NHTSA's Light Vehicle ESC Research Program

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Effectiveness of Electronic Stability Control for Preventing Crashes

ESC Effectiveness

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- Multiple studies have been conducted
- Europe
  - DaimlerChrsyler
  - Swedish Nat. Road Administration
  - European Accident Causation Survey
- Japan
  - Toyota
- United States
  - NHTSA
  - IIHS

DaimlerChrsyler

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- **German crash data**
  - **German Government Statistics Office (Statistischen Bundesamtes)**
  - **1999/2000 data compared to 2000/2001**
    - **Newly registered Mercedes vehicles**
    - **ESC standard equipment for MY1999**
- **Estimates based on statistical analyses**
  - **15% reduction in total accidents**
  - **30% reduction in single vehicle accidents**
- **Reductions in side-impacts, rollover crashes, and average injury severity**

Swedish Nat. Road Administration
(Tingvall, et al.)

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- Swedish crash data
  - Police reported accidents with at least one injured person
  - Accidents occurred during 2000 to 2002
  - Cars of similar/identical make model were used; 1998 to 2003 model years
- ESC effectiveness estimates based on statistical analyses
  - Dry roads: No significant effect
  - Wet roads: At least a 7.8% reduction*
  - Snow / Ice: At least a 12.1% reduction*
- Most significant accident reduction observed for large cars (both front- and rear-wheel drive), especially on low-mu surfaces

**Lower bound of the 95% confidence limit*

European Accident Causation Survey (Sferco, et al.)

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- **Potential ESC effectiveness based on statistical analyses of EACS data (i.e., the "opportunity" for ESC to improve safety)**
- **EACS contains data from approximately 1674 crashes in 5 European countries from 1995 to 1999**
- **Expert EACS investigators believe the presence of ESC could have improved the outcome of many accidents investigated**
  - **Injury accidents: 18%**
  - **Fatal accidents: 34%**
- **If accident causation was "loss of vehicle control", the benefits of ESC are expected to be even more apparent**
  - **Injury accidents: 42%**
  - **Fatal accidents: 67%**

Toyota
(Aga, et al.)

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- **Japanese crash data**
  - **Compiled by the Institute for Traffic Accident Research and Data Analysis (ITARDA)**
  - **3 popular Toyota passenger cars were considered**
- **Estimates based on statistical analyses**
  - **35% reduction in single car accidents**
  - **30% reduction in head-on collisions with other vehicles**
  - **35% reduction in casualties per year (for single car crashes and head-on collisions)**
- **ESC effectiveness appears to be highest in the range of approximately 40 - 100 kmph (25 – 75 mph)**

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(Dang)

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- **Examined single vehicle crashes**
  - Limited number of higher end vehicles
- **Two sources of data**
  - State data for all crash severities for five states (1997 – 2002)
  - FARS data (1997 –2003)
- **All severities of single vehicle crashes reduced**
  - Passenger cars: 35%
  - Sport utility vehicles: 67%
- **Fatal single vehicle crashes reduced by:**
  - 30% for passenger cars
  - 63% for sport utility vehicles

Insurance Institute for Highway Safety

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- **Calculated fatal crash risk per registered vehicle for vehicles with ESC standard versus those with no ESC or ESC optional**
- **Found that:**
  - **Fatal single vehicle crash risk reduced by 56%**
  - **Multi-vehicle fatal crash risk reduced by 17%**
  - **Risk for all fatal vehicle crashes reduced by 34%**
- **If ESC present on all light vehicles, it could**
  - **Prevent 800,000 single vehicle crashes per year**
  - **Saving 7,000 lives per year**

ESC Effectiveness - Summary

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- **Multiple studies, in several countries using different data sets and methodologies, have all found substantial reduction in single vehicle crashes due to ESC**
  - **Typically about a 30% reduction**
- **Each study indicates installation of ESC on all light vehicles should prevent many fatal crashes each year**

How Does Electronic Stability Control Prevent Crashes?

