Exploring the Merits of Commercial Vehicle Forward Collision Avoidance and Mitigation Systems (F-CAM)

Presented to:

Task Force on Vehicle Weights and Dimensions Policy

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Private Public Partnership Sponsor

NHTSA and Meritor WABCO

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Meritor WABCO – Alan Korn (Jon Morrison)

Terminology

- System is comprised of Forward Collision Warning + Autonomous Breaking
- Forward collision contributes to crash avoidance and autonmated braking contributes to collision mitigation

Commercial Vehicle Forward Collision Avoidance and Mitigation Systems

(F-CAM)

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Project Goals

- Characterize the performance of a current F-CAM system via test track experiments and simulation.
- Identify and profile the target crash population for F-CAM systems (i.e. truck-involved rear-end crashes).
- Estimate, via modeling and simulation, the effectiveness of F-CAM technologies in avoiding and mitigating rear-end crashes
- Obtain “case and control” data from fleets for statistical analysis of F-CAM safety performance in real-world application.
- Apply cost factors to crash reduction/mitigation estimates to determine total economic benefits

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Project Elements

- Crash data analysis
- Fleet data (2 national fleets analyzed)
- Test program
- Modeling
- Benefit analysis

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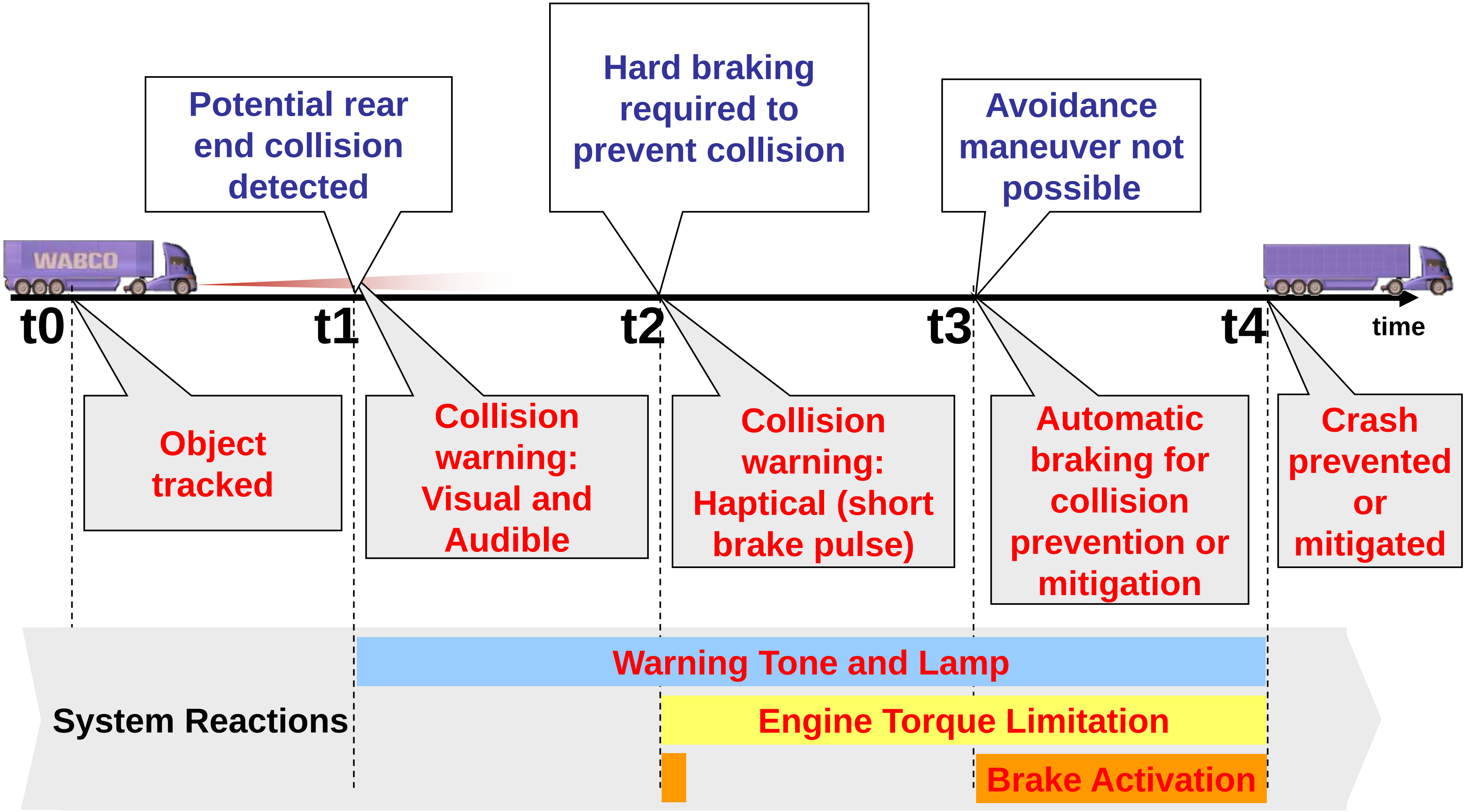
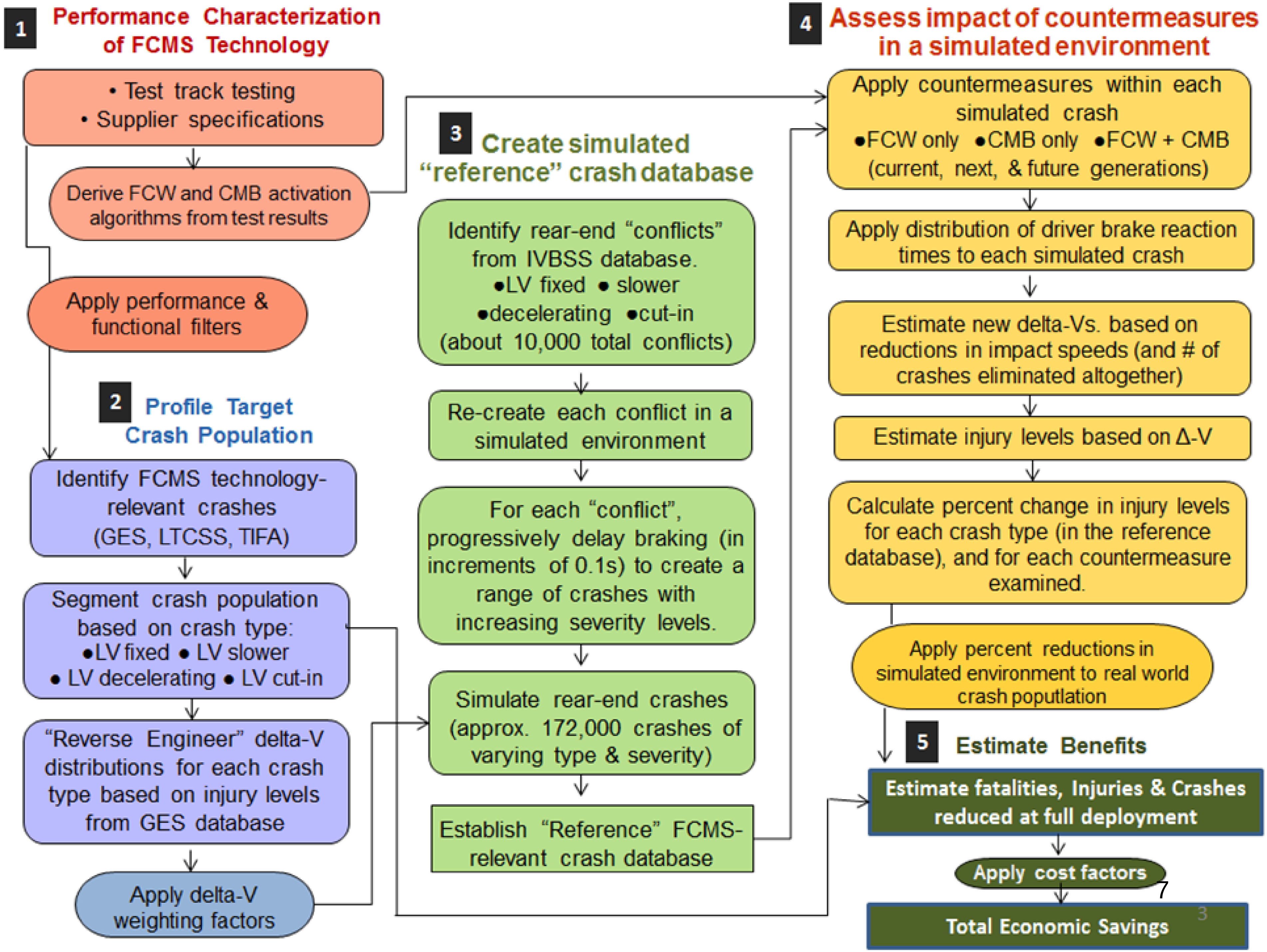
F-CAM Intervention Sequence




