

Single Vehicle Multiple Event Rollover Crashes: NASS and CIREN Analysis



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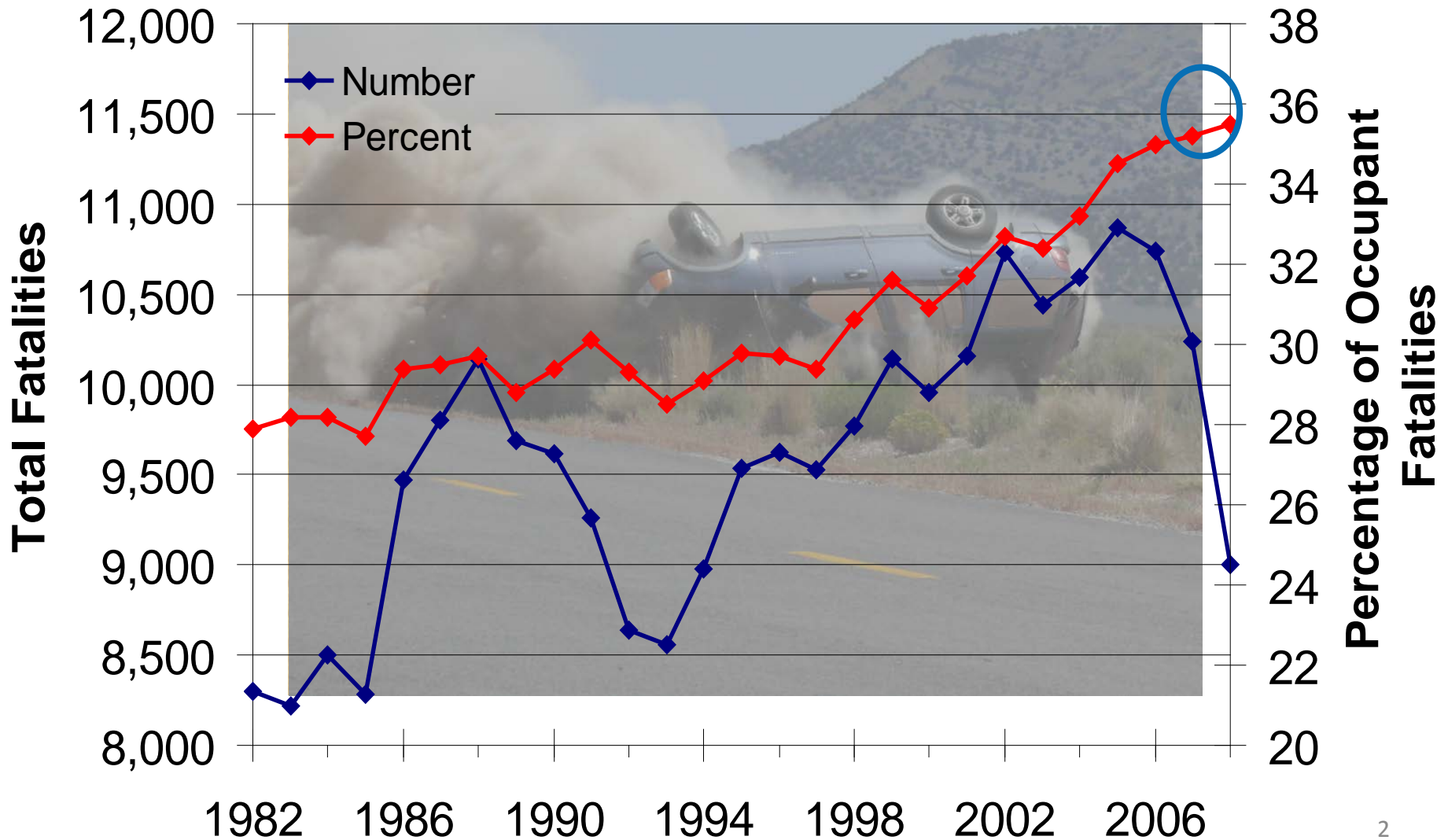
INOVA Fairfax Hospital

CIREN Center



Rollover fatality

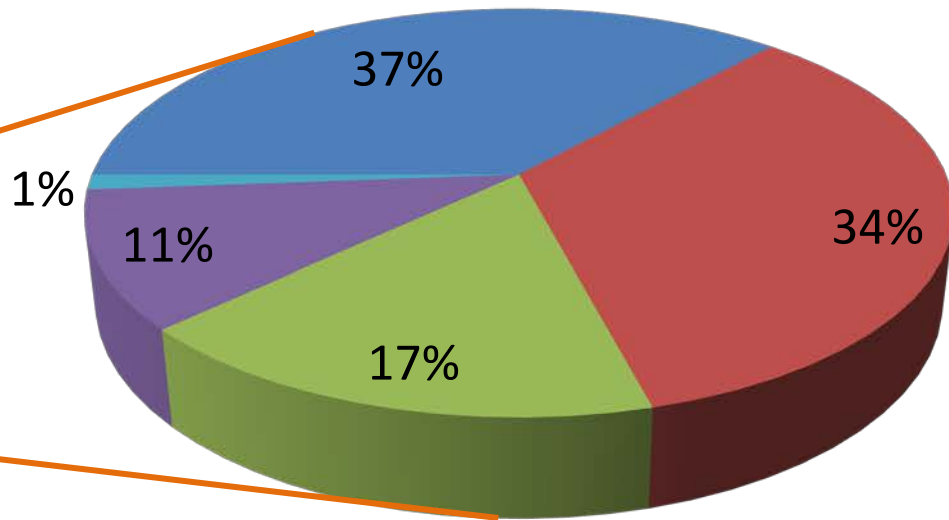
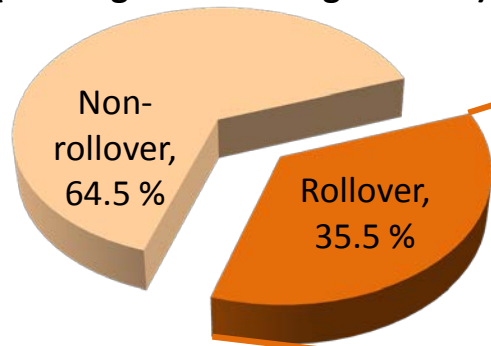
Source: NHTSA Traffic Safety Facts 2008



Fatal Rollover Crashes by 1st Event

Source: NHTSA Traffic Safety Facts 2008

Distribution of Fatal Occupants (Passenger cars and light trucks)

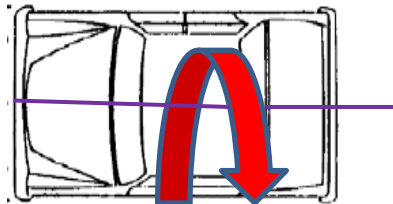


- Collision w/ MV (front, side, rear etc.)
- Collision w/ fixed obj. (pole, tree etc.)
- Collision w/ non-fixed (pedestrian, cyclist)
- Non-collision rollover
- Others

Rollover Statistics

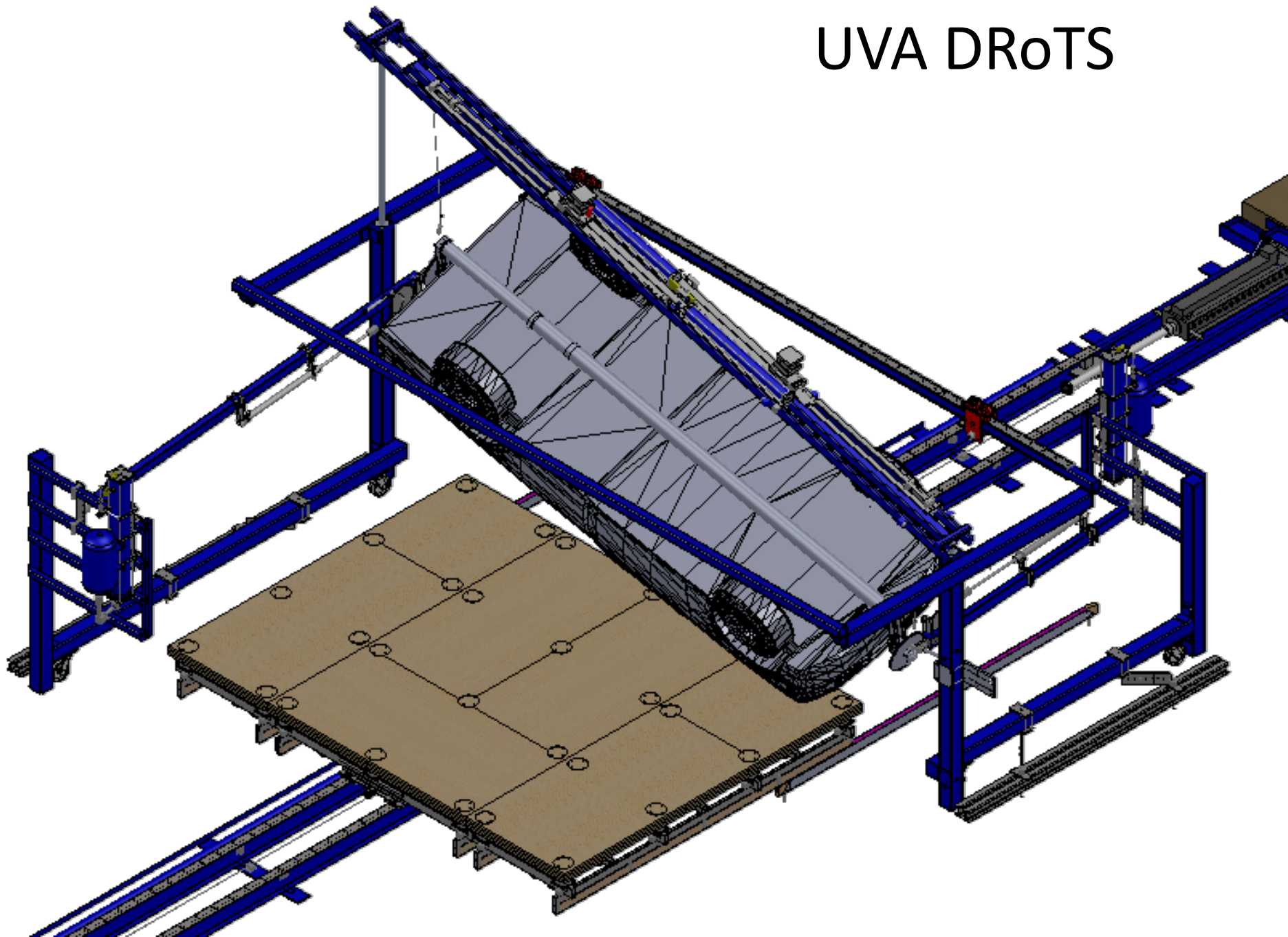
- **Fatality/injury statistics** for **planar crashes** normally **exclude rollover crashes** but **rollover fatality/injury statistics** include **planar events** except designated “pure” or Single Vehicle Single Event (SVSE) Rollovers
- Numerous experimental devices are available to study “pure” rollovers – single vehicle, single event (CRIS, 208 Dolly, JRS, DRoTS,..)

