Phase IV and NHTSA's Light Vehicle Dynamic Rollover Propensity Research

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NHTSA / VRTC

Overview of NHTSA's Recent Rollover Research Phases

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- **Phase IV**
  - Spring 2001
  - Response to TREAD Act
  - Consideration of many maneuvers
- **Phase V**
  - Spring 2002
  - Research factors that may affect dynamic rollover propensity tests
  - Rollover and handling rating development
- **Phase VI**
  - Summer 2002
  - Evaluation of 26 vehicles using results from Phase IV testing
  - Rollover and handling tests performed
- **Phase VII**
  - Winter 2002
  - Refinement of rollover maneuvers using results from Phase VI
- **Phase VIII (NCAP Rollover Demo)**
  - Spring/Summer 2003
  - Evaluation of 18 vehicles
  - Rollover maneuvers only

Phase IV Background

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TREAD Act Requirement:

Develop dynamic rollover propensity tests to facilitate a consumer information program

National Academy of Sciences:

"NHTSA should vigorously pursue the development of dynamic testing to supplement the information provided by SSF."

Phase IV Objectives

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- Test many maneuvers with a limited number of vehicles
- Select maneuvers appropriate for use in a Government rollover resistance rating system

Maneuver Recommendations

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- Recommendations received from Government and industry
- NHTSA
  - VRTC
  - Safety Performance Standards
- Alliance of Automobile Manufacturers
- Consumers Union
- Ford Motor Company
- Heitz Automotive, Inc.
- ISO 3888 Part 2 Consortium
  - VW
  - BMW
  - DiamlerChysler
  - Porsche
  - Mitsubishi
- MTS Systems Corporation
- Nissan Motors
- Toyota Motor Company
- UMTRI

Test Conditions

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- Test vehicles
  - 2001 Chevrolet Blazer
  - 2001 Ford Escape
  - 2001 Toyota 4Runner
  - 1999 Mercedes ML320
- Front and rear mounted aluminum outriggers
- All tests performed on a dry, high-mu asphalt surface
- Multiple configurations
  - Nominal Load
  - Reduced Rollover Resistance

Tires

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- **OEM specification**
  - As installed on vehicle when delivered
  - Make
  - Model
  - DOT Code
  - Inflation pressure
- **Frequent tire changes**
- **Inner tubes used during some maneuvers to prevent debeading**

Test Maneuvers

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Characterization

- Constant Speed, Slowly Increasing Steer (SAE J266)*

Fishhooks

- Road Edge Recovery (Roll Rate Feedback Fishhook)*
- Fishhook (Fixed Timing)*
- Nissan Fishhook

J-Turns

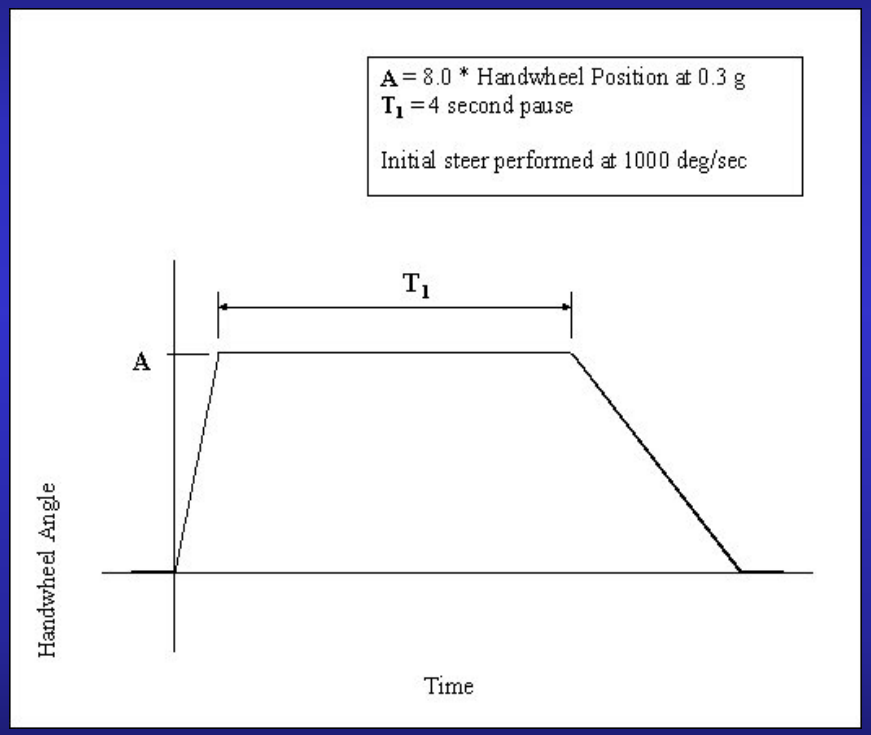
- NHTSA J-Turn*

Double Lane Changes

- ISO 3888 Part 2*
- Consumers Union Short Course*
- Ford Path-Corrected Limit Lane Change
- Open-Loop Pseudo Double Lane Change

