

# Tire Disablement and Vehicle Dynamics



**NTSB**

*L'Enfant Plaza,  
Washington, DC*

*December 10, 2014*

*Ashley (AI) Dunn, Ph.D., P.E.*



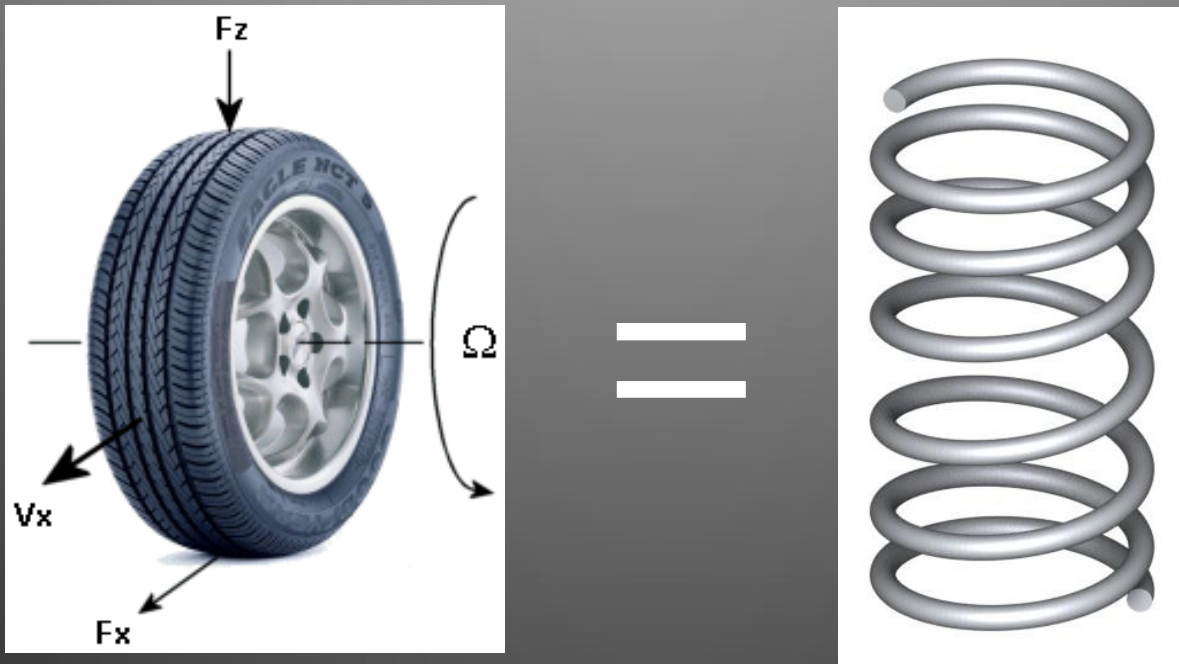
# Ashley (Al) Dunn, Ph.D., P.E.

- B.S.M.E. N. C. State University
- 10 yrs: Michelin Americas R & D
- Ph.D. in M.E. The Ohio State University
- 6 yrs: NHTSA Heavy Truck testing and modeling
- over 25 years in vehicle dynamics testing and modeling
- Last 8 years with S-E-A
  - Vehicle dynamics
  - Forensic Accident Reconstruction



