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Underride in rear-end fatal truck crashes

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16. Abstract

For the 1997 data year, UMTRI's Center for National Truck Statistics collected data on rear underride as part of its Trucks Involved in Fatal Accidents (TIFA) survey. The purpose of the survey was to evaluate the incidence of underride in fatal crashes in which the rear of the truck was struck. Supplemental data was collected on each such rear-end fatal crash. Data collected included whether the truck had a rear underride guard, whether the striking vehicle underrode the truck, and how much underride occurred. A primary goal of the effort was to evaluate rear underride of straight trucks.

Overall, 453 medium and heavy trucks were struck in the rear by a nontruck vehicle in a fatal crash in 1997. Some underride occurred in at least 272 (60.0%) of the rear-end crashes. For straight trucks, no underride occurred in 43 (29.1%) of the fatal rear-end crashes; there was some underride in 77 (52.0%) of the crashes; and underride could not be determined in the remaining 28 (18.9%) straight truck rear-end crashes. Despite the fact that three-fourths of tractor combinations had an underride guard on the trailer, underride was more common for tractor combinations. Some underride occurred in 192 (67.1%) of all tractor configurations struck in the rear during a fatal crash.

In 1997, there were 527 fatalities in rear-end crashes in which the truck was struck by a nontruck vehicle. Since about 15% of the crashes included three or more vehicles and thus involved other collisions in addition to the rear-end, tabulation of fatalities in the striking vehicle provides an alternative measure of the size of the underride problem. Four hundred seventy-five persons were fatally injured in the striking vehicle in rear-end collisions. Of these, at least 297 deaths occurred when the striking vehicle underrode a truck, 115 deaths occurred with no underride, and underride could not be determined for 63 deaths. One hundred fifty-seven deaths occurred in vehicles striking a straight truck; 79 involved underride.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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1.0 Introduction

For the 1997 data year, UMTRI's Center for National Truck Statistics collected data on rear underride as part of its Trucks Involved in Fatal Accidents (TIFA) survey. Underride can occur in a number of crash configurations, but the focus of the study was crashes in which the rear of a truck was struck. The purpose of the survey was to evaluate the incidence of underride in these fatal crashes. Supplemental data was collected on each rear-end crash involvement. Data collected included whether the truck had a rear underride guard, whether the striking vehicle underrode the truck, and how much underride occurred. A primary goal of the effort was to determine how frequently straight trucks are underridden in fatal crashes.

1.1 Data

The data collection of underride in rear-end crashes was implemented as a supplement to the TIFA survey. The TIFA file is in turn built on the Fatality Analysis Reporting System (FARS) file, produced by the National Highway Traffic Safety Administration. Records of medium and heavy trucks involved in a fatal crash are selected from the FARS file, and then additional data about the physical configuration of the truck and the type of company operating it are collected. The TIFA data collection is accomplished through telephone interviews with people who have knowledge of the truck at the time of the crash. Interviews are typically carried out with the driver, owner, safety director of the carrier operating the truck, the reporting police officer, and any other involved party. The combination of the FARS records and the additional descriptive data collected by these telephone interviews forms the TIFA file.

Cases in the TIFA file are actually a sample of FARS truck crash records. Rather than collecting data on each of the more than 5,000 trucks in a typical year of FARS, some sampling is done among the two best-understood truck configurations: straight trucks with no trailers and tractors pulling one trailer. The sampling procedure is simple. First, all cases where the truck driver was killed are taken for the TIFA file, to ensure complete coverage of this group. Next, all cases identified in FARS as a truck configuration other than a straight truck with no trailer or a tractor with one semitrailer are taken. The remaining trucks are all identified in FARS as either a straight truck with no trailer or a tractor pulling one semitrailer. One-half of these cases are selected for the TIFA survey. Sample weights are included in the TIFA file so that the correct population estimates can be calculated. The sample weights are equal to one for those cases taken with certainty and two for the group in which only half of the cases were selected for the TIFA file.

Cases for the rear-end underride supplemental survey were selected from the TIFA truck fatal involvements.[1] FARS data elements describing the crash configuration were used to select crashes in which the truck was struck in the rear by another motor vehicle.

Initially, we identified 366 crashes for the TIFA underride data collection survey. The disposition of these cases and some additional rear-end crashes identified during the data collection process is tabulated in table 1. As interviews for data collection proceeded with drivers, police officers, and other parties with knowledge of the crash, it was determined that in 130 of the crashes, the impact was not with the rear of the truck. In these crashes, most often the collision was a sideswipe or angle collision with the side of the truck, almost always at the rear of the vehicle, but not involving the actual back end of the truck. In an additional 27 crashes, the truck was struck by another medium or heavy truck (truck-truck crashes). In two crash involvements, the struck vehicle proved not to be a medium or heavy truck.

Table 1
Case selection and outcome of rear-end collision survey
1997 TIFA

source of selection and outcome of survey	N
selected as a rear-end; is rear-end	**207**
selected as a rear-end; NOT a rear-end	130
selected as a rear-end; truck-truck crash	27
selected as a rear-end; vehicle struck not a truck	2
total rear-ends initially selected	*366*
TIFA identified rear-end	**52**
TIFA identified rear-end; truck-truck crash	16
Truck rear-ended by nontruck	**259**

Finally, editors reviewed police reports on all TIFA truck crashes and identified an additional 68 crashes (52 rear-ends + 16 truck-truck) where the truck was rear-ended but which were not selected in the initial round of cases. In 16 of those TIFA-identified crashes, the striking vehicle was another truck. The result is a total of 302 rear-end crashes, 259 of which involved a truck struck in the rear by a motor vehicle other than a medium or heavy truck.[2] (The other 43 rear-end crashes were truck-truck, and thus not candidates for underride.) When the appropriate sample weights are applied, the 259 rear-end cases make up the 453 fatal rear-end involvements analyzed for underride in Section 2.2.

