Safety Benefits Methodology for RSC and ESC Systems in Commercial Vehicle Tractor Semi-Trailers

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Partners

- **Meritor WABCO**
- **University of Michigan Transportation Research Institute (UMTRI)**

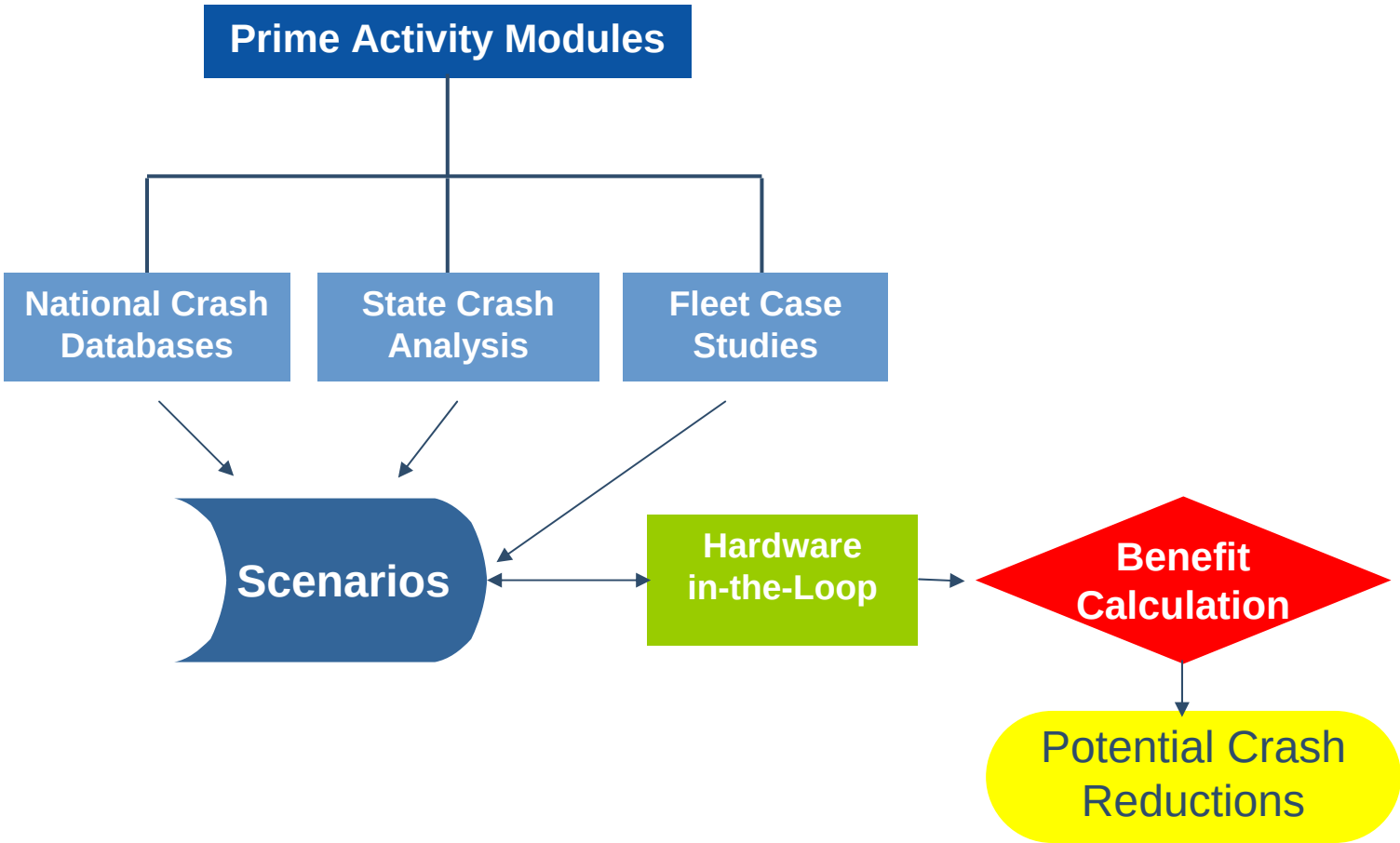
Project Goals

- **Define pre-crash scenarios and identify factors associated with loss of control and rollover**
- **Review applicability of stability control for each scenario**
- **Develop a measure of relative safety effectiveness of the approaches to stability control**

