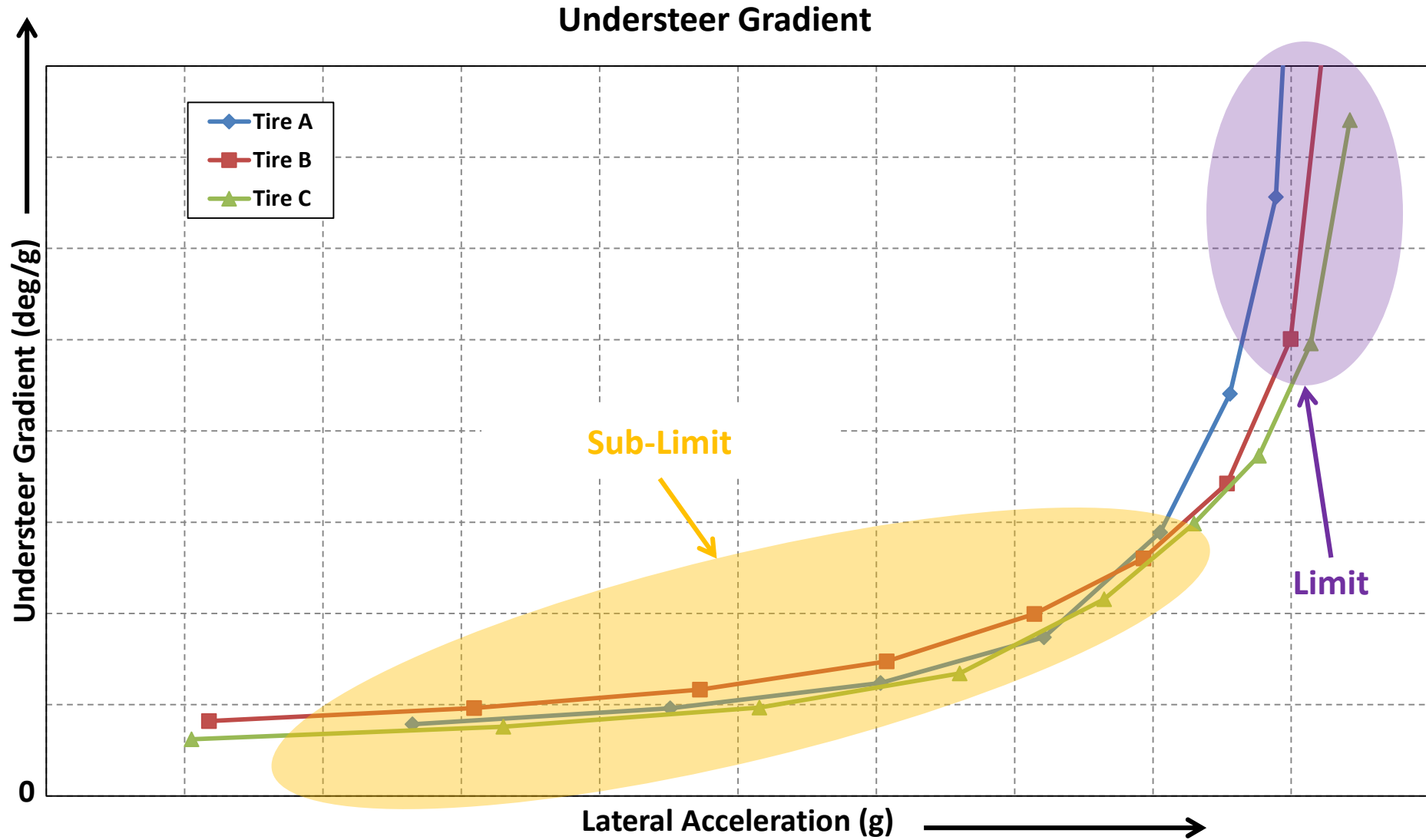
Image Credits –

1. https://www.avtoforum.net/attachment.php?attachmentid=2014711&req=587_81784x.jpg
2. http://A.bp.blogspot.com/_3DnA10K1T0k/1s8v1knuLDEI/AAAAAAAAAM0/B3DhwGACw/s1600/DSC_0002.JPG

Skidpad Data

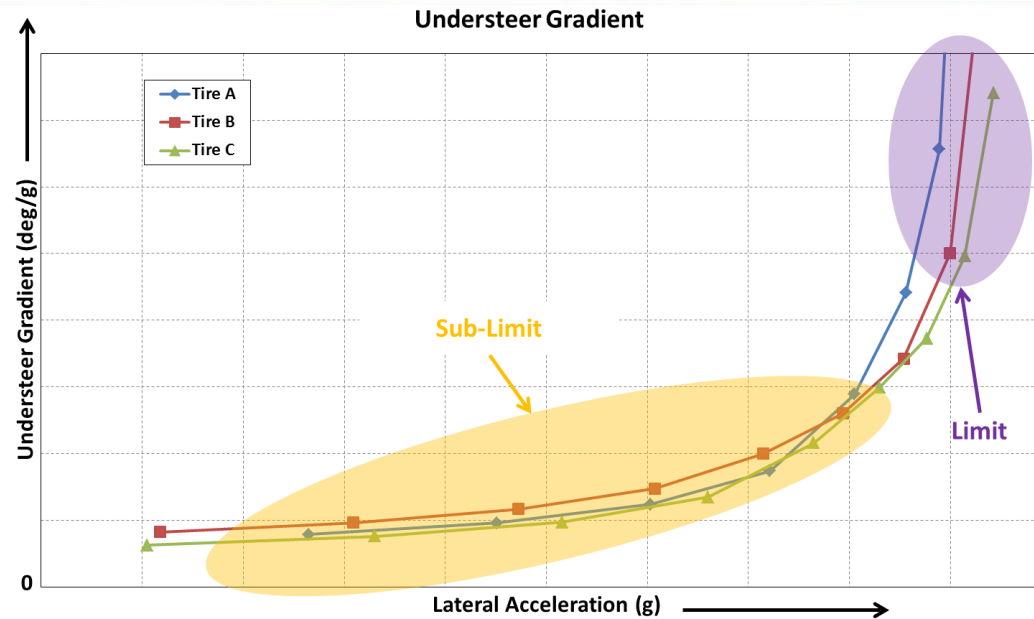


Understeer Gradient



Driver Comments

Tire C has most grip
Tire A better in low
lateral g but understeers
close to limit