**Discussed in this presentation*

J-Turn



Vehicle	Handwheel Input (degrees)
Blazer	401
4Runner	354
ML320	310
Escape	287

Note: Steering rate was based on successful Phase II testing

Fixed Timing Fishhook
(Symmetric)

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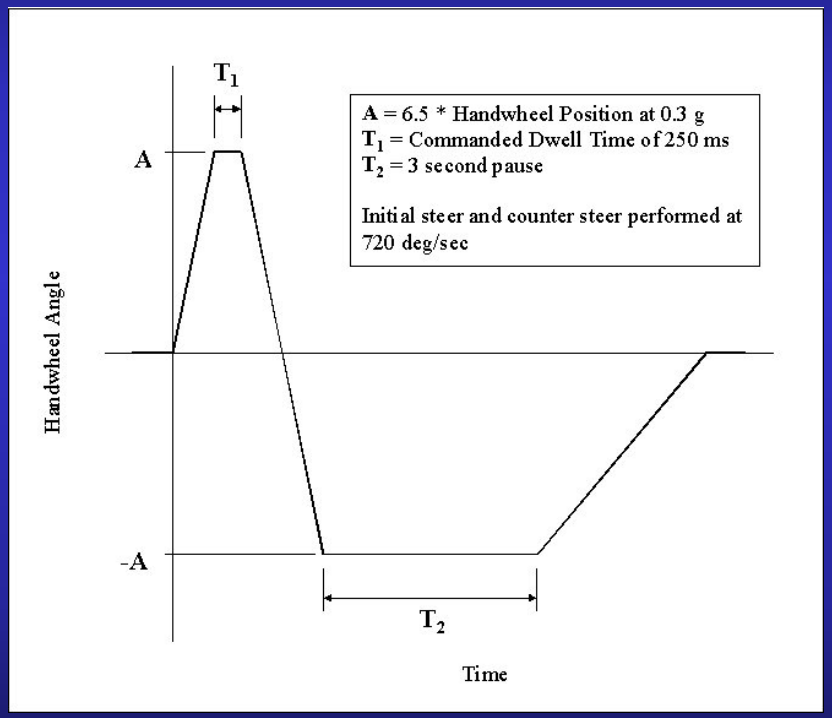
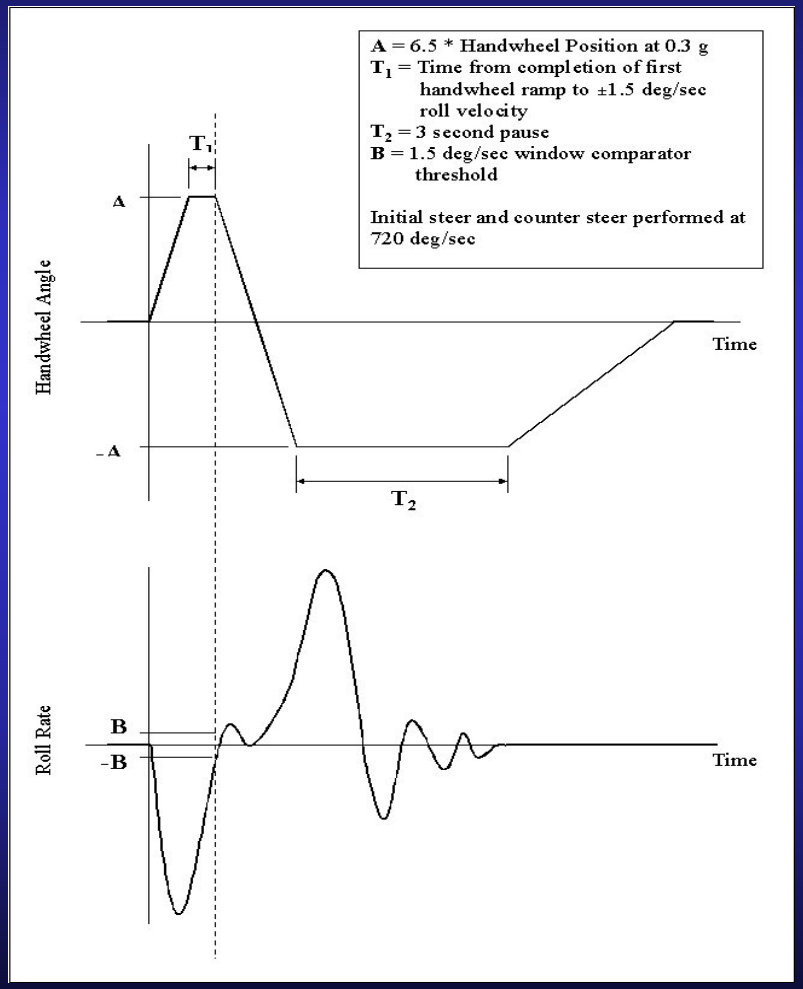


Vehicle	Handwheel Input (degrees)
Blazer	326
4Runner	287
ML320	252
Escape	233

Note: Steering rate was based on successful Phase II testing

Roll Rate Feedback Fishhook
(Symmetric)



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Question:

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Why use the handwheel angle at 0.3 g?