Technologies Investigated

- **Tractor-based electronic stability control (ESC)**
- **Tractor-based roll stability control (RSC)**

Project Flow



Prime Activity Modules

Fleet Case Studies

- Identify effectiveness of systems
- Identify crash types & scenarios
- Obtain fleet crash rate reduction estimates
- Obtain fleet cost effectiveness

State Crash Analysis

- Perform clinical analysis of PARs and crash reconstruction documents
- Confirm / modify crash scenarios hypotheses

National Crash Databases

- Determine the severity of selected crash scenarios
- Determine frequency of crash scenarios
- Estimate likely benefits

Hardware in-the-Loop

- Examine the detailed sequence of various crash scenarios
- Study the relative performance of systems
- Estimate speed ranges where systems are effective for various driving conditions

Differentiating ESC / RSC

- **ESC units contain RSC functionality – ESC also includes tractor steer axle braking**
- **ESC and RSC systems should perform similarly in first event rollover scenarios**
- **ESC and RSC should perform differently in loss of control scenarios**

Crash Data Sources

- **General Estimates System (GES)**
  - Nationally-representative
  - Coded from Police Reports
  - All crash severities
- **Trucks Involved in Fatal Accidents (TIFA)**
  - Census of truck fatal crash involvements
  - Supplements NHTSA FARS data
  - Configuration & Crash detail
- **Large Truck Crash Causation Study (LTCCS)**
  - K, A, or B crash severity
  - Rich detail about pre-crash events and truck configuration

Large Truck Crash Causation Study Cases

- **LTCCS provides detailed information about crash events**
  - Scene diagram
  - Detailed narrative
  - Detailed coded crash events (matches GES; can be approximated in TIFA)
  - Matches TIFA on detail of physical configuration of the vehicle (weights, lengths, axle count, cargo weight and type, etc.)
- **Specific limitations**
  - Relatively few cases: 963 crashes, 1128 vehicles
  - National representation not useful for this study (e.g., about twice as many rollovers as expected)