How ESC Helps:
Untripped Rollover Reduction

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- **Test using NHTSA Fishhook**
- **ESC can be tuned to prevent two wheel lift in NHTSA Fishhook**
  - **Not all tunings will prevent untripped rollover**
  - **Requires aggressive front wheel braking**
- **Untripped rollovers represent a small percentage of the rollover crash problem**

How ESC Helps:
Transient Oversteer Reduction

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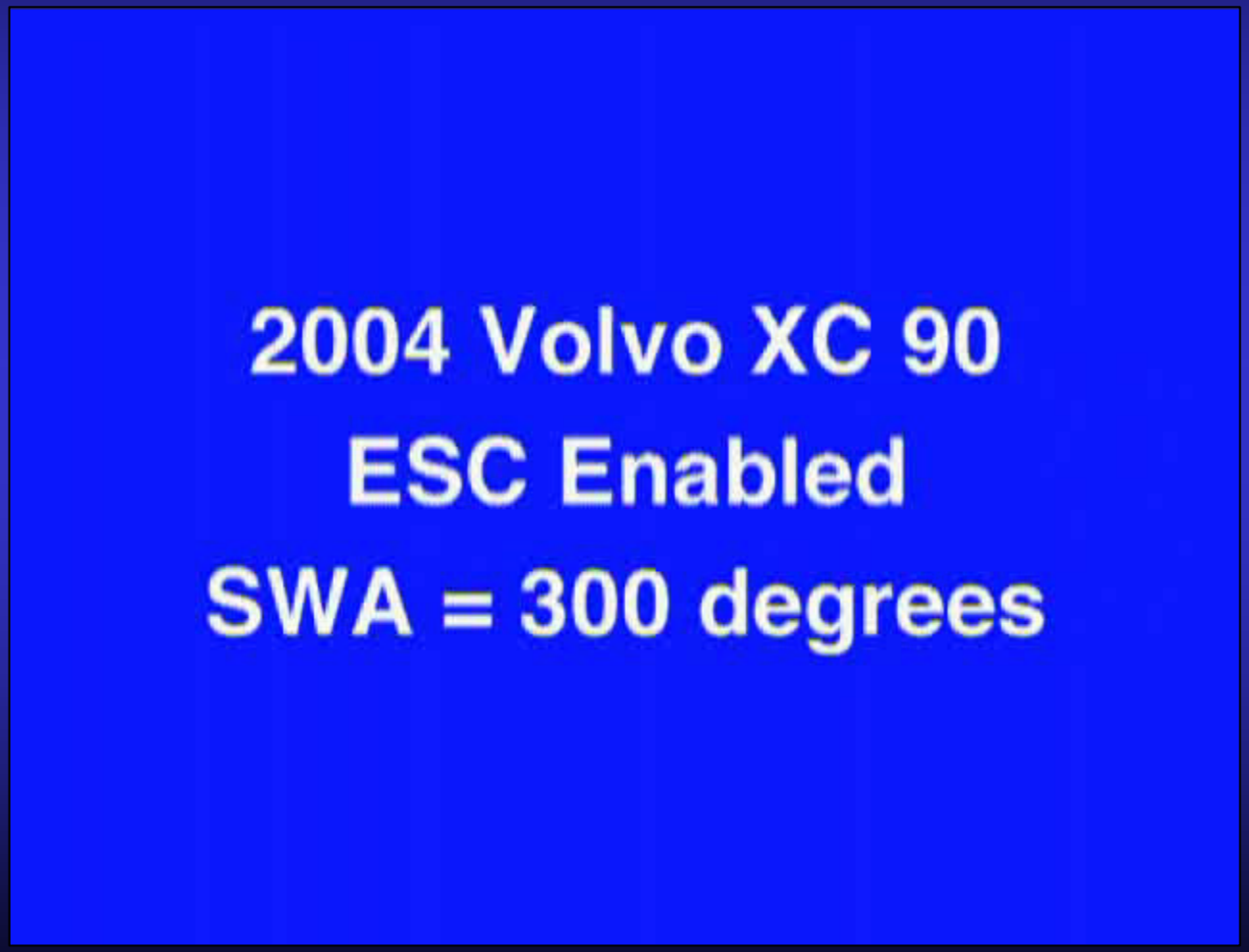
- **Test using variant of single sine steer**
  - **Will discuss test in greater detail later**
  - **NHTSA has selected**
- **Thought to be important mechanism for prevention of crashes**
  - **Approximately 25% of fatal single vehicle crashes believed to be due to transient oversteer**