To better characterize the whole population of straight trucks and understand the incidence of underride in rear collisions, we also collected data describing the rear of every straight truck in the TIFA survey, regardless of whether the truck was struck in the rear. For every straight truck, interviewers filled out the portion of the rear-end supplemental data form that covers vehicle description. Data collected on all straight trucks include cargo body overhang behind the rear duals, cargo overhang, height of cargo bed from the ground,

[1] "Truck fatal involvements" is the set of trucks involved in a traffic crash in which at least one person was fatally injured. In this context, an "involvement" is one truck involved in a fatal crash.

[2] For the remainder of the paper, except where explicitly indicated otherwise, a "rear-end" crash means a truck struck in the rear by a nontruck vehicle. Truck-truck rear-end crashes are excluded.

whether the vehicle was equipped with an underride guard, the height of the underride guard from the ground, width of the underride guard, and any other equipment[3] on the rear of the truck hanging below the cargo body.

2.0 TIFA underride survey results

This section of the paper is devoted to discussing the results of the survey of rear-end collisions and underride in fatal truck crashes. First, we will discuss survey results covering straight trucks in all fatal crashes, not just collisions in which a truck was struck in the rear. The focus is on the rear of straight trucks, especially characteristics of the rear of the vehicle that can affect underride in the event of a rear-end collision. Topics include cargo and cargo body overhang, the height of the cargo bed, and the frequency of mounted equipment and underride guards on the rear end. Then we will present some results on rear-end crashes, the frequency of underride guards, and the frequency and amount of underride.

2.1 Straight trucks involved in fatal crashes

Since one goal of the underride survey was to evaluate the effectiveness of underride guards for straight trucks, an attempt was made to collect data on the rear configuration of all straight trucks, regardless of whether they were struck in the rear end. The back ends of straight trucks can have a variety of configurations, which can affect the opportunity for underride to occur when the truck is struck in the rear. For example, there can be large differences in the amount of cargo body overhang, defined as the distance from the rear duals to the rear of the cargo body. In dump trucks, this distance is typically under 12 inches, but in dry vans hauling light-weight cargo, cargo body overhang can be 120 inches or more. Similarly, some straight trucks have equipment mounted at the rear of the cargo body, in place of or in addition to underride guards.

Figure 1 shows the distribution of cargo body overhang for all straight trucks in the TIFA survey. Overhang is defined as the distance in inches from the rear tires to the rear of the cargo body. This is the distance a vehicle potentially can underride a truck before it strikes the rear duals. We were unable to determine this distance in about 21% of the cases. The mean overhang for all straights where the distance could be determined was 53 inches, with a standard deviation of 33.3. About half of all straights had cargo body overhangs of 48 inches or less.

[3] "Equipment" throughout this paper refers to equipment mounted on the rear of the truck that extends below the level of the cargo body.

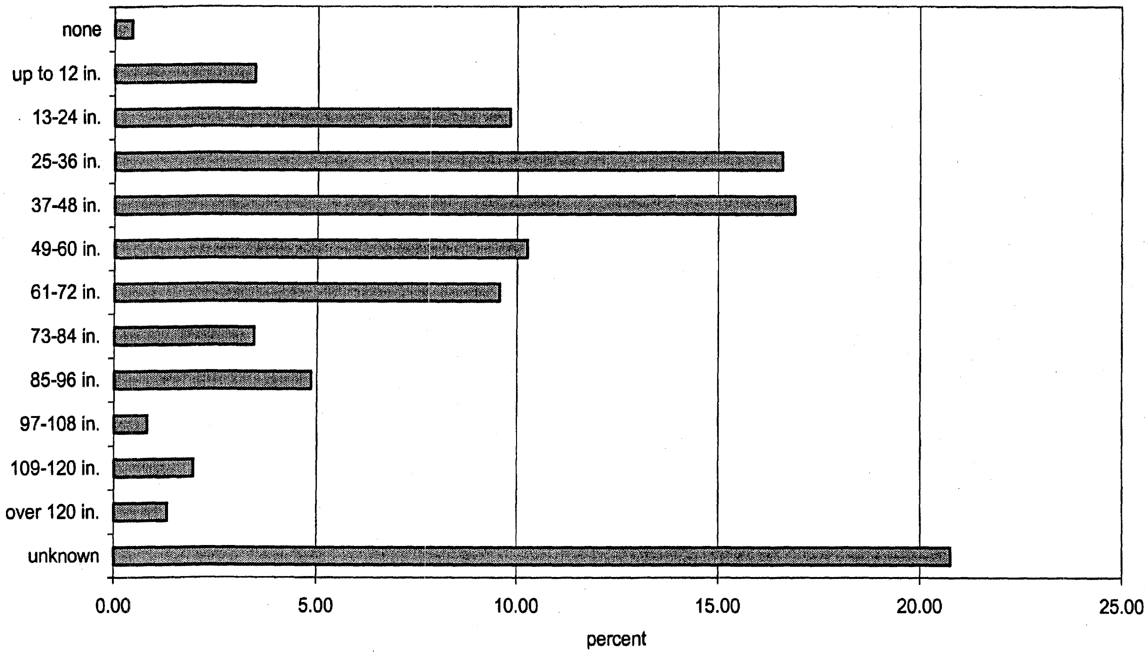

Figure 1: Cargo body overhang in straight trucks 1997 TIFA

Table 2 shows the average cargo body overhang by cargo body type. Only cases with known cargo body overhang are included. Some body types are represented by only a small number of cases, such as the 5 auto carriers, 84 refuse bodies, and 90 tanks. Mean overhang roughly accords with expectations. Vans often have large overhangs because they frequently carry low density cargoes. Flatbeds and tanks often have equipment mounted at the rear. The average overhang for dumps, at slightly over 39 inches, is longer than expected. But the dump category encompasses a variety of applications. Many of the vehicles with the largest overhangs were used in agriculture; examples include grain bodies and potato bodies which can have rear-unloading equipment, which would contribute to the overhang.