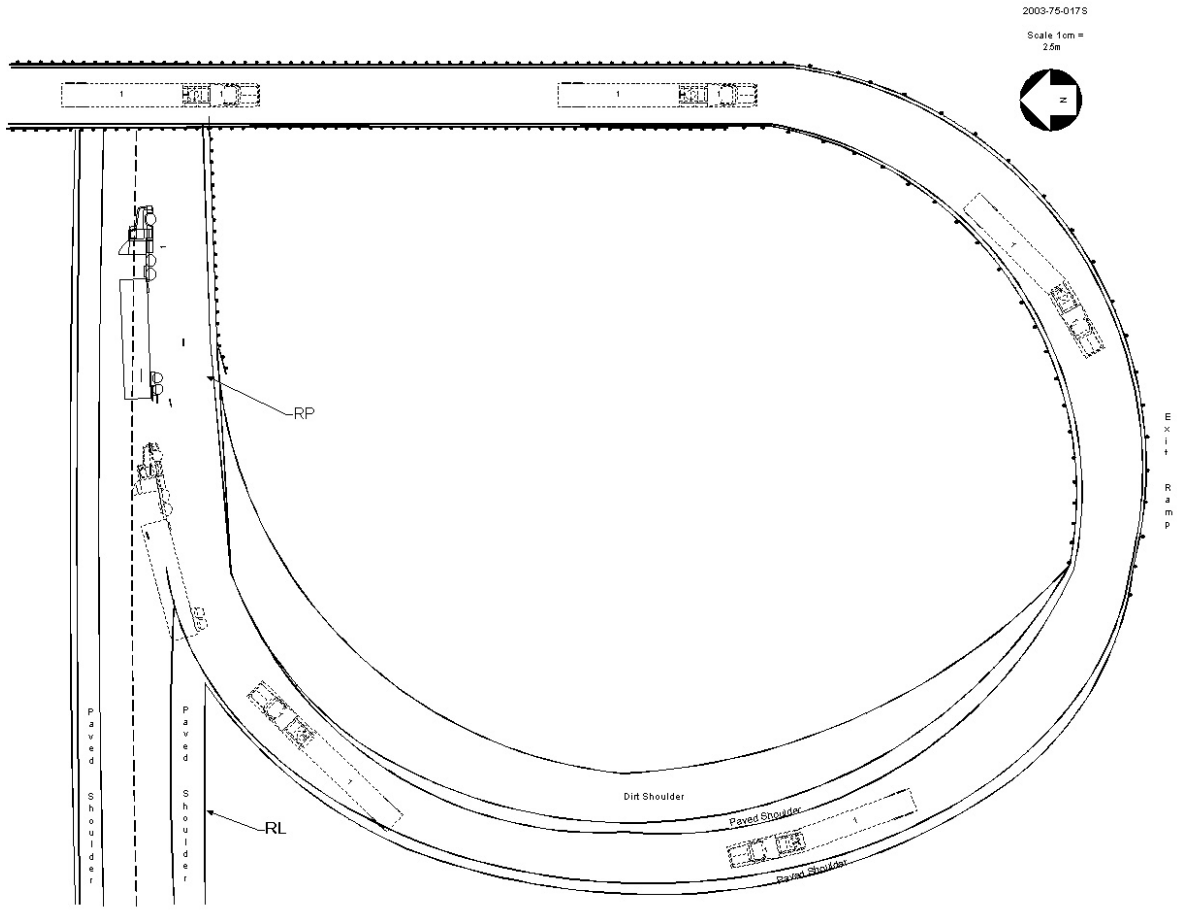
Use of LTCCS Cases

- **How LTCCS Was Used**
  - Use TIFA/GES to determine national distribution of yaw & roll instability crash scenarios
  - Apply algorithm to classify yaw and roll cases developed in TIFA/GES to LTCCS to establish crash types
  - Detail of LTCCS produced example crash types for engineering review and simulation
  - Refine GES data queries to select only relevant crashes

