PDHonline Course G493 (2 PDH)

Motor Vehicle Accident Reconstruction Special Topic 3 - Suspension and Steering Failures

Instructor: Peter Chen, P.E., CFEI, ACTAR

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PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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Discussion Areas

- Understanding the Importance of Suspension Failures as a Potential Cause of Motor Vehicle Accidents.
- Basics of Passenger Car/Truck Suspension Systems
- Introduction to Suspension Failure Analysis

NHTSA FAR Database

- The National Highway Traffic Safety Administration (NHTSA) keeps a database of traffic fatalities called the Fatal Accident Reporting System (FARS).
- The database can be found at www.nhtsa.gov/FARS. Take some time to investigate the website and the publicly available information that it holds.
- The database goes back to 1975, and the information recorded by NHTSA has changed over time.
- The FARS database contains data inputted by police or other traffic governing and/or investigating entities (i.e. sheriff's departments) detailing the factors behind traffic fatalities on U.S. roads.
- The FARS database may be queried by year and vehicle related Factors.

Query of FARS database

- A query of the FARS database in 2008 had some revealing information.
- Subsequent queries haven't greatly changed the general information gleaned in 2008.

STATE: All|YEAR: 2008|COUNT: Number of Vehicles/Drivers

OUTPUT OPTIONS: Submit Query | View Cases

Report:

Vehicle Related Factors(1)

State	None	Tires	Brake System	Steering System - Tie Rod, Kingpin, Ball Joint, Etc.	Suspension - Springs, Shock Absorbers, MacPherson Struts, Axle Bearing, Control Arms, Etc.	Power Train/Engine	Exhaust System	Headlights	Signal Lights	Other Lights	Horn	Wipers	Driver Seating And Control	Body, Doors, Hood, Other	Trailer Hitch	Wheels	Air Bags	Other Vehicles Defects	Safety Belts	Hit-and-Run Vehicle	Vehicle Registration For Handicapped	Vehicle Being Pushed By Non-Motorist	Reconstructed/Alt Vehicle
Alabama	1,202	27	3	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	24	0	0	0
Alaska	85	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1
Arizona	1,111	33	1	0	3	2	0	0	0	0	0	0	0	0	0	0	0	2	1	69	26	0	1
Arkansas	755	6	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	15	0	0	0
California	4,345	62	13	0	3	4	0	3	0	0	0	0	0	0	0	1	1	0	2	278	21	1	2
Colorado	681	3	2	0	0	1	0	0	0	3	0	0	0	0	0	1	0	0	0	21	0	0	1
Connecticut	341	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	15	0	0	0
Delaware	142	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	9	0	0	0
District of Columbia	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Florida	3,997	33	1	0	2	1	0	2	0	0	0	0	0	0	0	2	0	2	0	181	0	0	1
Georgia	1,907	36	2	1	0	2	0	2	0	0	0	0	1	0	0	1	0	2	1	45	61	0	0
Hawaii	129	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	1
Idaho	297	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0
Illinois	1,317	4	2	0	0	0	0	0	0	1	0	1	0	0	0	0	0	3	0	54	0	0	0
Indiana	1,059	7	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	24	19	0	0
Iowa	559	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0
Kansas	480	2	1	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	10	0	1	0

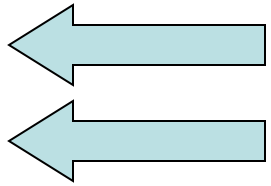
FARS Results:

Top Vehicle Related Factors-2008

- Out of 47338 Reports

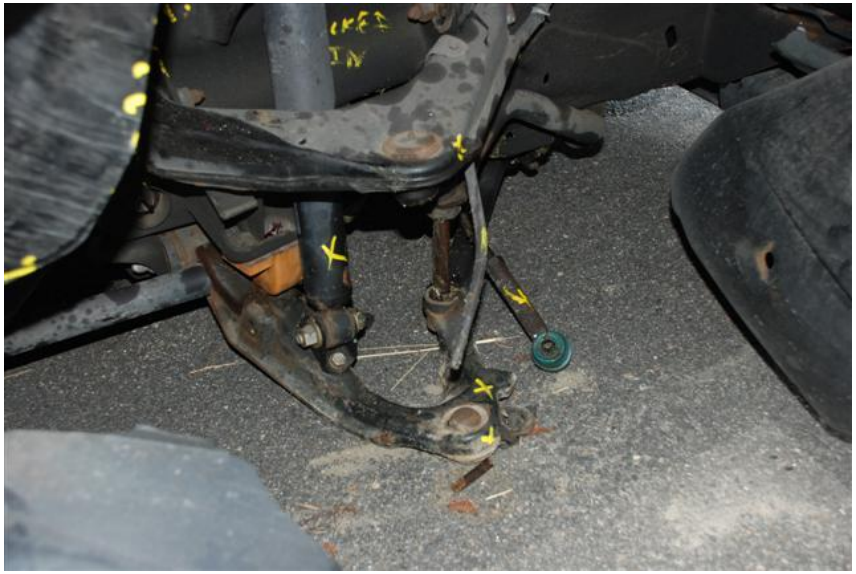
-Tires (492)
-Brake System (119)
-Steering System (20)