Example:
Transient Oversteer (disabled ESC)

Example:
Effect of ESC (enabled ESC)



How ESC Helps:
Excessive Understeer Reduction

- Do not know how to test for excessive transient understeer
  - Plan to develop test in future
- Thought to be important mechanism for mitigation or prevention of crashes
  - Magnitude of effect not known

How ESC Helps:
Slows Vehicle Down

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- **ESC gets brakes on in emergency situations**
  - Generally, this is better than not braking
- **ESC may also "pre-charge" a vehicle's brakes**
  - Low pressure brake application
  - Gets brakes on 0.10 to 0.15 seconds faster if needed
- **Thought to be important mechanism for mitigation or prevention of crashes**
  - Even small amount slowing down can mitigate or prevent some crashes
  - Magnitude of effect not known

How ESC Helps:

- **We do not have complete answer to question of how ESC helps**
- **Remains active research topic**

Current NHTSA ESC Research Program

Program Objectives

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- **Develop test to ensure that vehicle does not go out of control (spinout) due to transient oversteer**
  - **Objective satisfied, will discuss later**
- **Develop pass/fail criteria**
- **Prevention of excessive understeer will be worked upon later**
- **May or may not want to do further research on how ESC helps slow vehicles down**

Program Approach

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- **Building on non-linear handling research performed by Alliance of Automobile Manufacturers**
- **NHTSA is collaboratively gathering data to improve proposed test to ensure that vehicle does not spinout due to transient oversteer**
  - **Presently refining pass/fail criteria**

Five Maneuvers
Performed With A Steering Machine

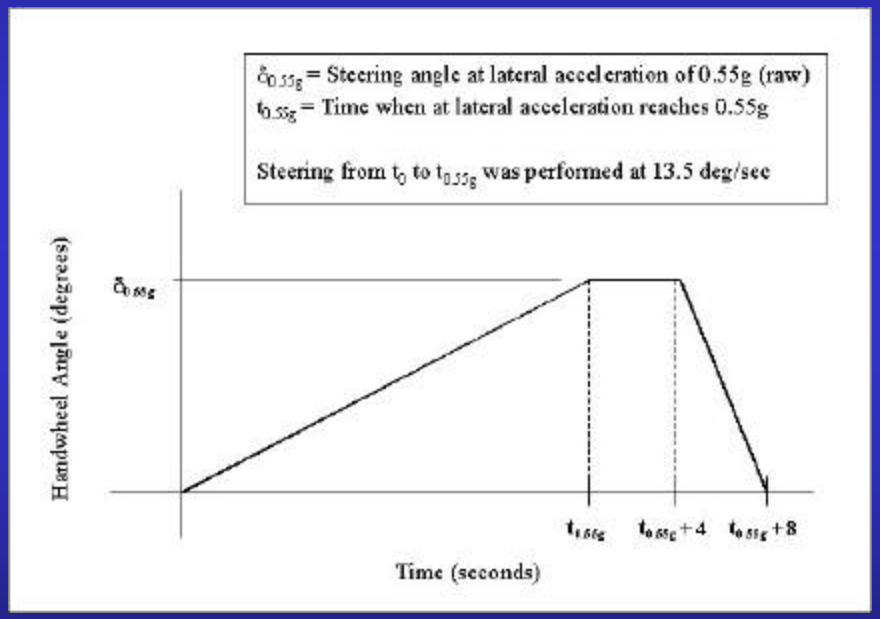
- **Slowly Increasing Steer**
  (for characterization use only)
- **0.7 Hz Sine with Dwell**
- **0.7 Hz Increasing Amplitude Sine**
- **500 deg/s Yaw Acceleration Steering Reversal**
- **500 deg/s Yaw Acceleration Steering Reversal w/Pause**

Test Conditions

- ESC enabled and disabled
- Test surface
  - Dry, high-mu asphalt
  - Maneuvers initiated while vehicle is being driven up a 1% grade
- Nominal load
  - Driver
  - Instrumentation
  - Outriggers if vehicle is an SUV, pickup, van, minivan, station wagon, or crossover vehicle