Driver Ranking

Peak Grip

1. Tire C
2. Tire B
3. Tire A

Limit Understeer

1. Tire C, Tire B
2. Tire A

Sub-Limit Understeer

1. Tire C, Tire B, Tire A

Driver Comments to Understeer Gradient

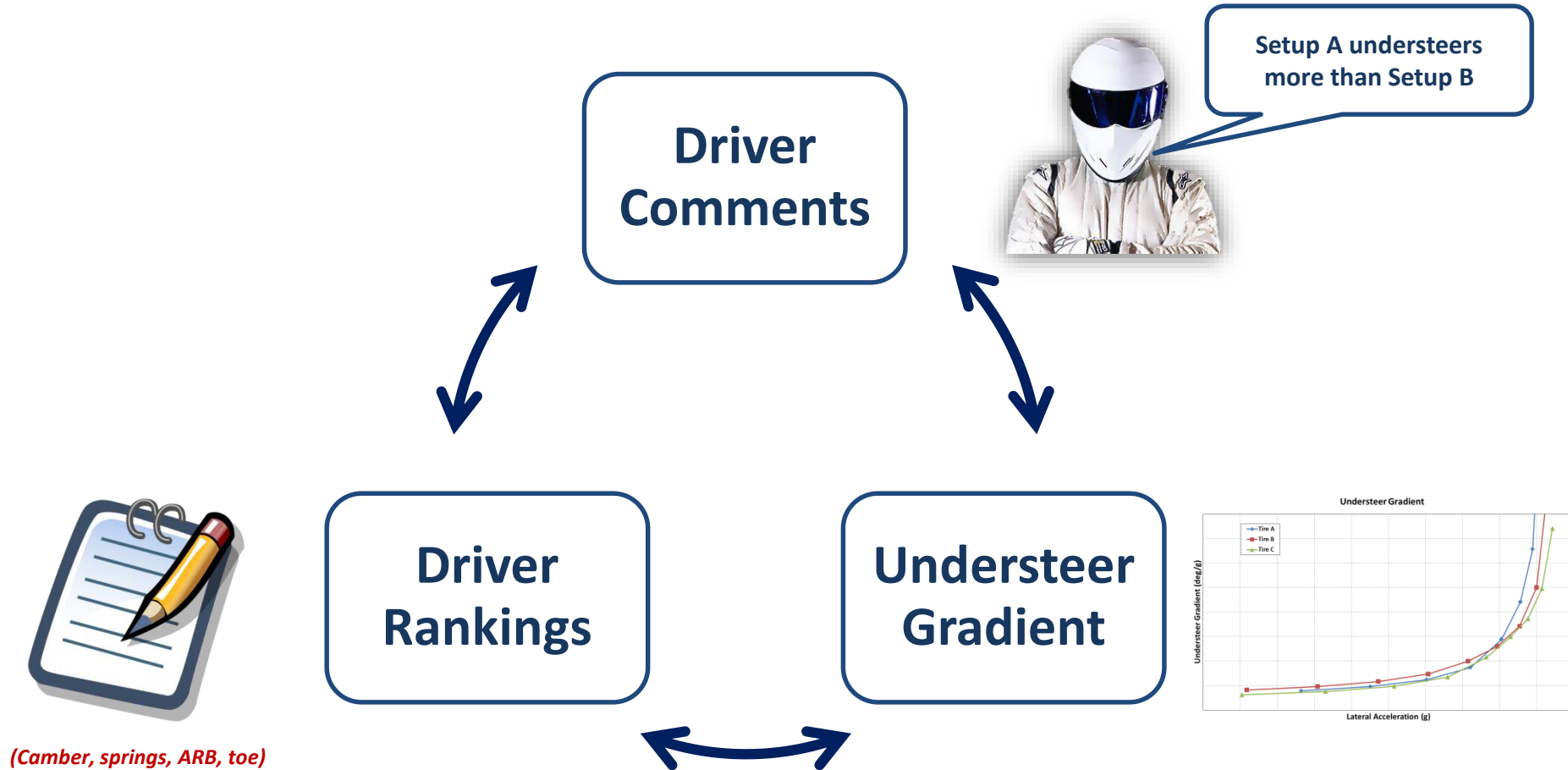


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2. <https://blog.shareaholic.com/wp-content/uploads/2014/10/1000000000.jpg>

Tire F&M Data

Tire Data from Tire Test Consortium

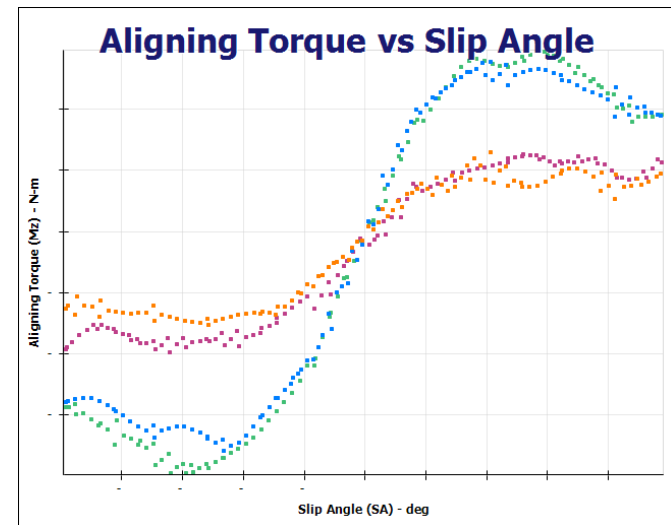
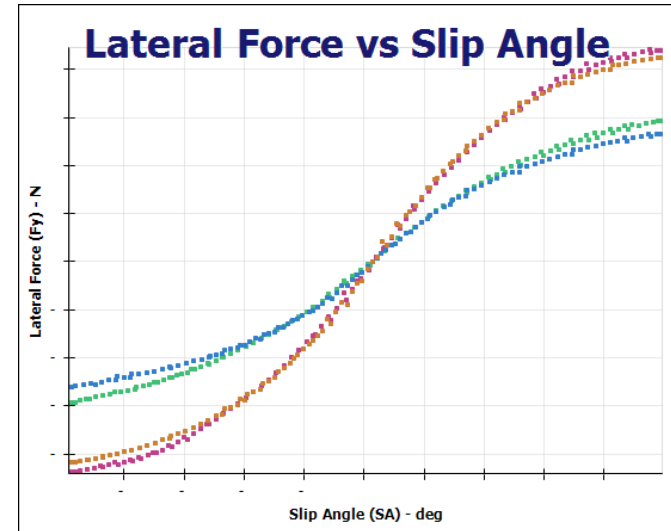
7