Use of 0.3 g Handwheel Data

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- **NHTSA needed an objective way of calculating J-Turn and Fishhook steering angles**
  - Vehicles respond differently to the same steering inputs
  - Maneuvers must adapt to the vehicle being evaluated
- **Handwheel data at 0.3 g is repeatable and easy to measure**
  - Not necessarily true for data based on maximum lateral acceleration

Closed-loop, Path-Following Double Lane Changes

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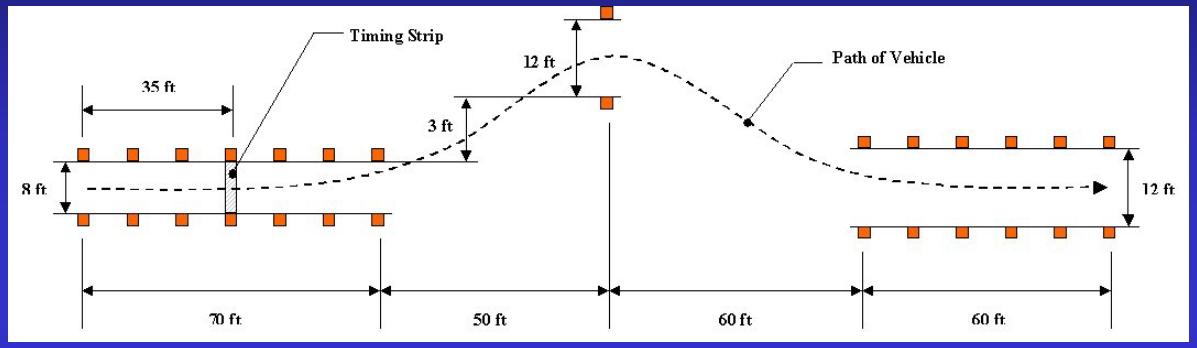
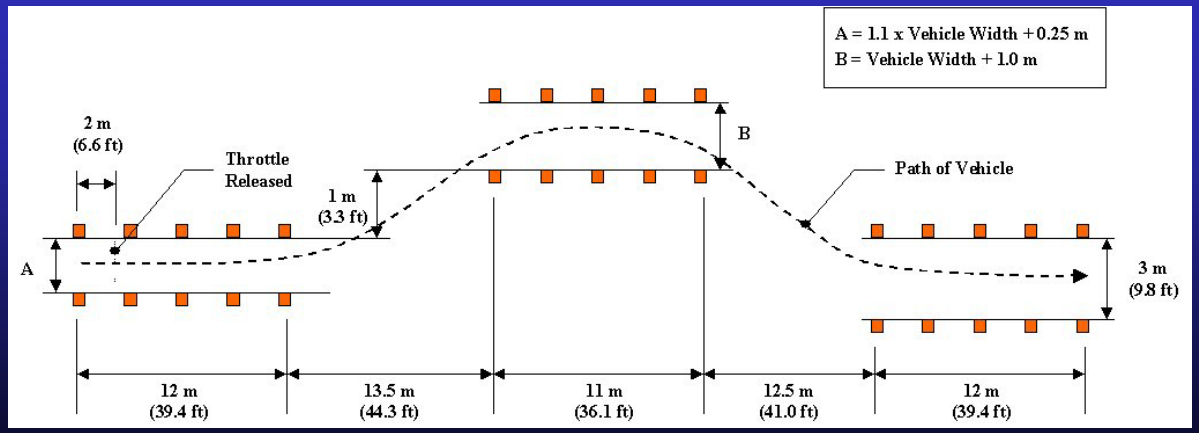
Consumers Union Short Course



ISO 3888 Part 2



Evaluation Technique

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- **Each maneuver evaluated in 4 categories**
  - Objectivity and Repeatability
  - Performability
  - Discriminatory Capability
  - Appearance of Reality
- **Ratings assigned as follows**
  - Excellent
  - Good
  - Satisfactory
  - Bad
  - Very Bad

Objectivity and Repeatability

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- One of the largest disadvantages of the ISO and CU Double Lane Changes
  - Driver input variability unavoidable
- Use of a steering machine insures accurate, repeatable, reproducible inputs

Objectivity and Repeatability
(Example: Steering Inputs)