Non collision rollover
(single event)

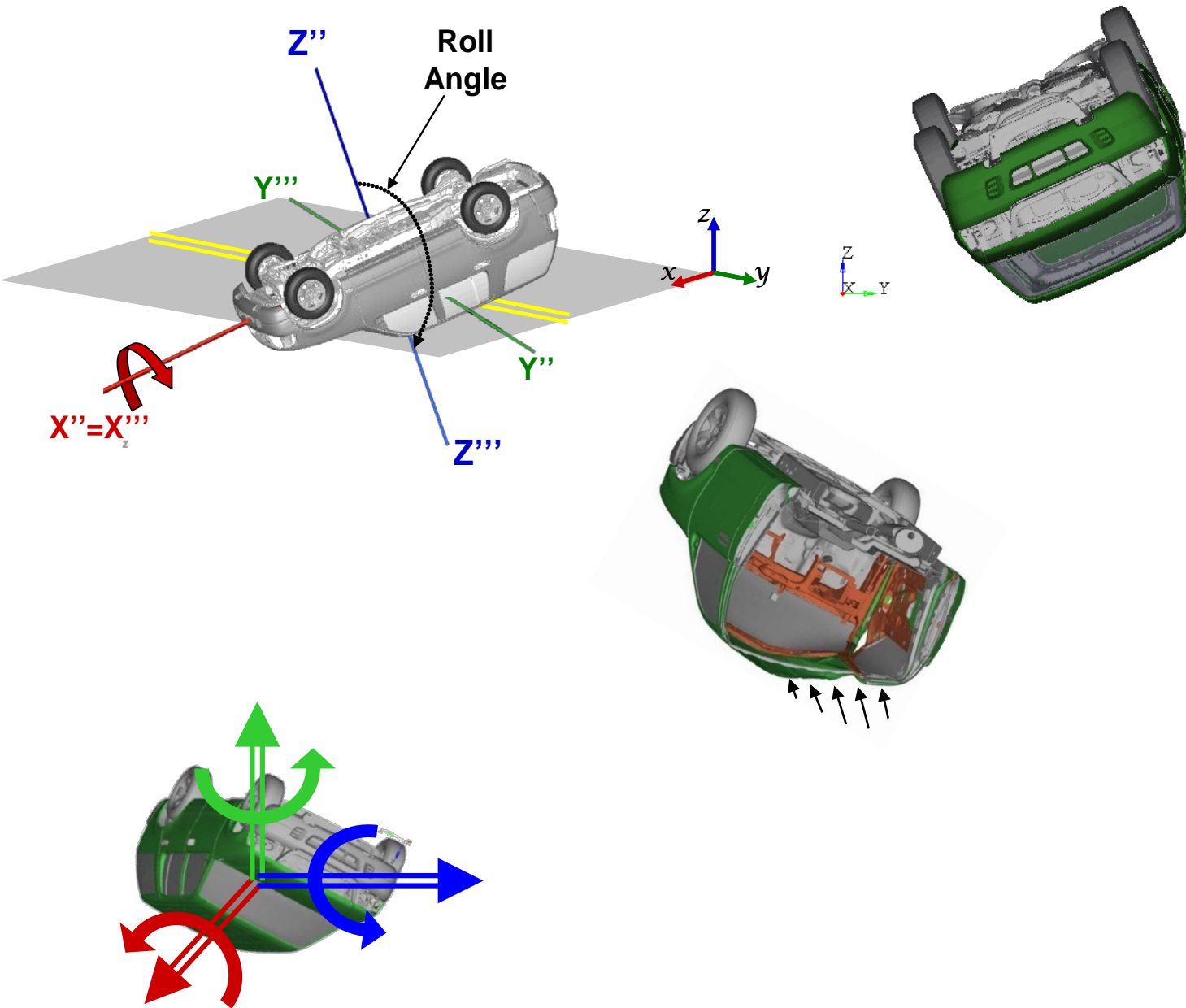


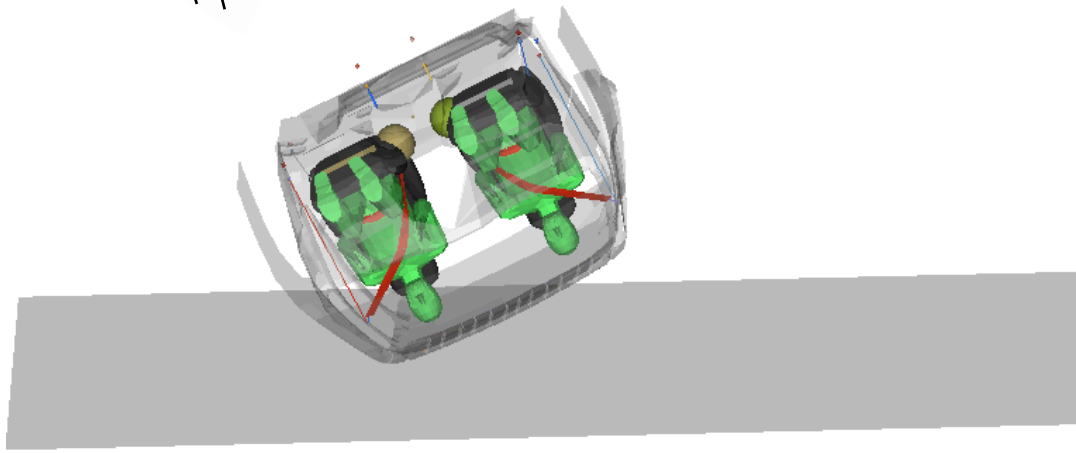
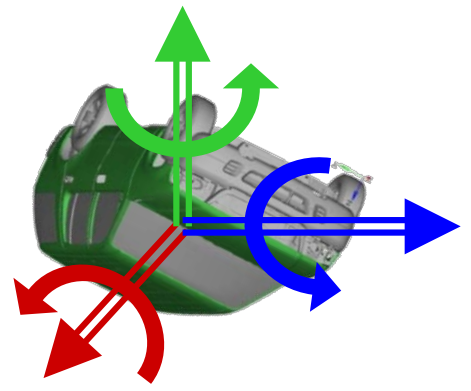
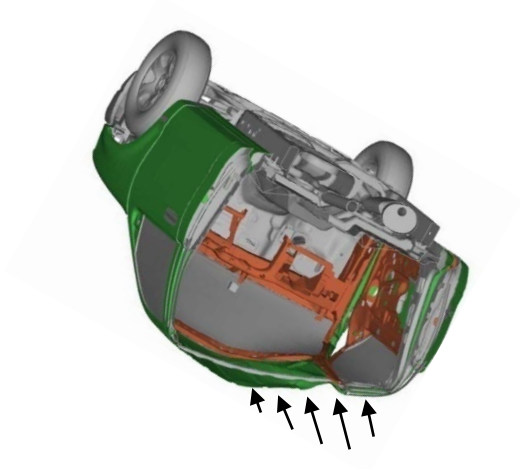
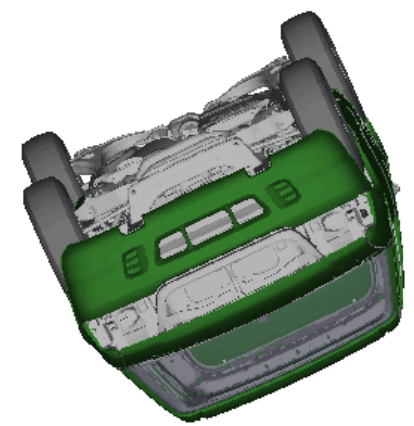
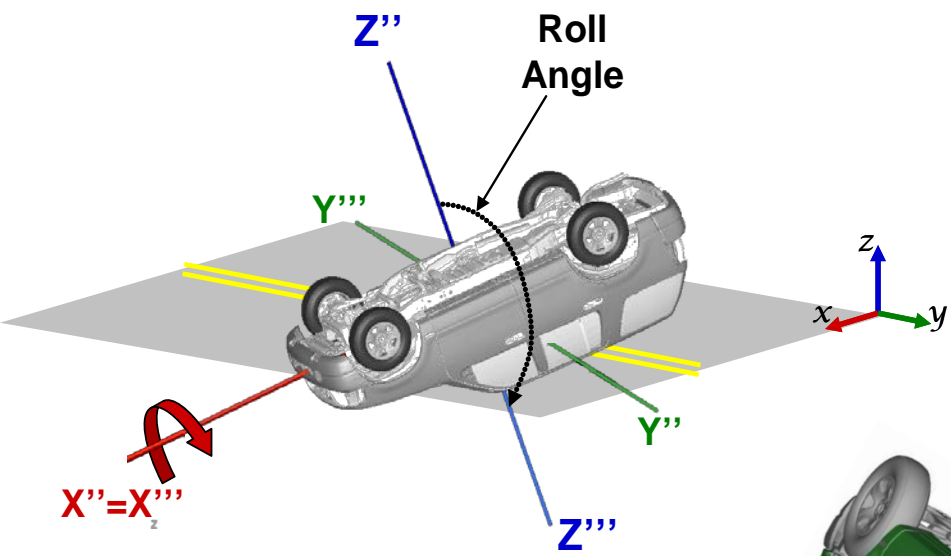


UVA DRoTS





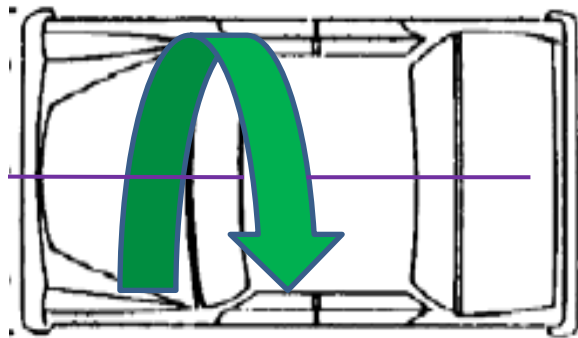




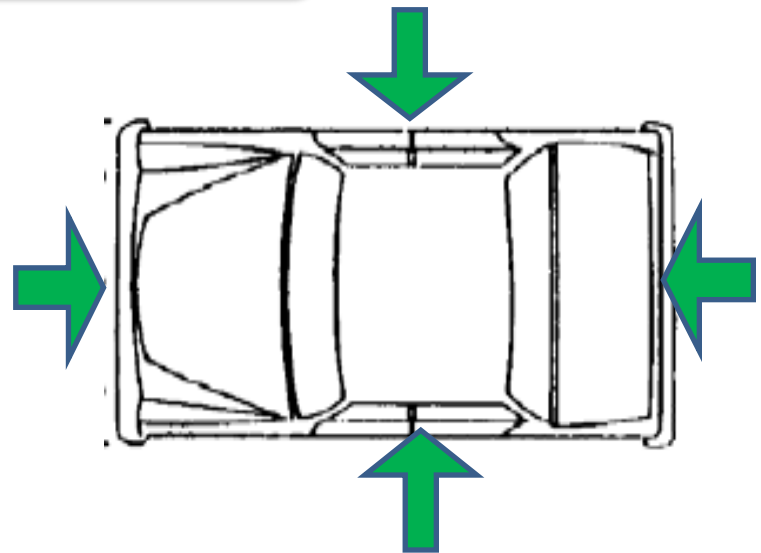


Besides a challenge, what are we missing by looking only at SVSE RO and not ME RO crashes ?

Rollover + planar event



+



Rollover Distributions (NASS CDS)

Selection criteria

Crash year 1998-2008

Only adult drivers (> 16 years)

1 ≤ quarter turns ≤ 16

Curb weight < 5,000 kg

N=12,155 (weighted 4.3 million)

4,328,547 rollover cases
~80,500 Fatalities

Single Vehicle:

82.0% of Cases
86.0% of Fatalities

Multiple Vehicle:

18.0% of Cases
14.0% of Fatalities

Focus of the current study

Single Event:

16.4% of Cases
12.4% of Fatalities

Multiple Event:

65.6% of Cases
73.6% of Fatalities

Multiple Event:

18.0% of Cases
14.0% of Fatalities

Pure Rollover (SVSE)

Multiple Event Rollover Crashes
(SVME, MVME)

Single vehicle rollover crashes

Single vehicle **single** Event:

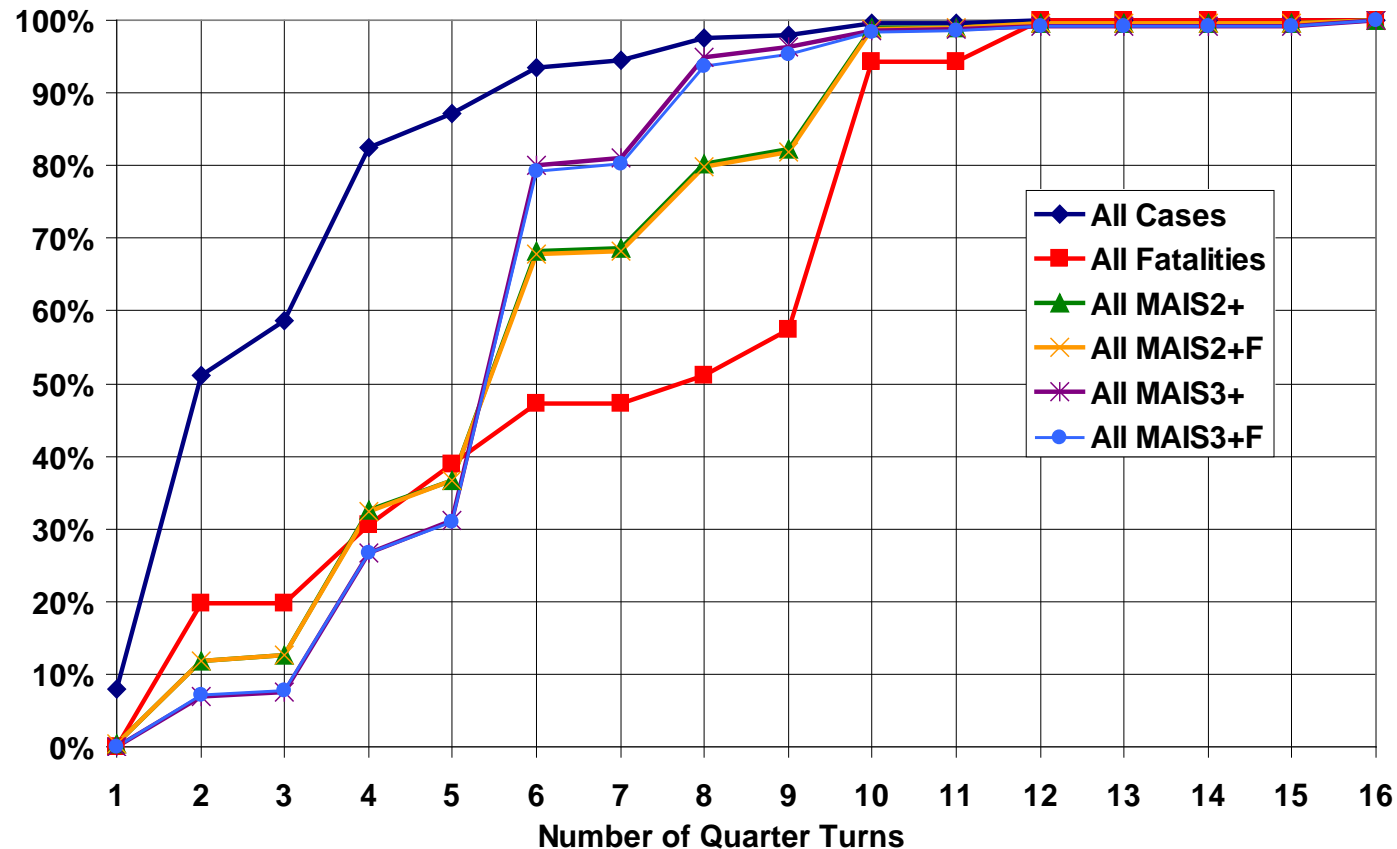
16.4% of Cases
12.4% of Fatalities

Single vehicle **multiple** Event:

65.6% of Cases
73.6% of Fatalities



Belted/non-ejected drivers



Single vehicle rollover crashes

Single vehicle **single** Event:

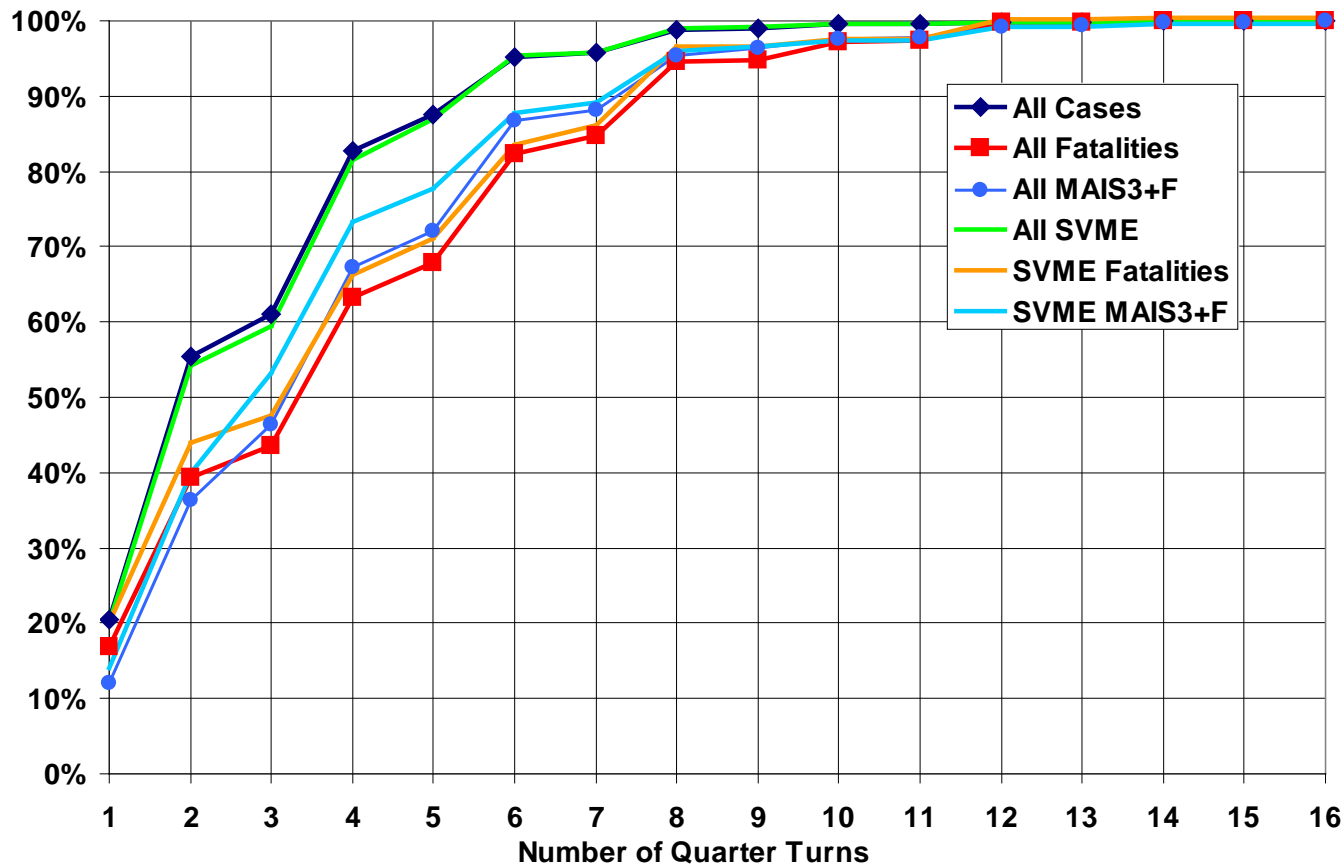
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Single vehicle **multiple** Event:

65.6% of Cases
73.6% of Fatalities



Belted/non-ejected drivers



Single vehicle rollover crashes

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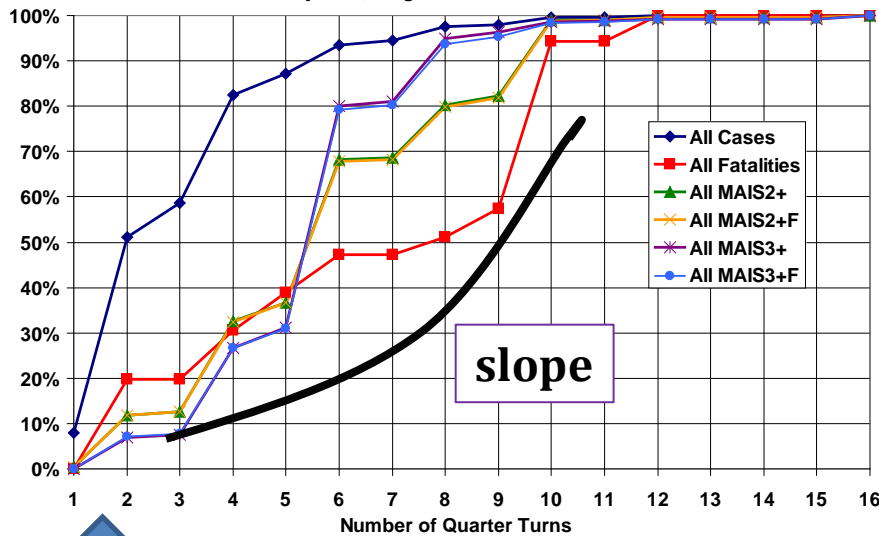
16.4% of Cases
12.4% of Fatalities

Single vehicle **multiple** Event:

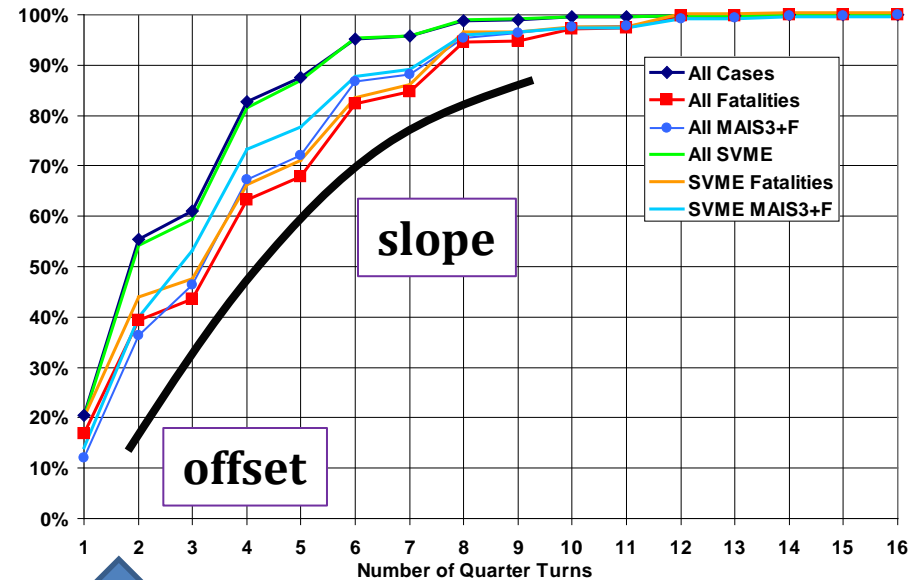
65.6% of Cases
73.6% of Fatalities



Belted/non-ejected drivers



1st quarter turn: NO fatality
1st roof impact: 20% of fatalities



1st quarter turn: 20% fatality
1st roof impact: 45% of fatalities

Previous Research

- **Digges and Eigen (2005, 2006, 2007) NASS Rollovers with damage from other crash events had majority of Harm for belted front-seat occupants and rollover crashes preceded by severe impacts** with fixed/non-fixed objects had **3X injury rate** compared to other RO
- **Ridella and Eigen (2008) CIREN descriptive injury analysis** for belted occupants in **SE** and **ME** ROcrashes
- **Ridella et al. (2010) NASS** injury frequency and distribution of front seat passengers in **SVSE** and **ME Rollovers**
- **Bose et al. (2011) Driver MAIS 3+ injuries more likely single body region in primary rollovers** compared to injuries sustained in rollovers with significant planar impacts

Project Objectives

- Given
 - **existing experimental and computational research** limited to **SVSE** (pure) rollover crashes, and
 - the high **importance** of **SVME** crashes in terms of **number of crashes, injuries, and fatalities**, and
 - recognizing that **crash analyses, testing techniques** and **countermeasure design** may need to consider **SVME**,

Project Objectives

1. **Identify and compare injury frequencies** in different modes of **rollover** and **non-rollover** crashes to examine injuries by event for SVME rollover crashes
2. Compare **injury patterns** (by body regions) in different modes of rollover and non-rollover crashes to see if they could be used as a **guide to distinguish injury attribution** (planar or rollover)
3. Determine the **distribution and type** of **planar impact** and the **sequence of events** associated with rollover crashes
4. Examine **relationship** between **rank 1 event** (vehicle damage) and **rank 1 injury**

Selection criteria (NASS-CDS)	
Crash year 1998-2008	Curb weight < 5,000 kg
Only adult drivers (> 16 years)	N= 59,215 (weighted 31.5million)
Belt restrained + non-ejected	Excludes end-over-end RO

All frequencies are reported in weighted numbers

Rollover ($1 \leq$ quarter turns ≤ 16)

2.44m (7.7% of all crashes)

Non-Rollover (quarter turns = 0)

28.9m (91.7% of all crashes)

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 28.9m (91.7% of all crashes)

Primary rollover
 1.42m (58% of all RO)

Object contacted
 (most severe event)
 =overturn

RO with Sig. Planar impacts
 (objected contacted during severe event)

Roll & Front
 13% of all RO

Roll & Left
 6% of all RO

Roll & Right
 9% of all RO

Roll & Top
 2% of all RO)

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Primary rollover Object contacted (most severe event) =overturn
1.42m (58% of all RO)

RO with Sig. Planar impacts (objected contacted during severe event)