rounds

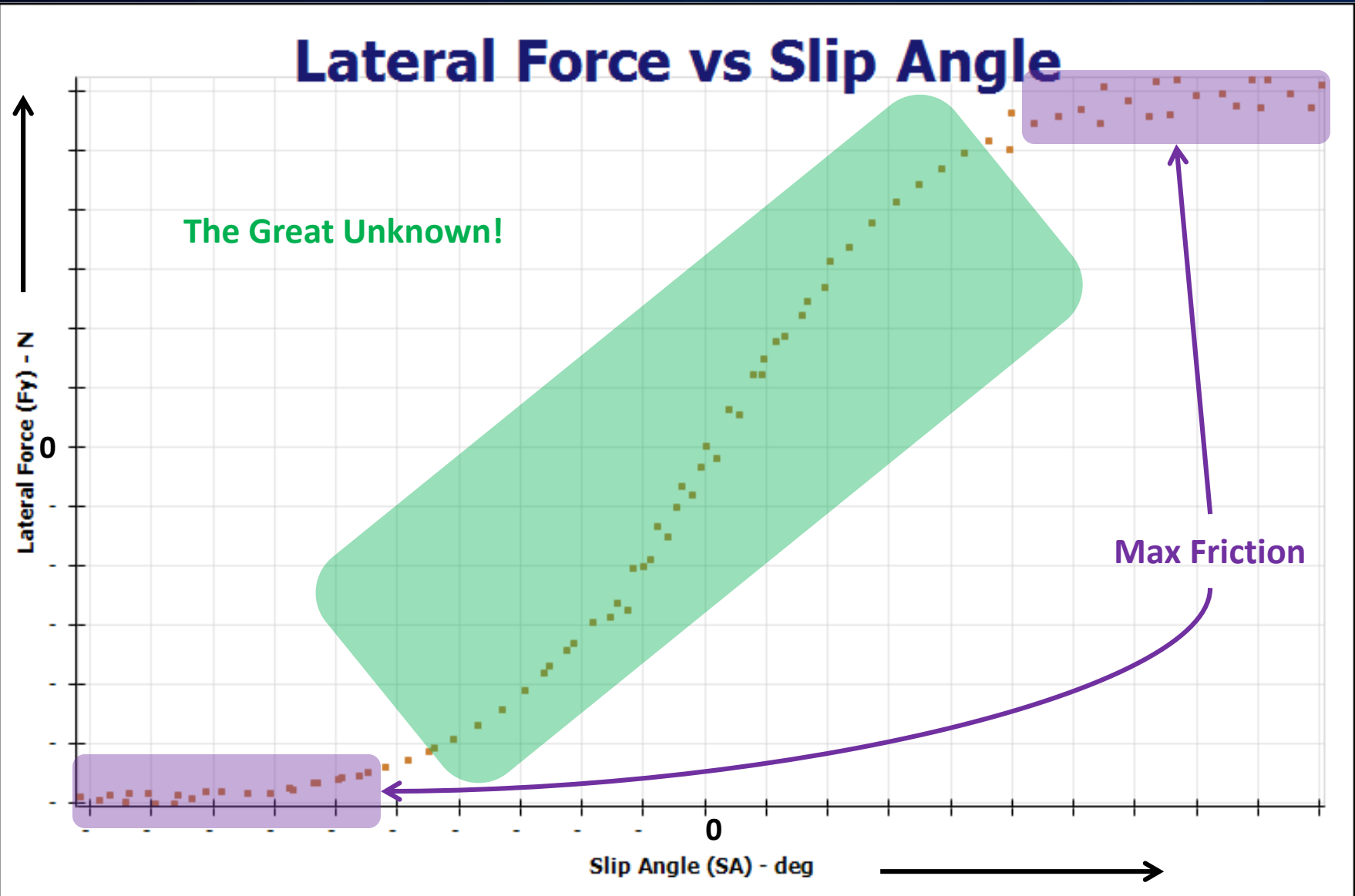
6

Tire
manufacturers

Extensive Tire Data Available!!!

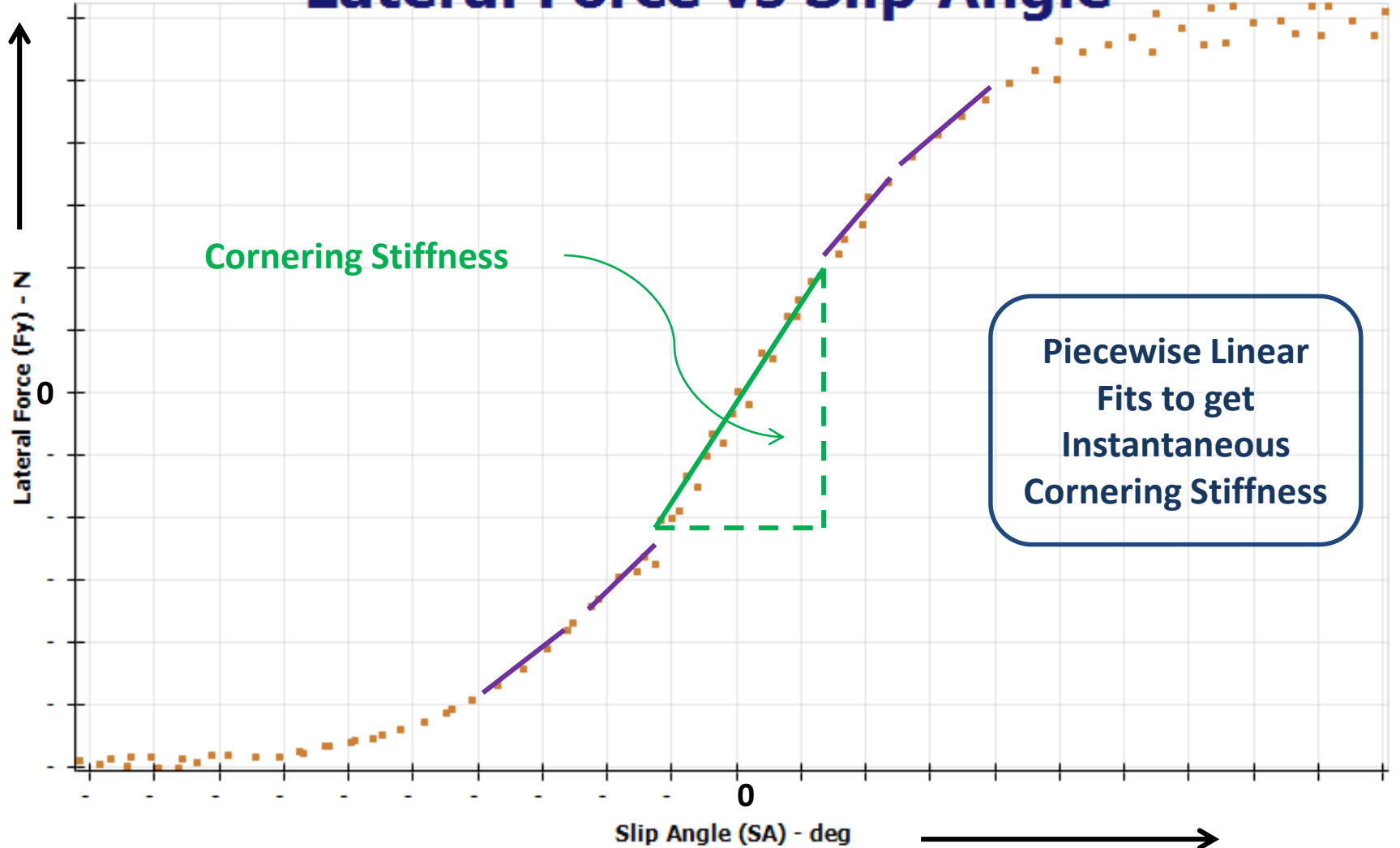


Using Tire F&M Data



Using Tire F&M Data

Lateral Force vs Slip Angle



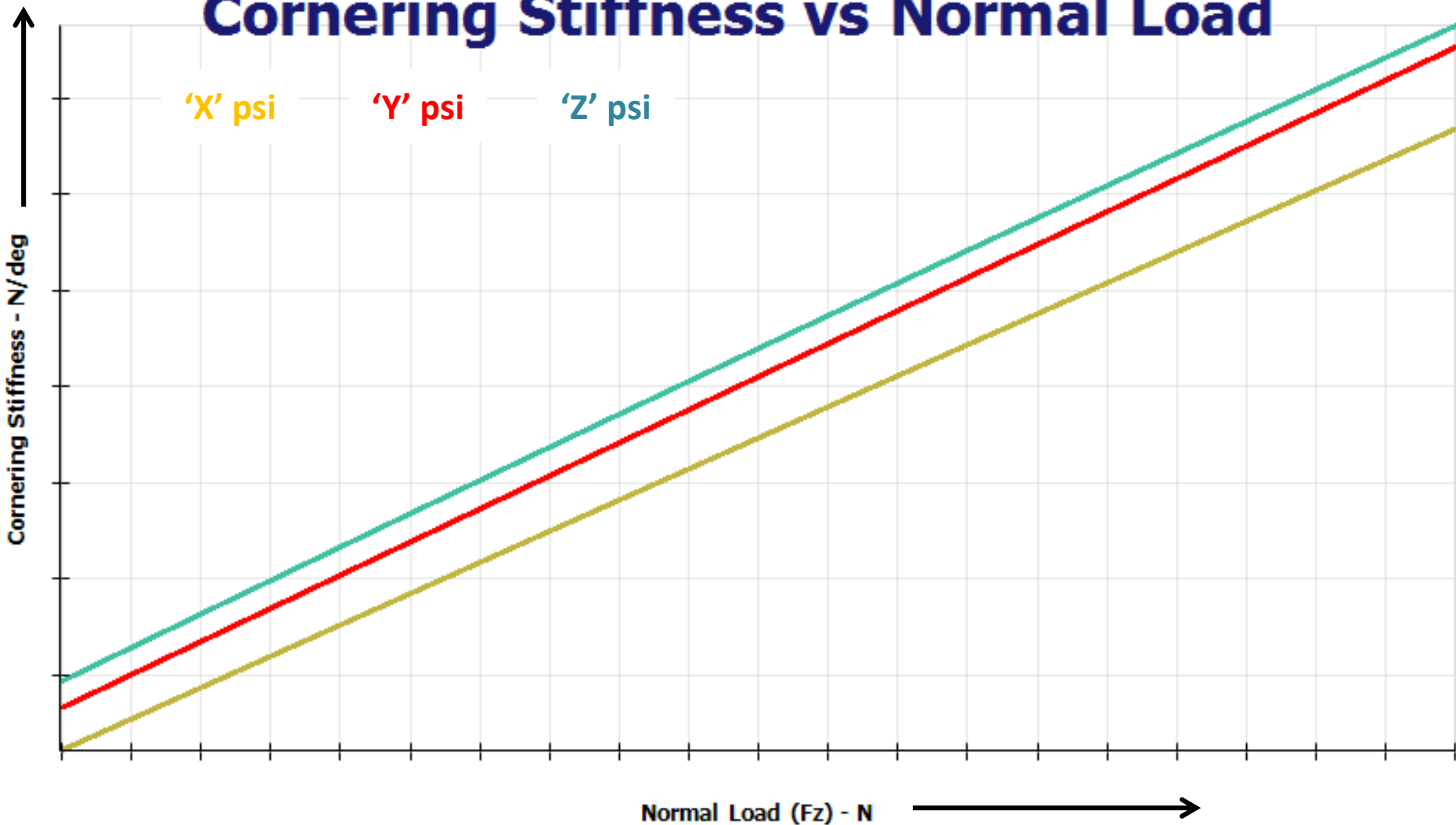
Using Tire F&M Data – Cornering Stiffness