1
Performance Characterization of FCMS Technology
• Test track testing
• Supplier specifications
Derive FCW and CMB activation algorithms from test results
Apply performance & functional filters
2
Profile Target Crash Population
Identify FCMS technology-relevant crashes (GES, LTCSS, TIFA)
Segment crash population based on crash type: •LV fixed • LV slower • LV decelerating • LV cut-in
"Reverse Engineer" delta-V distributions for each crash type based on injury levels from GES database
Apply delta-V weighting factors
3
Create simulated "reference" crash database
Identify rear-end "conflicts" from IVBSS database. •LV fixed • slower •decelerating •cut-in (about 10,000 total conflicts)
Re-create each conflict in a simulated environment
For each "conflict", progressively delay braking (in increments of 0.1s) to create a range of crashes with increasing severity levels.
Simulate rear-end crashes (approx. 172,000 crashes of varying type & severity)
Establish "Reference" FCMS-relevant crash database
4
Assess impact of countermeasures in a simulated environment
Apply countermeasures within each simulated crash •FCW only •CMB only •FCW + CMB (current, next, & future generations)
Apply distribution of driver brake reaction times to each simulated crash
Estimate new delta-Vs. based on reductions in impact speeds (and # of crashes eliminated altogether)
Estimate injury levels based on Δ-V
Calculate percent change in injury levels for each crash type (in the reference database), and for each countermeasure examined.
Apply percent reductions in simulated environment to real world crash popultation
5
Estimate Benefits
Estimate fatalities, Injuries & Crashes reduced at full deployment
Apply cost factors
Total Economic Savings
3

Target Crash Types

- Crash types selected as relevant to the technology
- Rear-end, striking
- Current generation:
  - Lead vehicle stopped at impact, but seen moving
  - Lead vehicle slower, steady speed
  - Lead vehicle decelerating
  - Lead vehicle cut-in

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Estimated Annual Rear-end Striking Crashes

TIFA 2003-2008, GES 2003-2008

- "Fixed" means LV was stationary (fixed) before coming in radar range of the subject vehicle, i.e., never seen moving.
- "Stopped" means LV seen moving by the subject vehicle's radar prior to coming to a stop.

Tractor Semitrailer

Crash type	Fatal	Injury	PDO	Total
	N	N	N	N
LV fixed	62	882	2,119	3,078
LV stopped	13	1,244	2,987	4,263
LV slower	90	1,199	1,794	3,082
LV decel.	18	1,502	3,152	4,750
LV cut-in	9	156	649	814
Total	**192**	**4,983**	**10,701**	**15,987***

"PDO" specifies property damage only crashes.
* Total includes 111 crashes of unknown injury severity.

Single Unit Truck

Crash type	Fatal	Injury	PDO	Total
	N	N	N	N
LV fixed	20	1,215	2,202	3,438
LV stopped	8	2,228	4,037	6,270
LV slower	26	318	902	1,246
LV decel.	8	1,222	3,815	5,096
LV cut-in	1	134	187	322
Total	**63**	**5,117**	**11,143**	**16,374***

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Fatalities and Injuries in Rear-end Striking Crashes

TIFA 2003-2008, GES 2003-2008

- "Fixed" means LV was stationary (fixed) before coming in radar range of the subject vehicle, i.e., never seen moving.
- "Stopped" means LV seen moving by the subject vehicle's radar prior to coming to a stop.

Tractor Semitrailer

Crash type	Injury severity				Total injuries
	Fatal	A-injury	B-injury	C-injury	
LV fixed	78	139	335	861	1,413
LV stopped	16	158	431	1,179	1,782
LV slower	107	601	865	727	2,300
LV decelerating	22	303	605	1,251	2,180
LV cut-in	9	87	48	115	259
Total	**231**	**1,287**	**2,284**	**4,132**	**7,934**

Single Unit Truck

Crash type	Injury severity				Total injuries
	Fatal	A-injury	B-injury	C-injury	
LV fixed	22	156	278	1,272	1,728
LV stopped	9	277	493	2,306	3,085
LV slower	30	116	154	241	542
LV decelerating	10	189	334	1,426	1,959
LV cut-in	1	2	38	141	182
Total	**72**	**740**	**1,298**	**5,386**	**7,496**

