An Introduction to Electronic Stability Control

September 20, 2010

Robson Forensic

Engineers, Architects, Scientists & Fire Investigators

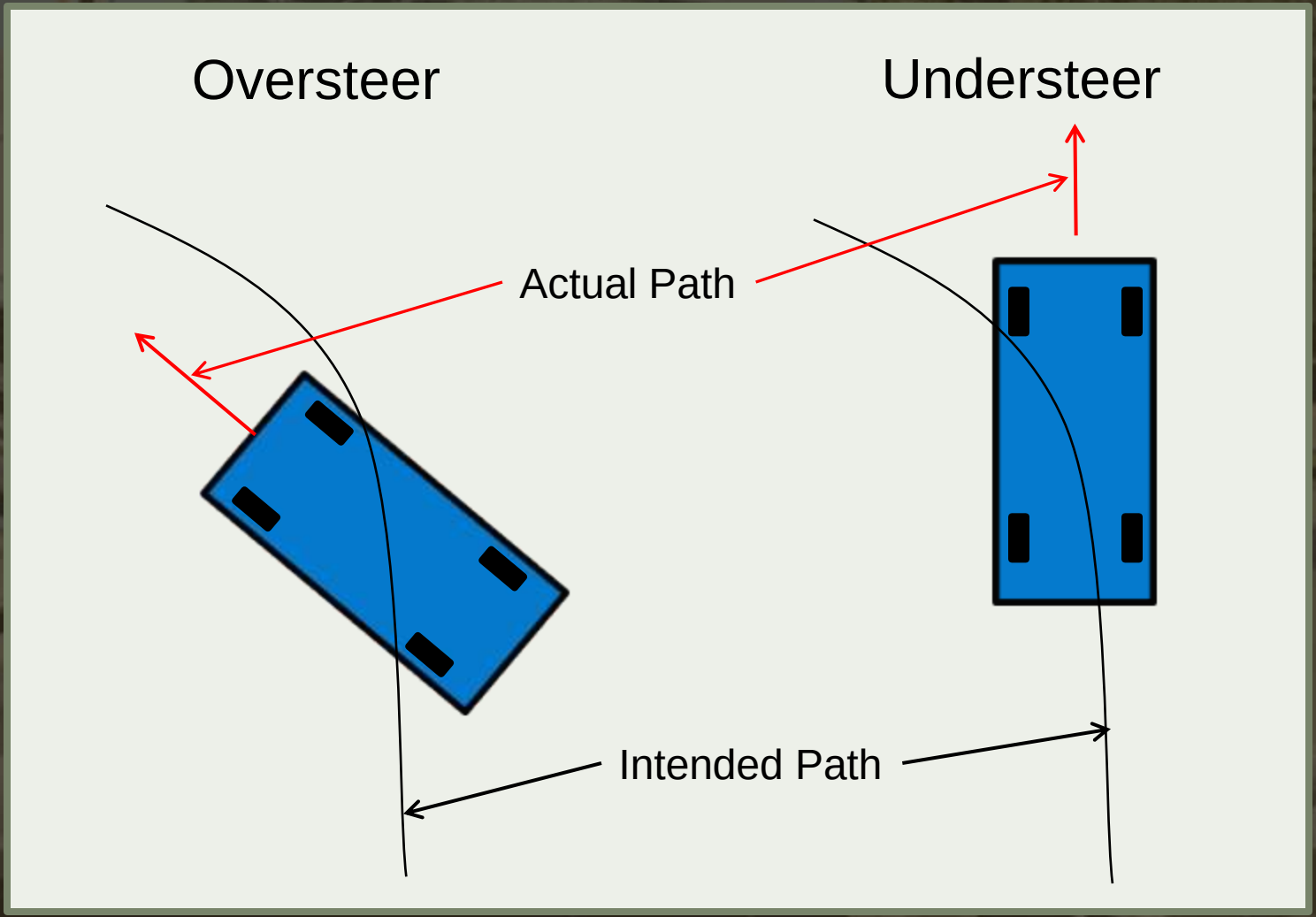
Table of Contents

- What is Electronic Stability Control (ESC)?
- What conditions does ESC try to correct?
- A brief timeline of ESC
- Reduction in fatal crash risk attributed to ESC
- What are trade names for ESC?
- Crash types common to ESC failure
- How it works
- Types of ESC failures
- System limitations
- Other considerations

What is ESC?