Cornering Stiffness vs Normal Load

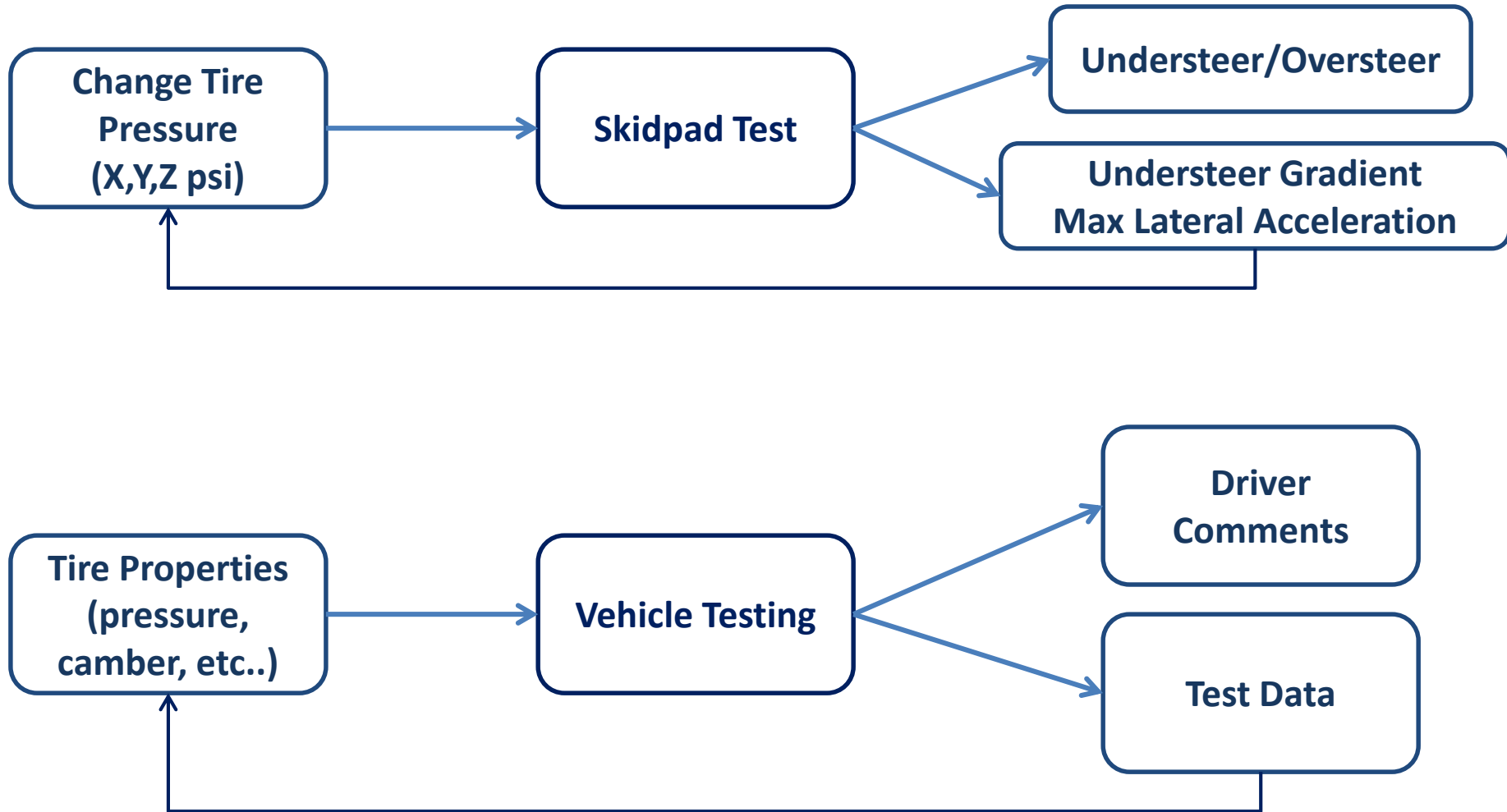
'X' psi

'Y' psi

'Z' psi



Using Tire F&M Data – Vehicle Testing



Flowchart

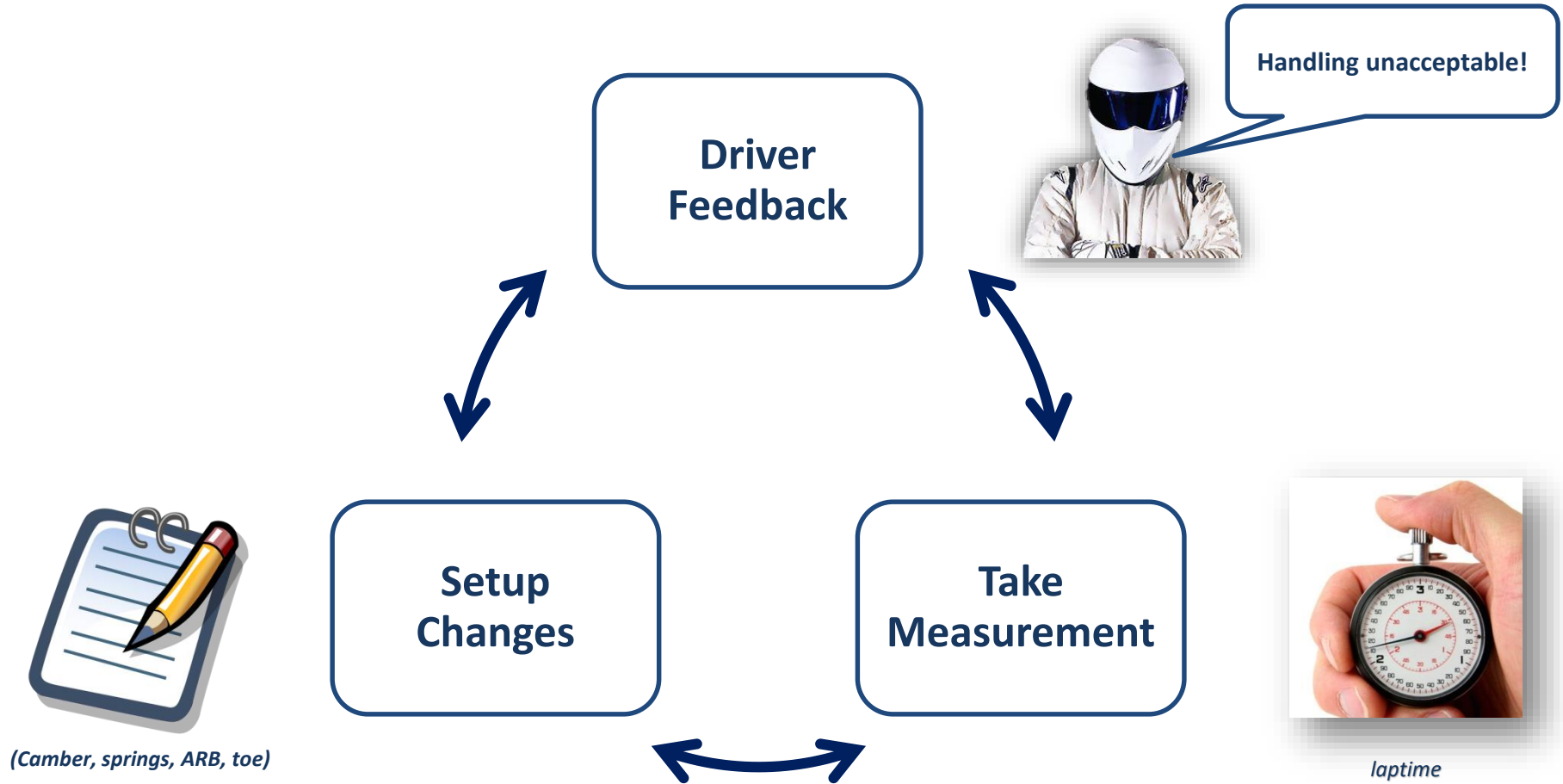
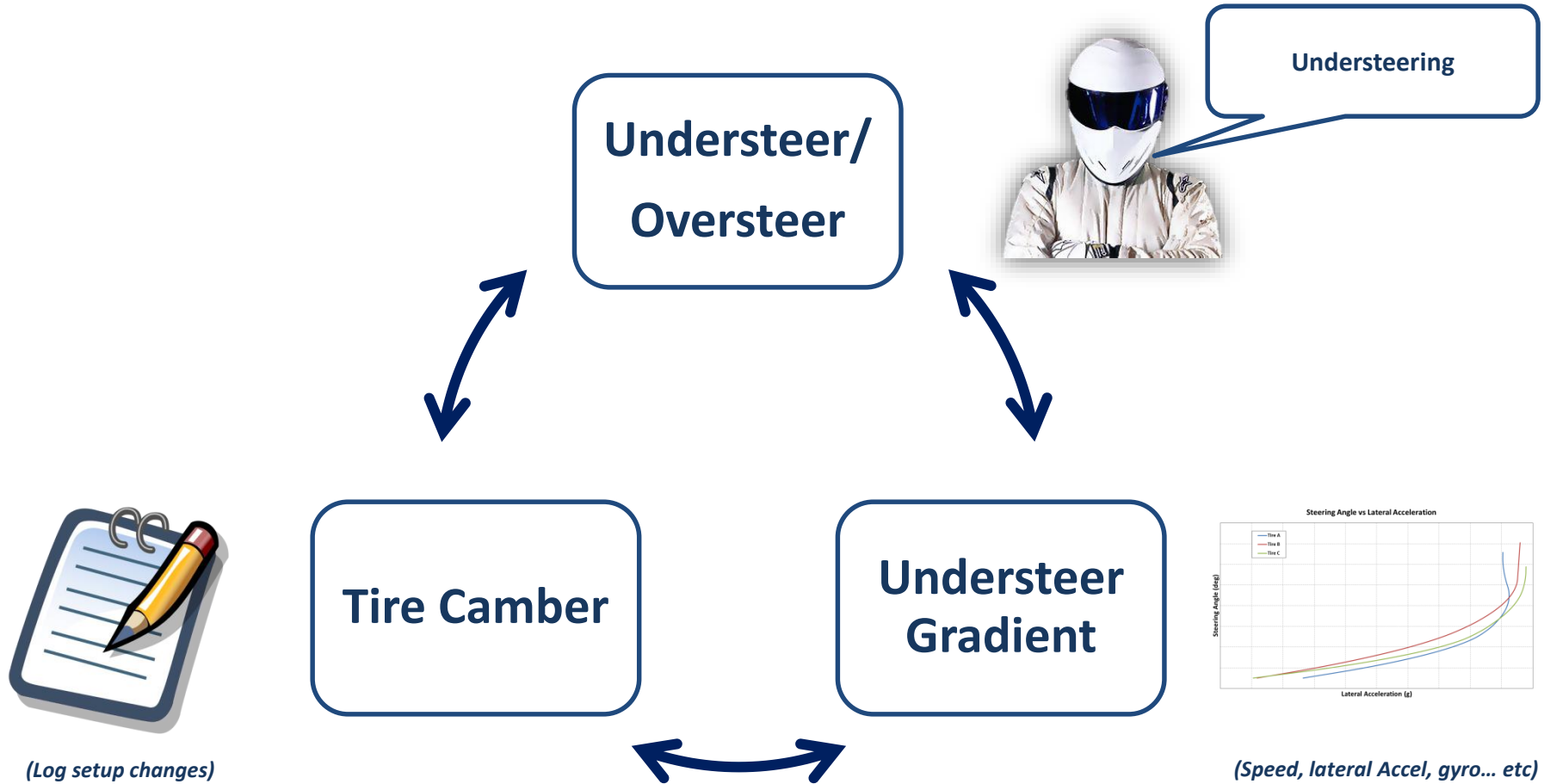


Image Credits –