# Vertical Stiffness

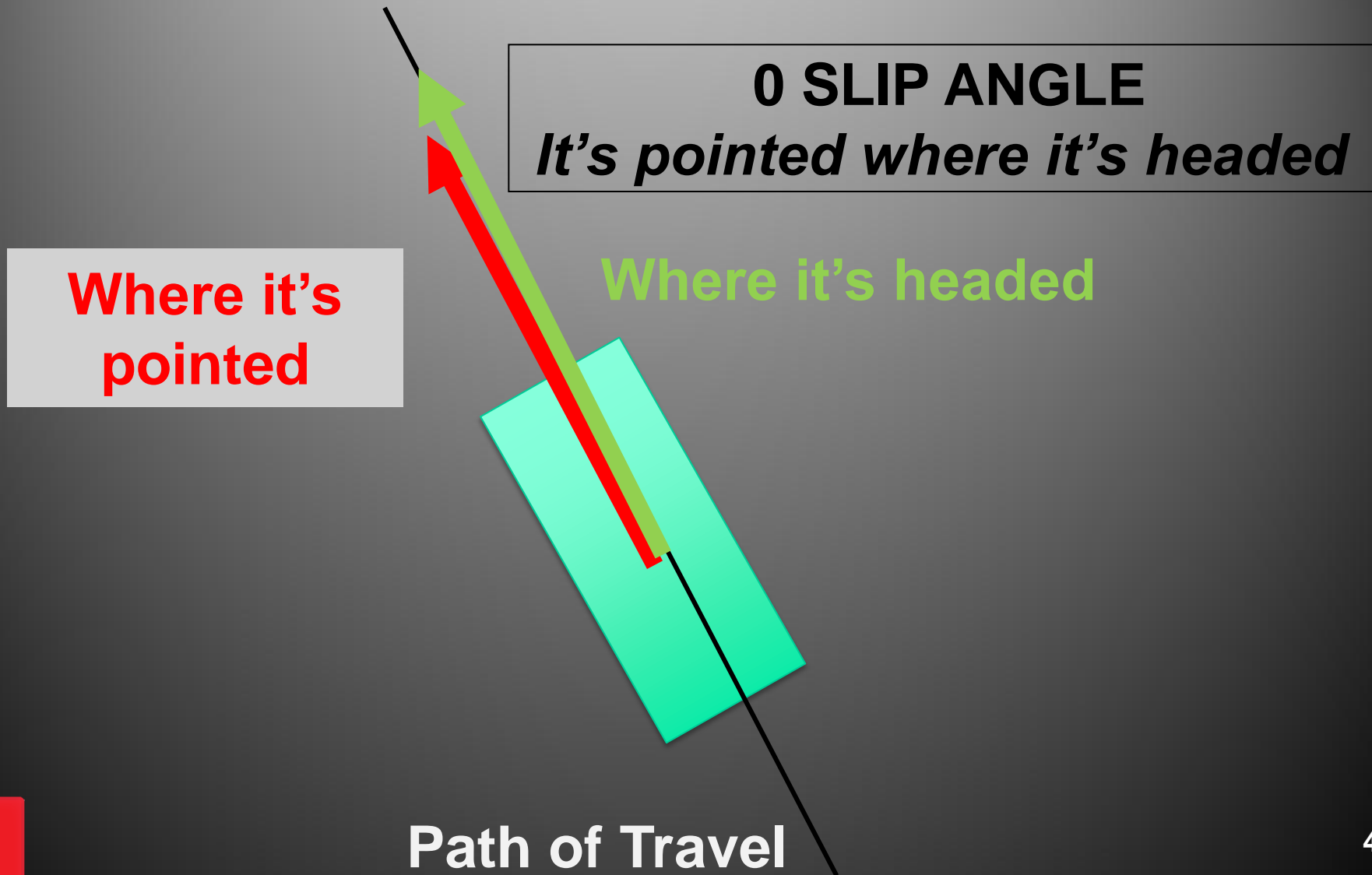
It's a big spring



10 X suspension



# SLIP ANGLE defined



# SLIP ANGLE defined

$\alpha$  SLIP ANGLE

Where it's headed

Where it's pointed

Path of Travel



# Tires Don't Have it Easy...

## NHTSA Fishhook Maneuver



# Tires Don't Have it Easy...

What the Tires Experience ...



# Understeer / Oversteer

Understeer = Plowing out

I turn the steering wheel  
more but the vehicle DOES  
NOT turn more

Oversteer = Spinning out

I turn the steering wheel less  
but the vehicle CONTINUES  
TO TURN (YAW)





# Understeer / Oversteer

Understeer = Plowing out

- Stable
- predictable



# Understeer / Oversteer



Oversteer = Spinning out

- Unstable
- Difficult to Control

# How can WE Affect Understeer / Oversteer

- Too much throttle
  - RWD → oversteer
  - FWD → understeer
- Too much braking
  - Front → understeer
  - Rear → oversteer
- Chassis Roll Stiffness
- **Tire Cornering Stiffness**



# Tire Failure Modes

- **Sudden Deflation**
  - Blowout
- **Tread Separation**
  - Axle tramp
  - Steel Cord Traction (...not much ...)
  - Eventual deflation possible
- **Tire DeBeading**
  - Peeling tire off of rim (not today...)



# Tire Failure Modes

## One item at a time

### Sudden Deflation, i.e., Blowout

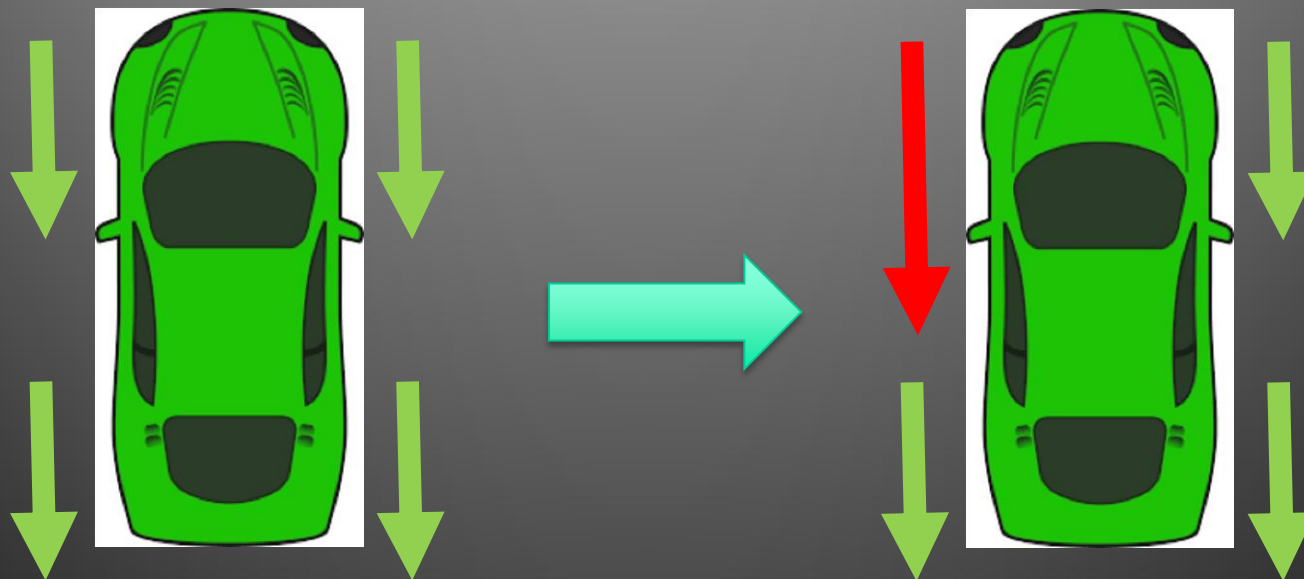
- Vertical Stiffness suddenly decreases
  - ... at least momentarily
- Cornering Stiffness suddenly decreases
- Rolling Resistance increases