Non-Rollovers Planar impacts

Roll & Front
13% of all RO

Roll & Left
6% of all RO

Frontal
47% of all

Rear
7.3% of all

Roll & Right
9% of all RO

Roll & Top
2% of all RO

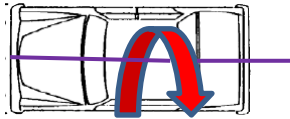
Side (near)
5.9% of all

Side (far)
10.2% of all

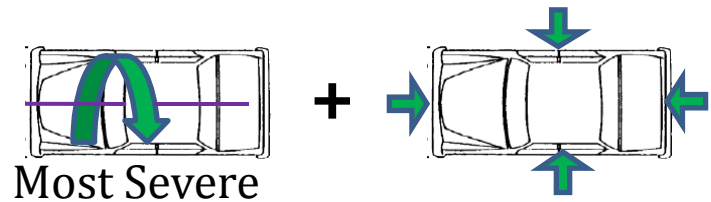
Undercarriage
<1% of all

Body-region Distribution (AIS 3+)

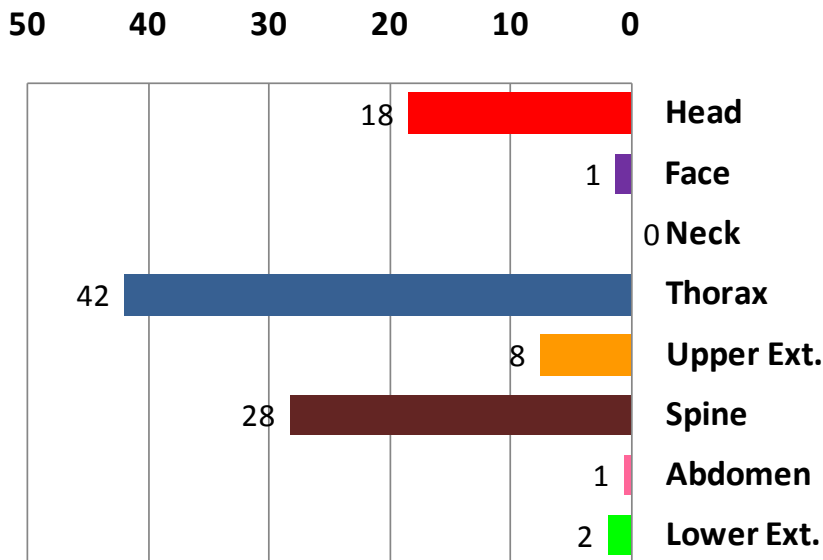
Pure Rollovers
(SVSE)



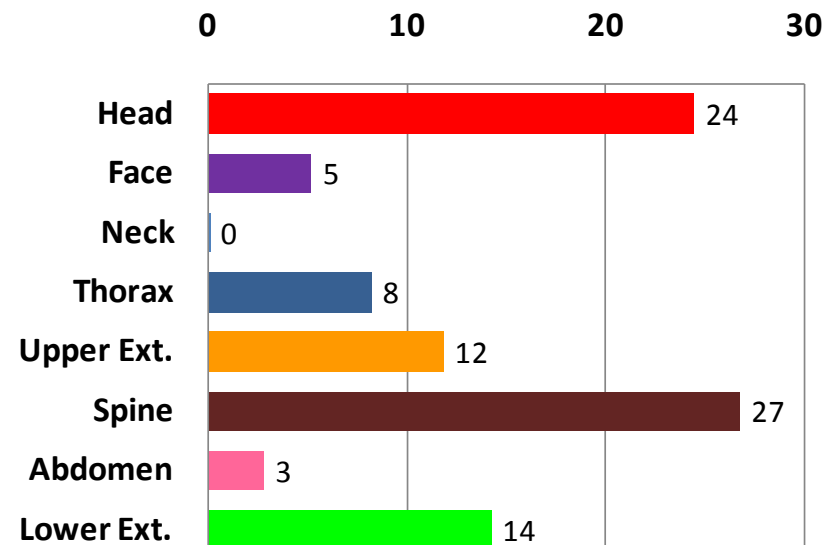
Primary Rollovers
(Object in most severe event=overturn)



Percentage of all AIS 3+ injuries (%)



Percentage of all AIS 3+ injuries (%)



Top 10 AIS injury codes (AIS 3+)

Pure Rollovers (SVSE)

AIS	Injury	Injury freq. %
3	Subarachnoid Hemorrhage	6
3	Unilateral lung contusion	6
4	Bilateral lung contusion	5
3	C-spine facet fx.	8
3	C-spine pedicle fx.	4
3	Open/displaced radius fx.	3
4	Small subdural hematoma	3
3	2-3 rib fx. with hemo/pneumothorax	**
3	C-spine lamina fx.	4
3	Open/displaced ulna fx.	4

Cumulative freq. 70%

Primary Rollovers (Object in most severe event=overturn)

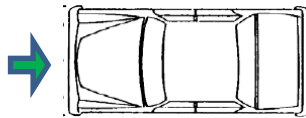
AIS	Injury	Injury freq. %
3	Subarachnoid Hemorrhage	11
3	Unilateral lung contusion	7
3	C-spine facet fx.	5
4	Bilateral lung contusion	3
3	Open/displaced radius fx.	7
3	C-spine lamina fx.	3
3	Open/displaced ulna fx.	5
3	C-spine pedicle fx.	3
3	Closed humerus fx.	2
4	Small subdural hematoma	2

Cumulative freq. 48%

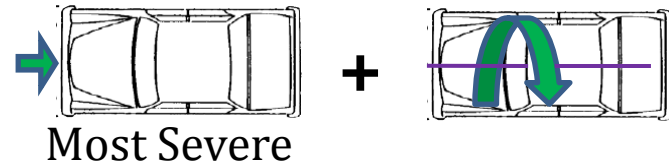
** low number of raw cases

Body-region Distribution (AIS 3+)

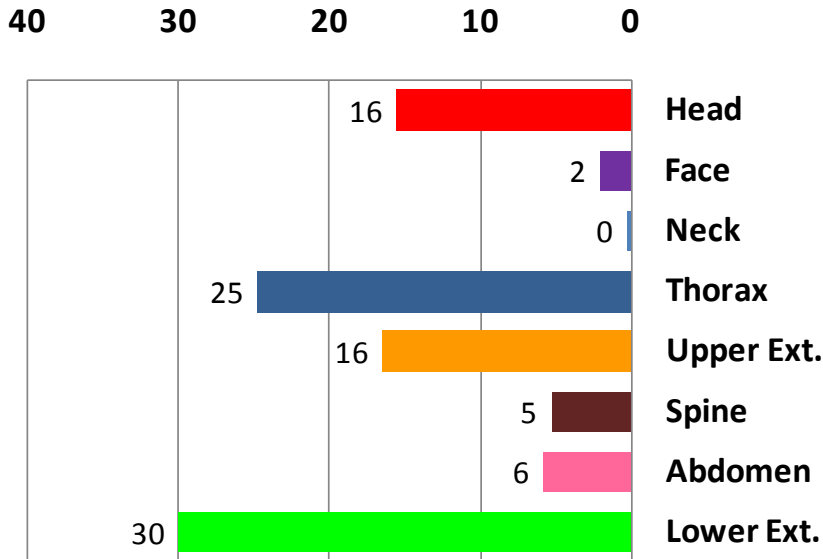
Frontal (no rollover)
(by rank 1 general area of damage)



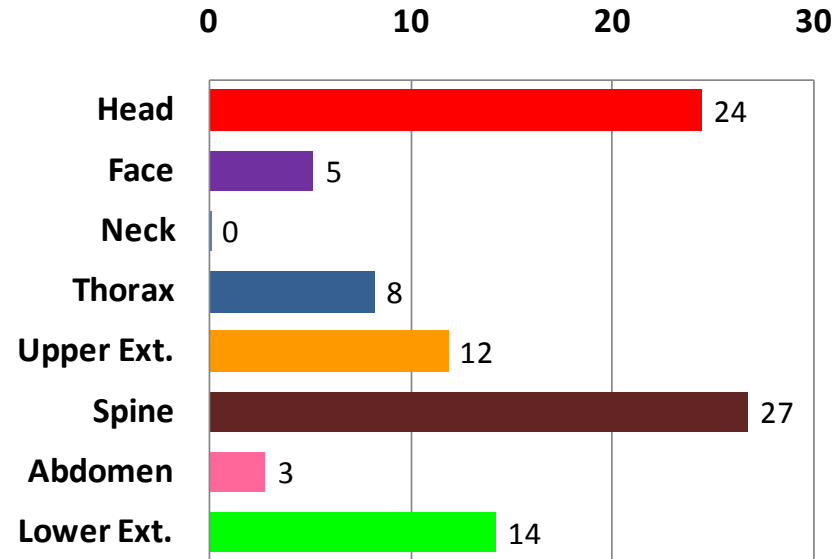
Rollover with Sig. Frontal
(by object contacted and general area of damage)



Percentage of all AIS 3+ injuries (%)



Percentage of all AIS 3+ injuries (%)



Top 10 AIS injury codes (AIS 3+)

Frontal (no rollover)
(by rank 1 general area of damage)

Rollover with Sig. Frontal
(by object contacted and general area of damage)

AIS	Injury	Injury freq. %
3	Femur shaft fx.	8
3	Open/displaced radius fx.	8
3	Open/displaced ulna fx.	5
3	Tibia shaft fx.(Open/displaced)	5
3	Subarachnoid Hemorrhage	2
3	Unilateral lung contusion	5
3	Pelvis fx. (open/displaced)	3
4	Bilateral lung contusion	2
3	Tibia condyle fx. (open/displaced)	4
3	Thoracic cavity injury with hemo/pneumothorax	5

Cumulative freq. 47%

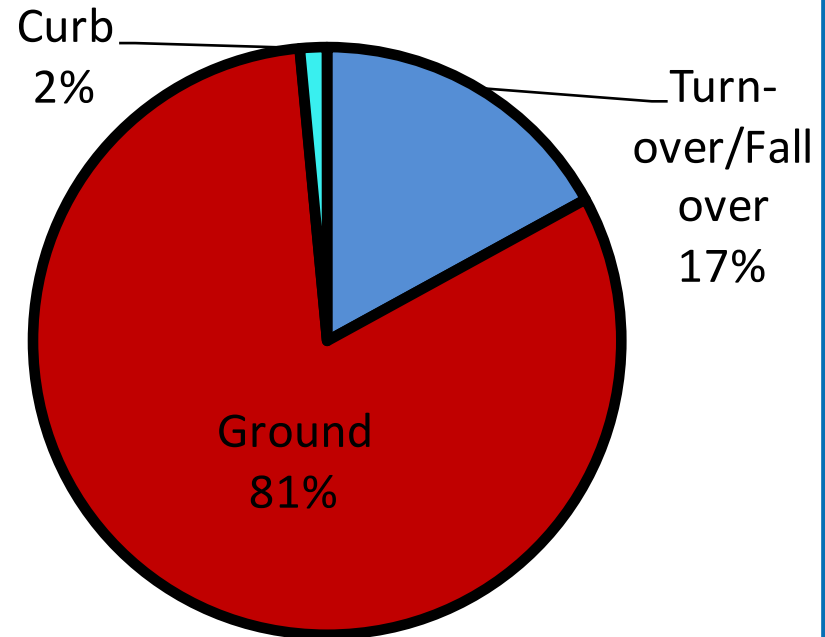
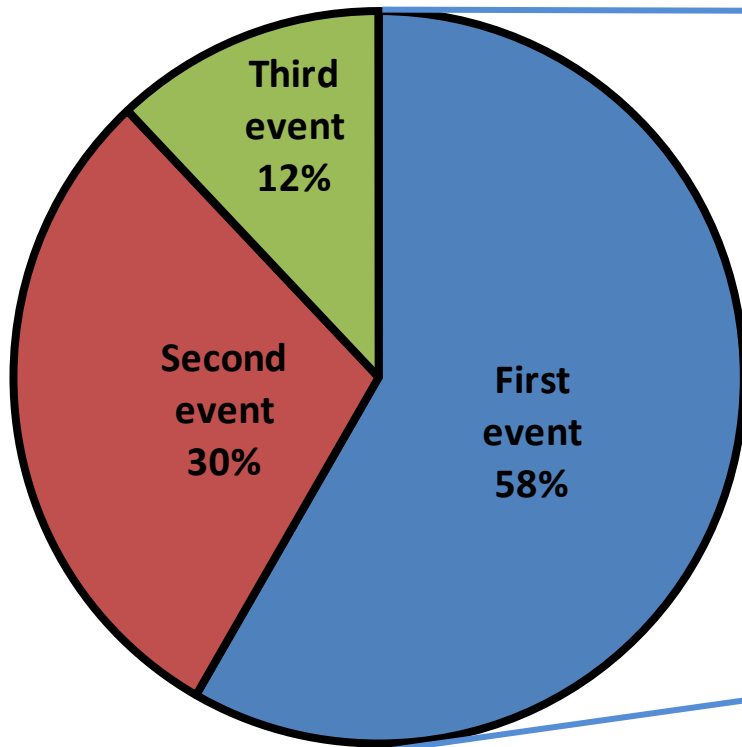
AIS	Injury	Injury freq. %
3	Subarachnoid Hemorrhage	4
3	C-spine facet fx.	15
3	Femur shaft fx.	1
3	Orbit fx. (open/displaced)	5
3	Unilateral lung contusion	3
3	Closed humerous fx.	4
3	Open/displaced radius fx.	4
3	Basilar fx. without CSF leak	6
3	Tibia shaft fx.(Open/displaced)	10
3	Open/displaced ulna fx.	2