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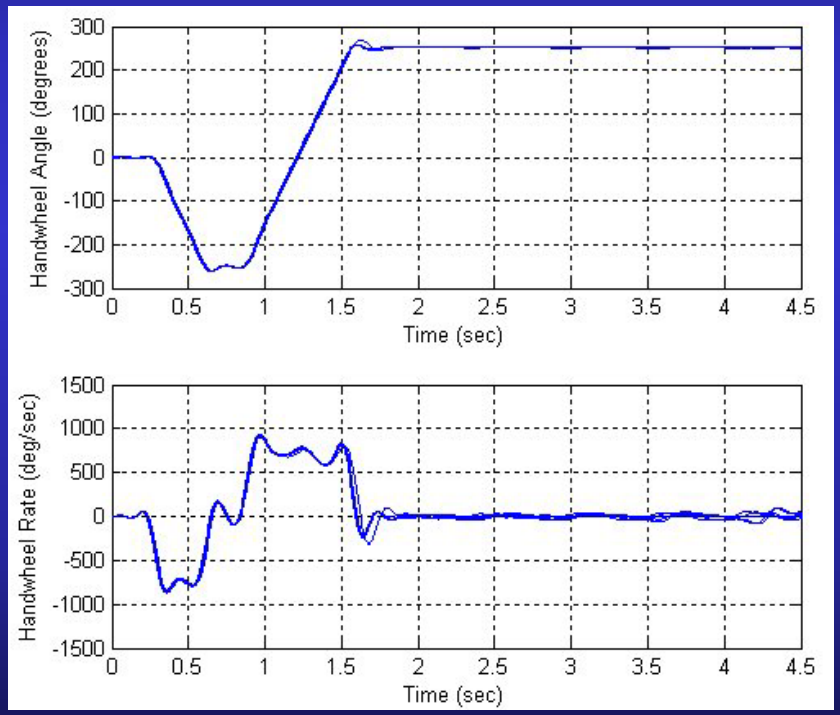
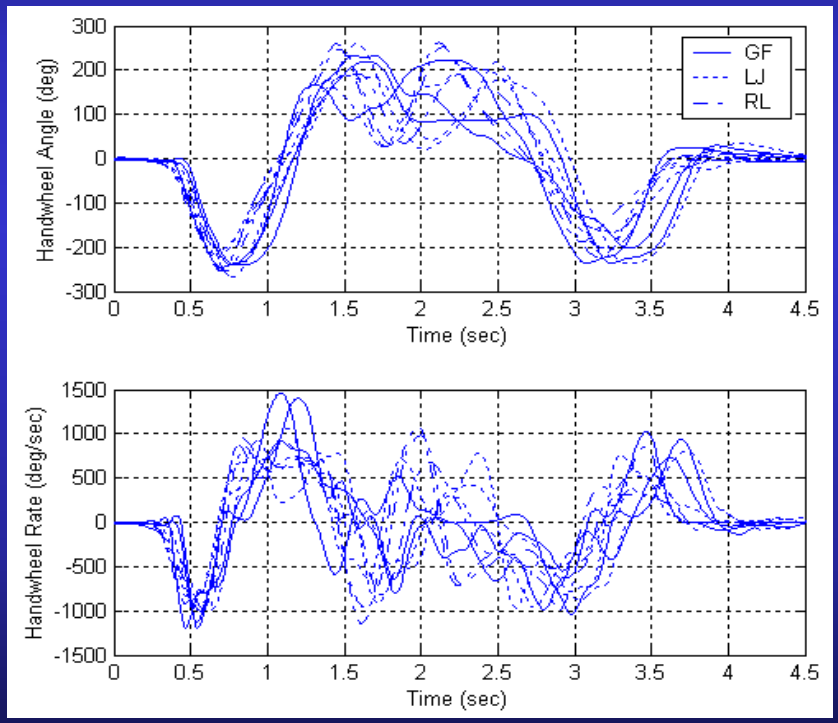
Steering Machine-Based Fixed Timing Fishhook



Six tests are presented

Driver-Based ISO 3888 Part 2 Double Lane Change



Nine tests are presented

Performability

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- Each procedure was well developed
- ISO and CU Double Lane Changes
  - Simplest to perform
  - Require little instrumentation
- CU Short Course does not adapt course layout to vehicle
- RRF Fishhook offers better adaptability than does the FT Fishhook

Discriminatory Capability

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- **Lack of discriminatory capability is another large disadvantage of ISO or CU Double Lane Changes**
  - Entire range of max entrance speeds no more than 5.7 mph
  - Driver variability accounts for up to 70% of this range
  - ISO and CU Double Lane Changes were not capable of producing two-wheel lift during “clean” runs
- **J-Turn and Fishhooks sensitive to changes that reduce rollover resistance**

Discriminatory Capability
(Example: Metric Comparison)

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Roll Rate Feedback Fishhook

Vehicle	Configuration			
	Nominal Load		Reduced Rollover Resistance	
	Left-Right (mph)	Right-Left (mph)	Left-Right (mph)	Right-Left (mph)
Toyota 4Runner (VSC on)	--	--	--	49.6
Toyota 4Runner (VSC disabled)	--	--	39.5	37.7
Chevrolet Blazer	40.3	40.1	36.8	36.2
Ford Escape	--	--	46.0	--
Mercedes ML320 (ESP on)	49.9	--	Tests not performed	
Mercedes ML320 (ESP disabled)	46.4	50.6		