# Tire Failure Modes

## Blowout – Front

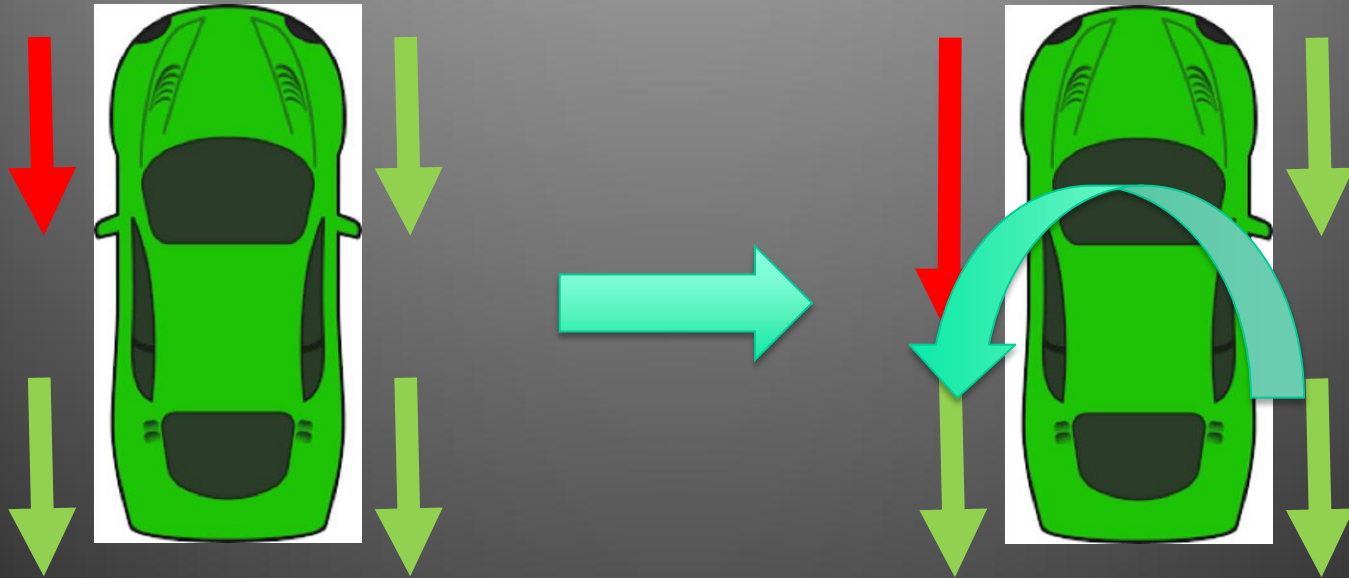
The loss of pressure creates a higher longitudinal drag at the position where the tire fails:



# Tire Failure Modes

## Blowout - Front

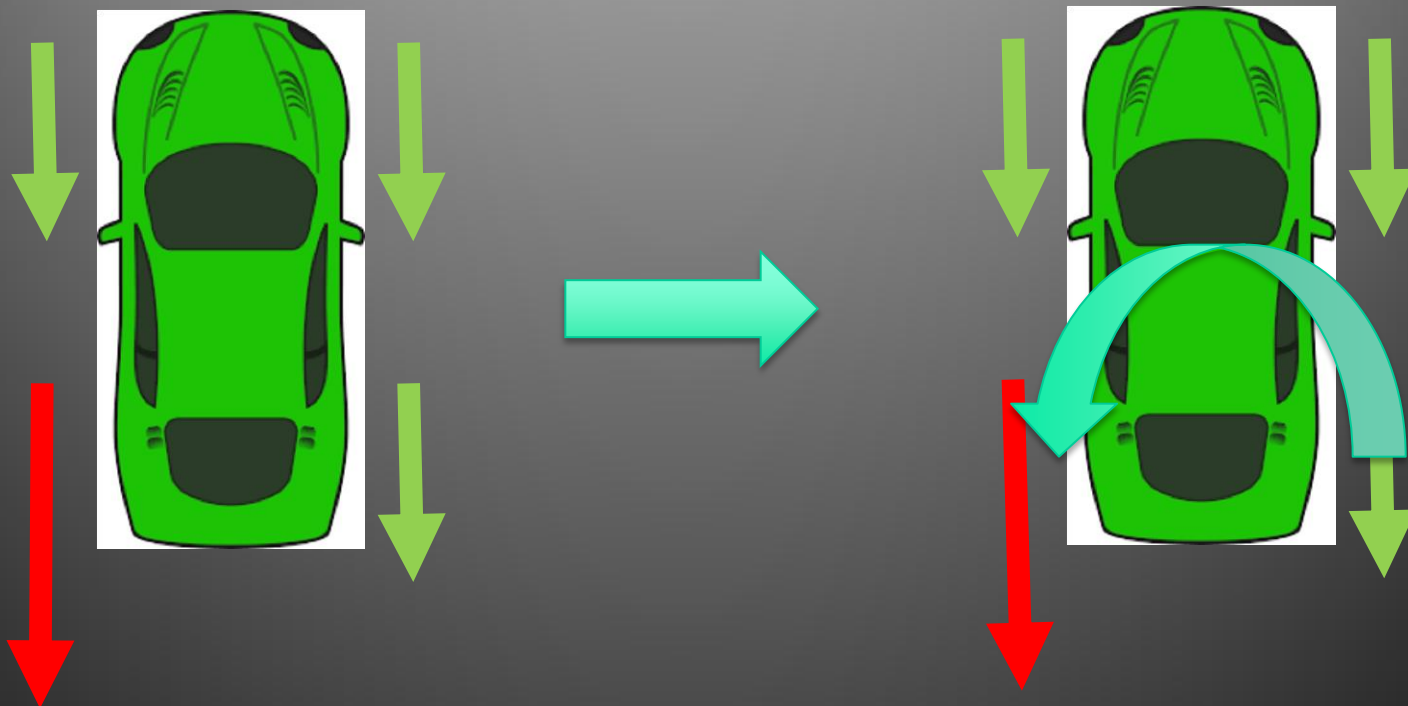
Imbalance of force causes a yaw moment



# Tire Failure Modes

## Blowout - **REAR**

Let's change the location of the **BLOWOUT**

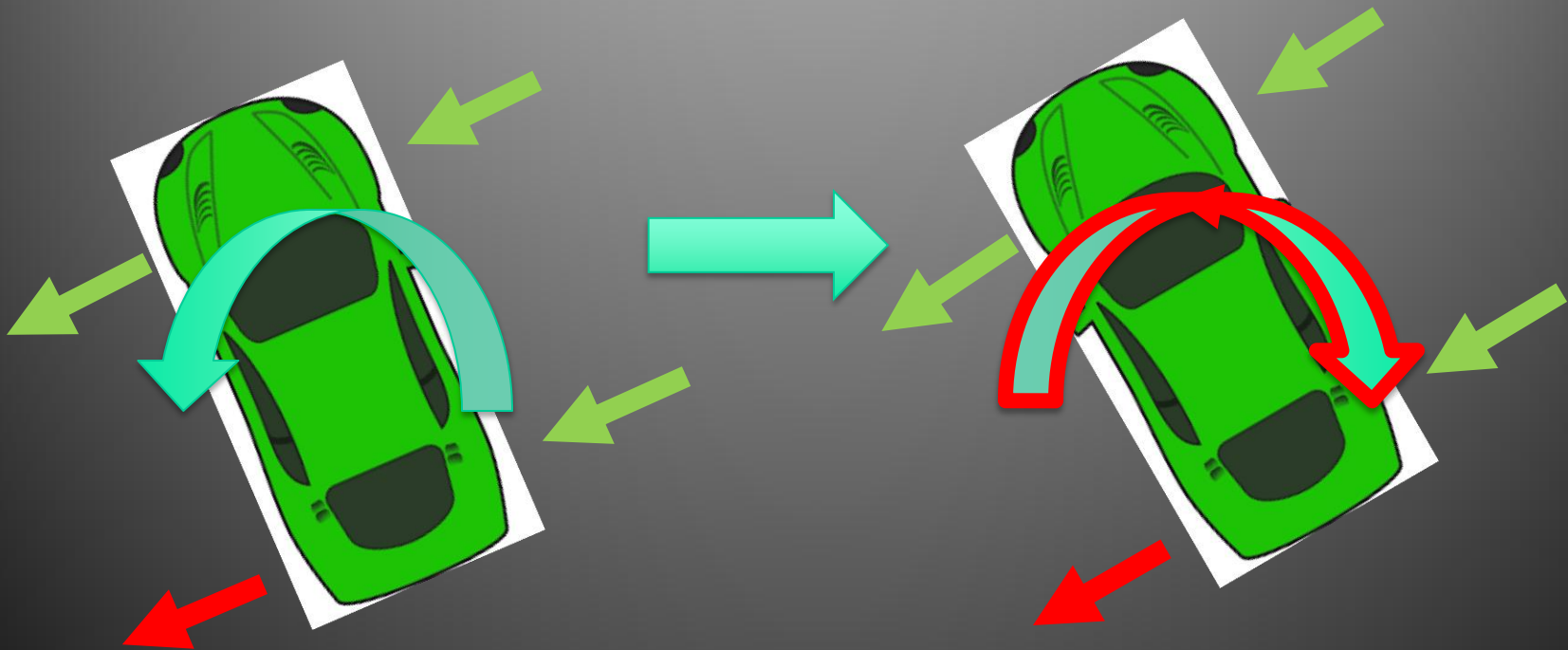




# Tire Failure Modes

## Blowout - **REAR**

Sensitivity to Overcorrection is Real



# Tire Failure Modes

## One item at a time

### Tread Separation

- Vertical Stiffness is same
  - But we get large vertical excitation !!
- Cornering Stiffness suddenly decreases
- Rolling Resistance increases