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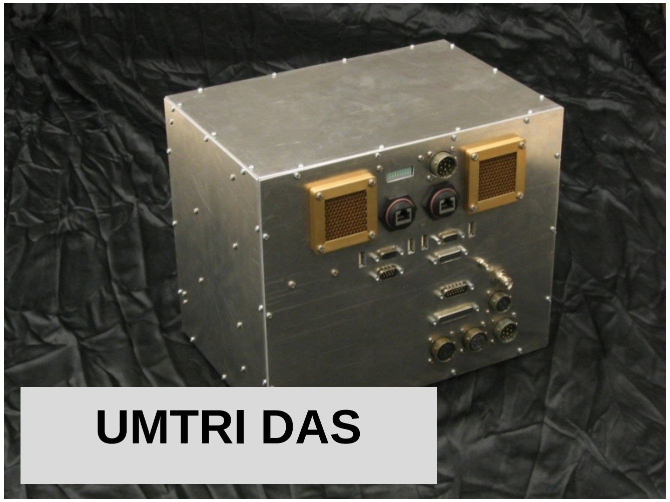
Subject Vehicle Highlights

SV Brush Guard



UMTRI DAS

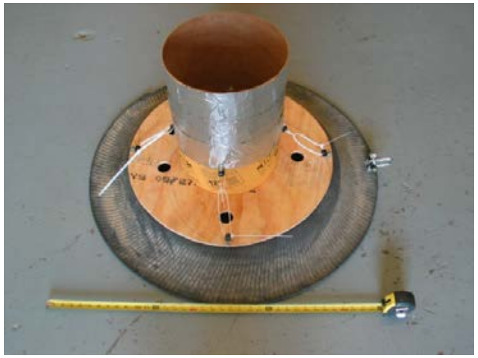
Forward Radar

Multiple DVI

DAS Interface

Towable Target Evolution and Highlights

"Seed"



Initial UMTRI Radar only Target

Initial Vision Compatible Target

Vision Compatible Target

Final Vision Compatible Target

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Establishing the Simulated “Reference” (or baseline) Crash Database

IVBSS Heavy Truck Feld Operational Test

- 1,000,000 km by 18 drivers over 10 months
  Mix of P&D and Line-haul
- Initial Conditions (Speeds, Distance, PovAx)
  - Lead Vehicle Braking, N = 8210 events
  - Lead Vehicle Slower, N = 1471 events
  - Cut-in, N = 382 events
  - Fixed, N = 470 events
- Driver Braking Profile
- Driver Brake Reaction Time