-Hit and Run Vehicle (1586)
-Vehicle Registration for Handicap (176)
-Other Vehicle Defects (39)
-Headlights (22)
-Other Working Veh (Not Constr., Police, Fire, EMT) (21)
-Unknown (473)



Other Factors:

- Airbags (5)
- Reconstructed/Altered Vehicles (17)
- Construction Vehicles (9)
- Police, Fire, EMT (15)



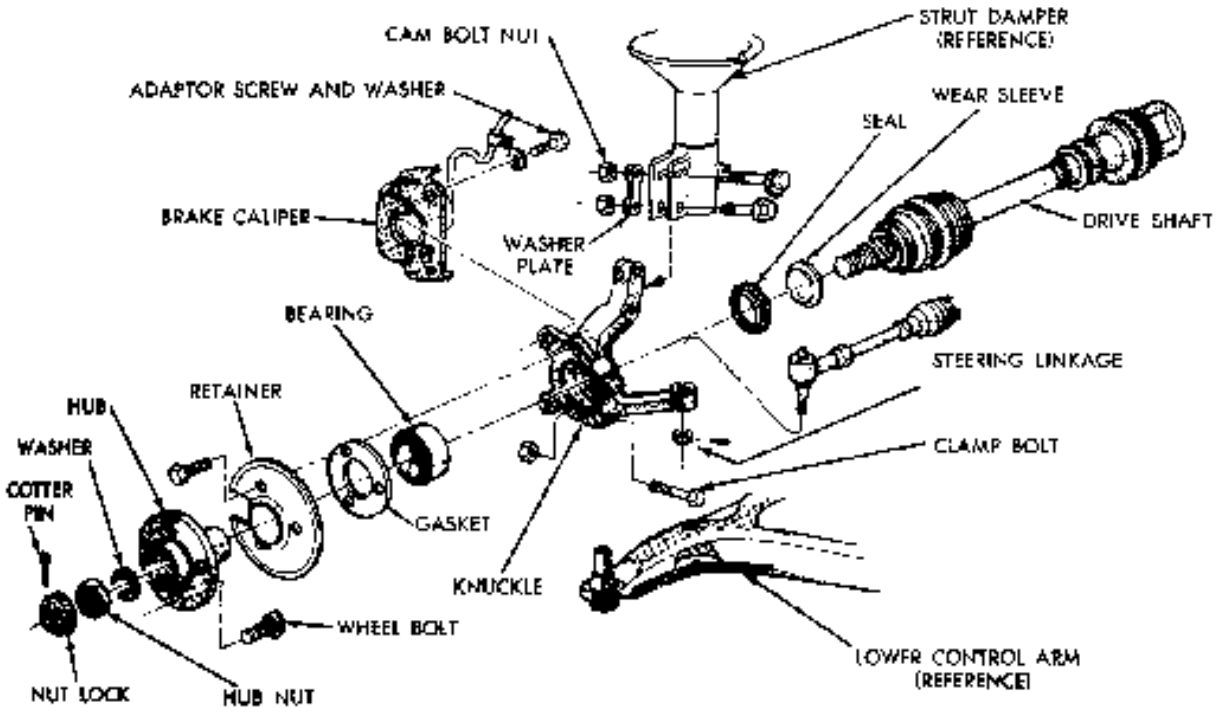
Conclusions from FARS Query

- Other than factors not related to motor vehicle components, the FARS database showed that Steering (a Part of the Suspension System) was a the top vehicle component identified as a factor in motor vehicle fatalities.