- An electro-mechanical system that senses:
  1. the driver's intended path
  2. the vehicle's actual path
- and uses brake and throttle control to alter the actual path to meet the intended path.
- ESC is augmented on some vehicles with Roll Over Mitigation or Roll Stability Control. This is an additional algorithm in the ESC unit that focuses on preventing a vehicle from rolling over, not directional stability.
- Another enhancement of ESC is Trailer Sway dampening (TSD). This algorithm senses when a trailer is causing sway and uses the vehicles, and sometimes the trailers, brakes to control the vehicle-trailer combination

What conditions does ESC try to correct?



A Brief Timeline of ESC

- **1995**: Mercedes-Benz makes ESC standard on some European sold S–class vehicles
- **1996**: Mercedes-Benz adapts ESC to the A-class to pass the European "Moose Test"
- **1998**: BMW makes ESC standard equipment on most European sold models
- **1999**: Mercedes-Benz makes ESC standard equipment on all models
- **2003**: NTSB study results in recommendation that ESC be fitted to all 15 passenger vans
- **2004**: Toyota, Ford, Chrysler, and GM announce ESC will be standard on their SUV's within 2 years
- **2007**: Final Ruling by NHTSA for FMVSS 126: Mandated ESC be standard equipment on every light vehicle (less than 10,000 lb GVWR) by Model Year 2012

Reduction in fatal crash risk attributed to ESC[1]

- Overall ESC is associated with a 33% reduction in fatal crash involvement risk, including a:
  - 20% reduction in multiple vehicle fatal crash risk
  - 49% reduction single vehicle fatal crash risk
  - 53% reduction for SUV's
- SUV fatal crash involvement risk was lowered by:
  - 57% for multiple-vehicle roll-over crashes
  - 75% for single-vehicle roll-over crashes
  - 38% for multiple-vehicle crashes on wet/slippery roads
  - 63% for single vehicle crashes on wet/slippery roads

[1] Statistics are from the paper: Effects of Electronic Stability Control on Fatal Crash Risk, Charles M. Farmer, May 2010.

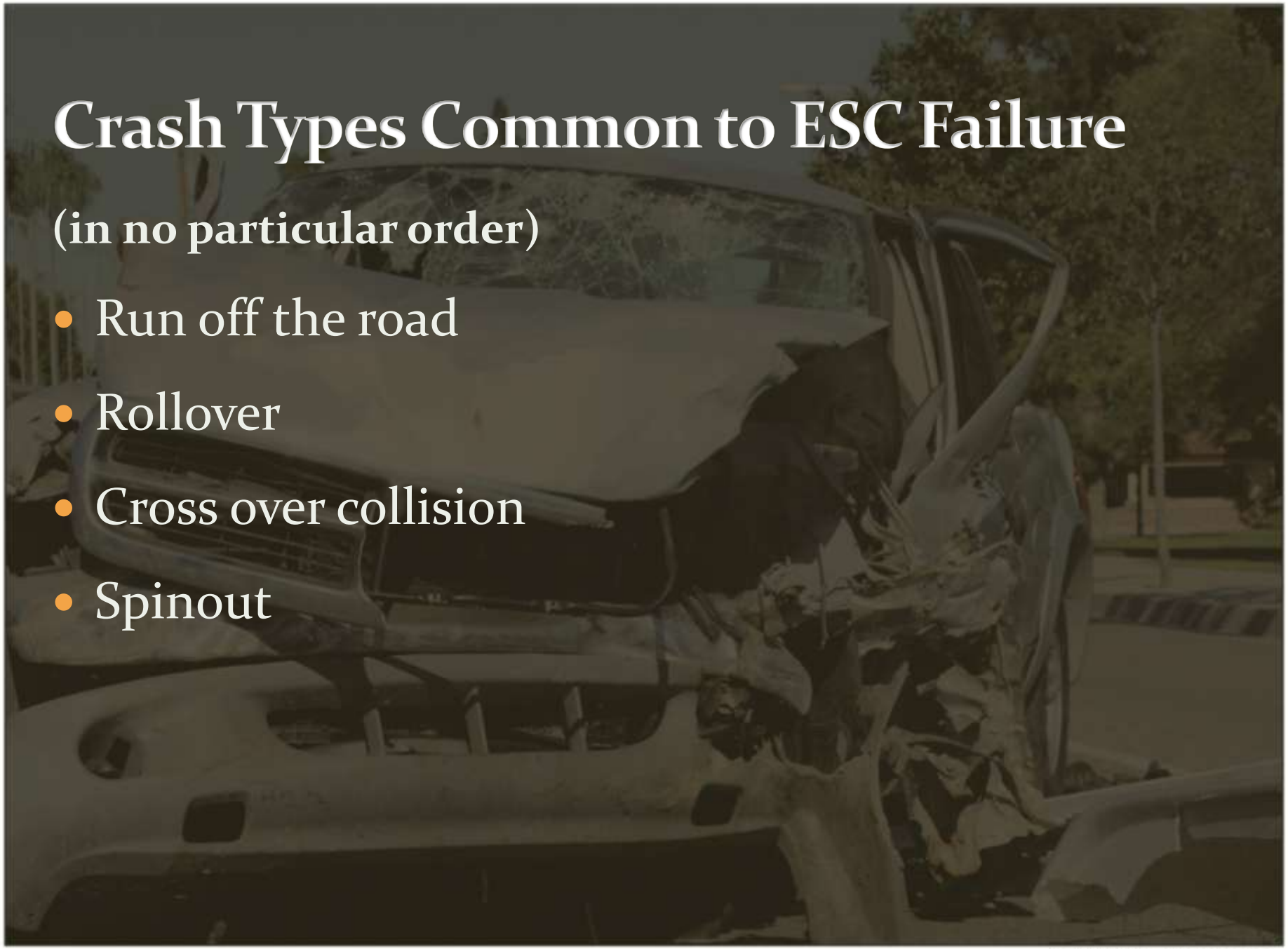
What are trade names for ESC?