LTCCS Rollover Case

Road curved
Dry surface
Cargo: loaded

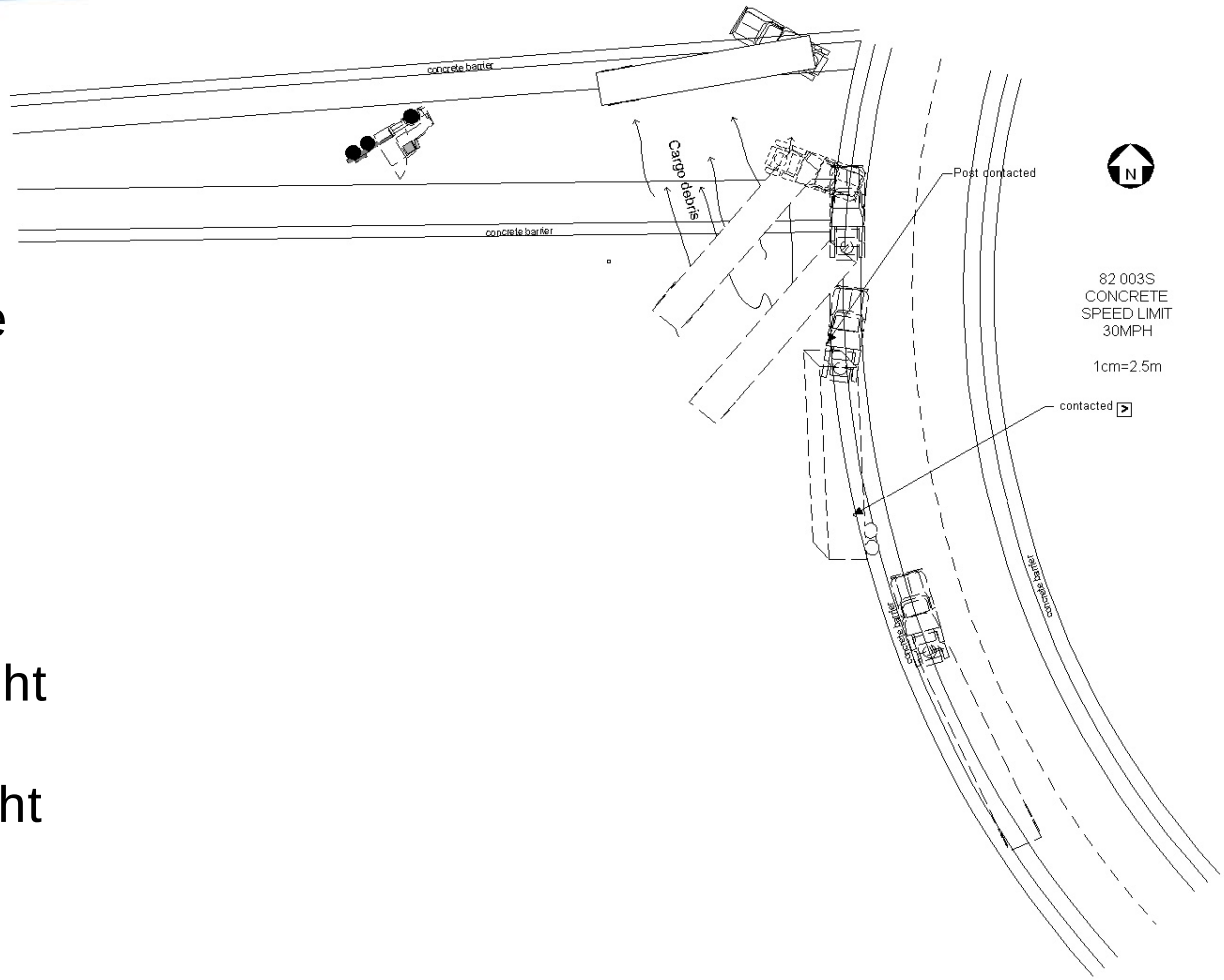
3-axle tractor pulling bottom dump.
31,000 lbs cargo (dirt)
61,800 gross weight
Est. 40 mph



Rollover Crash Factors

- **Rollover crashes occur when the limits of lateral acceleration are exceeded**
- **Function of speed, CG height, and road characteristic**
- **Most rollovers on curves of 50m – 500m radius**
- **Rollovers related to freeway road geometry: ramps, interconnecting roads, and bridges where curve radii are less than 500 m**

LTCCS Yaw Instability Case



Road curved
Wet roadway surface
Cargo: loaded

3-axle tractor pulling
reefer
van trailer
Unknown cargo weight
(>20% full)
Unknown gross weight
Unknown speed

Loss of Control Crash Factors

- LOC are yaw instability events
- Less likely to be related to road curve
- Includes challenging maneuver such as hard braking, steering
- LOC associated with lightly loaded vehicles on low friction surfaces
- LOC includes understeer and oversteer