# Stability AND Controllability

## One item at a time

### Tread Separation



# Stability AND Controllability

## One item at a time

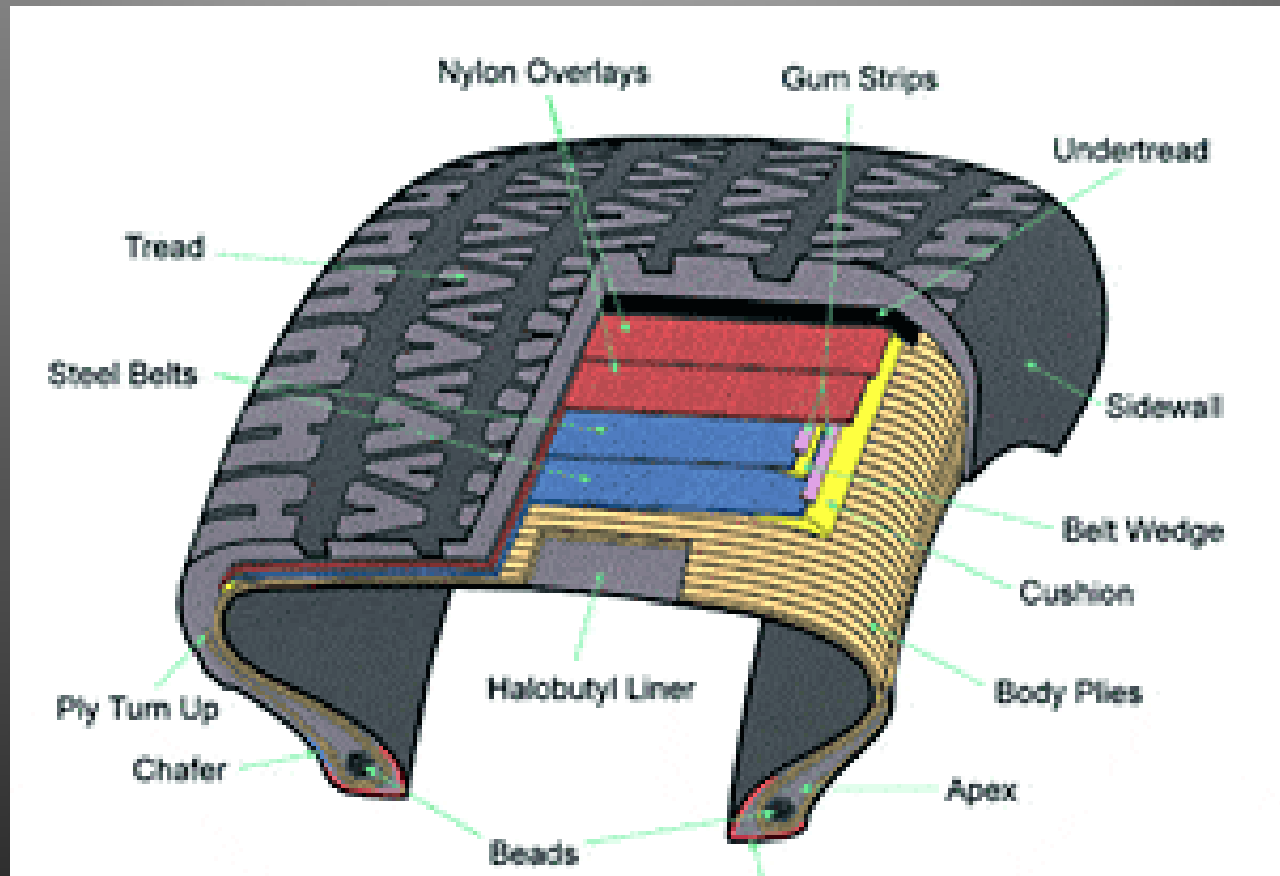
### Tread Separation



# Stability AND Controllability

## One item at a time

### Tread Separation – riding on steel



# Stability AND Controllability

## One item at a time

### Tread Separation –



# Tread Separation Axle Tramp

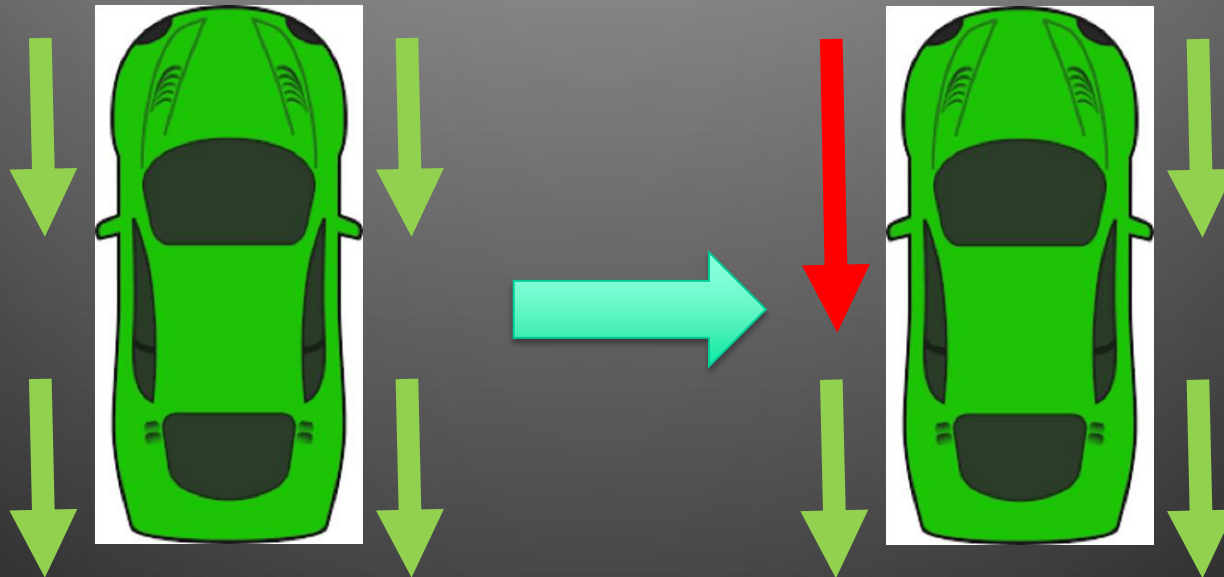
As the tread is coming off, the vertical  
excitation to the axle is significant