- AdvanceTrac – Ford, Mercury, Lincoln
- Dynamic Stability Control – Aston Martin, BMW, Jaguar, Rover, Volvo
- Electronic Stability Control – Honda, Hyundai, Kia
- Electronic Stability Program – Audi, Chrysler, Dodge, Jeep, Volkswagen, Mercedes-Benz
- Porsche Stability Management
- StabiliTrak – General Motors
- Vehicle Dynamic Control – Infiniti, Nissan
- Vehicle Stability Assist – Acura
- Vehicle Stability Control – Lexus, Toyota

Crash Types Common to ESC Failure

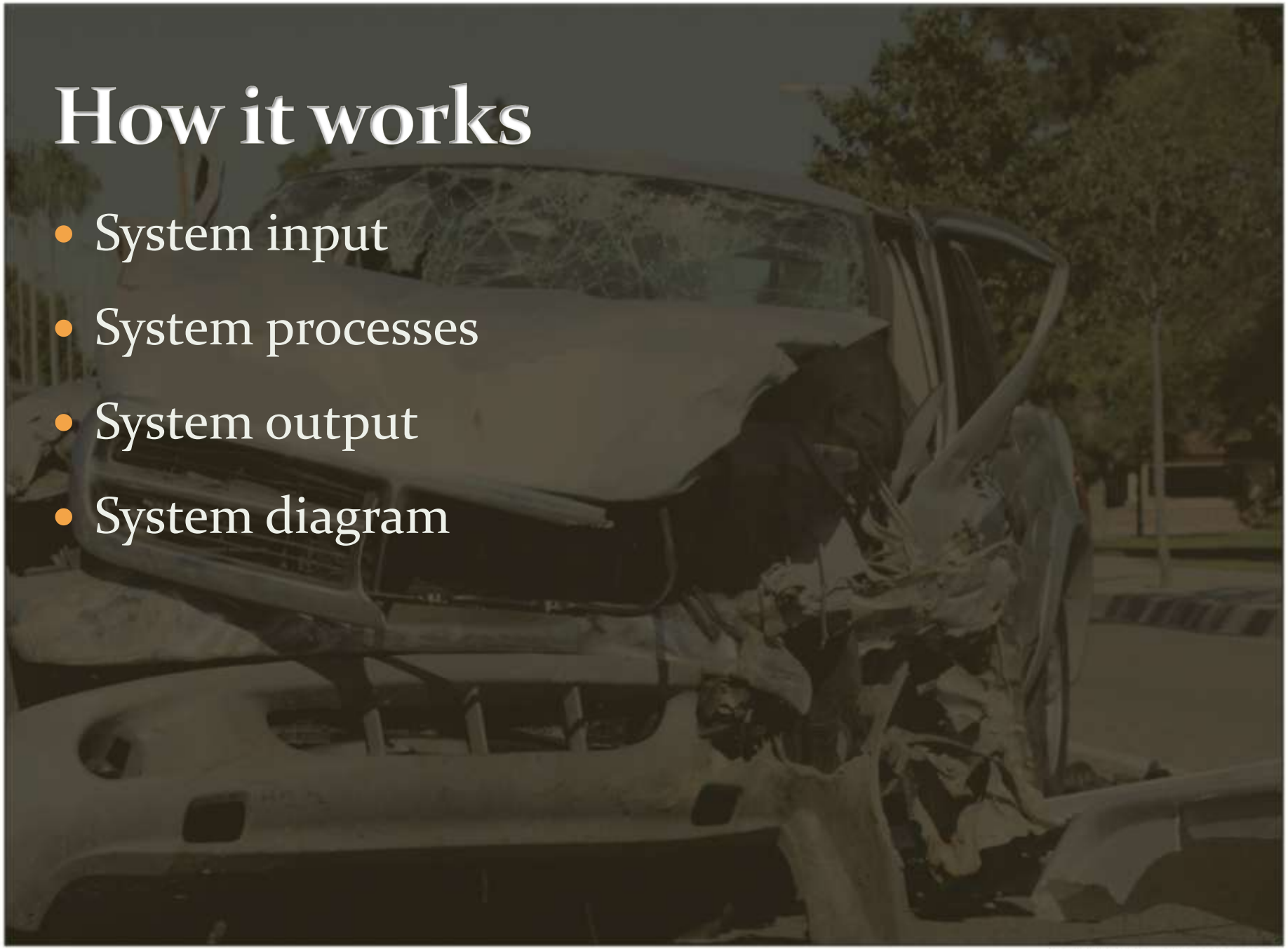
(in no particular order)