Cumulative freq. 54%

Sequence of events in rollover crashes

Rollover is the **most severe** event (non-collision over turn)

Rollover initiation object

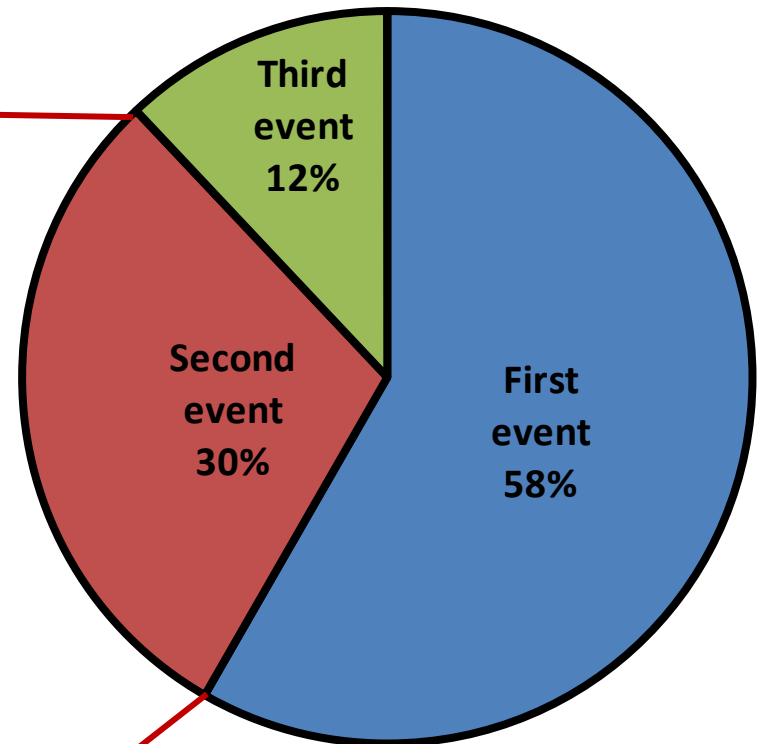
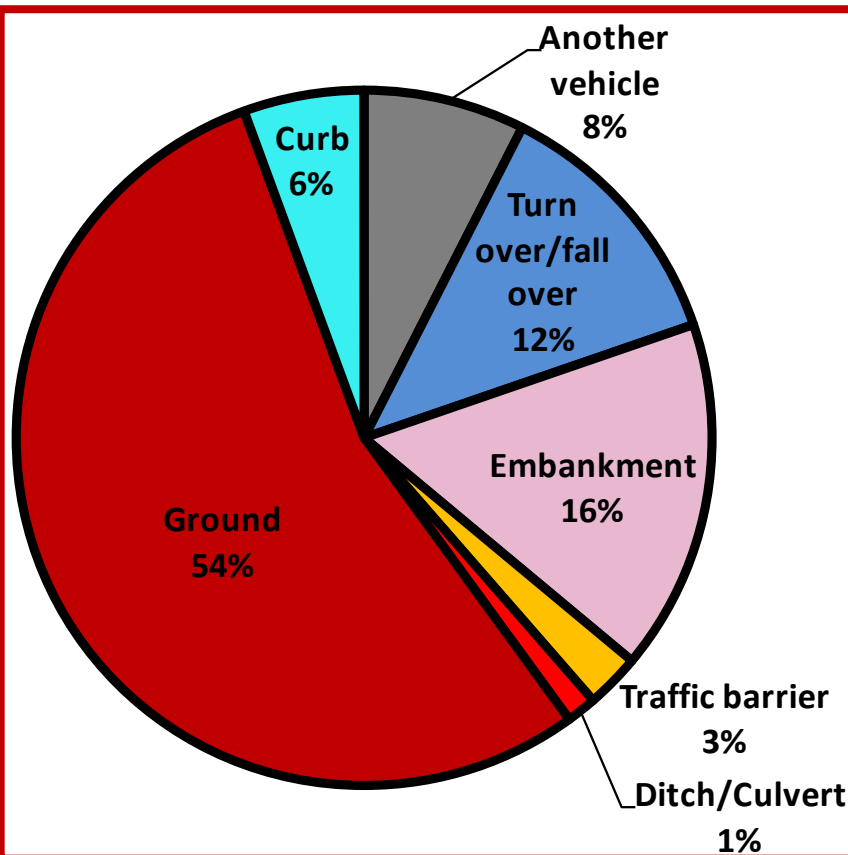


Sequence of the “rollover event” in the crash

Sequence of events in rollover crashes

Rollover is the most severe event (non-collision over turn)

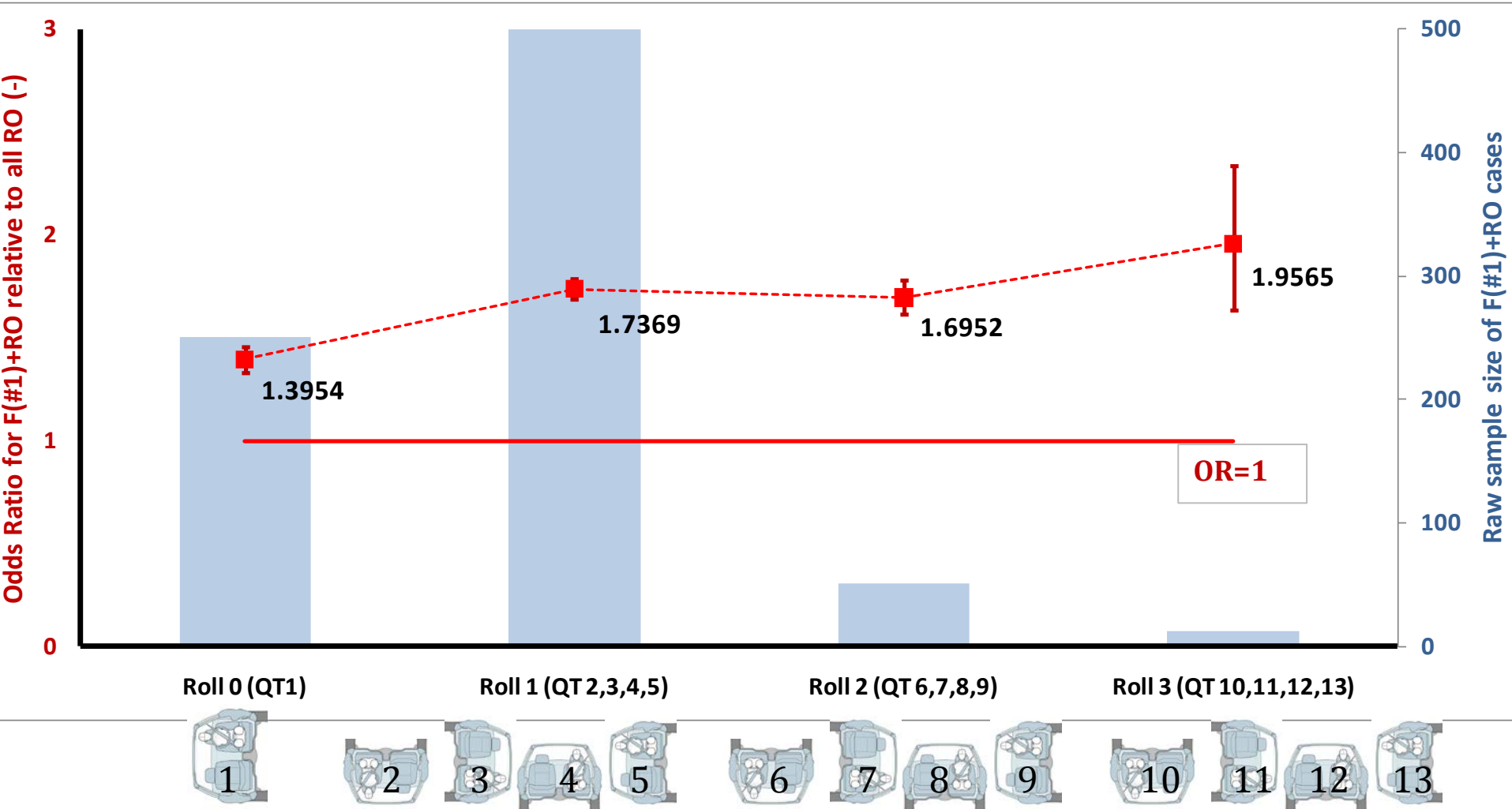
Rollover initiation object



Sequence of the "rollover event" in the crash

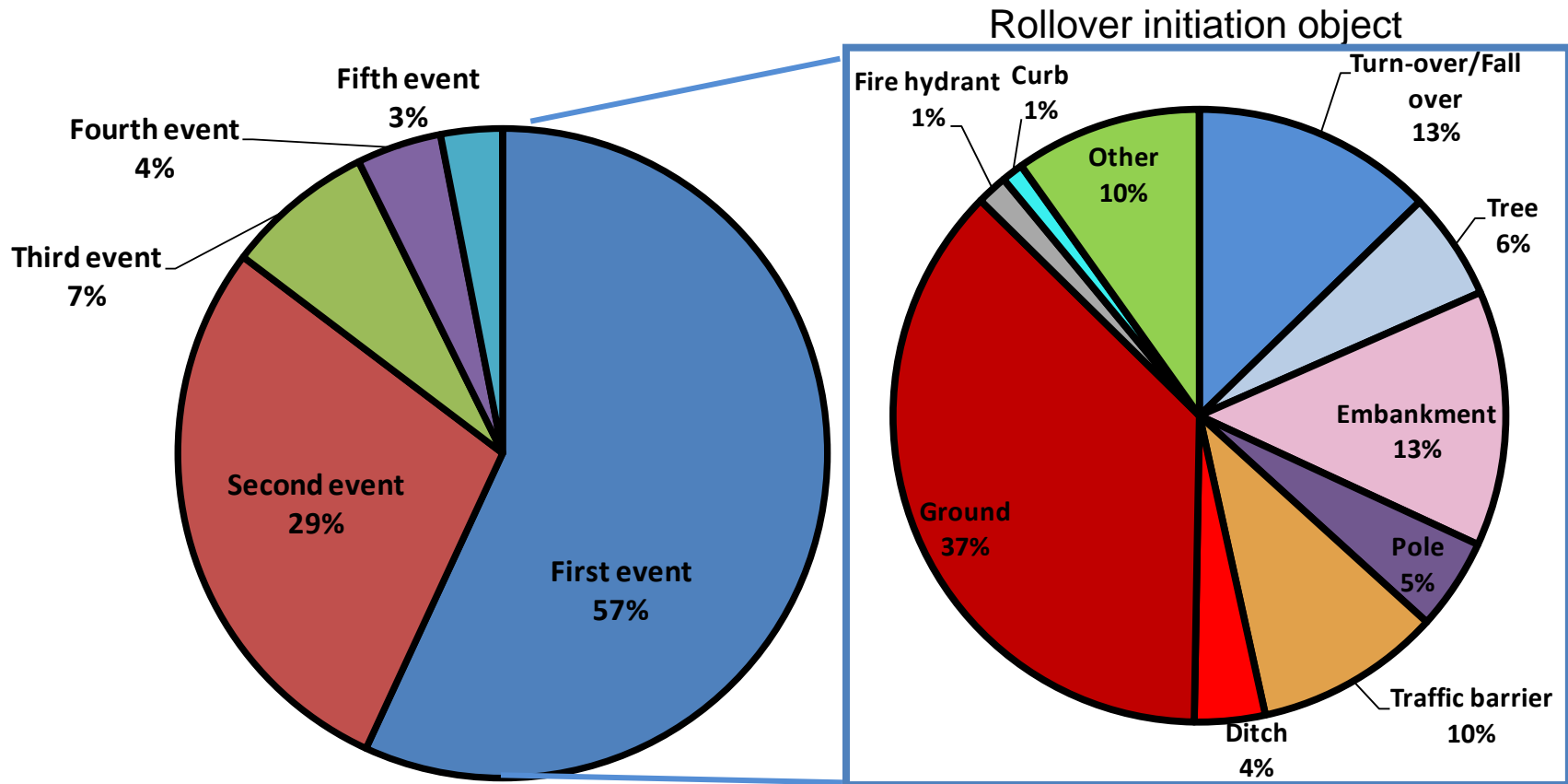
Increased odds of sustaining a MAIS 3+ injury when a Frontal(rank=1) precedes a Rollover (Baseline: all RO, Exposure: F(#1), Outcome: MAIS3+)