Table 2
Average cargo body overhang, straight trucks weighted frequencies, known overhang only 1997 TIFA

body type	N	overhang (inches)	std. dev.
van	318	64.5	32.8
flatbed	163	54.6	28.5
tank	90	51.8	29.7
auto carrier	5	112.8	87.0
dump	349	39.2	29.5
refuse	84	65.2	32.5
other	267	51.3	30.6
all straights	1276	52.9	33.3

Figure 2 shows the height of the cargo body bed from the ground for all straight trucks. Researchers were unable to determine this distance in 15% of the cases. Respondents were unable to give a precise estimate in some cases, though they were willing to tell us whether the bed was higher than the top of the tires or below that level. Overall, the mean bed height was 41.5 inches with a standard deviation of 12.1 inches. The figure shows the distribution in six-inch increments. As might be expected, the largest category is from 43 to 48 inches, but some quite low bed heights were reported, including nine cases at 12 inches!

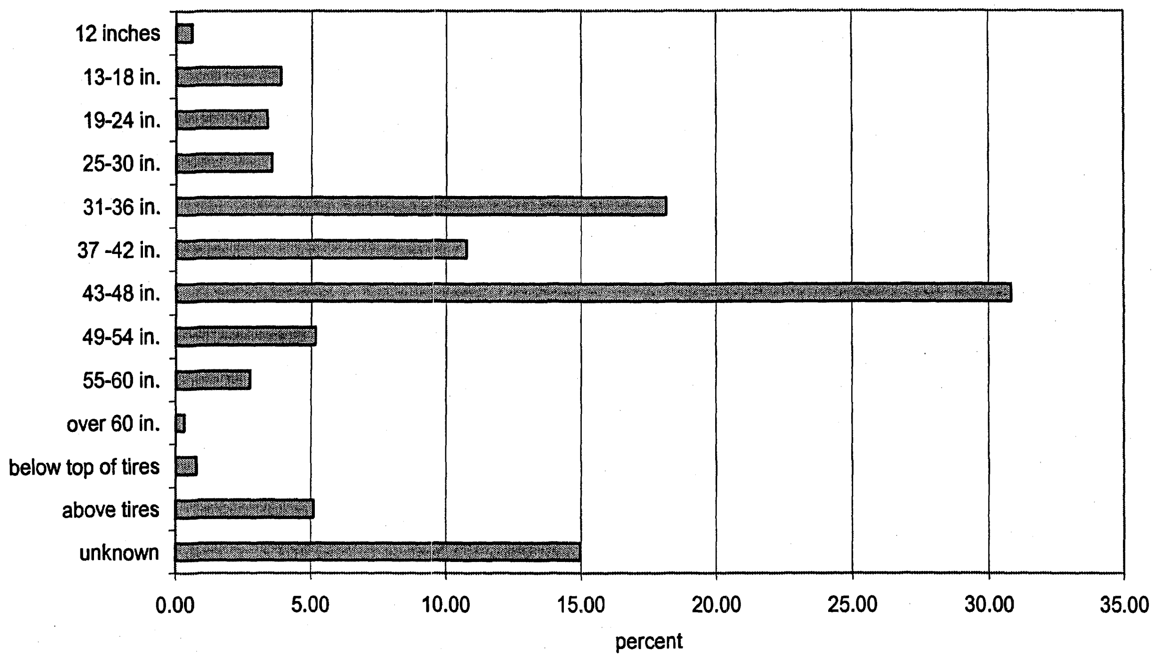

Figure 2: Cargo body bed height from ground in straight trucks 1997 TIFA

Only about 26% of straight trucks were reported to have an underride guard mounted to the rear (table 3). Almost 56% of straight trucks did not have an underride guard, and interviewers were unable to determine if the truck had an underride guard in 18.1% of the cases. Presence of an underride guard varied widely by cargo body style. Over 42% of refuse trucks had an underride guard, compared to no auto carriers and only 15.9% of dumps. Over 35% of vans had an underride guard, as did 33.0% of flatbeds and 30.3% of tanks.

Table 3
Reported underride guard, by cargo body style
straight trucks
weighted frequencies, 1997 TIFA

	yes		no		unknown		total	
	N	%	N	%	N	%	N	%
van	140	35.3	197	49.6	60	15.1	397	100.0
flatbed	68	33.0	100	48.5	38	18.4	206	100.0
tank	33	30.3	54	49.5	22	20.2	109	100.0
auto carrier	0	0.0	5	23.8	16	76.2	21	100.0
dump	68	15.9	272	63.6	88	20.6	428	100.0
refuse	44	42.3	45	43.3	15	14.4	104	100.0
other	66	19.5	226	66.9	46	13.6	338	100.0
unknown	0	0.0	0	0.0	7	100.0	7	100.0
total	419	26.0	899	55.8	292	18.1	1610	100.0