# Tire Failure Modes

## Tread Separation – Front

The irregularity, flapping tread, and axle tramp combining to cause higher drag at the position where the tire fails:

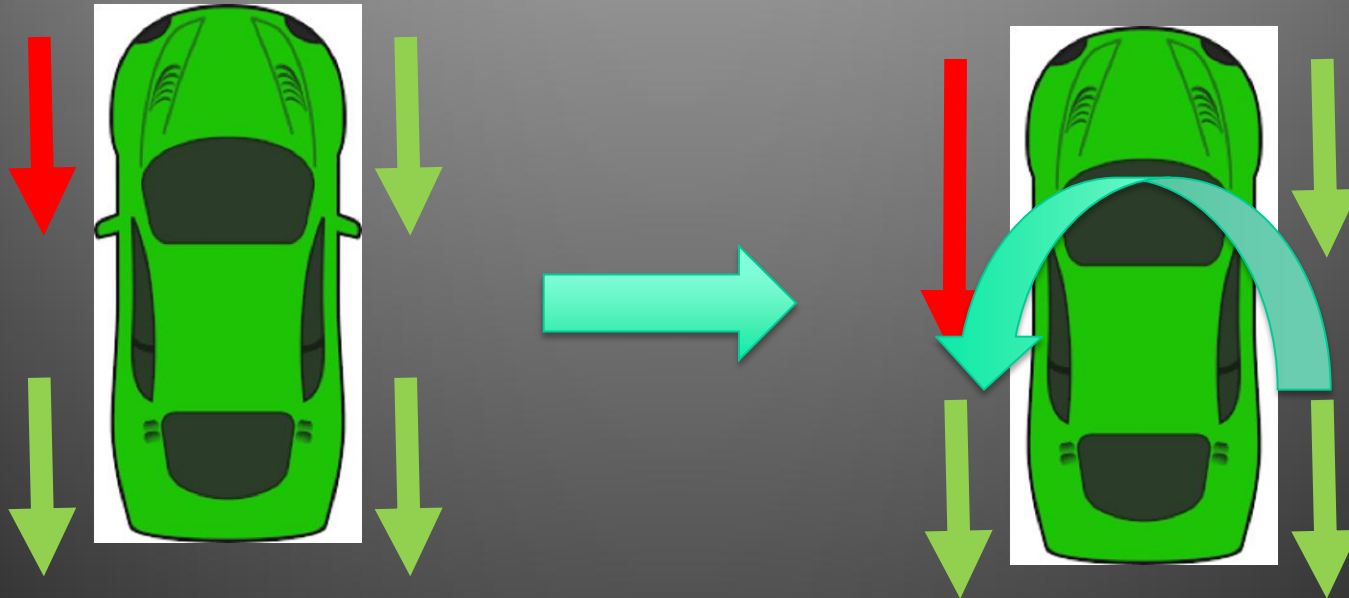