(Equivalent QT Distributions)



Sequence of events in rollover crashes

Collision with fixed object is the **most severe** event in the rollover

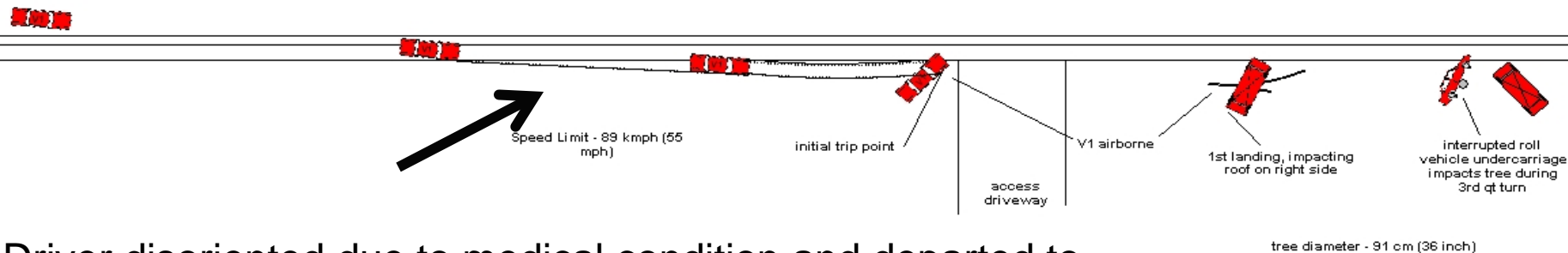


Sequence of the "sig. planar event" in the crash

Counter SVM E Example: 1st Event Minor

V1 - 2007 Ford Focus, 4-door sedan

Z →



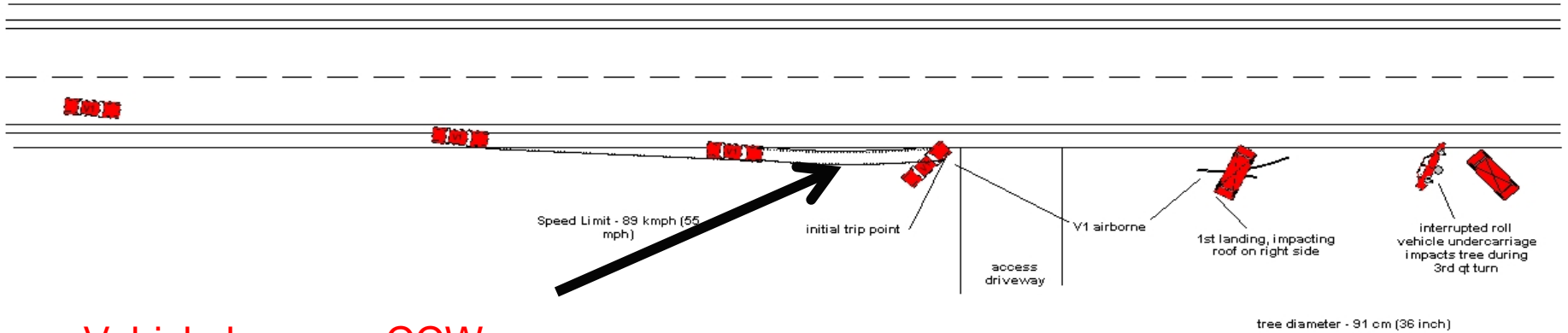
Driver disoriented due to medical condition and departed to the right side of the road.



Crash Summary

V1 - 2007 Ford Focus, 4-door sedan

Z →



Vehicle began a CCW yaw as he attempted to return to the road.



Crash Summary

V1 - 2007 Ford Focus, 4-door sedan

Z →

roadway

roadway

roadway

roadway

1st landing, impacting roof on right side

interrupted roll vehicle undercarriage impacts tree during 3rd qt turn

Speed Limit - 89 kmph (55 mph)

initial trip point

V1 airborne

access driveway

tree diameter - 91 cm (36 inch)

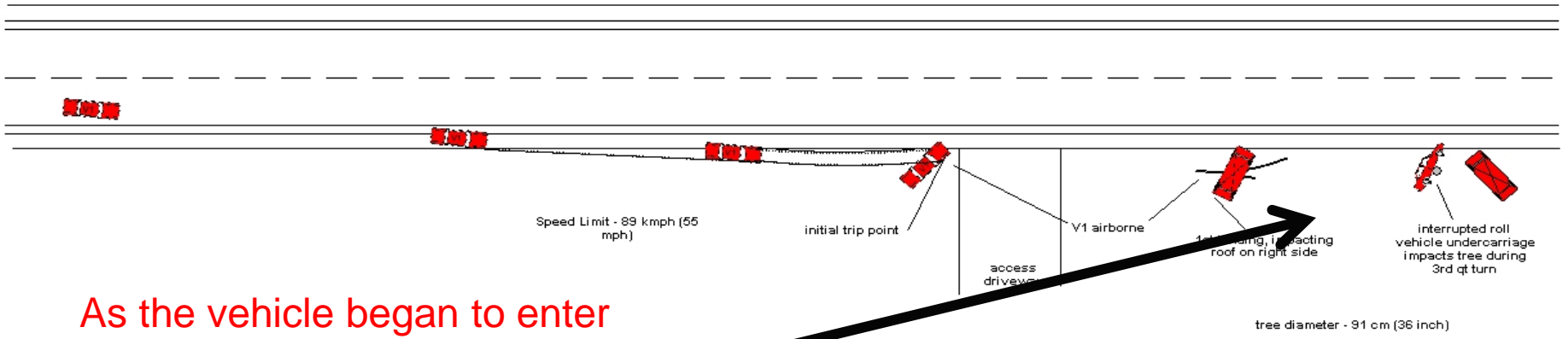
He struck a low driveway berm with his right front wheel. This induced a right side leading rollover.



Crash Summary

V1 - 2007 Ford Focus, 4-door sedan

Z →



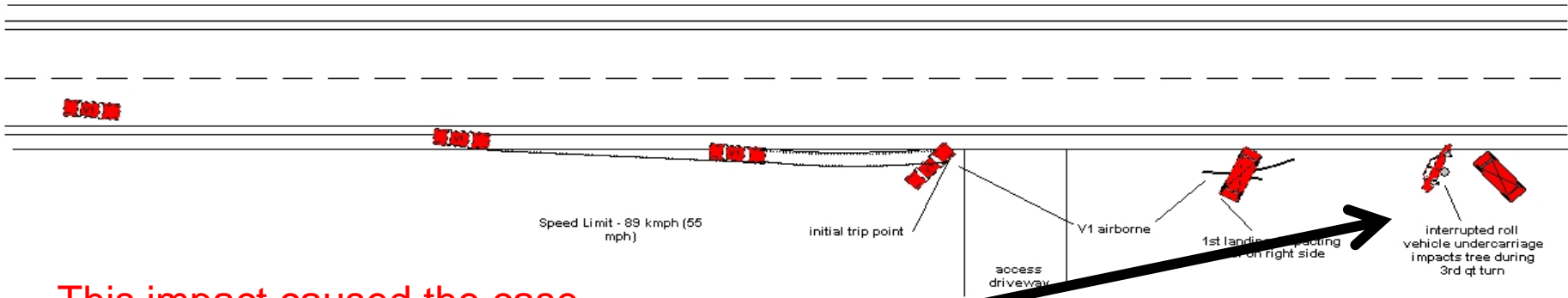
As the vehicle began to enter into the third quarter turn, the undercarriage struck a tree.



Crash Summary

V1 - 2007 Ford Focus, 4-door sedan

Z→



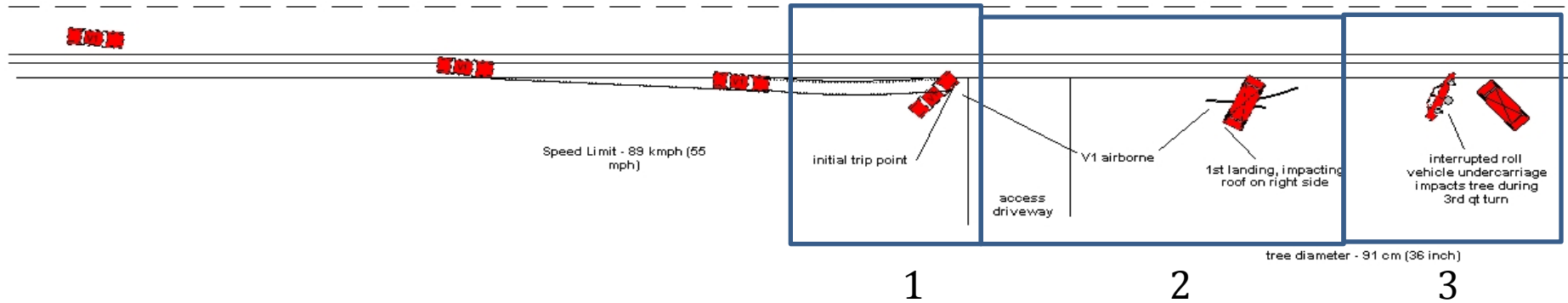
This impact caused the case vehicle to rotate 180 degrees around the tree where it separated from the tree, completed its rollover sequence and came to rest on its roof facing east.



Crash Summary

V1 - 2007 Ford Focus, 4-door sedan

Z →



Event	Object Contacted	Force Dir	Location	Total	Long	Lateral	Energy	Impact	Barrier	Est	Rank
1	Ditch or culvert	30	01RFwN02	999	999	999	-9999	999	999	7	3
2	Overturn->rollover(exclude	Non-Horizontal	00TYD003	999	999	999	-9999	999	999	8	2
3	Tree(> 10 cm in diameter)	Non-Horizontal	00UPDw03	999	999	999	-9999	999	999	8	1