1. https://www.avtoforum.net/wp-content/uploads/2014/11/100_81784a.jpg
2. <https://blog.shareaholic.com/wp-content/uploads/2014/10/1000000000.jpg>

Closing the loop



Simulation

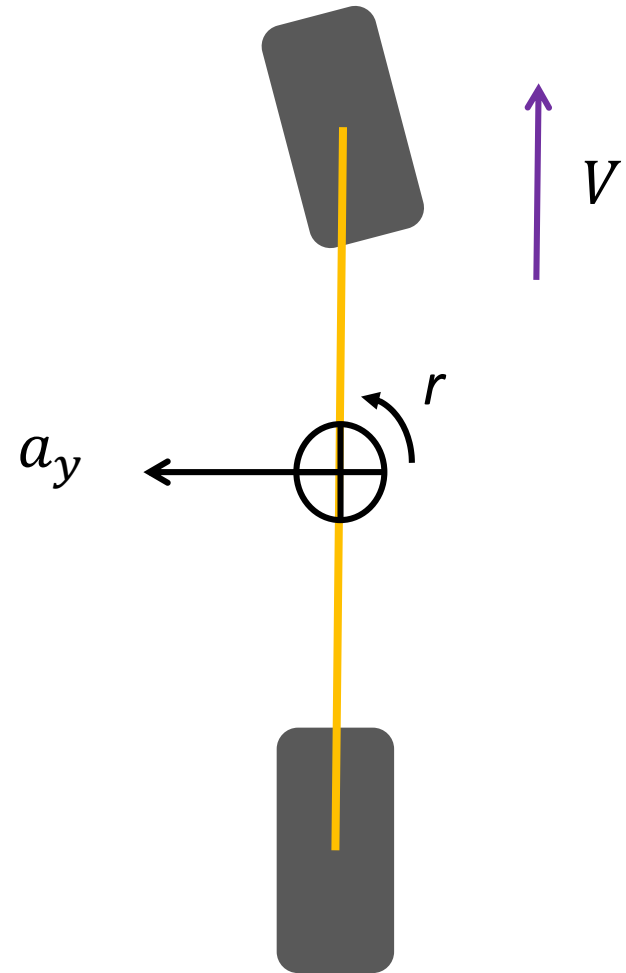
Using Tire F&M Data with Simple Simulation