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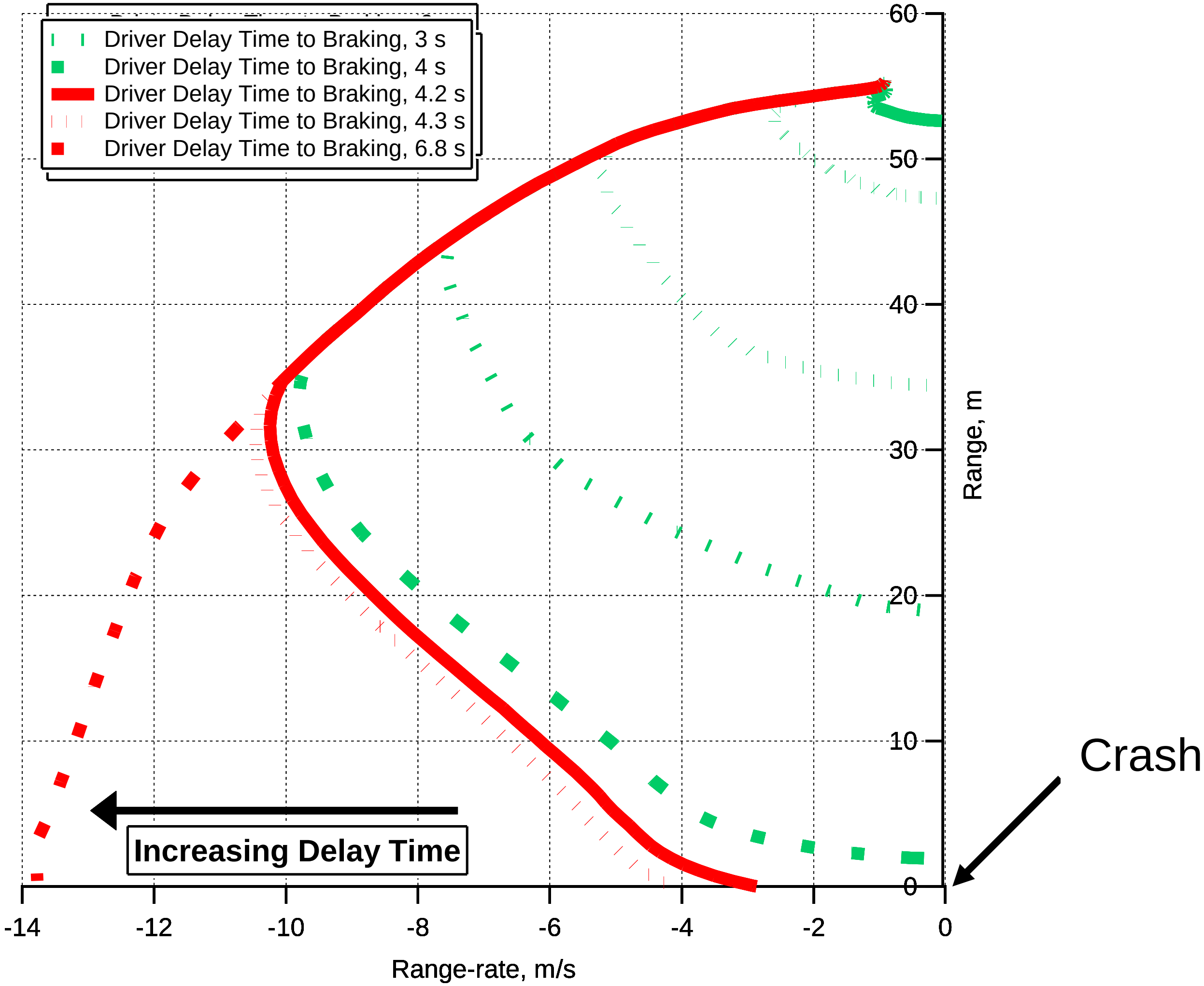
Effect of Delay Time on Severity



Increasing Crash Severity

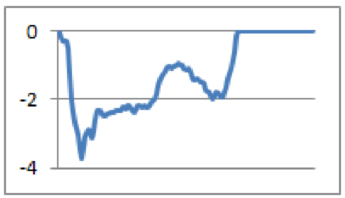
<u>Initial Conditions:</u>

Sv Speed = 40 mph

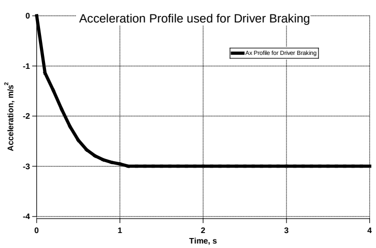
Pov Speed = 38 mph

Range = 55 m

<u>Pov Decel Profile</u>



<u>Sv Decel Profile</u>



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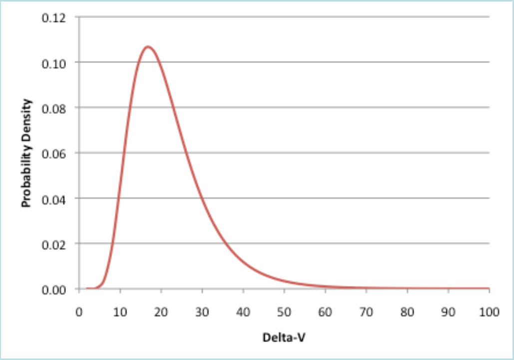
Estimating delta-V distribution for historical rear-end crash population

- We get baseline delta-V distribution by finding the distribution of delta-V that reproduces the injury patterns for truck-into-car rear ends in GES



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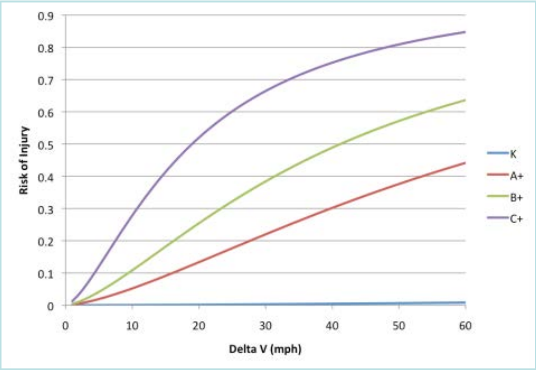

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Injury Level	Estimated Probability of Injury	Observed Proportion
K	0.0008	0.005
A	0.0698	0.041
B	0.0694	0.080
C	0.1837	0.187
O	0.6763	0.687

Delta-V (Exposure) X Risk (given dV) = Injury

- Unique delta-V distributions are developed for each crash type (LV slower, decelerating, stopped, cut-in).