Passenger Car/Truck Suspension Systems

- Two most common types for front wheel drive vehicles: MacPherson Strut, Double Wishbone Suspension,
- Two most common type for solid axles: Leaf Springs and Coil Springs

Suspension and Steering Components



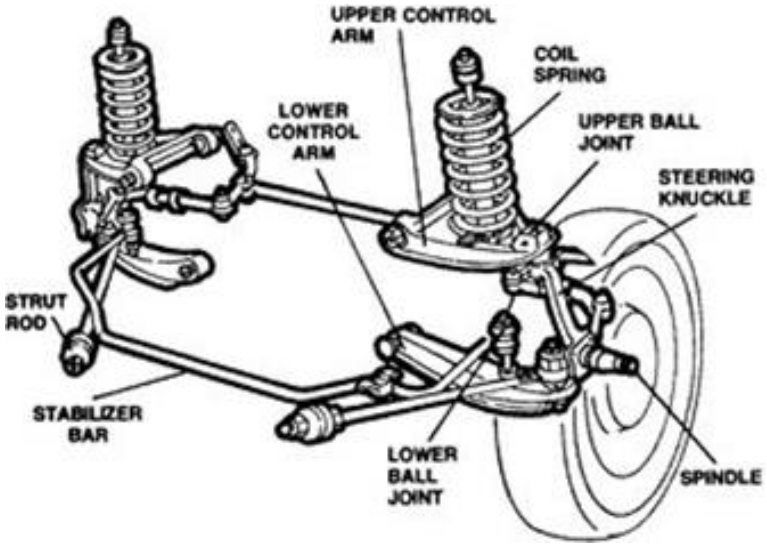
8.1a An exploded view of a typical earlier model steering knuckle assembly and related components

- Basic Front Wheel Drive System Shown
- Note: No Upper Control Arm
- The Knuckle Attaches Directly to Strut

MacPherson Struts

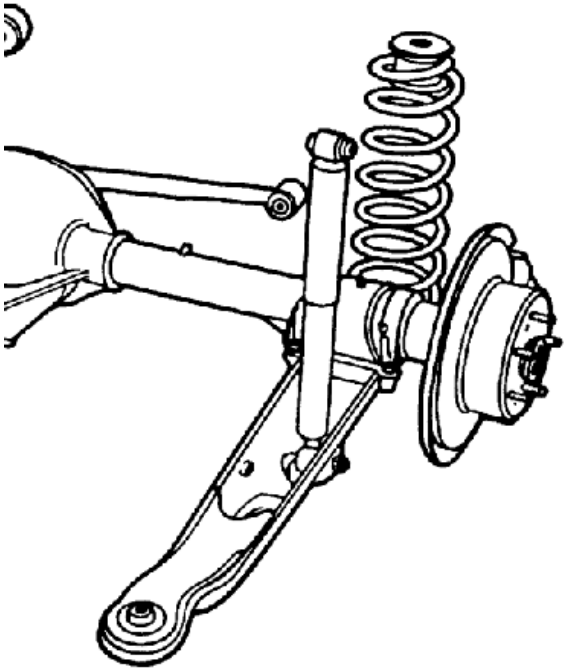
- MacPherson Struts typically used for unibody frame vehicles.
- Top is typically mounted to the frame and has the ability to pivot.
- Bottom is attached to steer knuckle either directly or through a truncated version of an upper control arm.
- Coils act as the load support, while struts/shocks act as damper.

Double Wishbone Suspension



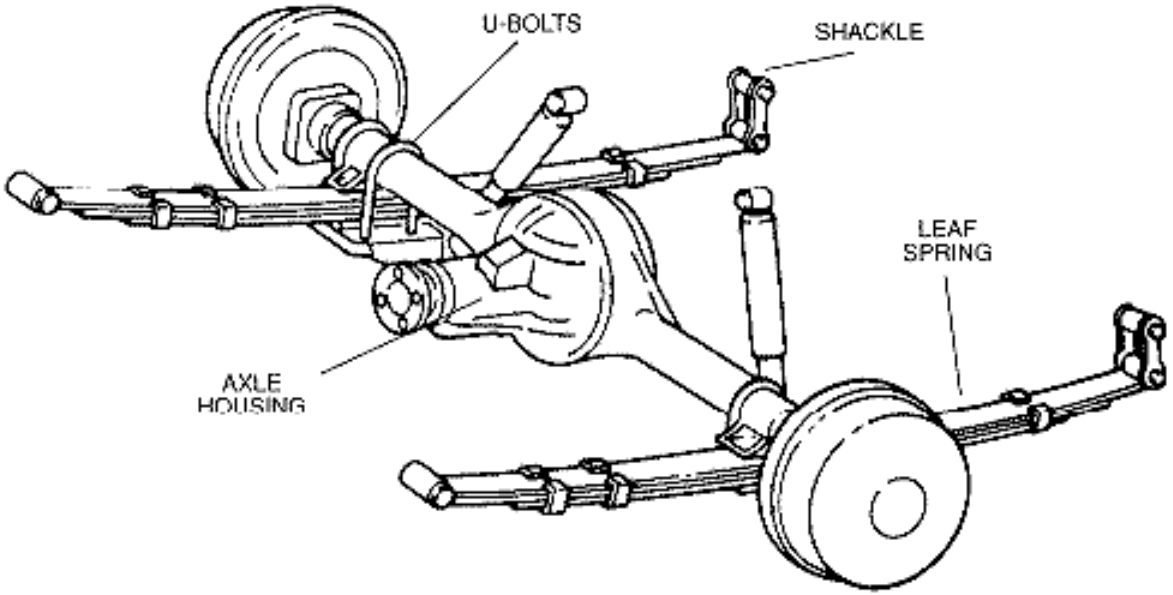
- Double Wishbone has a true upper control arm connected to the steering knuckle
- Double Wishbone allows for true linear motion of the knuckle.
- Takes more room than the MacPherson Strut type suspension
- Preferred suspension for high performance automobiles and off-road high ground clearance vehicles.