Minimum two-wheel lift entrance speeds

ISO 3888 Part 2 Double Lane Change

Vehicle	Configuration		
	Nominal Load	Reduced Rollover Resistance	Difference
Toyota 4Runner (VSC on)	37.6	39.3	-1.7
Toyota 4Runner (VSC disabled)	37.0	38.0	-1.0
Chevrolet Blazer	41.0	39.0	2.0
Ford Escape	38.0	37.3	0.7
Mercedes ML320 (ESP on)	38.0	37.4	0.6
Mercedes ML320 (ESP disabled)	38.9	37.1	1.8

Maximum "clean" run entrance speeds

Discriminatory Capability
(Two-Wheel Lift Summary, Nominal Load)

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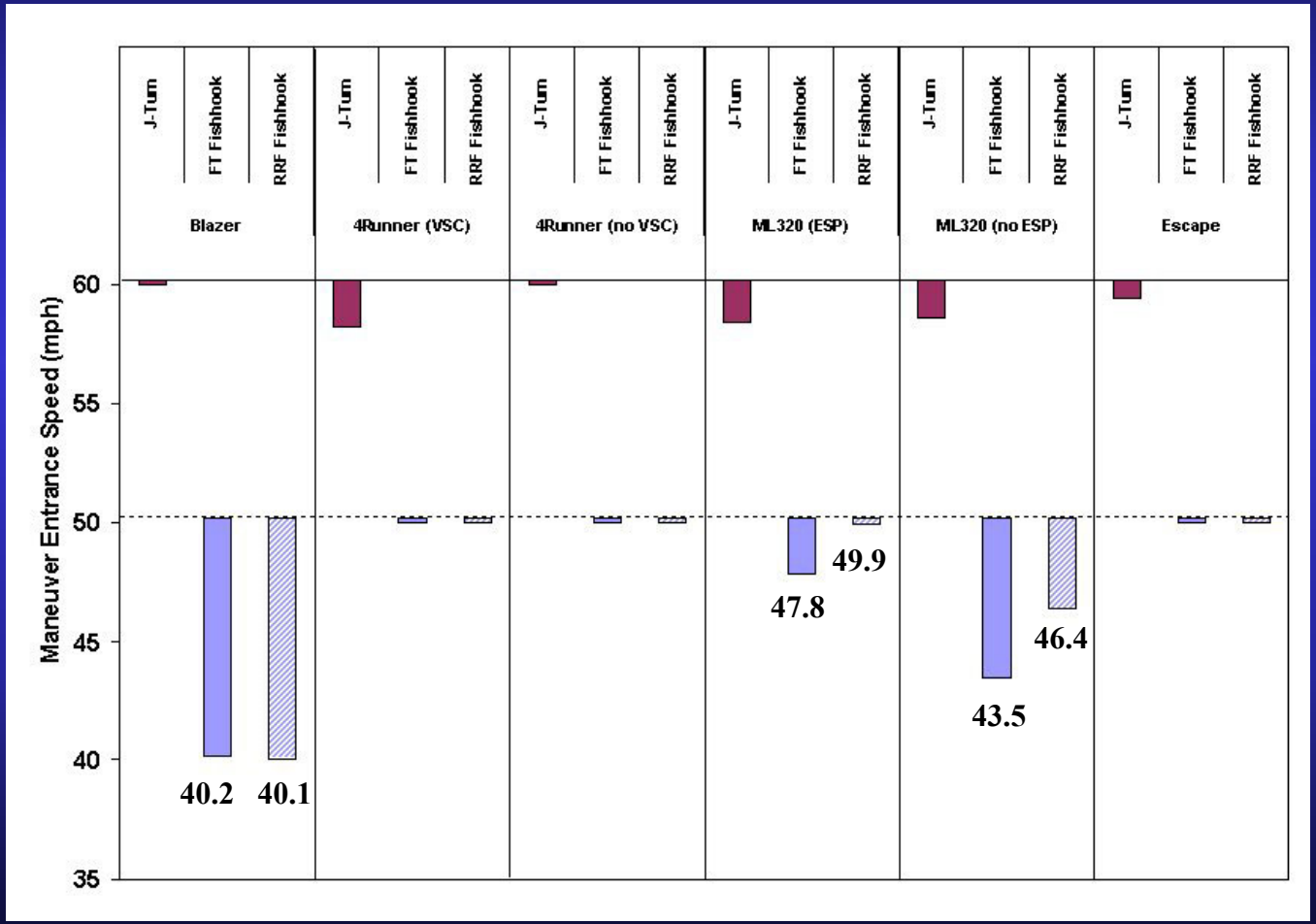

Discriminatory Capability
(Two-Wheel Lift Summary, RRR)