- Run off the road
- Rollover
- Cross over collision
- Spinout



How it works

- System input
- System processes
- System output
- System diagram



System input:

- Wheel speed, 4 total (traction)
- Steering wheel angle (intended path)
- Yaw, or rotation (actual path)
- Throttle position
- Vehicle speed

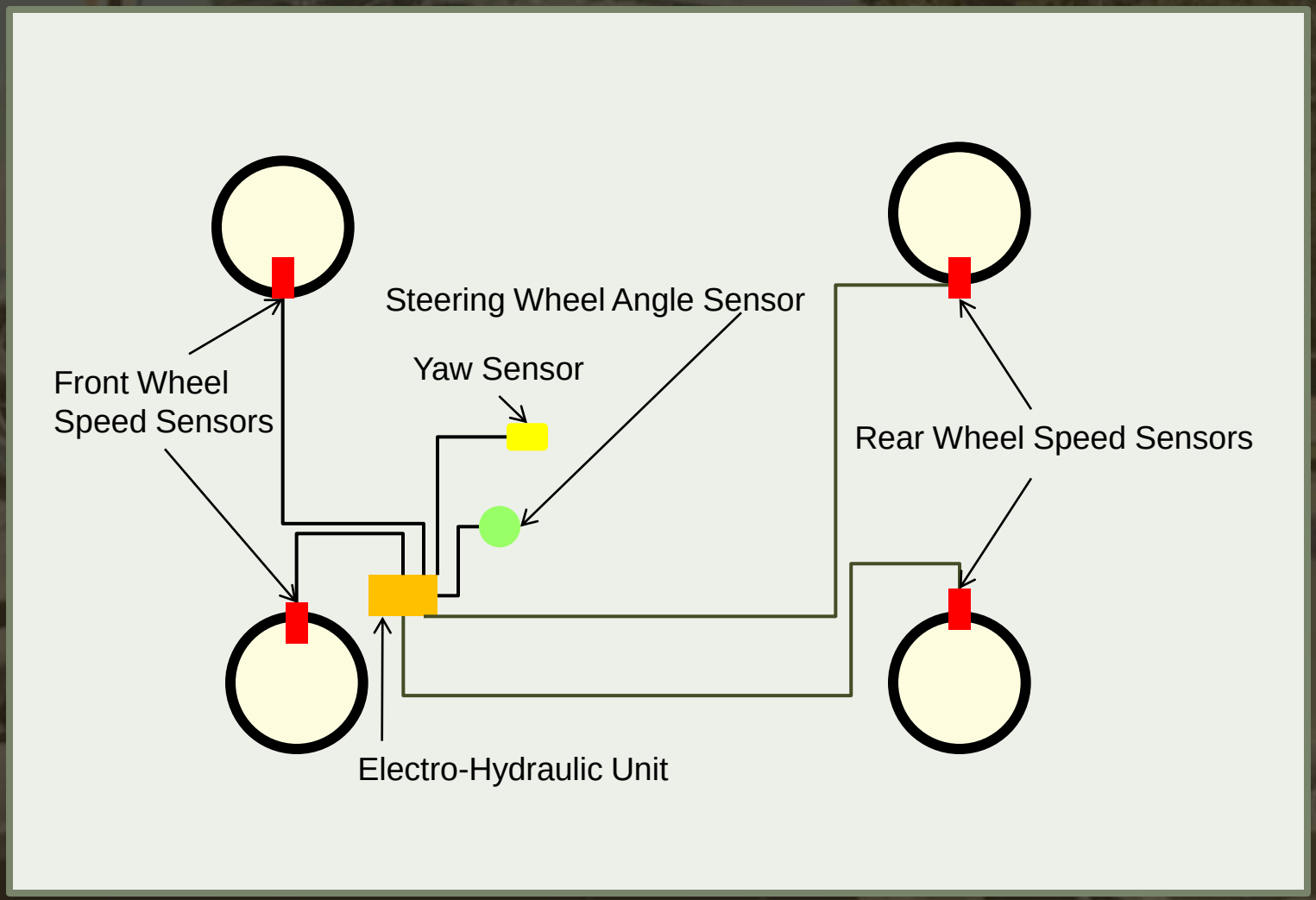
System processes:

- Compares intended with actual trajectory
- Processor is set to analyze which wheel(s) to brake and what, if any, throttle adjustments need to be made
- Computing power has vastly increased since Anti-Lock Brake Systems (ABS) were introduced in the 1980's
- Within two wheel revolutions the module can determine the traction available at each corner of the vehicle
  - At 50MPH, this is approximately 0.2s and 14 feet

System output:

- Individual wheel brake application via ABS hydraulic pump and valves in the electro-hydraulic unit
- Some systems can activate the brake pedal to quickly build brake pressure (active booster)
- Engine torque reduction request
- Telltale illumination and/or audible warning for driver feedback in cabin
- Brake pedal feedback
- Audible pump motor noise (slight grinding)

System diagram:



When do you have a potential ESC case?

- ESC not available
  - Complex analysis of vehicle age, communication protocol, and other factors
- ESC is an extra-cost option
  - Safety should not cost extra!
- System performance
- System failures

ESC Not Available

- FMVSS 126 mandates ESC be standard equipment on all light duty vehicles (GVWR < 10k lbs) for the 2012 model year, with the following phase-in schedule:
  - 2009 model year = 55% of production
  - 2010 model year = 75% of production
  - 2011 model year = 95% of production
- Not all ESC systems have Roll Over Mitigation (not covered by 126):
  - Additional algorithm that doesn't focus on directional control, but rather on preventing a roll over
- Not all ESC systems have Trailer Sway Dampening (not covered by 126):
  - Additional algorithm that senses and corrects vehicle sway when towing a trailer
- ESC is a complex system requiring communications with multiple other ECU's in the vehicle
  - The older the vehicle, the less likely the vehicle's communication network can support ESC

ESC as an Extra Cost Option

- In some vehicles ESC was introduced as a stand alone option or part of an option package or trim level
  - Development work was completed, why not offer it as standard equipment?
- Consider the Cadillac Escalade and its lower priced platform mates the Chevrolet Tahoe and GMC Yukon, all produced by GM
  - All 3 share a common platform including frame, suspension geometry, body stampings, wheelbase, etc.
  - GM made ESC standard on the Escalade for the 2002 Model Year, while offering it as an option starting in 2003 for the Tahoe and Yukon.
  - GM would make ESC standard on the Tahoe and Yukon for the 2006 Model Year, 4 years after the Escalade.

System performance

- Crash occurs in a foreseeable circumstance
  - Low friction conditions
    - Wet road
    - Snow and ice covered road
    - Dirt/gravel road
  - Evasive maneuver
    - Lane change
    - Double lane change
    - Sudden turn

System failures

- Causes of system failures:
  - Sensor fault
  - Wiring short/ground
  - Wiring connector water intrusion
  - Internal module defect
- Gauge Cluster “Telltale” should be illuminated if there are any failures active in the system that would interfere with its ability to work properly

Proving system is responsible

- Site and vehicle inspection
  - Evidence preservation
- Crash reconstruction
  - Vehicle speed
  - Hazardous roadway condition
  - Hazardous weather condition
  - Driver actions
  - Proving vehicle was recoverable

System limitations

- ESC will not void the laws of physics:
  - If speed is too high to negotiate a curve, system can't prevent a runoff
  - System can make arc of travel larger, preventing a spin out or plow out
- ESC can not prevent a tripped roll-over:
  - System can help prevent the condition that caused the spin out or plow out that led to a tripped roll over

System limitations (continued)

- Vehicle modifications affecting ESC system performance:
  - Larger than OE wheels and tires
  - Aftermarket brake system parts
  - Modified suspension system
  - ESC software does not compensate for these modifications

Other Considerations

- ESC mode at time of crash
  - ESC on
  - ESC partial off
  - ES full off
    - When in partial or full off mode the full benefits of the system can't be realized
- Vehicle was recoverable:
  - Accident Reconstruction
  - Black Box data