The TIFA survey also determined if there was any equipment mounted on the rear of the truck extending below the level of the cargo body. The purpose of this question was to determine the incidence of rear-mounted equipment that might affect underride. Some equipment, such as liftgates, can be quite substantial and serve as an underride guard, although most of the reported equipment was probably too flimsy to have much effect. Overall, 26.0% of straights involved in fatal crashes in 1997 had mounted equipment, 58.1% did not, and 15.9% were unknown (table 4). Once again, cargo body style was related to the presence of mounted equipment. Almost 35% of vans reported some sort of equipment, compared to about 23% of tanks and flatbeds, and only 14.3% of dumps. A wide variety of equipment is included here. Steps or step bumpers were mentioned about 27% of the time, bumpers accounted for another 15% of the equipment, and liftgates were present on about 10% of the straight trucks. Other items mentioned were various types of hitches, tool boxes, pumps, spreaders, and wheel lifts.

Table 4
Reported equipment below cargo bed, by cargo body style
straight trucks
weighted frequencies, 1997 TIFA

	yes		no		unknown		total	
	N	%	N	%	N	%	N	%
van	138	34.8	204	51.4	55	13.9	397	100.0
flatbed	47	22.8	119	57.8	40	19.4	206	100.0
tank	25	22.9	69	63.3	15	13.8	109	100.0
auto carrier	2	9.5	3	14.3	16	76.2	21	100.0
dump	61	14.3	301	70.3	66	15.4	428	100.0
refuse	17	16.3	75	72.1	12	11.5	104	100.0
other	128	37.9	165	48.8	45	13.3	338	100.0
unknown	0	0.0	0	0.0	7	100.0	7	100.0
total	418	26.0	936	58.1	256	15.9	1610	100.0

Finally, table 5 shows the combination of underride guards and rear-mounted equipment that might serve to impede underride. All told, 33.9% of straight trucks in a fatal crash had neither an underride guard nor any rear-mounted equipment. For the most part, trucks either had a guard (19.3%) or mounted equipment (20.0%). Only about 5% were reported to have both an underride guard and some sort of mounted equipment. The unknown category combines cases coded unknown on whether there was an underride guard or any equipment or both.

Table 5
Underride guard
or equipment below cargo bed
Straight trucks only
weighted frequencies, 1997 TIFA

	N	%
both	77	4.8
guard only	311	19.3
equipment only	322	20.0
neither	545	33.9
unknown	355	22.0
total	1610	100.0

The rear-end survey also attempted to collect information about the height of the guard from the ground and the width of the guard. These questions proved very difficult to answer. Missing data rates for the variables are 85% to 90%.

2.2 Underride in fatal rear-end crashes

This section examines underride in fatal rear-end truck crashes, as identified in the 1997 TIFA file. As described above, the underride survey effort collected data describing the rear of trucks, focusing on underride guards, mounted equipment, overhang, and cargo bed height. All of those factors may affect underride in rear-end collisions. Accordingly, the present section will first review the frequency of rear-end crashes and underride, and then present tables examining the association between the rear structures of trucks and underride. Of course, the TIFA file is limited to crashes in which a fatality occurred, so we cannot calculate differential probabilities of fatality for underride guards. Nevertheless, these data can be used to detect associations between the type of rear-end structure and whether and how much underride occurs.

2.2.1 Underride by truck configuration

Table 6 shows the incidence of rear-end fatal crashes by truck configuration. A total of 453 such rear-ends occurred in 1997. These are all crashes in which the truck was struck in the rear by a nontruck vehicle. Crashes in which the striking vehicle was another truck (truck-truck) are excluded, as are rear-end crashes in which the truck itself was the striking vehicle, regardless of the type of the struck vehicle. Overall, a truck was struck in the rear by a nontruck vehicle in about 8.8% of fatal crashes involving a truck in 1997. The rear-end rate was 9.4% for straight trucks with no trailer, 8.9% for tractor-semitrailers, and 7.2% for tractors pulling two or more cargo-carrying trailers.

Table 6
Incidence of rear-end by truck configuration
weighted frequencies, 1997 TIFA

	rear-end		no rear-end		total	
	N	%	N	%	N	%
straight only	131	9.4	1266	90.6	1397	100.0
straight + trailer	17	8.0	196	92.0	213	100.0
bobtail tractor	4	3.0	130	97.0	134	100.0
tractor-semitrailer	270	8.9	2750	91.1	3020	100.0
tractor, 2 or more	16	7.2	205	92.8	221	100.0
tractor, other combo	0	0.0	23	100.0	23	100.0
unknown	15	12.3	107	87.7	122	100.0
total	453	8.8	4677	91.2	5130	100.0

Table 7 presents the fundamental results of the underride survey. It shows underride occurrence in rear-end fatal crashes by truck configuration. Considering straight trucks, 148 straights were involved in a fatal rear-end collision where the striking vehicle was a not a truck. In those 148 rear-ends, there was no underride in 43 involvements (29.1%), some underride in 77 involvements (52.0%), and underride was unknown in 28 involvements (18.9%). There were 286 tractors with one or more cargo-carrying trailers struck in the rear. No underride occurred in 68 crashes (23.8%), some underride occurred in 192 crashes (67.1%), and underride could not be determined in 26 involvements (9.1%). Overall, underride occurred in 272 of the 453 rear-ends (60.0%).