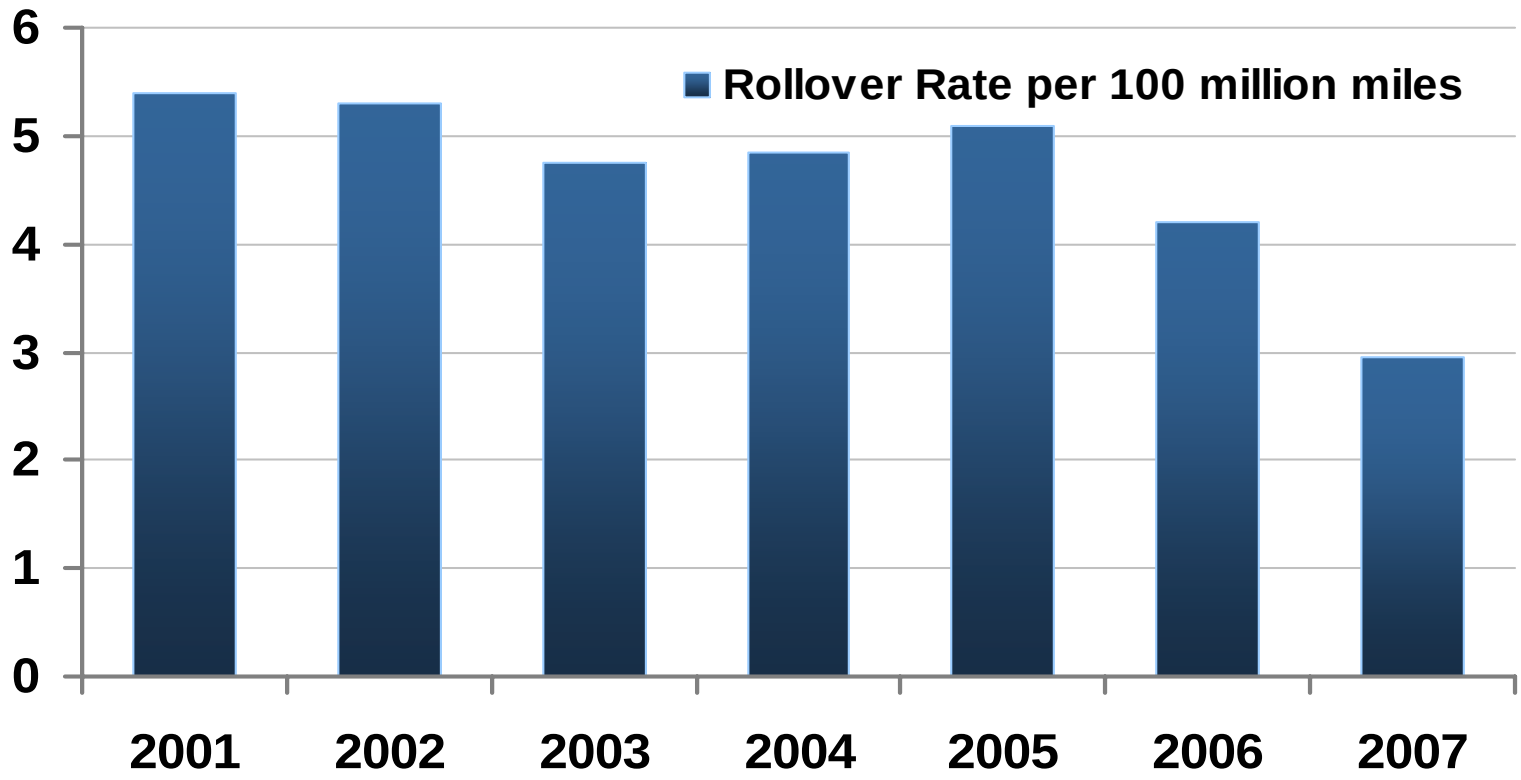
Review of LTCCS Yaw & Roll Instability Crashes

- **Assess for**
  - Accuracy of coding
  - Suitability for HIL simulation
  - Crash details (radius of curvature, curve entry speed)
  - Relevance of roll & yaw control technologies (likely, probably, unlikely, unknown)

Fleet Data

- **Crash data from a large for-hire carrier were analyzed by UMTRI**
- **35,055 crashes from 2001-2007**
  - 379 Rollovers, 421 Jackknifes
- **Fleet began adopting RSC in February 2004**
- **RSC reduced the probability of a rollover for trucks with system**

Fleet Data
Yearly Rollover Rate



Yearly Average for Tractor Semi-Trailers

	Crashes	Injuries	Fatalities
Total for Tractor Semi-Trailers	178,000	58,700	3,329
Rollover	4,700	3,400	385
Loss of Control	15,800	8,500	138

Five Year Annual Average of GES, TIFA 2000-2004

Benefit Equation

B = Benefit in Terms of Reduced Number of Crashes

$$\mathrm{B} = [P_{wo}(C) - P_{w}(C)] \times \mathrm{Exposure}$$

$P_{wo}(C)$ = Probability of Crash Without Technology

$P_{w}(C)$ = Probability of Crash With Technology

Exposure = All Trucks in the Population

Benefit Equation For a Given Crash Scenario, S

$$B = N_{wo} \times P_{wo}(S \mid C) \times \left[1 - \frac{P_w(C \mid S) \times P_w(S)}{P_{wo}(C \mid S) \times P_{wo}(S)} \right]$$

