

# A Preliminary Examination of Lane Keeping Support Systems

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# What Crashes Can LDW / LKS Address?

- ⌘ The 2004 GES crash data contain 5,942,000 police reported crashes that involved at least one light vehicle
- ⌘ Using these crash data, Najm, et al. have identified three common pre-crash scenarios relevant to LDW and LKS
- ⌘ Frequency and cost of these crashes = high societal harm

Scenario	Frequency; <i>Rank Order</i>	Economic Cost (\$); <i>Rank Order</i>	Functional Years Lost (Harm Metric); <i>Rank Order</i>
Road Edge Departure Without Prior Vehicle Maneuver	975,000; <i>5<sup>th</sup></i>	9,005,000,000; <i>3<sup>rd</sup></i>	270,000; <i>2<sup>nd</sup></i>
Vehicle(s) Not Making a Maneuver – Opposite Direction	124,000; <i>15<sup>th</sup></i>	6,407,000,000; <i>7<sup>th</sup></i>	206,000; <i>4<sup>th</sup></i>
Vehicle(s) Drifting – Same Direction	98,000; <i>17<sup>th</sup></i>	1,383,000,000; <i>17<sup>th</sup></i>	37,000; <i>17<sup>th</sup></i>

# System Overview

- ≡ Lane Keeping Support (LKS) is an extension of lane departure warning (LDW) technology
  - Cameras used to track lane lines
  - LKS requires more hardware than LDW
- ≡ Key difference: while LDW warns the driver if they breach their lane, LKS attempts to actively help the vehicle maintain and/or reestablish lane position
  - LKS expected to have greater effectiveness than LDW
  - LKS is not necessarily “lane centering”
- ≡ LKS systems do not necessarily include separate LDW alerts

# How Does LKS Work?

- ≡ LKS interventions are presently executed in one of two ways
  - ▶ Automatic brake intervention
    - ▶ Brake torque applied at one or more wheels
    - ▶ Used to create a yaw moment
  - ▶ Use of the vehicle's steering system to automatically turn the steering wheel in the necessary direction
- ≡ Other options may appear in the future
  - ▶ Active differentials
  - ▶ Sophisticated all-wheel drive systems



# Vehicles Equipped with LKS

- Thus far, the only vehicles sold in North America with LKS are select Infiniti and Toyota/Lexus models



2010 Toyota Prius

2008 Infiniti EX35

- Intended to assist the driver, not to provide autonomous control
- Some vehicle manufacturers offer LKS in other markets

# 2009 LKS Test Track Evaluation

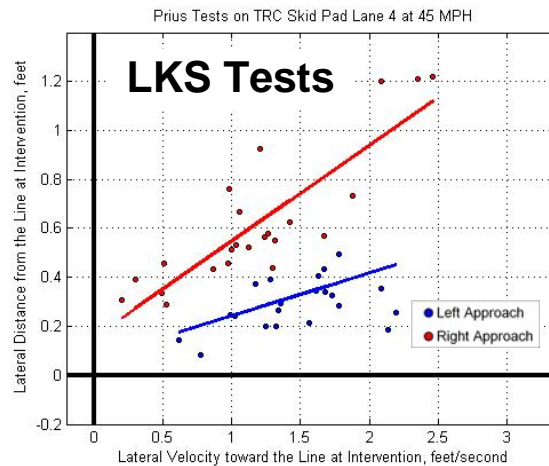
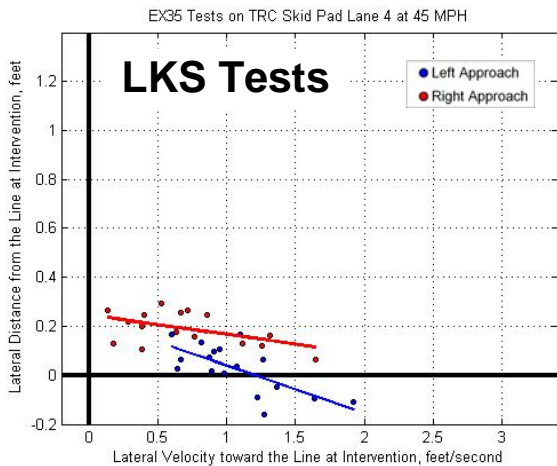
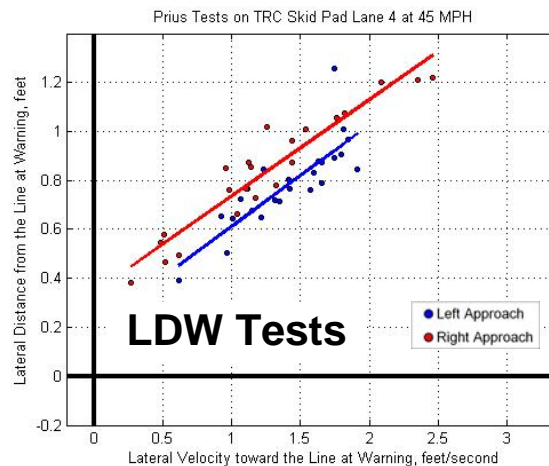
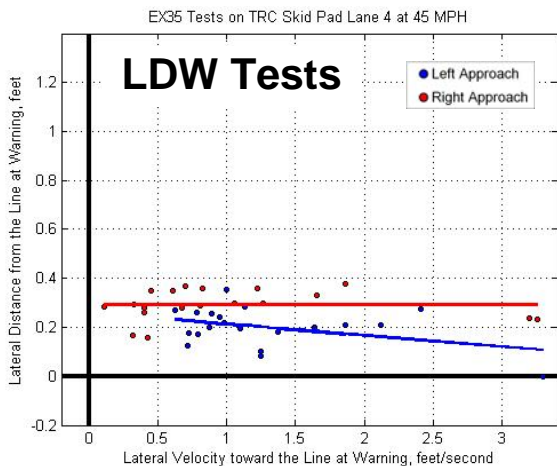
- ≡ Straight lane departure effectiveness
  - NCAP LDW test courses; single lane line markings
  - Lanes delineated with two solid white lines
  - Steering capable of producing low to high lateral velocities
- ≡ Curved lane departure effectiveness
  - 500 m nominal radii (ISO/WD 11270)
  - Lanes delineated with solid white markings (one and two lines)
  - Straight-to-curve transitions
  - Lane position established, steering released
- ≡ 35, 45, 55, 65 mph test speeds (except NCAP course)
- ≡ Left and right departures
- ≡ Prohibited operation tests (turn signal-based)