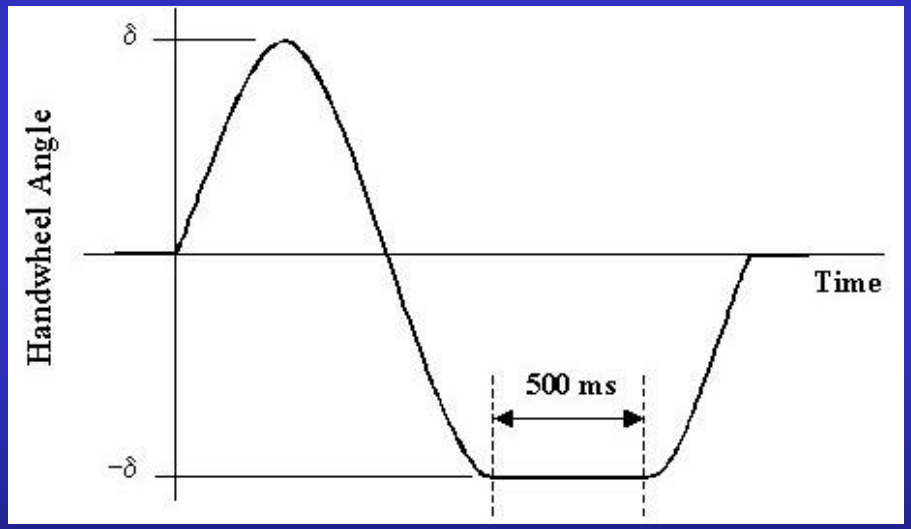
Maneuver Description
Slowly Increasing Steer

- **Low severity**
  - Used for characterization only
  - Raw AY of 0.55g
- **Provides the SWA at 0.3g**
  - Data is required by all other maneuvers performed in this study
  - Must first be corrected for roll effects
- **Driver attempts to maintain constant vehicle speed via throttle modulation**
  - 50 mph



Maneuver Description
0.7 Hz Sine with Dwell

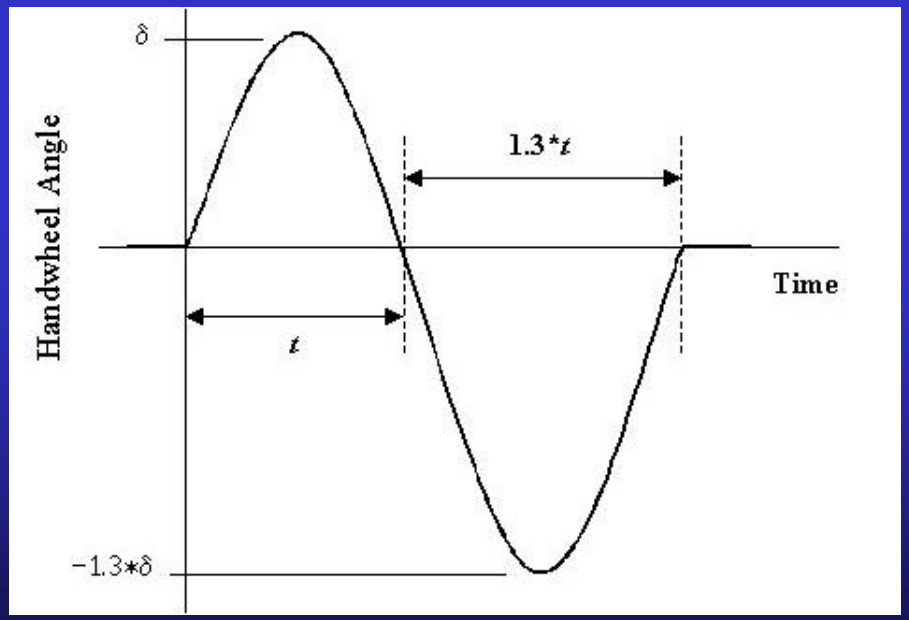
- Steering frequency fixed at 0.7 Hz, but with a 500 ms pause after the 3rd quarter-cycle
- Severity increased with SWA
  - Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,
  - Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,
  - Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater
- 50 mph entrance speed
- Dropped throttle