Vehicle Photographs



Vehicle Photographs



Vehicle Photographs





Left front



left rear



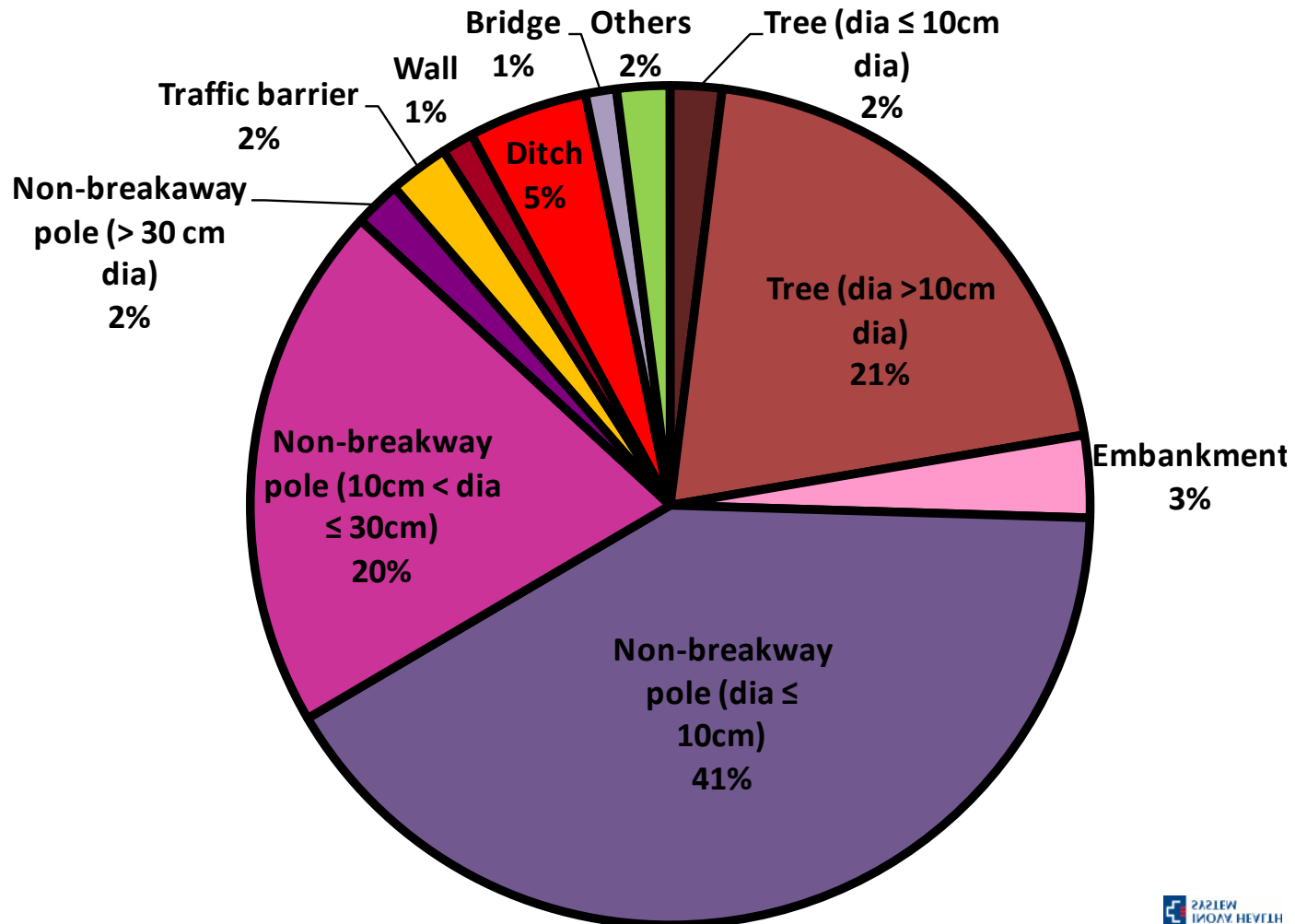
Right front



right rear

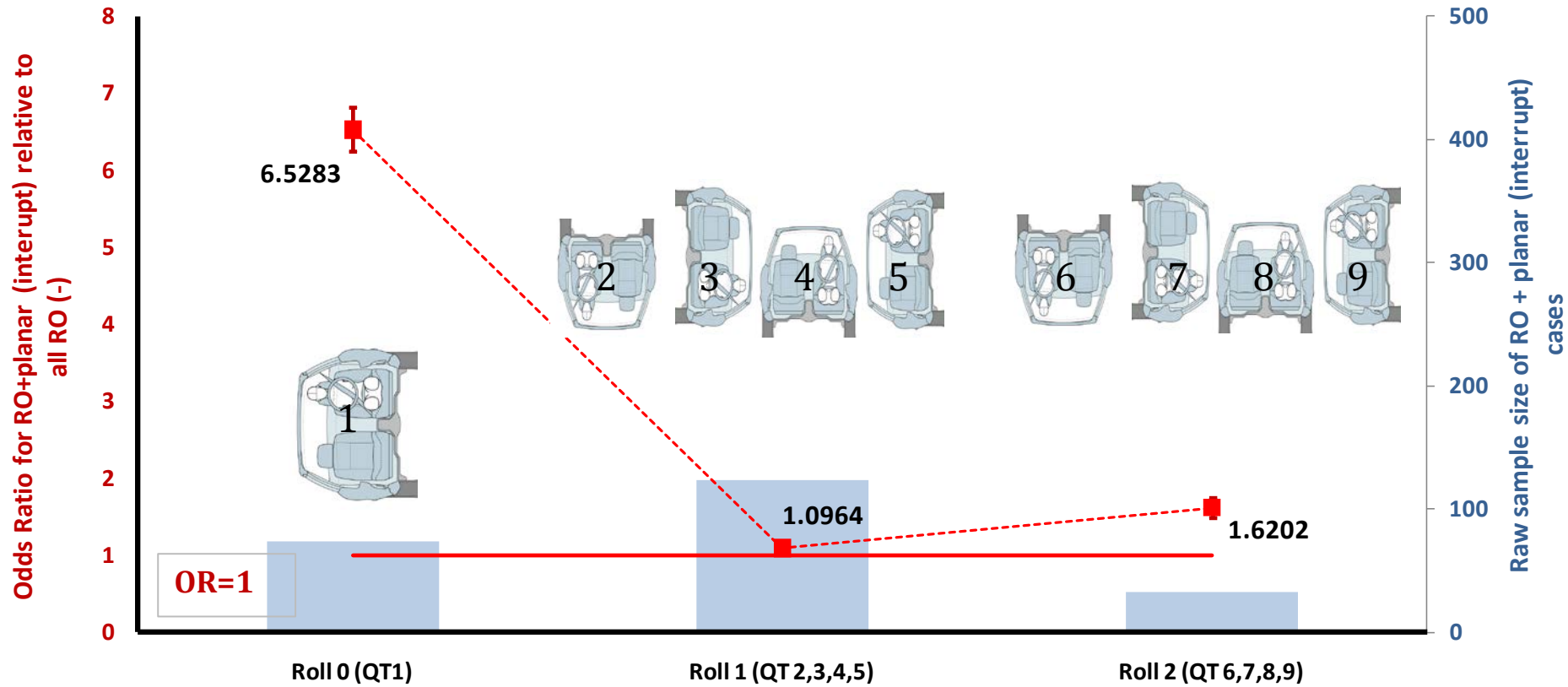
Distribution Object Contacted in Interrupted RO

Collision with fixed object is the **most severe** and **last** event in the rollover crash



Risk of Injury when a Planar Impact Ends the RO

Increased odds of sustaining a MAIS 3+ injury when a planar impact (rank 1) interrupts a rollover
(Baseline: all RO, Exposure: Planar(interrupt), Outcome: MAIS3+)



Roll number = roof inversions
(equivalent RO QT distributions)

Scene/Occupant

- Case vehicle
 - 2003 GMC Envoy
- General crash type
 - Non-horizontal rollover collision (Interrupted Rollover)
- Gender
 - Male
- Age
 - 35
- Seat position
 - Front left (driver)
- HT/WT
 - 175 cm, 83 kg



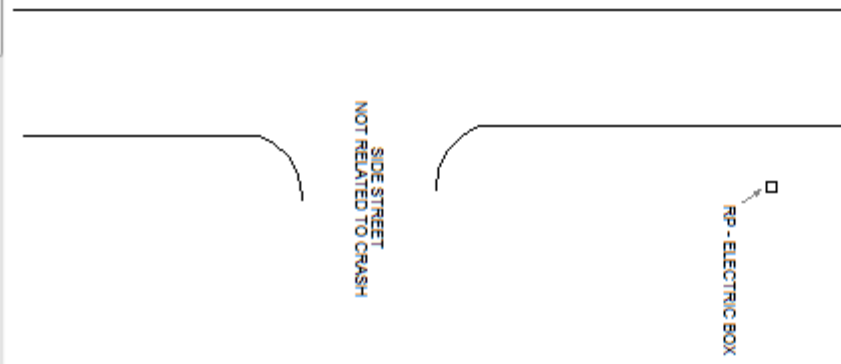
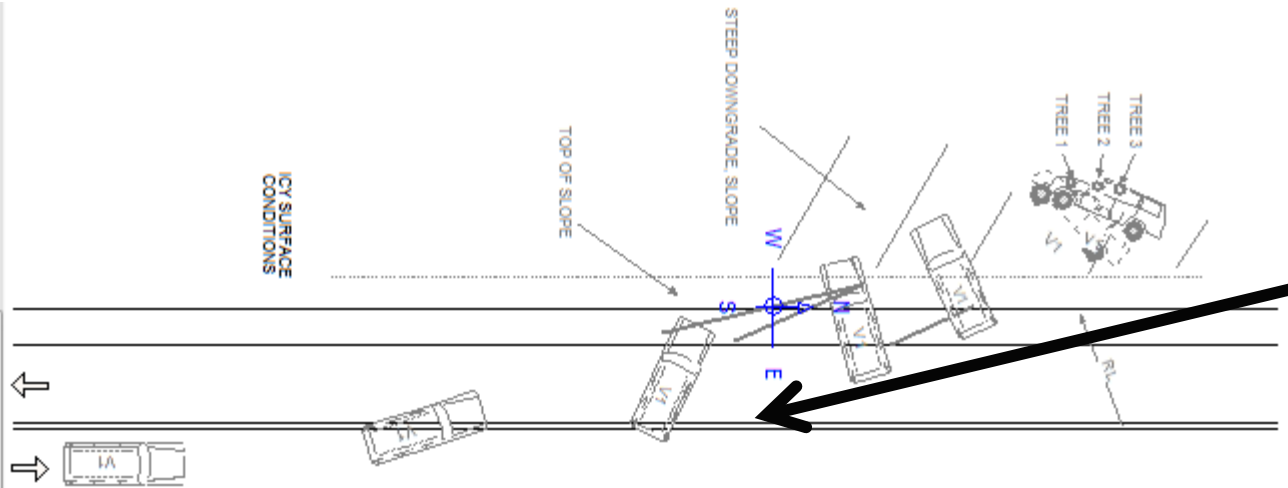
Impact

- CDC
 - 00TPDW5
- Restraint status
 - Manual
Lap/Shoulder
- Airbag status
 - Frontal (no deploy)
 - No side airbag



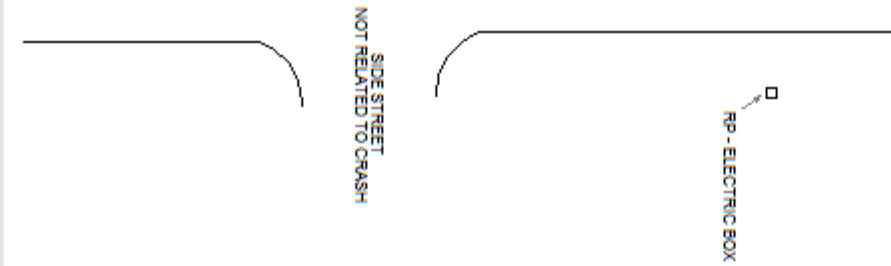
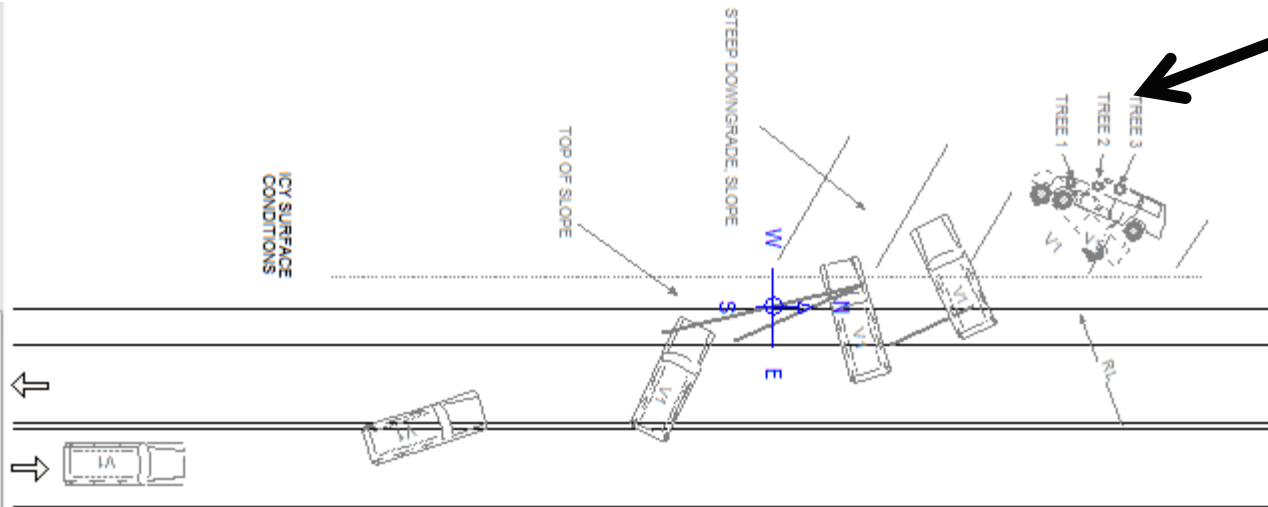
Crash Outline

The vehicle lost control due to icy condition, went into southbound lane rotating CCW and departed roadway to the left, down an embankment.