Table 7
Underride in rear-end fatal crashes by truck configuration
weighted frequencies, 1997 TIFA

truck configuration	none	underride: less than halfway to windshield	more than halfway to windshield	to windshield	some but unknown amount	unknown	total
straight only	41	23	8	41	5	13	131
straight + trailer	2	0	0	0	0	15	17
bobtail tractor	0	2	0	0	0	2	4
tractor-semitrailer	65	54	28	88	11	24	270
tractor, 2 or more	3	4	1	4	2	2	16
unknown	0	0	0	1	0	14	15
total	111	83	37	134	18	70	453
				row percentages			
straight only	31.3	17.6	6.1	31.3	3.8	9.9	100.0
straight + trailer	11.8	0.0	0.0	0.0	0.0	88.2	100.0
bobtail tractor	0.0	50.0	0.0	0.0	0.0	50.0	100.0
tractor-semitrailer	24.1	20.0	10.4	32.6	4.1	8.9	100.0
tractor, 2 or more	18.8	25.0	6.3	25.0	12.5	12.5	100.0
unknown	0.0	0.0	0.0	6.7	0.0	93.3	100.0
total	24.5	18.3	8.2	29.6	4.0	15.5	100.0

2.2.2 Underride and underride guards/mounted equipment

The TIFA survey collected information on rear underride guards and mounted equipment in the population of trucks that had been rear-ended, including both straight trucks and tractor combinations. Only thirteen rear-ended trucks had both an underride guard and some sort of rear-mounted equipment (table 8). About half the rear-end crash population had a guard only, and these were mostly tractor combinations. Tractor-combinations tended to have only guards. Almost 75% of rear-ended tractor combinations had an underride guard, but very few had mounted equipment. On the other hand, 41.9% of straight trucks had neither an underride guard nor equipment, 27.0% had equipment only, 14.2% had only an underride guard, and 6.8% had both an underride guard and rear-mounted equipment. (Truck configurations are aggregated to power unit type to avoid needless proliferation of empty cells. Almost 90% of straight trucks pulled no trailer, and 98.6% of tractors had at least one trailer.)

Table 8
Underride guard or equipment below cargo bed
in rear-end fatal crashes by power unit type
weighted frequencies, 1997 TIFA

	all straights		all tractors		total	
	N	%	N	%	N	%
both	10	6.8	3	1.0	13	2.9
guard only	21	14.2	215	74.1	236	52.1
equipment only	40	27.0	2	0.7	42	9.3
neither	62	41.9	28	9.7	90	19.9
unknown	15	10.1	42	14.5	72	15.9
total	148	100.0	290	100.0	453	100.0

Overall, the TIFA survey results do not show that either underride guards or mounted equipment had much effect on the amount of underride, although sample sizes are small with only one year of data (table 9). For trucks with an underride guard only, over 35% of the rear-end collisions resulted in underride up to and beyond the windshield of the striking vehicle. Only trucks with both an underride guard and mounted equipment had a higher proportion of underrides to the windshield. Trucks with nothing on the rear were underridden to the windshield in 27.8% of the involvements, and experienced no underride at all in 26.7%. Considering all degrees of underride, trucks with a guard suffered slightly more underride than trucks with no rear-end protection, 69.5% to 66.7%.

Table 9
Underride in rear-end fatal crashes by underride guard/equipment
weighted frequencies, 1997 TIFA

underride guard or equipment	underride None	less than halfway to windshield	more than halfway to windshield	to windshield	some but unknown amount	unknown	total
both	2	2	2	7	0	0	13
guard only	65	45	24	84	11	7	236
equipment only	14	9	0	13	0	6	42
neither	24	21	9	25	5	6	90
unknown	6	6	2	5	2	51	72
total	111	83	37	134	18	70	453
			row percentages				
both	15.4	15.4	15.4	53.8	0.0	0.0	100.0
guard only	27.5	19.1	10.2	35.6	4.7	3.0	100.0
equipment only	33.3	21.4	0.0	31.0	0.0	14.3	100.0
neither	26.7	23.3	10.0	27.8	5.6	6.7	100.0
unknown	8.3	8.3	2.8	6.9	2.8	70.8	100.0
total	24.5	18.3	8.2	29.6	4.0	15.5	100.0

This result is counter to what would be expected, although it may be due to small sample sizes and a host of other complicating factors. The severity threshold of the TIFA file may serve to decrease variation in the amount of underride by rear-end structure, since a fatality must occur for the crash to be included in the file. It could be that many of the collisions are beyond the design limits of the guards, and so the guards have no effect. Other complicating factors include the cargo body height, the height and front-end structure of the striking vehicle, overhang of the cargo body, and the height of the underride guard from the ground. Data on these questions were collected but the number of involvements in one year of data was too small to sort out the impact of the various factors.

2.2.3 Fatalities in rear-end crashes

A total of 527 persons were fatally injured in rear-end crashes in 1997 (table 10). This total includes fatal injuries to any involved party, including the truck driver and any passengers, occupants of the striking vehicle, occupants of any other vehicle, and pedestrians or other nonmotorists. Of the 527 fatalities, 475 (90.1%) occurred in the striking vehicle and 52 were suffered by some other involved party, most often either an occupant of another vehicle in the crash or a pedestrian. (About 15% of the fatal rear-end crashes involved more than two vehicles.) Almost a quarter of the fatal injuries in the striking vehicle occurred in crashes with no underride. A total of 297 fatalities (62.5%) in the striking vehicle occurred in crashes where there was at least some underride. Of those underride fatalities, almost half involved underride to the windshield or beyond.