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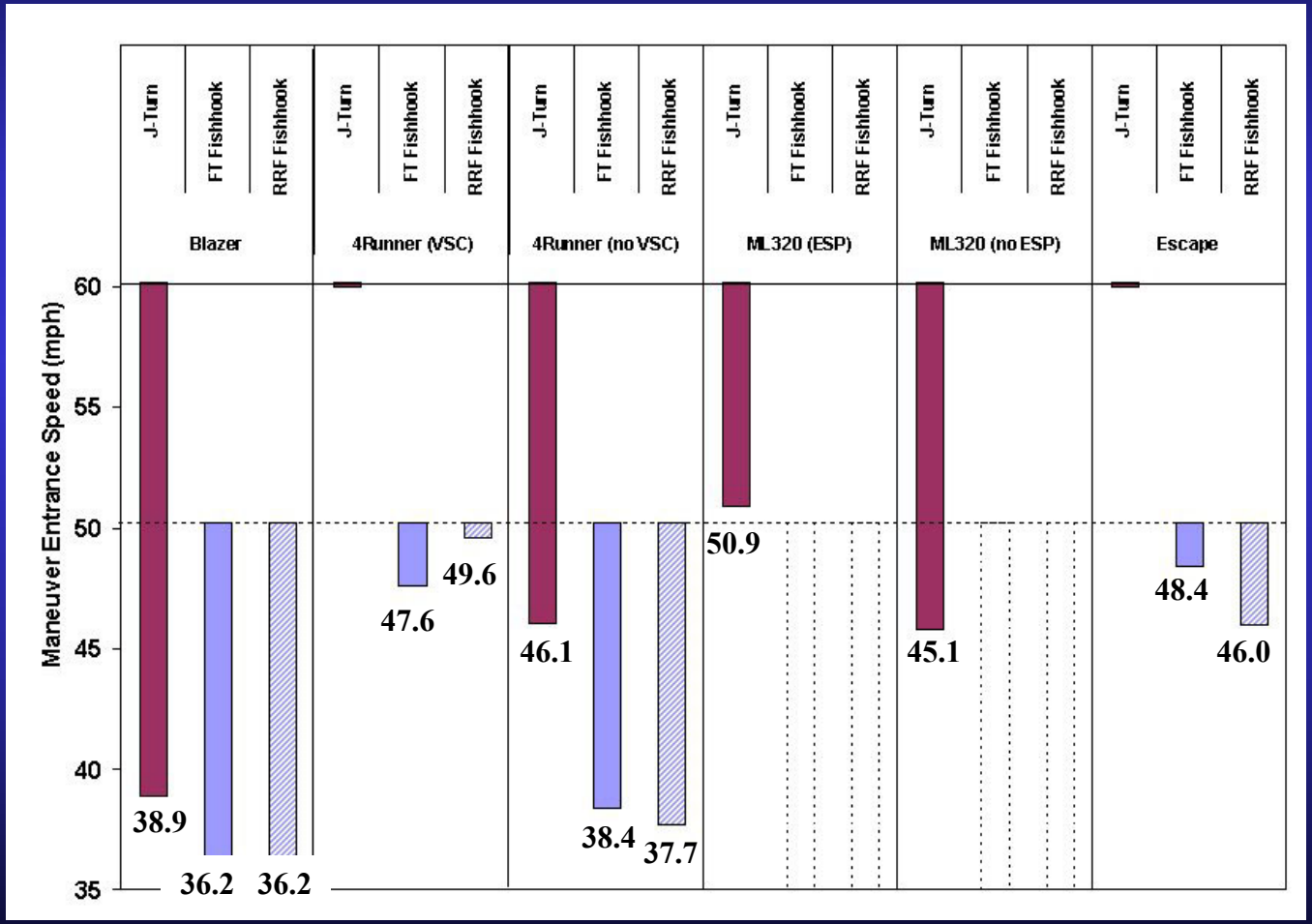

Discriminatory Capability
(Video Comparison)

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Appearance of Reality

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- Each rollover resistance maneuver related to a real driving scenario
- ISO and CU Double Lane Changes emulate emergency crash avoidance maneuvers
- Fishhooks emulate road edge recovery maneuvers
  - Also very similar to first two steering inputs of the double lane changes
- J-Turn steering least likely to actually be used, but possible

Question:

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Are actual drivers able to input the steering angles and steering rates used for the NHTSA J-Turn and Fishhook maneuvers?

Answer: Yes!

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- The ranges of NHTSA J-Turn and Fishhook handwheel angles and rates were within those observed during CU Short Course testing
- Maximum steering inputs
  - J-Turn: 1000 deg/sec for up to 0.40 seconds
  - Fishhook: 720 deg/sec for up to 0.45 seconds
  - CU Short Course
    - 1187 deg/sec for up to 0.50 seconds
    - 1026 deg/sec for up to 0.75 seconds
    - 831 deg/sec for up to 1.00 seconds

Question:

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Can the NHTSA J-Turn and Fishhook maneuvers be performed on a two-lane public roadway?