Maneuver Description
0.7 Hz Increasing Amplitude Sine

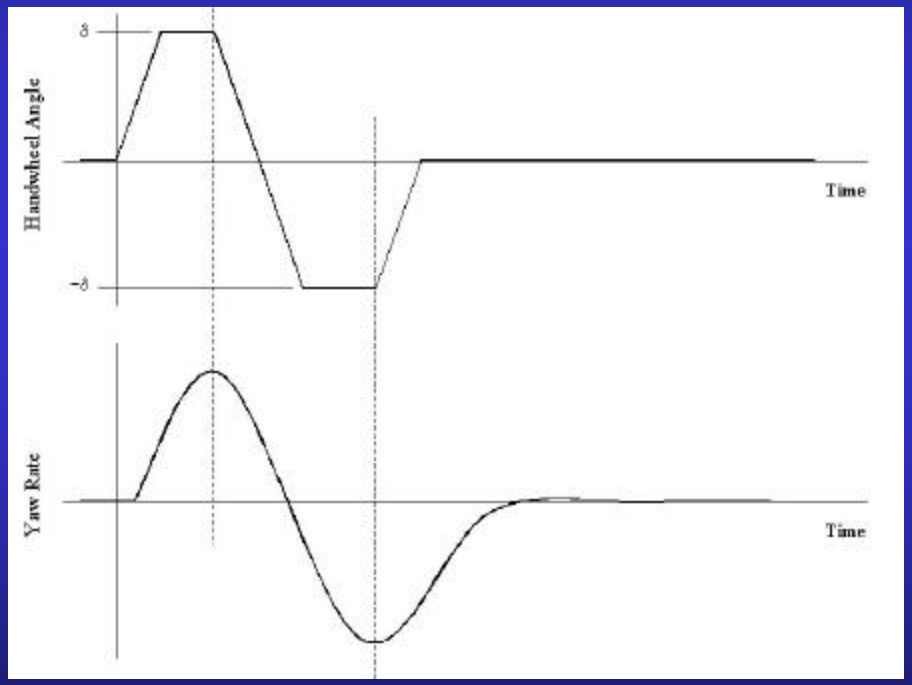
- Steering of frequency first ½ cycle fixed at 0.7 Hz
- 2nd ½ cycle amplitude is 1.3 times that of the 1st ½ cycle
- Duration of the 2nd ½ cycle is 1.3 times that of the 1st ½ cycle
- Severity increased with SWA
  - Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,
  - Lowest 2nd Steer SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,
  - Highest 2nd Steer SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater

- 50 mph entrance speed
- Dropped throttle



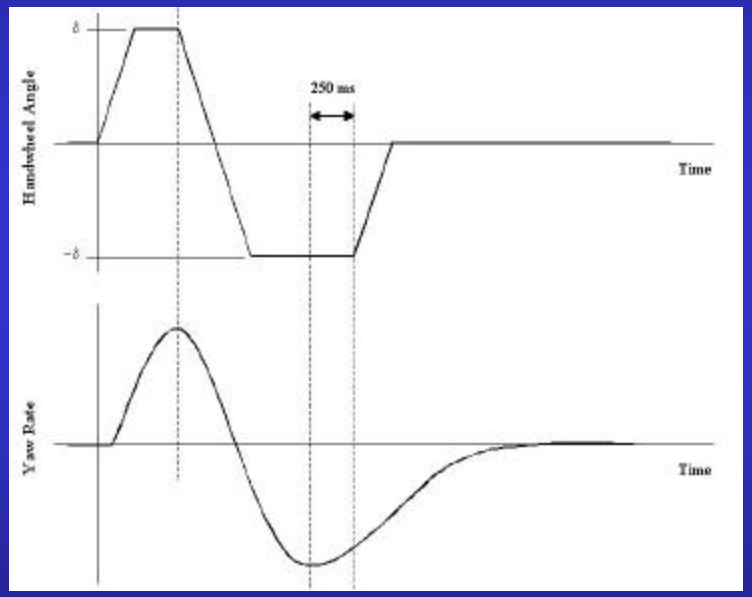
Maneuver Description
Yaw Acceleration Steering Reversal

- Maneuver adapts to the vehicle being evaluated rather than relying on one frequency
- Steering reversals both initiated at peak yaw rate
- Severity increased with SWA
  - Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,
  - Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,
  - Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater
  - 500 deg/s ramp rates