Table 10
Fatalities in striking vehicle and other fatalities in crash
rear-end crashes by amount of underride
weighted frequencies, 1997 TIFA

	striking vehicle		other fatalities		total	
amount of underride	N	%	N	%	N	%
none	115	24.2	25	48.1	140	26.6
less than halfway to windshield	92	19.4	7	13.5	99	18.8
more than halfway to windshield	41	8.6	0	0.0	41	7.8
to windshield	147	30.9	0	0.0	147	27.9
some but unknown amount	17	3.6	1	1.9	18	3.4
unknown	63	13.3	19	36.5	82	15.6
total	475	100.0	52	100.0	527	100.0

Table 11 tabulates the fatalities in the striking vehicle in rear-end crashes by the amount of underride and the power unit type of the truck. The percentages shown in the table are total percents, i.e., the proportion of the cell of all rear-end striking vehicle fatalities. Thus 10.3% of the fatalities involved straight trucks where there was no underride. Almost two-thirds of the rear-end striking-vehicle fatalities occurred in collisions with tractor combinations. Almost half of the fatalities (216, 45.5%) occurred in collisions with tractor combinations where there was some underride. Straight trucks accounted for about one-third of the fatalities in striking vehicles, and only 79 of the 297 fatalities in which underride occurred.

Table 11
Fatalities in striking vehicle
rear-end crashes by amount of underride and power unit type
weighted frequencies, 1997 TIFA

	all straights		all tractors		unknown		total	
amount of underride	N	%	N	%	N	%	N	%
none	49	10.3	66	13.9	0	0.0	115	24.2
less than halfway to windshield	26	5.5	66	13.9	0	0.0	92	19.4
more than halfway to windshield	8	1.7	33	6.9	0	0.0	41	8.6
to windshield	41	8.6	104	21.9	2	0.4	147	30.9
some but unknown amount	4	0.8	13	2.7	0	0.0	17	3.6
unknown	29	6.1	34	7.2	0	0.0	63	13.3
total	157	33.1	316	66.5	2	0.4	475	100.0

3.0 Underride in FARS

FARS is a data system based on police accident reports. The FARS system includes a variable to record all police-reported underrides, including side underrides and even some front underrides (though rare, they are possible). Though there is some mismatch in coverage, the TIFA rear-end underride data allow an independent comparison with the police accident reports documented in the FARS data. By matching the FARS and TIFA crashes, we can gauge the completeness of police underride reporting, and identify cases that were likely missed or misreported.

Beginning in 1994, FARS included a data element to record police-reported instances of underride. Underride is coded when an investigating officer reports that one vehicle underrode another vehicle in transport, a parked vehicle, or a transport device used as equipment. Note that underride is coded for the vehicle that goes under another vehicle, not the vehicle underridden. The focus of interest here is on the extent to which the investigating officers report that a vehicle in the crash underrode a truck. To determine underride using the FARS file, the procedure is to examine the other vehicles in the crash and see if underride is coded for them.

In the 1997 FARS file, 223 vehicles were coded as having underridden another vehicle in a fatal crash. These include all vehicles coded 1-6 on the UNDERIDE variable. In order to understand how truck underride is captured in FARS, we decided to build an analysis file from the 1997 FARS data. The file consisted of one record per underride, with variables describing both vehicles in the event. The first set of descriptive variables in the record described the vehicle that did the underriding. Appended to that record were variables describing the vehicle that was underridden.

We were able to determine the type of vehicle underridden in each crash where it was a vehicle in transport. Of the 223 vehicles coded underride, 23 were involved in single-vehicle crashes. Twenty-one of them collided with a parked vehicle. In two crashes, the underridden "vehicle" was a transport device used as equipment. There is no information to characterize those underridden vehicles or devices further, because parked vehicles are not vehicles in transport and not included in the FARS file. Accordingly, in these cases, the variables describing the underridden vehicle were set to missing data.

Of the remaining 200 underrides, 167 were involved in two-vehicle crashes. The initial strategy was to take the other vehicle as the vehicle underridden. However, in seven of these involvements, the underride variable indicated that the underride was not with a motor vehicle in transport. In these cases, the underridden vehicle variables were set to missing data. The remaining 33 crashes involved more than two vehicles. Review of police reports for each crash allowed identification of the vehicle underridden. Descriptive variables for that vehicle were included in the file. The result was a file with all 223 underrides in the 1997 FARS file. Appended to each underride vehicle record are variables describing the vehicle underridden, except where a record was unavailable because it was legally parked or a transport device used as equipment.

3.1 Analysis of FARS underride crashes

Table 12 shows the distribution of underride crashes identified in FARS by state, along with the number of truck fatal involvements in each state. The ratio between each state's percentage of truck underrides and the percentage of truck fatal involvements in each state is also shown to give an indication of the completeness of reporting in each state. Ratios equal to one indicate that underride was recorded in FARS in exact proportion to the number of trucks involved in a fatal crash in that state. Ratios greater than one indicate that the number of reported underrides is high in proportion to truck fatal involvements in the state. Ratios less than one indicate that reported underrides are low in relation to the proportion of truck fatal involvements.