Answers: 1. **Yes** *(Fishhook)*
2. **Not Likely** *(J-Turn)*

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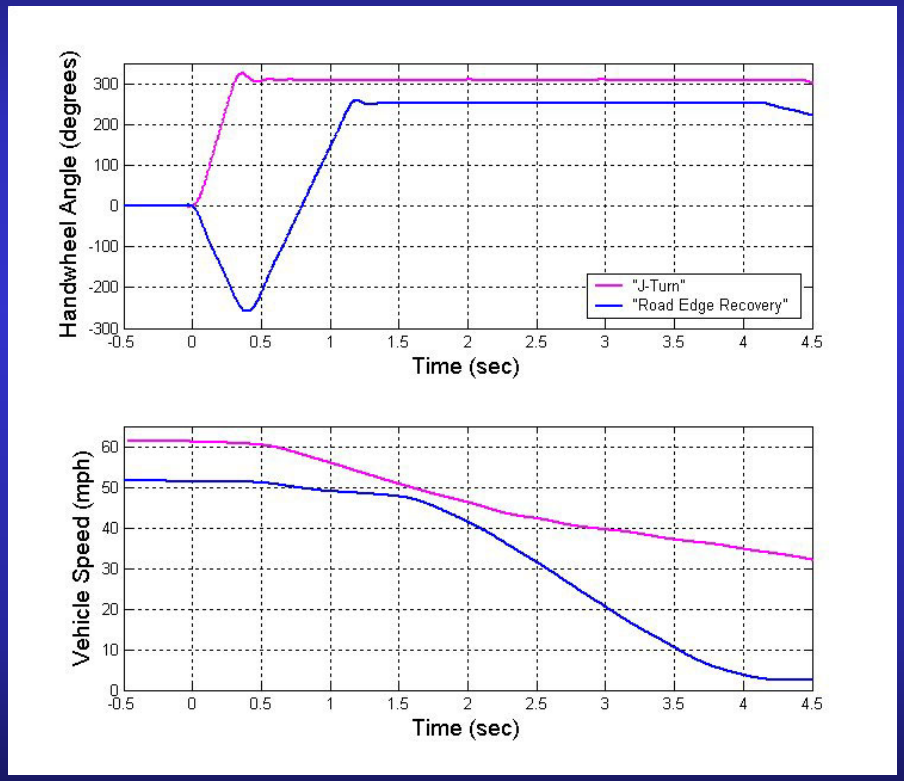

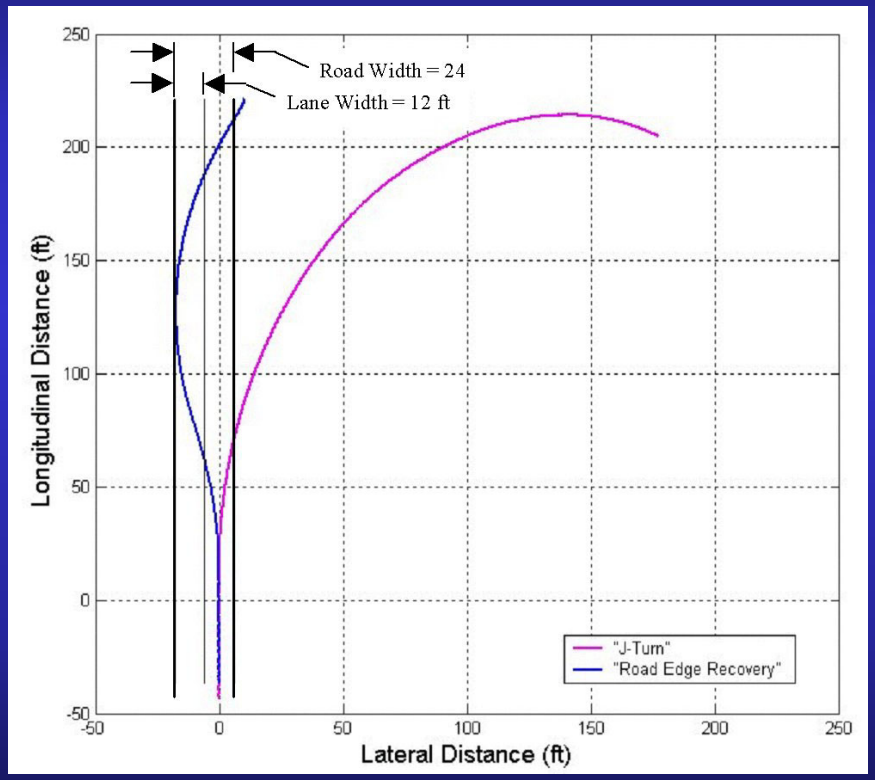

Path of the vehicle C.G. is indicated

Overall Assessment

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- Roll Rate Feedback Fishhook deemed the best overall maneuver (see below)
- J-Turn the most basic maneuver, can be a useful compliment to the Roll Rate Feedback Fishhook
- Both maneuvers selected for use in Phases V, VI, and VII of NHTSA's rollover research

Criteria	J-Turn	FT Fishhook	RRF Fishhook	ISO 3888-2	CU Short Course
Objectivity and Repeatability	*Excellent*	*Excellent*	*Excellent*	*Bad*	*Bad*
Performability	*Excellent*	*Good*	*Excellent*	*Good*	*Satisfactory*
Discriminatory Capability	*Excellent**	*Excellent*	*Excellent*	*Very Bad*	*Very Bad*
Face Validity	*Good*	*Excellent*	*Excellent*	*Excellent*	*Excellent*

**When limited to vehicles with low rollover resistance and/or disadvantageous load configurations*

Question:

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Can the Slowly Increasing Steer maneuver be abbreviated since only linear range lateral acceleration data is used?