# Tire Failure Modes

## Tread Separation – Front

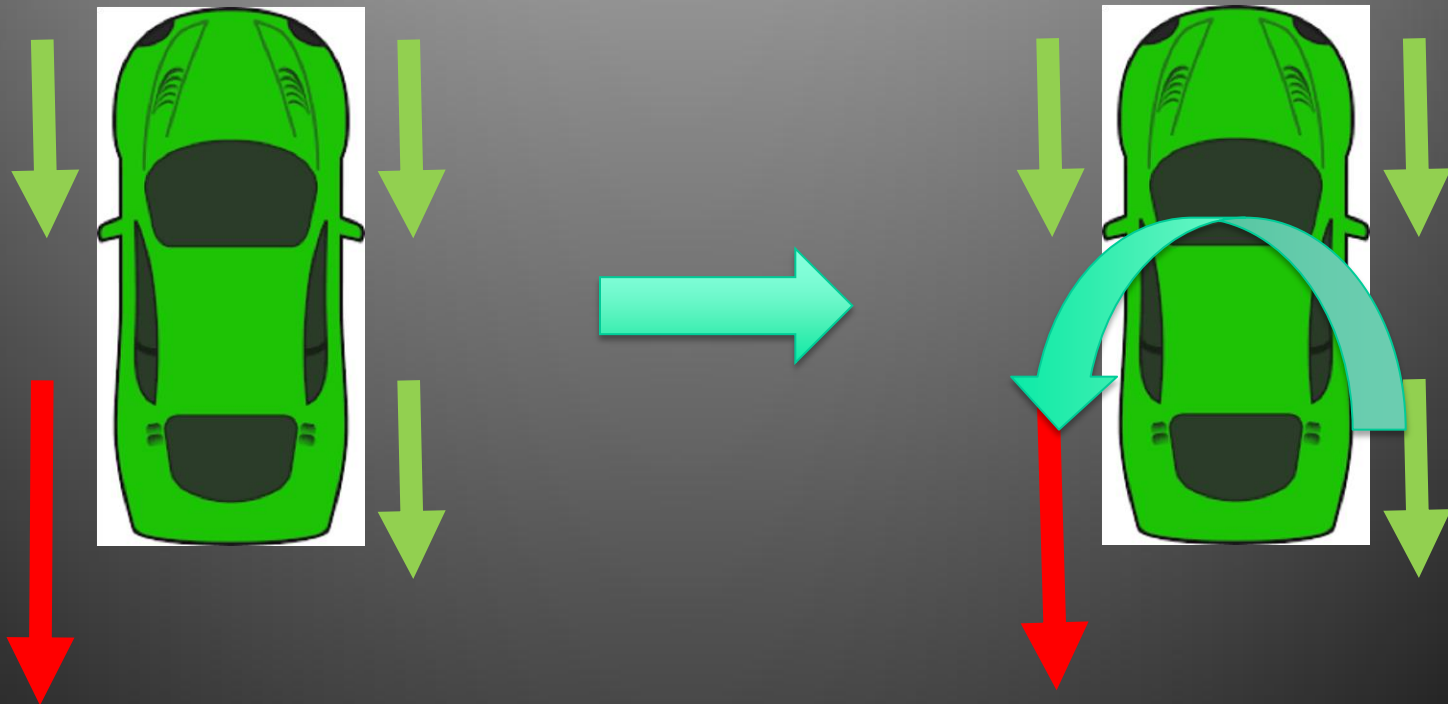
Imbalance of force causes a yaw moment



# Tire Failure Modes

## Tread Separation – REAR

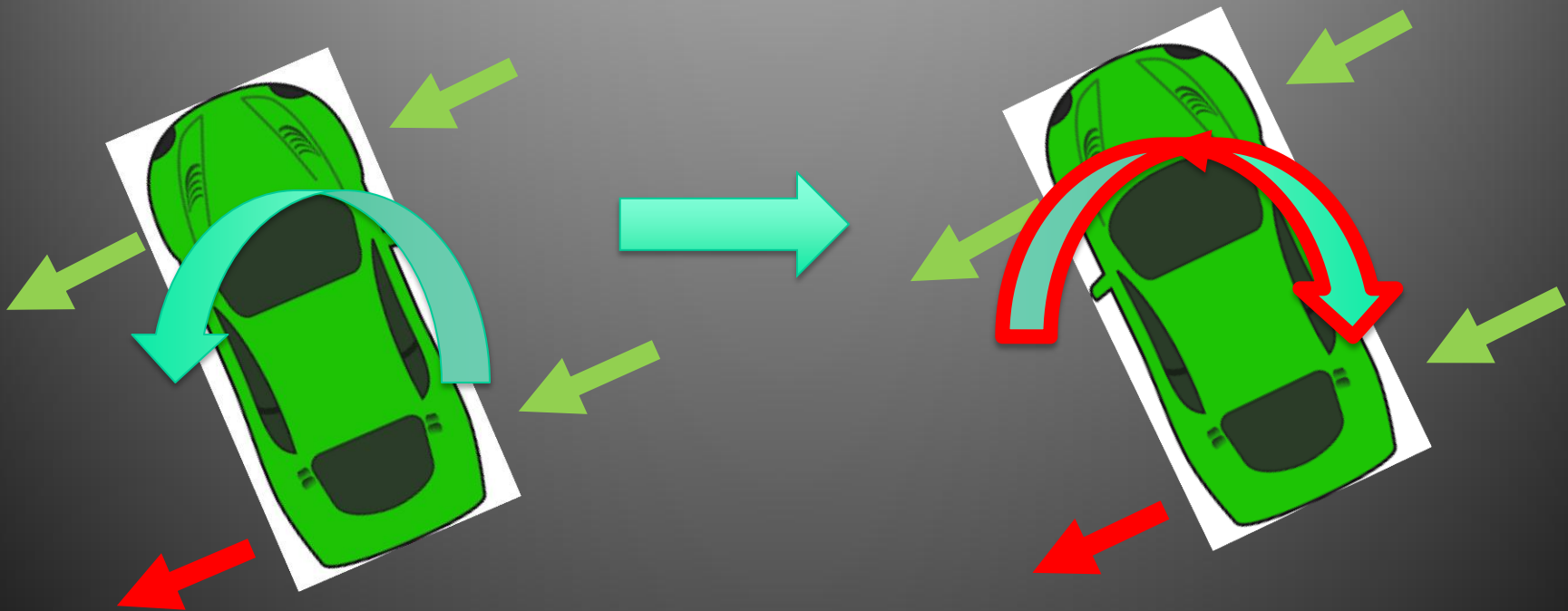
Let's change the location of the **TREAD SEPARATION**