Coil Spring Suspension



- Coil Spring Suspension typically have a cantilever arm with a coil and strut attached to the frame for motion control.
- Coil Spring Suspension requires less space than Leaf Springs.
- Coil Spring Suspension has a lower carrying capacity and deflection limit than Leaf Springs

Leaf Spring Suspension



- Leaf Springs require more space and mounting points that coil springs
- Leaf Springs have a much higher load carrying capacity and spring rate that coil springs.
- Leaf Springs can handle higher deflections than coil springs.

Example: Solid Axle Coil

- 2004 Chevy Venture
- Solid rear non-rotating axle
- Coil Suspension
- Shock/Strut angled to rear of unibody

Example: Solid Axle Leaf Spring

- Ford E150 Van
- Solid rear non-rotating axle
- Leaf Springs
- Strut Angled Forward to Frame

Example: Hybrid System

- Toyota Uplander
- Hybrid System for Rear All Wheel Drive System
- MacPherson Strut Linked with Sway Bar
- Lower Control “Arm” Connected to Frame by Linkages.
- Front of Lower Control Arm Attached with Linkage Similar to Coil Spring Suspension.
- Lower Control Arm also linked with a Sway Bar.

Example: Front MacPherson Strut

- Toyota Highlander

Equations of Motion

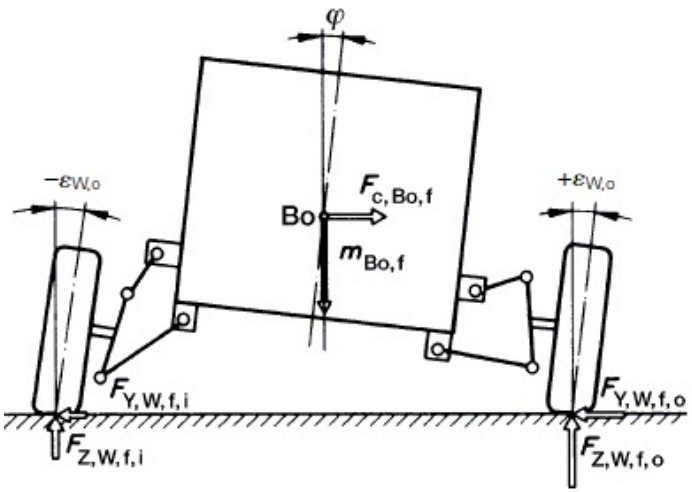
- Fs = -kx where k is the spring constant, and x is the displacement of the spring
- Fd = -cv where c is the damping coefficient and v is the velocity or dx/dt
- Ftotal = Fs+Fd
- Ftotal = ma where m is mass, and a is acceleration
- Therefore:
  Ftotal = m d^2x/dt^2 = -c dx/dt -kx or
  m d^2x/dt^2 + c dx/dt + kx = 0
- Undamped natural frequency is $\omega_0 = \sqrt{\frac{k}{m}}$

Design of Suspension System

- Suspension and steering system design requirements are not specifically defined by the NHTSA.
- However, suspension design is integral to meeting the overall requirements of braking as defined by the Code of Federal Regulations, 49 CFR 571.105.
- Please read the following CFR (right click and open hyperlink) and take note of testing and performance requirements of S5.1:
- http://www.ecfr.gov/cgi-bin/text-idx?SID=09b37f45567997a739afdaad939f2e24&node=49:6.1.2.3.38.2.7.5&rgn=div8
- During braking, the dynamic loads and forces are defined by the suspension system and therefore effect the design of the braking system.