Answer: Yes!
(Provided enough data is considered)

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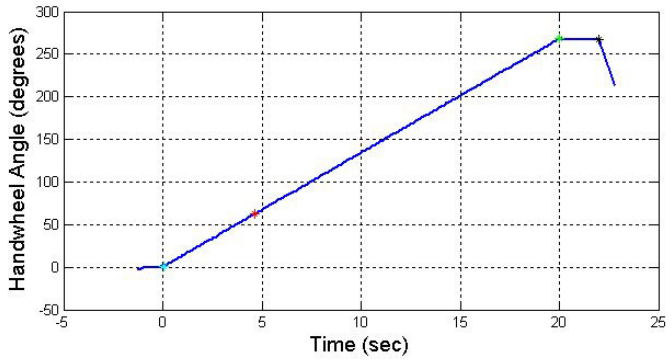

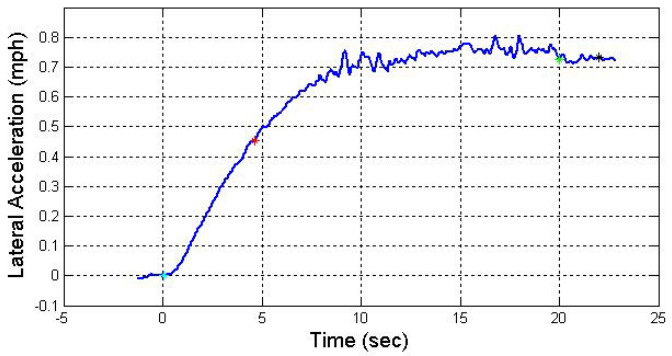

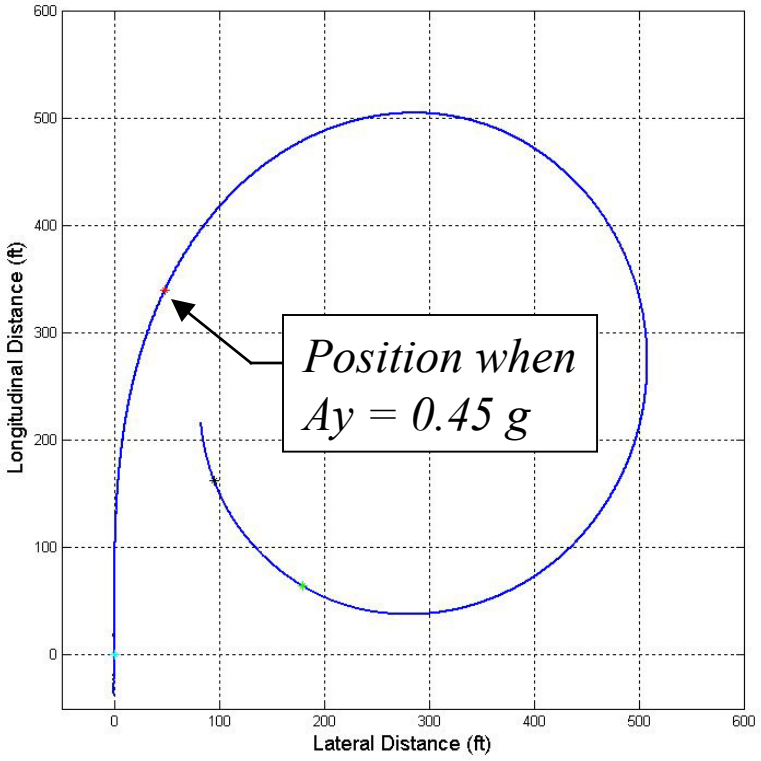

Concluding Remarks

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- **Phase VI and VII Technical Reports**
  - Complete, awaiting approval
  - Scheduled to be released with the next rollover notice
- **NCAP Rollover Demo testing is presently underway**
  - Ratings to be released as 2004 model year ratings

Additional Information

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- Phase IV Technical Report (DOT HS 809 513)
- SAE Papers
  - 2003-01-1008
  - 2003-01-1009
- http://www-nrd.nhtsa.dot.gov/vrtc/ca/rollover.htm
- Rollover Docket
  - http://dms.dot.gov/
  - “Simple Search” for number 9663