From GES Data

From HIL Simulation

From Fleet Data

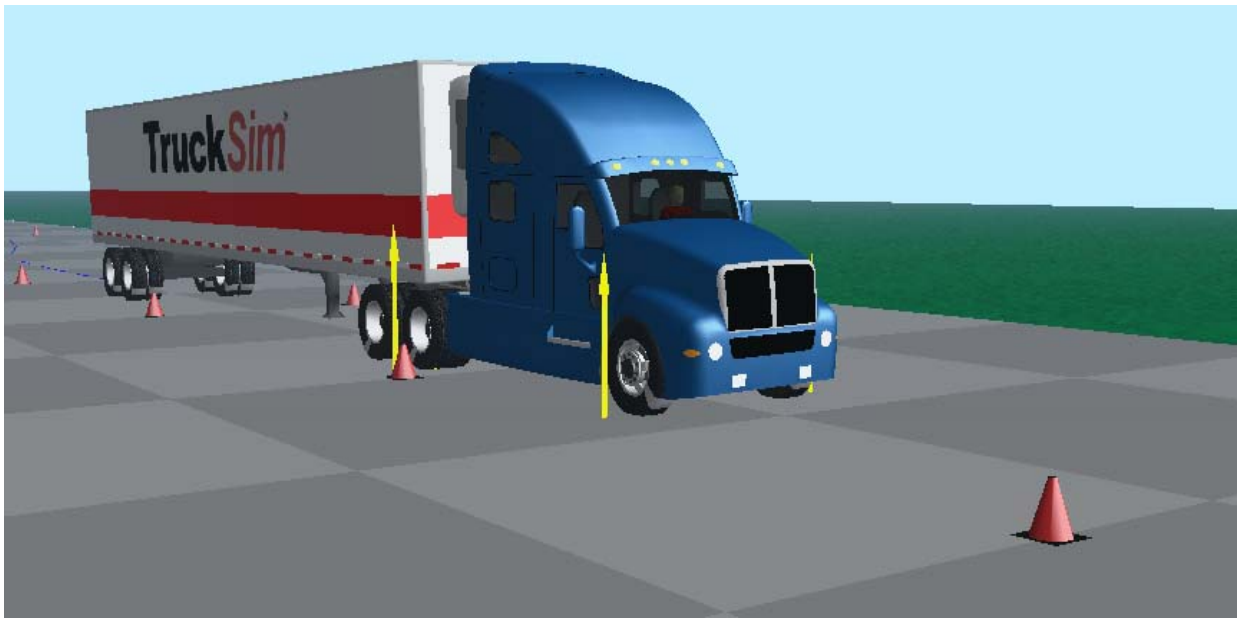
Crash Scenarios

- **Crash scenarios determined from LTCCS analysis**
- **Factors include road geometry, road friction, truck loading, etc.**
- **Crash data cases, N for each scenario used in benefits calculation**

Example Scenarios	N
Curve, dry, empty	N1
Curve, dry, loaded	N2
Curve, not dry, empty	N3
Curve, not dry, loaded	N4
Straight, dry, empty	N5
Straight, dry, loaded	N6
Straight, not dry, empty	N7
Straight, not dry, loaded	N8

Hardware-in-the-Loop

- **TruckSim offers Real-time Simulation in Combination with SIMULINK and the TruckSim Animator**



Hardware-in-the-Loop

- **Pneumatic and electronic control elements, from air reservoirs, through treadle and other system valves to brake actuation chambers**
- **Brake chambers installed on real S-cam brakes with appropriate pressure/deflection properties**
- **HIL Validation - Power unit components for 3-axle power unit and 2-axle semi trailer**
- **Simulations provide system effectiveness in crash scenarios of interest**

Summary

- **Hardware-in-the-Loop analysis is currently underway will be completed in Spring 2008**
- **NHTSA will present potential benefits of ESC and RSC in Final Report**
- **www.nhtsa.dot.gov**