2 DoF Bicycle Model

Lateral and Rotational

Can use nonlinear tire model

Simple and easy to setup

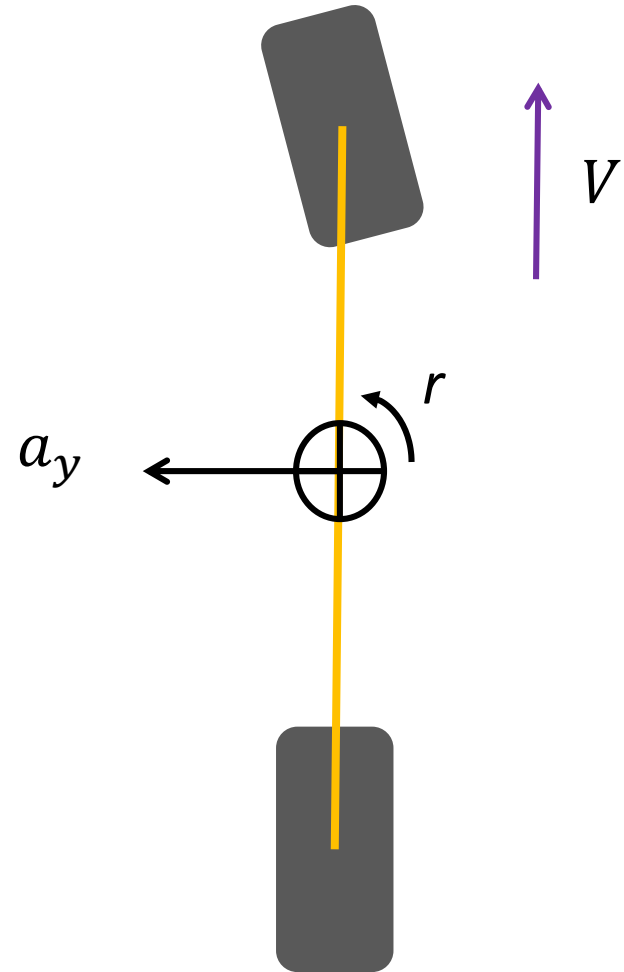


Simple Bicycle Model Simulation

Understeer Gradients

Max Lateral Acceleration

Yaw Velocity Gain



Bicycle Model Simulations – FSAE Vehicle