Table 12
Truck underrides reported in FARS
and total truck fatal involvements by state
FARS 1997, TIFA 1997

	FARS underrides		all truck fatal involvements		ratio of FARS underride % to truck
state	N	%	N	%	involvement %
Hawaii	1	0.4	3	0.1	7.67
New Hampshire	3	1.3	14	0.3	4.93
Connecticut	5	2.2	24	0.5	4.79
Idaho	4	1.8	33	0.6	2.79
Arizona	9	4.0	75	1.5	2.76
Wyoming	3	1.3	25	0.5	2.76
Delaware	2	0.9	17	0.3	2.71
Oregon	7	3.1	77	1.5	2.09
New Jersey	7	3.1	83	1.6	1.94
Louisiana	11	4.9	132	2.6	1.92
Nevada	2	0.9	24	0.5	1.92
New Mexico	4	1.8	51	1.0	1.80
Massachusetts	3	1.3	39	0.8	1.77
Tennessee	10	4.5	137	2.7	1.68
Missouri	10	4.5	139	2.7	1.65
Washington	6	2.7	84	1.6	1.64
Vermont	1	0.4	15	0.3	1.53
California	25	11.2	393	7.7	1.46
Nebraska	3	1.3	49	1.0	1.41
Maryland	5	2.2	92	1.8	1.25
Georgia	11	4.9	221	4.3	1.15
Wisconsin	4	1.8	81	1.6	1.14
Texas	20	9.0	429	8.4	1.07
Maine	1	0.4	22	0.4	1.05
Illinois	8	3.6	177	3.5	1.04
Florida	13	5.8	295	5.8	1.01
South Carolina	4	1.8	95	1.9	0.97
Pennsylvania	7	3.1	181	3.5	0.89
Colorado	3	1.3	81	1.6	0.85
Indiana	6	2.7	164	3.2	0.84
Kansas	3	1.3	87	1.7	0.79

Table 12
Truck underrides reported in FARS
and total truck fatal involvements by state
FARS 1997, TIFA 1997

state	FARS underrides N	FARS underrides %	all truck fatal involvements N	all truck fatal involvements %	ratio of FARS underride % to truck involvement %
Michigan	4	1.8	133	2.6	0.69
Arkansas	3	1.3	122	2.4	0.57
Alabama	4	1.8	167	3.3	0.55
New York	3	1.3	158	3.1	0.44
North Carolina	4	1.8	210	4.1	0.44
Ohio	2	0.9	207	4.0	0.22
Kentucky	1	0.4	118	2.3	0.19
Virginia	1	0.4	124	2.4	0.19
Alaska	0	0.0	9	0.2	0.00
Dist of Columbia	0	0.0	3	0.1	0.00
Iowa	0	0.0	76	1.5	0.00
Minnesota	0	0.0	91	1.8	0.00
Mississippi	0	0.0	110	2.1	0.00
Montana	0	0.0	22	0.4	0.00
North Dakota	0	0.0	13	0.3	0.00
Oklahoma	0	0.0	103	2.0	0.00
Rhode Island	0	0.0	3	0.1	0.00
South Dakota	0	0.0	16	0.3	0.00
Utah	0	0.0	51	1.0	0.00
West Virginia	0	0.0	55	1.1	0.00
Total	223	100.0	5130	100.0	1.00

The distribution of underride in the table suggests that reporting is incomplete in some states. Iowa, Minnesota, Mississippi, Oklahoma, Utah, and West Virginia all had more than 50 fatal truck involvements, but no reported underrides. North Carolina reported only 4 among 210 involvements, Ohio only 2 of 207, New York only 3 of 158, Virginia only 1 in 124, and Kentucky only 1 of 118.

As a comparison, the TIFA rear-underride data collection effort identified a total of 272 underrides, even though those crashes were limited to impacts on the rear of the truck. Of the 453 rear impacts (excluding truck-truck rear-ends), roughly 25% (111 crashes) involved no underride, underride was identified in 60% (272) of the crashes, and underride could not be determined in the remaining 15% (70). Considering the cases in the states apparently underreporting underride, four underride crashes were identified in Minnesota, four in Oklahoma, four in Utah, six in North Carolina, five in New York, four in Ohio, thirteen in Virginia, and eleven in Kentucky. Since the TIFA underride effort was limited to rear-ends, those counts represent the minimum number of underrides for those states.

Table 13 shows the body type of the underriding vehicle in the FARS-identified underride crashes. The body type codes used by FARS are shown. Most underriding vehicles (72.6%) are automobiles, while almost 12% are utility vehicles, vans, or minivans. Pickup trucks accounted for 14.3% of the underride vehicles. Note that three of the vehicles were "cab-chassis based" light trucks with gross vehicle weight rating (GVWR) of 10,000 pounds. These vehicles are the largest that FARS computerized consistency checks allow as underriding. FARS data-processing procedures will not accept the underride code for any vehicle with a GVWR over 10,000 pounds.

Table 13
Body type of underriding vehicle
FARS 1997

body type	N	%
convertible	2	0.9
2dr sedan/HT/coupe	48	21.5
3dr/2dr hatchback	18	8.1
4dr sedan/HT	79	35.4
5dr/4dr hatchback	5	2.2
station wagon	5	2.2
hatchback/unk doors	1	0.4
sedan/HT/unk doors	2	0.9
other/unk auto type	2	0.9
compact utility	8	3.6
large utility	2	0.9
utility station wagon	2	0.9
minivan	11	4.9
large van	3	1.3
compact pickup	17	7.6
standard pickup	15	6.7
cab chassis based	3	1.3
total	223	100.0

Table 14 shows the distribution of body type for the vehicle underridden. Note that, except for parked vehicles and transport devices used as equipment which are not identified, only trucks were underridden. One school bus was also included.

Table 14
Body type of vehicle underridden
FARS 1997

body type	N	%
parked vehicle, etc.	30	13.5
school bus	1	0.4
SUT low GVW	3	1.3
SUT medium GVW	7	3.1
SUT high GVW	12	5.4
truck/tractor	165	74.0
unknown medium/heavy	5	2.2
total	223	100.0

SUT = single unit truck
GVW = gross vehicle weight

3.2 Differences between FARS and TIFA underride crashes

FARS identified 223 crashes in which underride occurred. The overlap of FARS and TIFA underride crashes is small. Underride in FARS is coded for all crash configurations, while the TIFA effort focussed on rear-end crashes. TIFA is a sample file, so some of the FARS underride crashes simply were not sampled for the TIFA file. And the FARS file covers all vehicle types, while TIFA includes only trucks. Most (171 of the 223, or 77 percent) of the FARS underride crashes are not included in the TIFA survey of rear-end crashes because of these differences in coverage. Table 15 shows the breakdown of these 171 involvements by the reason the cases are not in TIFA.