# Tire Failure Modes

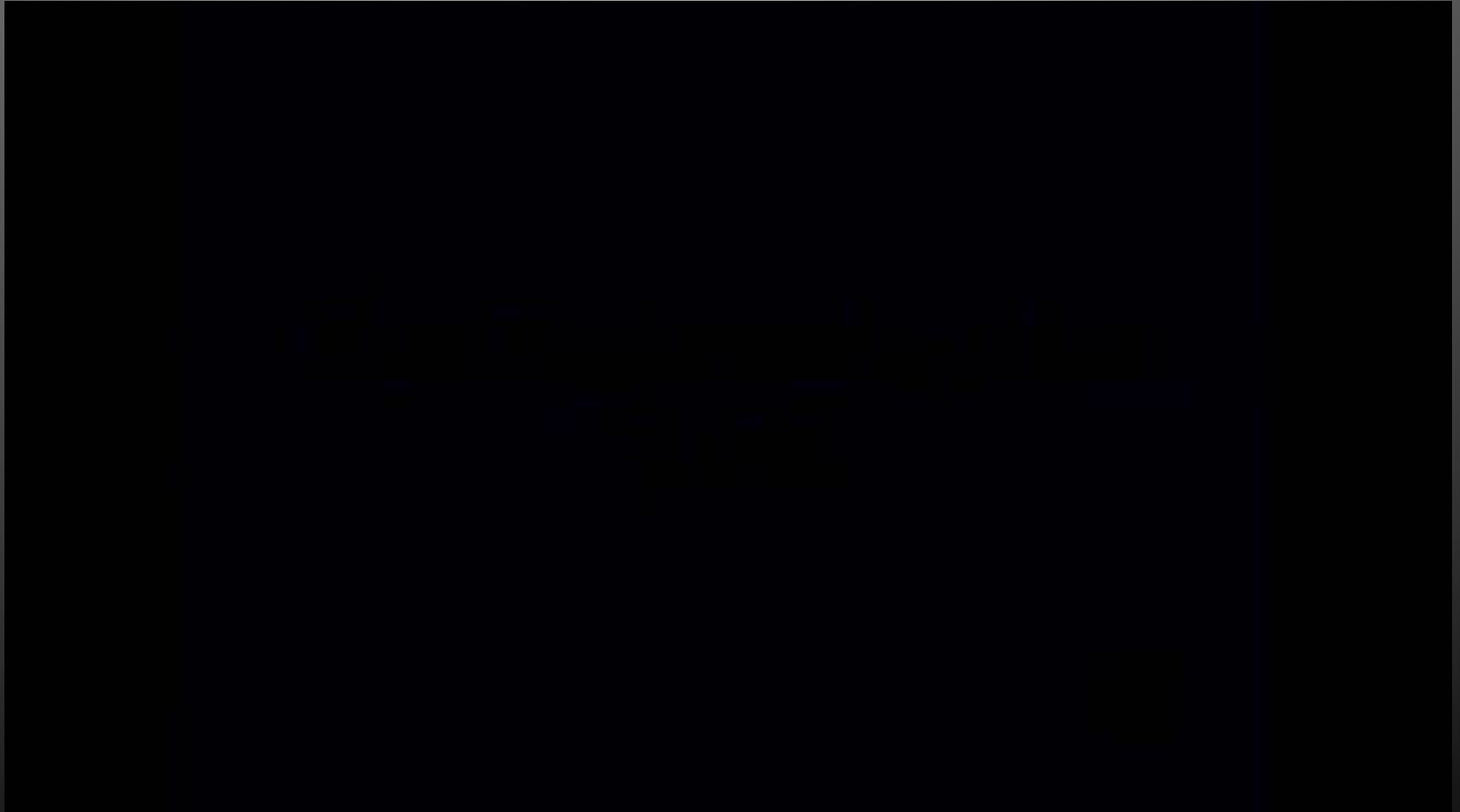
## Tread Separation – **REAR**

Now, the Left Rear Tire is running on nylon and steel:



# Tread Separation at the Rear Play by Play

Right Rear Tread Separation – from outside of vehicle



# Tread Separation at the Rear Play by Play

Right Rear Tread Separation – underbody view of tire



# Tread Separation at the Rear Play by Play

Right Rear Tread Separation – tire zoom



# Tread Separation at the Rear Play by Play

Right Rear Tread Separation – now with oversteer...

Partial Tread  
Separation Test

Tires at 35 psi

abc NEWS  
.com



# Stability AND Controllability

## One item at a time

### Tread Separation

Was imminent failure obvious to the most casual observer?

How can a driver miss the warning signs?





# Disaster Mitigation

## Can drivers be taught to respond properly?

- Lack of Driver Diligence Remains a Problem
- Good Driver Behavior can be Learned
- Stability Control DOES NOT change the Laws of Physics
  - Friction is not increased
  - Center of Gravity is not decreased
  - Initial Conditions cannot be changed



# TRUCK – Steer Axle Tire Blowout Test

55 mph – dry concrete – blow left steer axle tire



# Thank You for your time today!

Ashley L. (AI) Dunn, Ph.D., P.E.