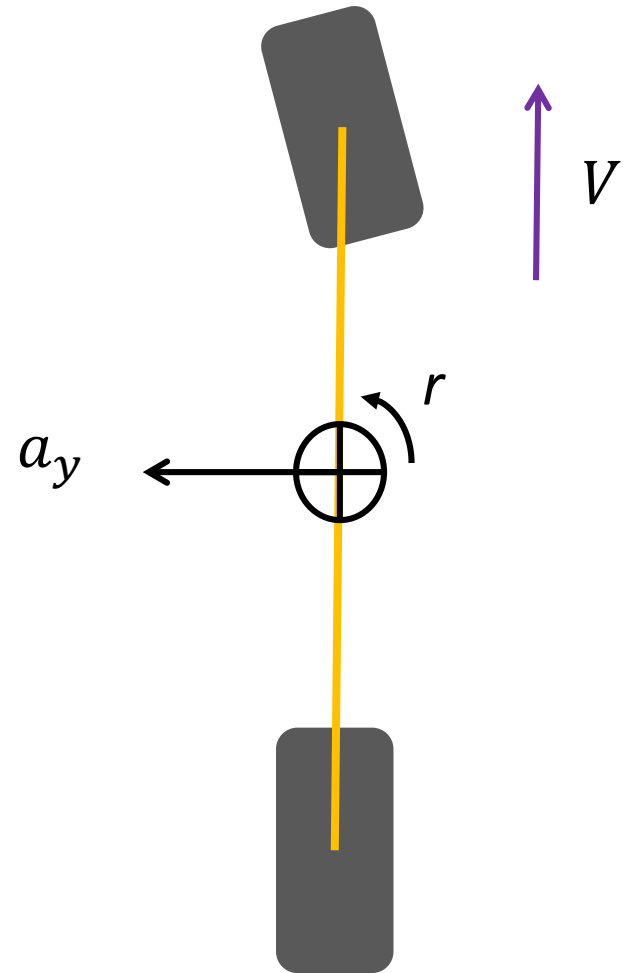
Mass = 250Kg

Wheelbase = 1600mm

FWD = 49%

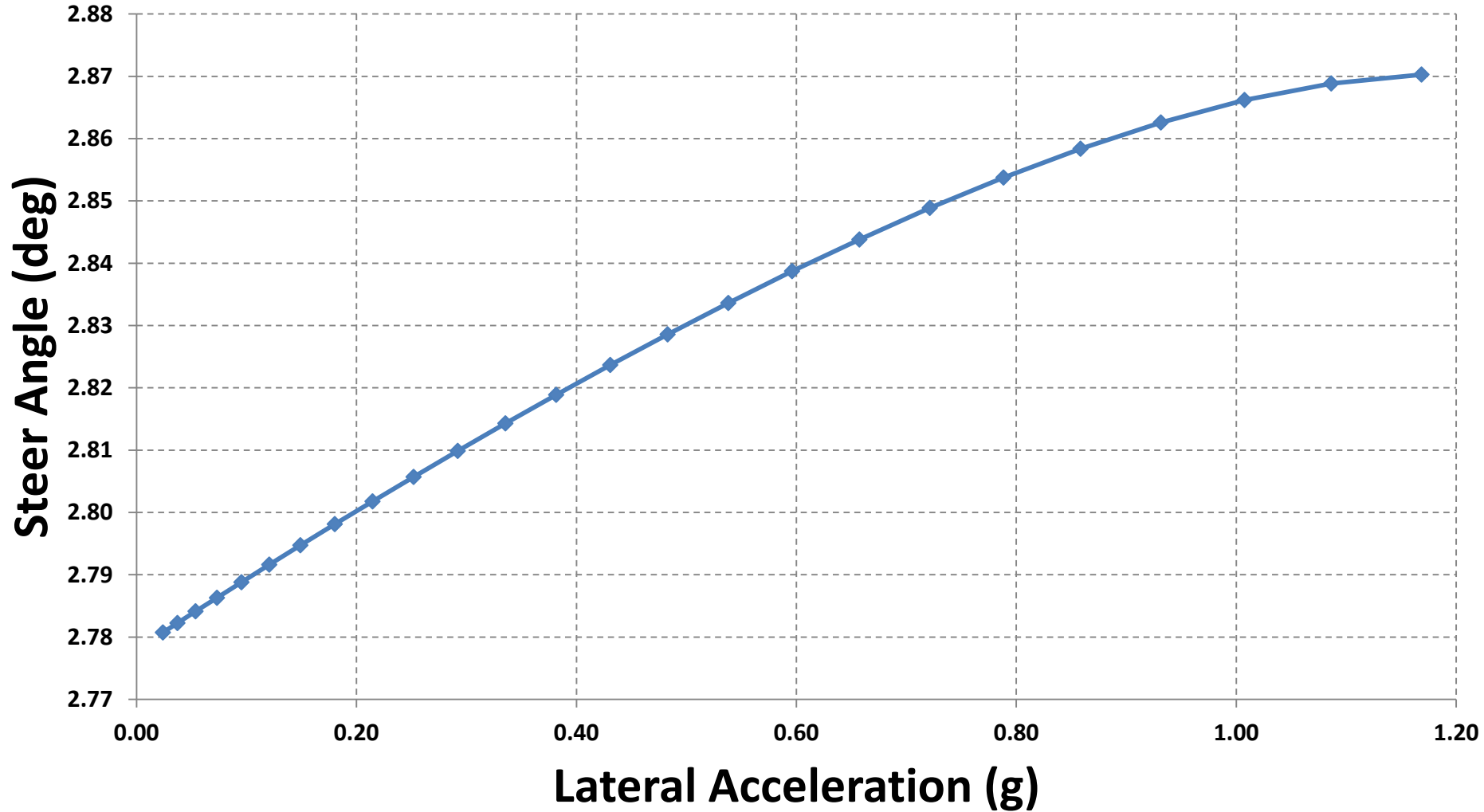
33m Circle Skidpad

94 Pacejka Model
using TTC Data

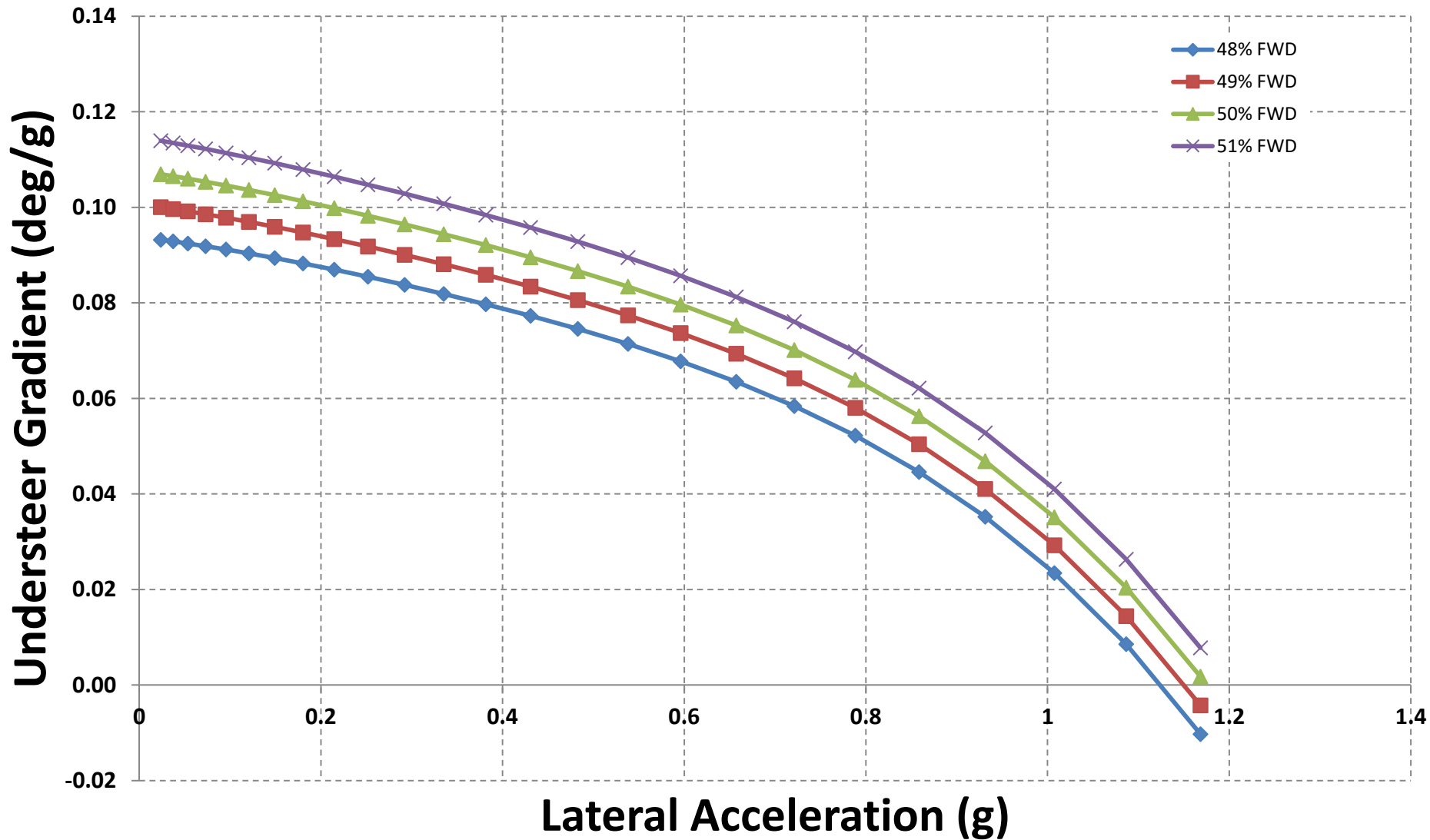


Bicycle Model Simulations

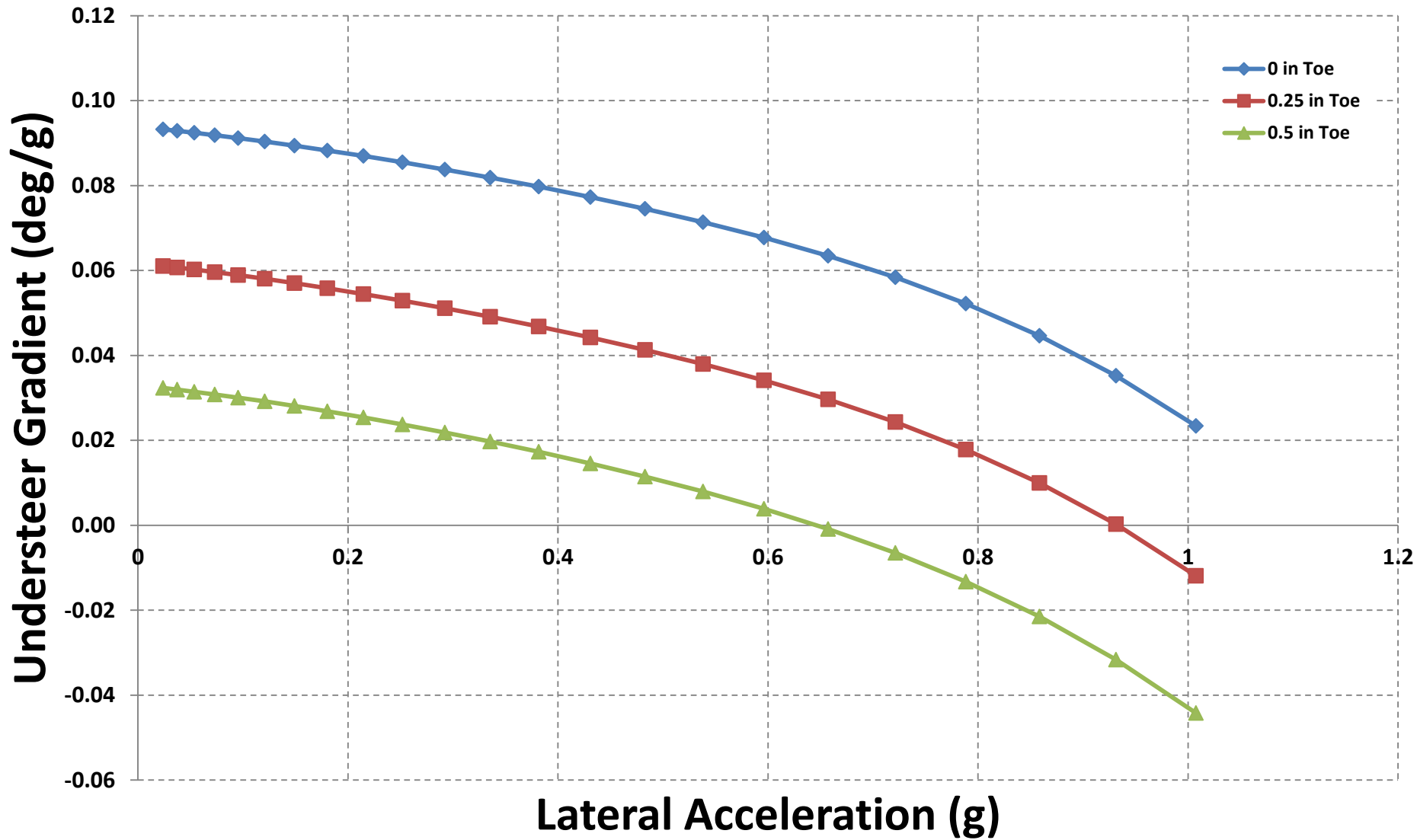