# Preliminary Results

# Straight Lane Performance

- ≡ For the vehicles tested, LKS interventions occurred after the audible LDW alerts
- ≡ Generally speaking, LKS effectively mitigated low lateral velocity lane departures
- ≡ LKS interventions often produced secondary departures
  - ▶ Effect observed with steering and brake-based interventions
  - ▶ Typically invoked subsequent LKS interventions
- ≡ Some secondary interventions were unable to effectively manage the LKS-induced departures
  - ▶ Example: The LKS intervention found to prevent a right side departure produced a left-side departure later down the road.

# LDW vs. LKS Intervention Comparison (45 mph, Two Solid White Lane Lines)



2008 Infiniti EX35

2010 Toyota Prius

# Straight Lane Performance Example

Straight Road, Single Lane Line  
NCAP LDW Course  
(TRC Vehicle Dynamics Area)

Straight Road, Two Lane Lines  
(TRC Skid Pad Lane 4)

# Ping Pong Example

When should LKS systems “time out”?

Cabin view

Outside view. Test has multiple LKS interventions, concludes with a lane departure.

# Curved Lane Performance

- ≡ LKS was unable to effectively mitigate straight-to-curved road lane departures
  - Departures occurred almost immediately after the transition
- ≡ Inconsistent low lateral velocity performance
  - Low lateral velocity tests first required the driver establish lane position
  - Important to avoid the rapid release of the steering wheel
  - Steering-based performance found to be better than that observed for brake-based operation
  - Very few curve-based departures were actually prevented by LKS
- ≡ No LKS-induced secondary departures were produced



# Curve Performance Example

500m Radius

Without an initial steering input

With an initial steering input

# Concluding Remarks

# Concluding Remarks (continued)

- ≡ LKS is a new technology with low market penetration
  - ▶ Population of vehicles so-equipped is very limited
  - ▶ Intervention strategies have not yet converged
  - ▶ Control authority of contemporary systems appears to be low
- ≡ Many factors must be considered when estimating LKS safety benefits
  - ▶ Test track performance
  - ▶ Real world effectiveness



# Concluding Remarks (continued)

- ≡ Understanding real world availability is essential
  - ▶ Percent of time the system is tracking the travel lane correctly
- ≡ Effect of environmental factors must be quantified
  - ▶ Glare
  - ▶ Lane line quality
  - ▶ Pavement cracks
  - ▶ Test surface grade
  - ▶ Crosswinds
- ≡ Difficult to accurately assess real world performance within the confines of a test track
  - ▶ Field operational tests (FOT) better suited to this quantification



# Concluding Remarks (continued)

- ≡ NHTSA is presently considering the most appropriate way to objectively quantify LKS performance
  - ▶ Test procedures
  - ▶ Evaluation metrics
  - ▶ Operational limits
- ≡ Test track performance expected to coincide with driver interface assessment
  - ▶ Should the driver be alerted when an LKS intervention occurs?
  - ▶ What should the relationship between LKS and LDW be?
  - ▶ Driver understanding and acceptance are important considerations
- ≡ An agency decision point on LKS is expected in 2011

# Contact Information

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