Maneuver Description
Yaw Accel Steering Reversal w/Pause

- Maneuver adapts to the vehicle being evaluated rather than relying on one frequency
- 1st steering reversal initiated at peak yaw rate, 2nd reversal at peak yaw rate + 250 ms
- Increased dwell after second yaw rate peak gives the vehicle more time to respond to the second peak SWA
- Severity increased with SWA
  - Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,
  - Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,
  - Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater
  - 500 deg/s ramp rates



Program Approach

- Each of these maneuvers has advantages and disadvantages
  - Much emphasis was placed on better understanding these factors for each maneuver
- Recently, the "Sine with Dwell" was selected as NHTSA's preferred test maneuver
- Results from NHTSA and industry indicate this maneuver offers the best combination of severity, performability, and repeatability for a broad range of vehicles

2005 Testing

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- Evaluate 50 vehicles in 2005
  - NHTSA: 24 vehicles
  - Industry: 26 vehicles
- Vehicles separated into two groups
  - Priority #1
  - Priority #2
- Data from "Priority #1" vehicles presently being analyzed
- NHTSA hopes to have a more well-defined pass/fail criteria by July 1, 2005

Pass/Fail Criteria

- Spinout must not occur
  - Need definition of spinout
- Vehicle must still be responsive
  - E.g., Must achieve a minimum lateral displacement during test
  - Proposed magnitude: 12-feet
- No two-wheel lift
- No tire debeading or rim-to-pavement contact

What is a "Spinout"

- **NHTSA does not know of a generally accepted, quantitative definition**
- **People generally know spinout when they see it**
- **However, there are some vehicles/cases which are not clear**

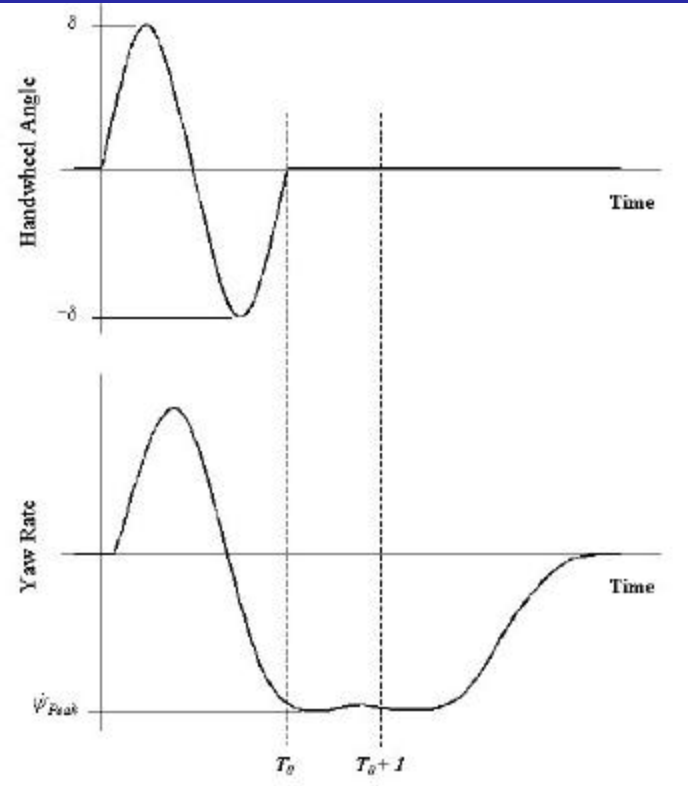
What is a “Spinout”

What is a "Spinout"
Preliminary NHTSA Definition

$$Percent\ \dot{y}_{Peak} = 100 * \left(\frac{\dot{y}(t)}{\dot{y}_{Peak}} \right)$$

$$Set\ t = t_0 + 1$$

$$Spinout\ occurs\ if\ \ Percent\ \dot{y}_{Peak} \geq 60\%$$



What is a "Spinout"

- **Other people/organizations are developing alternative definitions of spinout**
  - **NHTSA welcomes alternate definitions!**
- **Will pick the best, most robust definition from among those suggested**

Additional Information on NHTSA's Research

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- **ESC Docket**
  - **http://dms.dot.gov/search/searchFormSimple.cfm**
  - **Number 19951**
- **VRTC ESC Website**
  - **http://www-nrd.nhtsa.dot.gov/vrtc/ca/esc.htm**