Steer Angle vs Lateral Acceleration



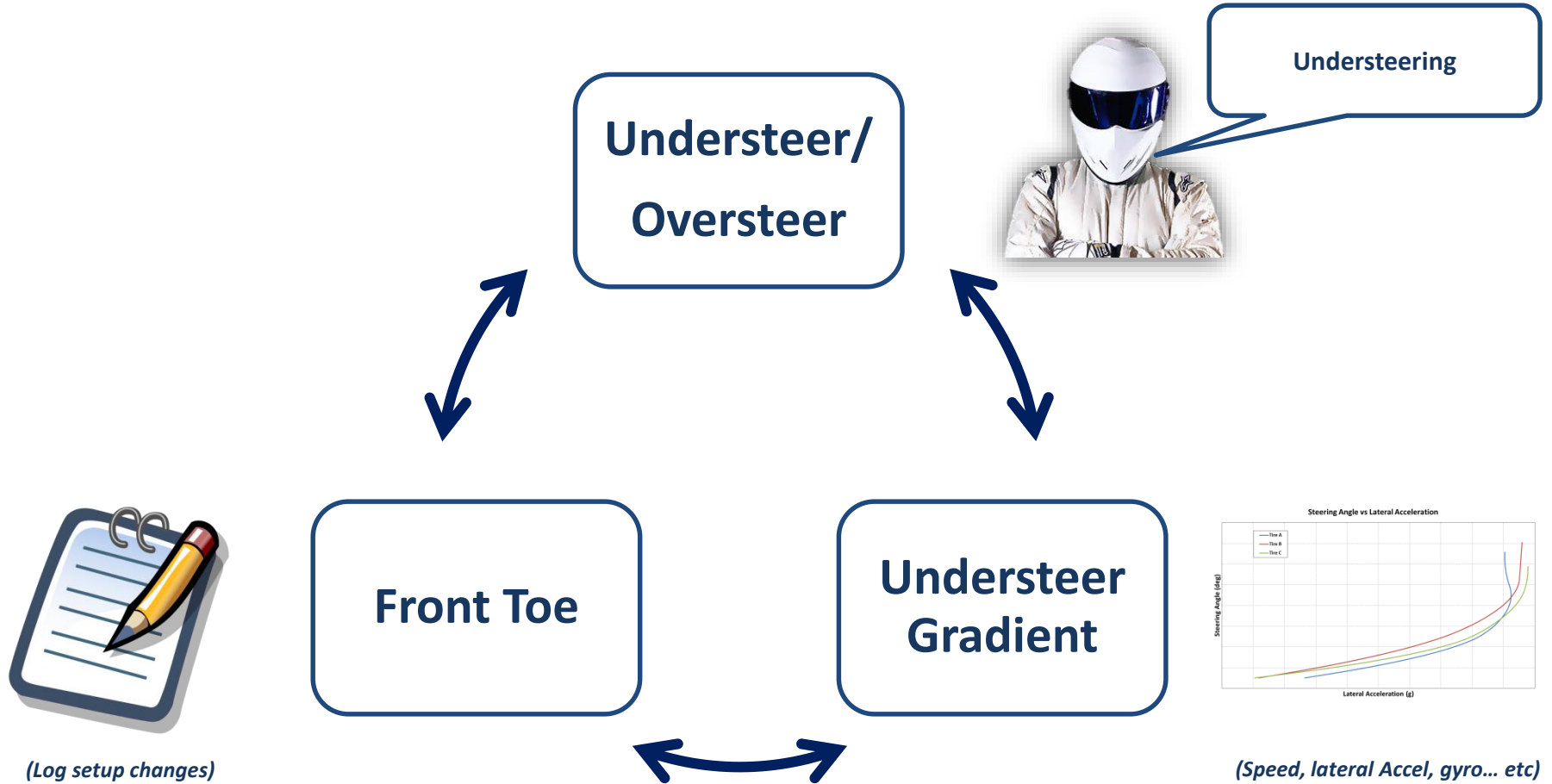
Bicycle Model Simulations



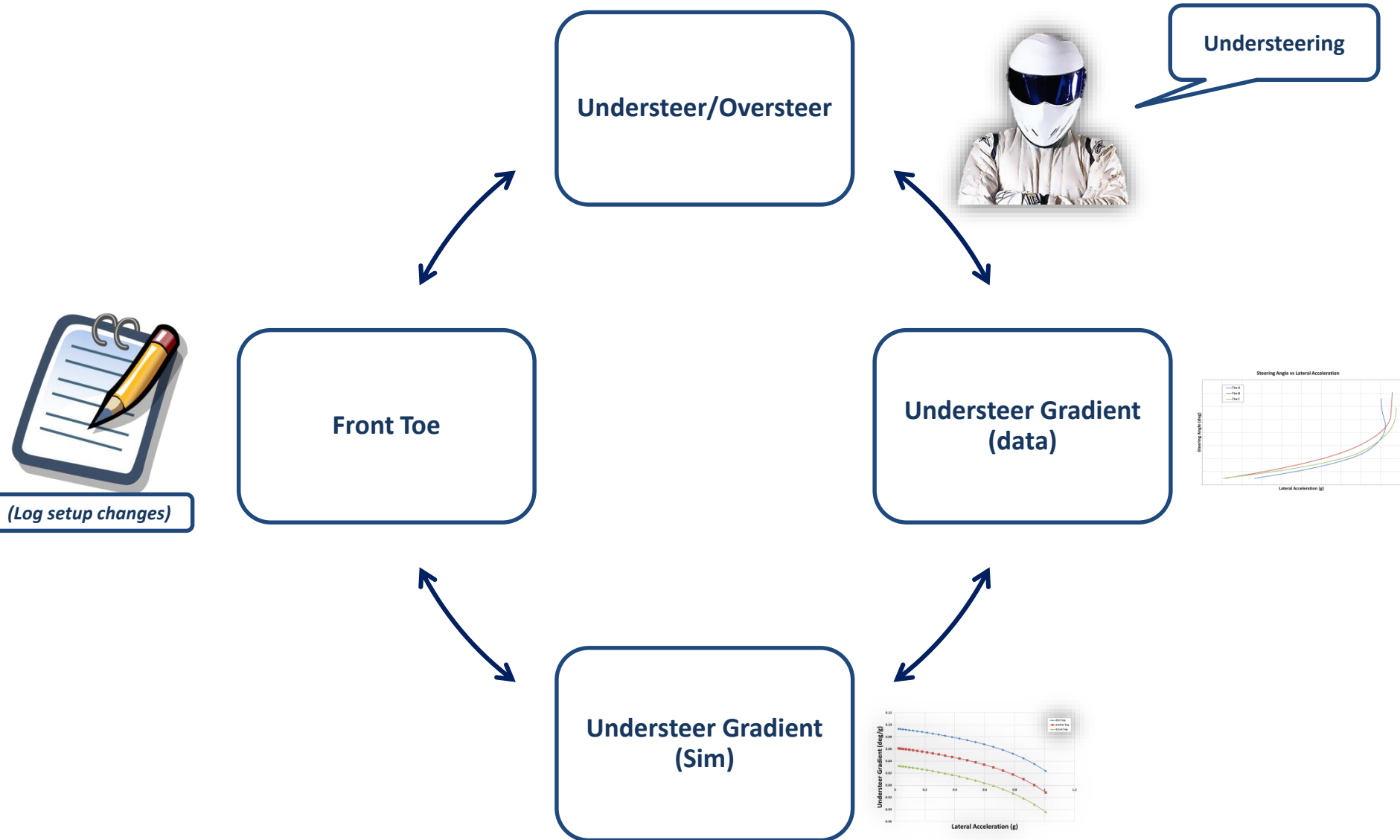
Bicycle Model Simulations



Closing the loop



Closing the loop with Simulation





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Thank you