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Evaluate system performance compared to baseline

System evaluation:

1) FCW—accounts for a distribution of driver brake reaction times from 0.5-2.7 sec, based on literature and braking in IVBSS
2) CMB—three systems; driver not in loop.
3) Combination—best performance of either FCW or CMB for each case

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Technology Simulation Methodology

- Based on the rules for a FCW, calculate the simulation time when an FCW would have been given to the driver
- Map Driver Brake Reaction Time Distribution on to Baseline Simulations
- For each Baseline simulation that resulted in a crash—rerun with the three CMB algorithms and save the results

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Characteristics of Future Systems

- System can reliably detect moving and fixed vehicles
- CMB automated braking deceleration levels
  - nominal 0.35 g for the second generation system
  - nominal 0.60 g for the third generation system

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Reduction in Injury Severity

Tractor Semitrailer

Device	Fatal	Injury	No injury
Subsystem Contribution			
FCW only	31%	27%	11%
CMB only 2nd gen.	26%	32%	10%
CMB only 3rd gen.	44%	42%	19%
Complete System Contribution			
Second Generation	**44%**	**47%**	**20%**
Third Generation	**57%**	**54%**	**29%**
Current Generation	**24%**	**25%**	**9%**

Single Unit Trucks

Device	Fatal	Injury	No injury
Subsystem Contribution			
FCW only	28%	25%	11%
CMB only 2ND Gen.	27%	33%	13%
CMB only 3rd Gen.	42%	46%	23%
Complete System Contribution			
Second Generation	**43%**	**46%**	**24%**
Third Generation	**55%**	**57%**	**34%**
Current Generation	**22%**	**21%**	**10%**

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Total Annual Economic Benefit
(2013 Dollars)

Tractor Semitrailer

Device	Fatal	Injury	No injury	Total
Subsystem Contribution				
FCW only	$528.9	$544.8	$34.4	$1,108.1
CMB only 2nd gen.	$446.2	$633.6	$31.9	$1,111.7
CMB only 3rd gen.	$741.2	$792.8	$60.6	$1.594.6
Complete System Contribution				
Second Generation	**$745.0**	**$919.5**	**$65.8**	**$1,730.3**
Third Generation	**$972.7**	**$1046.1**	**$93.1**	**$2,112.0**
Current Generation	**$412.4**	**$513.0**	**$29.5**	**$954.9**

Single Unit Trucks

Device	Fatal	Injury	No injury	Total
Subsystem Contribution				
FCW only	$142.3	$395.3	$30.5	$568.1
CMB only 2nd Gen.	$134.6	$500.8	$35.4	$670.8
CMB only 3rd Gen.	$211.7	$690.2	$62.4	$964.3
Complete System Contribution				
Second Generation	**$214.7**	**$703.8**	**$63.9**	**$982.4**
Third Generation	**$275.6**	**$853.9**	**$89.7**	**$1,219.2**
Current Generation	**$112.9**	**$342.8**	**$25.8**	**$481.5**

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Conclusions

Tractor semitrailers

- The annual reduction in fatalities and injuries relative to the base population for current generation systems is:

Current technology 24% and 25% respectively ($0.9 billion/yr)

Second generation 44% and 47% respectively ($1.7 billion/yr)

Third generation 57% and 54% respectively ($2.1 billion/yr)

Single Unit Trucks

- The annual reduction in fatalities and injuries relative to the base population for current generation systems is:
- Current technology 22% and 21% respectively ($0.5 billion/yr)
- Second generation 43% and 46% respectively ($1.0 billion/yr)
- Third generation 55% and 57% respectively ($1.2 billion/yr)

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Conclusions

- Current generation F-CAM systems provide significant reduction in the frequency and severity of truck rear-end striking crashes
- The research indicates that future systems will provide additional benefit:

  Second generation – factor 1.9

  Third generation – factor of 2.3

  (relative to current generation systems)

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Thank You!

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