Design of Suspension System

- The suspension system is designed to keep tire contact to the road during regular straight line driving by responding to bumps or nonlinearity in the road.
- The suspension system is also designed to maintain tire contact to the road during steering.
- As demonstrated in the diagram below, cornering requires vertical and lateral degrees of freedom at the wheels



What is a Swaybar?

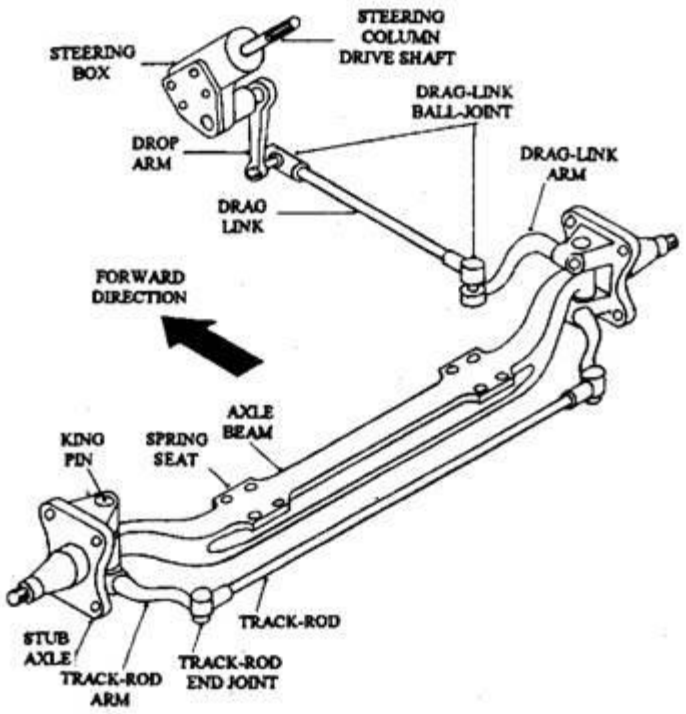
- A sway bar typically attaches to the bottom of the MacPherson strut (via a link), or to the lower control arm under the unibody or frame, or to the axles on a leaf or coil and spring; to the opposite side strut or arm or axle.
- The sway bar acts to attempt to link the relative motion of the wheels to each other.
- A push up on one wheel will cause the sway bar to pull or push up on the other wheel. In this manner the sway of the vehicle is reduced.
- During cornering or turning, the sway bar transfers compression on the outside wheel to the inside wheel.

Rack and Pinion Steering

- The most common system for steering is Rack and Pinion Steering.
- Steering input via the steering wheel is converted to mechanical power to rotate the steering knuckle via a push and pull of linkages.
- Modern vehicles usually supplement the steering input with power steering, steering assist, or electronic steering assist.
- Please review the following video: https://youtu.be/o2kyozK9GII

Conventional Steering System

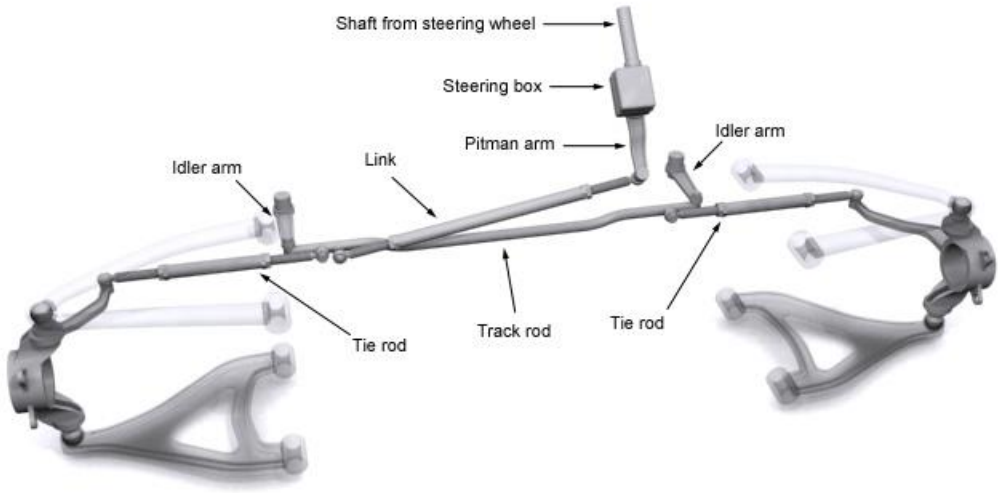
- Conventional Steering System is typically found on commercial trucks.
- Steering input is used to turn a gearbox which rotates a lever arm. The lever arm is used to pull a drag link which pulls a lever arm on the steering knuckle to turn the wheel.
- Usually the steer wheels are sequenced together via a tie-rod (track rod).