Table 15
Underride crashes in FARS that do not overlap with the TIFA rear-end underride file

Trucks FARS coded with underride were not sampled for TIFA.	90
FARS underride crashes involving an underride of a parked vehicle or transport device used as equipment. Legally parked trucks are not included in TIFA.	30
School bus; TIFA includes only trucks	1
Trucks FARS coded with underride in angle collisions; the TIFA survey covered underride in rear-end crashes only	50
Total	171

Subtracting these 171 crashes from the 223 FARS underrides leaves 52 crashes identified in FARS as a rear-end crash in which the truck was underridden. These 52 involvements were surveyed for the TIFA rear-end underride survey. There were substantial differences in the outcome for these cases. In 19 of the crashes, though FARS had identified a rear-end collision, examination of the police report and interviews with involved parties led TIFA coders to identify some other crash configuration, not a rear-end. In addition, the FARS data and the TIFA data had conflicting results in 5 of the remaining 33 crashes. In 2 of the 5 conflicts, FARS recorded an underride and TIFA was unable to determine the underride status of the crash. For the remaining 3 conflicts, FARS recorded an underride and TIFA recorded no underride. FARS and TIFA agreed in the remaining 28 crashes.

The other piece of the differences between underride in FARS and TIFA is the additional underride crashes identified by TIFA. Table 16 summarizes the unweighted and weighted values for all TIFA-identified underrides along with the FARS underride status. There were 128 crashes where TIFA recorded an underride in a rear-end crash and FARS did not record an underride.

Table 16
Underride in rear-end crashes
TIFA survey and FARS coding

TIFA shows:	FARS shows:	unweighted	weighted
underride	underride	28	51
underride	no underride	128	221
no underride	underride	3	6
no underride	no underride	58	105
underride unknown	underride	2	3
underride unknown	no underride	40	67
total rear-end collisions		259	453

TIFA identified rear-end truck underrides in 156 (28+128) crashes, with a weighted total of 272 (51+221) crashes. Of these crashes, only 28 (unweighted, 51 weighted) were identified as involving an underride by FARS. That is, FARS identified approximately 18 percent (28/156) of the TIFA-identified rear-end truck underrides. Note that the weighted total of 221 additional rear-end underride crashes is almost equal to the total of 223 underrides identified by FARS among all fatal crashes.

This is in no way a criticism of FARS. FARS analysts work from police reports and other materials where the recording of underride is not a regular part of the program. The only place underride is recorded on police reports is in the narrative, so it is mentioned only if the reporting officer chooses to do so. In contrast, TIFA interviewers specifically probed a wide variety of respondents in each rear-end crash to determine if underride occurred. Moreover, it must be noted that the approach taken in the TIFA file of focusing on trucks misses underrides of legally parked trucks because records for those parked vehicles will not appear in FARS.

The comparison of FARS and TIFA was limited to investigating rear underrides and has not addressed the problem of side and angle underrides. From table 15, 50 angle underrides were identified in FARS. Those underrides were not addressed here because they involved angle collisions, in which the rear of the truck was not contacted. Nevertheless, it does appear that the coding of the FARS underride variable misses a substantial number of underrides. The total number of all underrides must be at least twice the number recorded in FARS, and likely somewhat more, if side underrides are missed at the same rate as rear-end underrides. Moreover, it also appears that underride reporting is inconsistent state-to-state, with some states reporting no underrides or substantially fewer than would be expected from the volume of fatal truck crashes.

4.0 Future work

Performing the TIFA survey of underrides was an education in the difficulty of identifying underride, so the above results imply no criticism of the FARS analysts. However, the TIFA survey clearly has uncovered significant new information about rear underride. Accordingly, it may be appropriate to expand coverage to underrides in all crash configurations. This would provide an improved global estimate of the underride problem in truck crashes, as well as allow the estimation of differences between side and rear underride.

Two other courses could improve coverage of underride. The TIFA file is a sample file, so a number of involvements are not sampled for coverage. Vehicle sample weights provide correct estimates of the number of trucks rear-ended and underridden, but the match of FARS underride crashes with TIFA illustrates the limitations of TIFA sampling. Ninety FARS underride crashes were not covered by the TIFA sample, so the extent of underride in those cases is unknown. One improvement would be to examine all truck involvements not sampled for the TIFA file to identify rear-end crashes. All rear-end crashes could then be included in the rear-end underride survey. A second possibility would be to drop sampling in TIFA and return the survey to a census file.

All three hypothetical changes to the TIFA protocol (1. cover all underrides in all crash configurations, not just where the truck was struck in the rear; 2. examine cases not sampled for the TIFA survey to identify rear-end crashes; 3. return TIFA to a census survey) would have funding implications. Returning TIFA to a census file would have many advantages beyond the underride question, but it would provide definitive coverage of rear-end crashes and underride. It also would be the most costly. Expanding underride coverage to all crash configurations also would be a significant expansion of the scope of the project. A limited increase in rear-end coverage to include the nonsampled truck crashes would be only a modest expansion, though potentially complicated to implement. In any case, the present effort is clearly useful, regardless of whether the scope is expanded.