Note: RH Side Steering Shown

Pitman Arm Steering System

- Pitman Arm Steering system also uses a gearbox and lever arm (called Pitman Arm) to transfer steering input to a linkage system.
- Pitman Arm Steering system or hybrids there-of are typically used for double wish-bone suspension and performance or race cars.



SAFETY MESSAGE

- Inspecting Suspension and Steering systems can be hazardous to your health.
- ALWAYS use jack stands or blocking when raising a vehicle for inspection.
- ALWAYS use parking brakes and wheel stops.
- NEVER loosen any nuts/bolts that are involved in holding the top strut or bearing plate on the McPherson Struts. The spring is in high compression.
- NEVER loosen any nuts or bolts on the shock or strut itself as they are under gas compression.
- Remember that coils and/or struts under compression may pop to free state suddenly and without warning. See the following video around the 10:30 second mark: http://youtu.be/dLVvS6CuNlQ

SAFETY MESSAGE PART 2

- DO NOT attempt to remove leaf springs without the proper supports to jack or block the vehicle, the axle, and/or the leaf springs, and wheel stops. Preferably a full garage lift should be used.
- Remember after an accident, springs, shock/struts, leaf springs, steering linkages may contain residual tension or compression or spring energy due to deformation of the vehicle or parts.
- Wear safety glasses, safety shoes, and additional PPE as necessary and do the least amount of disassembly necessary to preserve evidence.

Steering Defect Investigations

- By far, the most common claim during a steering defect investigation is the claim that the vehicle failed to respond to steering input by the driver.
- Typically the accident reconstructionist will have to examine roadway marks, vehicle debris, and the vehicle to determine failure sequences and mode.
- Roadway examination may be provided via Police Accident Reconstruction.
- Some Electronic Data Recorder (EDR) data from airbag and supplementary restraint systems may contain steering input data.
- Beyond examination of the vehicle steering system parts, the investigator may have examine any steering assists (power, power assist, electronic assist).
- In addition, with more cars going to electric fly-by-wire systems, the investigator may have to examine electrical control systems.

Steering Defect Investigations (cont.)

- Typically for passenger cars, the steering system is protected by the front bumper, the engine, then sub-frame or engine mounts or other vehicle structure making investigation and determination of accident scenario easier.
- Trucks, Jeeps, or other Pitman Arm or Conventional Arm systems may have linkages or gears mounted forward of vehicle structure and may be damaged during a frontal collision.
- Remember that steering system is a part of the suspension system and failure of a suspension system component could result in loss of or alteration of steering.
- Also remember that typically when driving straight on a flat road, under complete mechanical or electrical loss of steering, gyroscopic forces will tend to keep the vehicle driving forward in a straight line direction.

Suspension Defect Investigations

- By far, the most common claim during a suspension defect investigation is the claim that a suspension component failed leading to a sudden drop and pull in steering.
- Typically the accident reconstructionist will have to examine roadway marks, vehicle debris, and the vehicle to determine failure sequences and mode.
- Roadway examination may be provided via Police Accident Reconstruction.
- Some Electronic Data Recorder (EDR) data from airbag and supplementary restraint systems may contain loss of ABS or loss of traction control indicating separation of signal wires to wheel bearing sensors. Signal wires are typically mounted to and from the suspension system.

Suspension Defect Investigations (cont.)

- The suspension system components are typically at the bottom of the vehicle and will experience drag marks upon loss of a wheel or a cascade failure of the suspension system.
- Suspension system components may fail due to collision forces especially side impacts to the wheel or axle areas, or offset frontal collisions in which the wheels interact.
- Gouge marks and/or debris field prior to impact could be indicative of a failure prior to impact.
- Gouge marks and/or debris field at or after impact could be indicative of failure due to impact.
- Suspension component failures can lead to loss of steering.
- Typically a suspension failure leading to loss of a wheel and a drop will also result in a steering pull towards the corner or side of the failure.