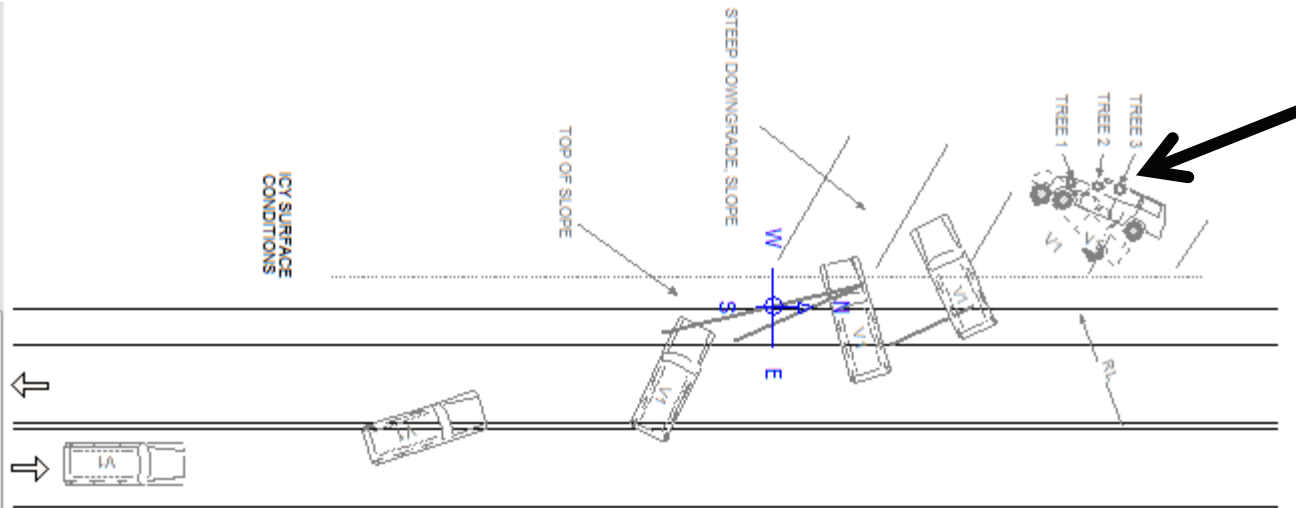
Crash Outline

After departing off the paved shoulder. Vehicle tilted to the right, and the top hood and windshield impacted a small tree, resulting in minor damage



Crash Outline

The roof top impacted a second and third tree, resulting in significant passenger roof intrusion.

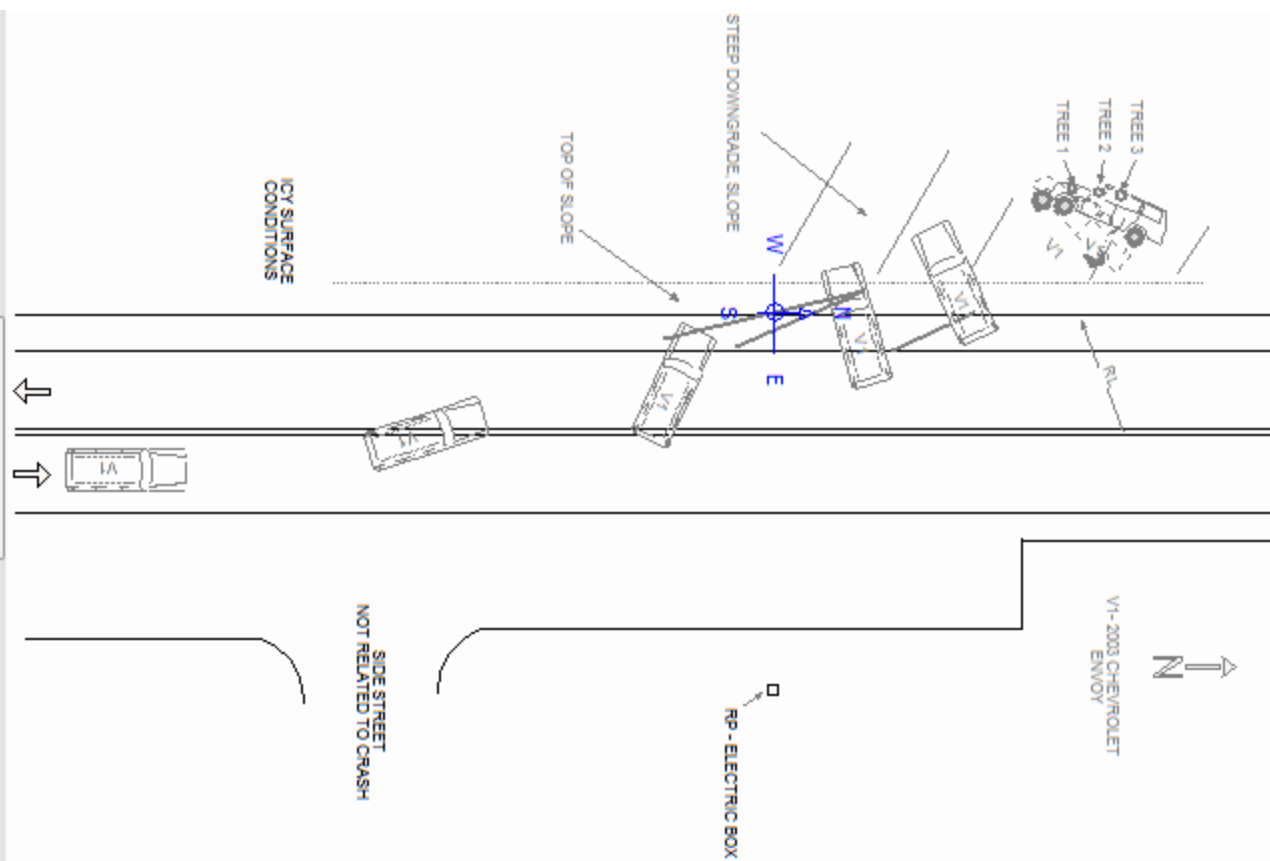


SIDE STREET
NOT RELATED TO CRASH

RP - ELECTRIC BOX



Crash Outline



Lower right side contacted the ground, completing the one quarter turn rollover event, and resulting in minor right side damage. V1 came to final rest angled on the embankment with its lower right side against the ground and its top leaning on the struck trees.

Event	Veh #	Area of Damage	Contacted	Class	Area of Damage
1	1	Top	Tree(<= 10 cm in diameter)	Not a motor vehicle	Not a motor vehicle
2	1	Top	Tree(> 10 cm in diameter)	Not a motor vehicle	Not a motor vehicle
3	1	Top	Tree(> 10 cm in diameter)	Not a motor vehicle	Not a motor vehicle
4	1	Right Side	Overturn->rollover(excludes end-over-end)	Not a motor vehicle	Noncollision

Vehicle Photographs









left front



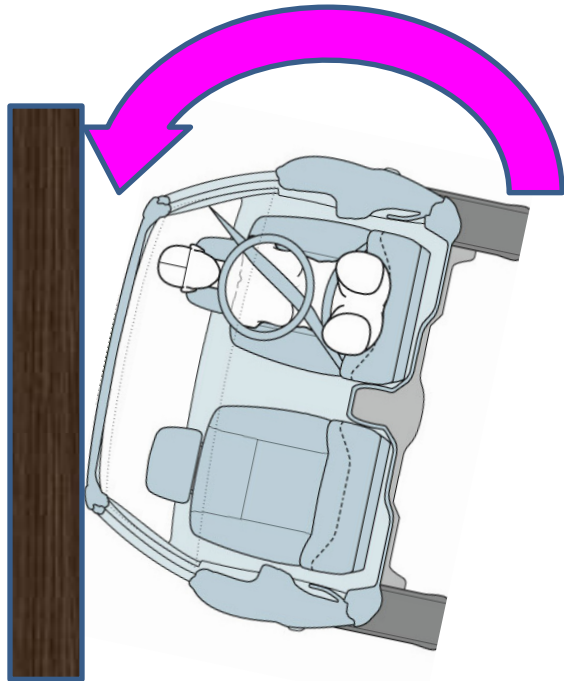
left rear



right front



right rear



Select Intrusions (from > 30)

Row	Position	Area	Intruded Component	Comparison	Intruded	Intrusion	Magnitude	Crush Direction
Front Seat	Right	Interior	B-pillar	110	73	37	≥ 30 to < 46 cms	Vertical
Second Seat	Right	Interior	Roof (or convertible top)	75	38	37	≥ 30 to < 46 cms	Vertical
Front Seat	Right	Interior	Roof (or convertible top)	108	73	35	≥ 30 to < 46 cms	Vertical
Second Seat	Middle	Interior	Roof (or convertible top)	75	45	30	≥ 30 to < 46 cms	Vertical
Second Seat	Right	Interior	C-pillar	84	66	18	≥ 15 to < 30 cms	Vertical
Second Seat	Left	Interior	Roof (or convertible top)	75	50	25	≥ 15 to < 30 cms	Vertical
Front Seat	Left	Interior	Roof (or convertible top)	108	82	26	≥ 15 to < 30 cms	Vertical
Front Seat	Middle	Interior	Roof (or convertible top)	108	79	29	≥ 15 to < 30 cms	Vertical

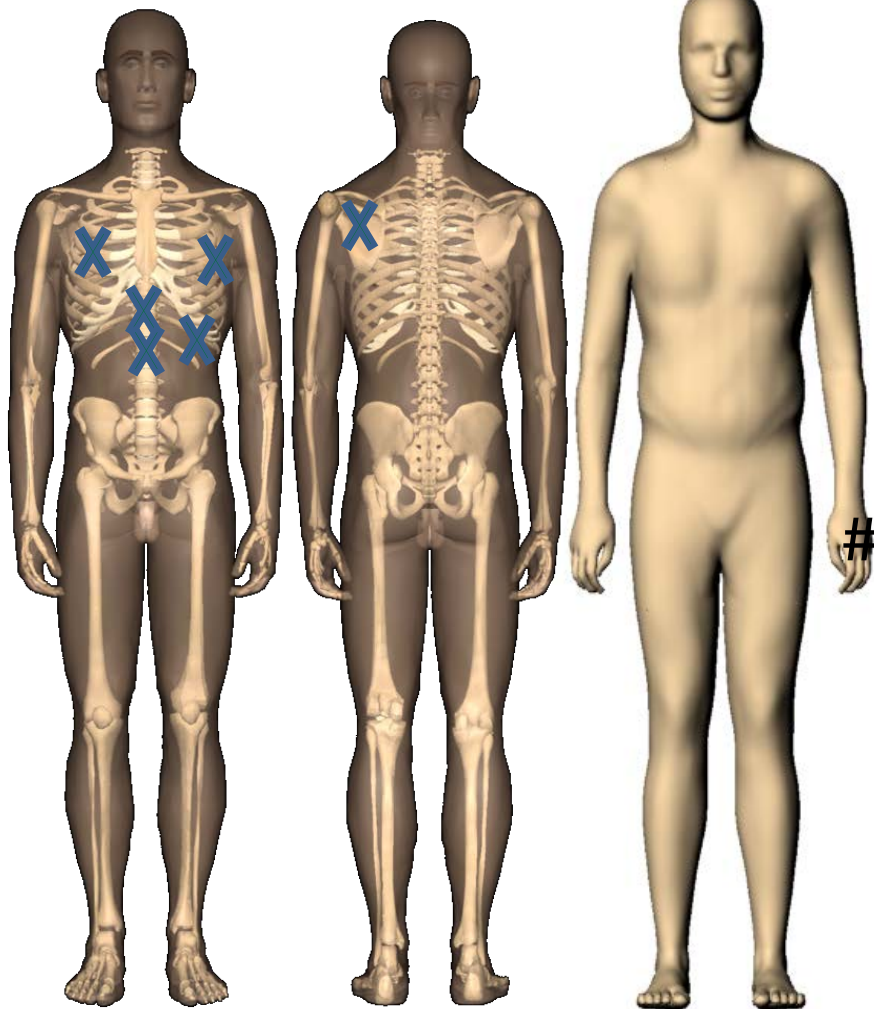


Contacts

Contact	Area	Component	Occ #	Body Region	Evidence	Confidence
A	Roof	Roof or convertible top	1	Shoulder - Left	Scuffed	Certain
B	Roof	Roof or convertible top	1	Back	Combination (Specify)	Certain
C	Roof	Roof maplight/console	1	Hand - Right	Scuffed	Possible
D	Floor	Floor or console mounted transmis	1	Hip - Right	Cracked	Certain
E	Floor	Floor or console mounted transmis	1	Hip - Right	Combination (Specify)	Possible
F	Interior	Belt restraint webbing/buckle	1	Multiple Regions (spec	Other (Specify)	Probable
G	Left Side	Left B-pillar	1	Multiple Regions (spec	Combination (Specify)	Possible



Occupant Injuries




Abrasion = #

Contusion/hematoma = 

Fracture = X

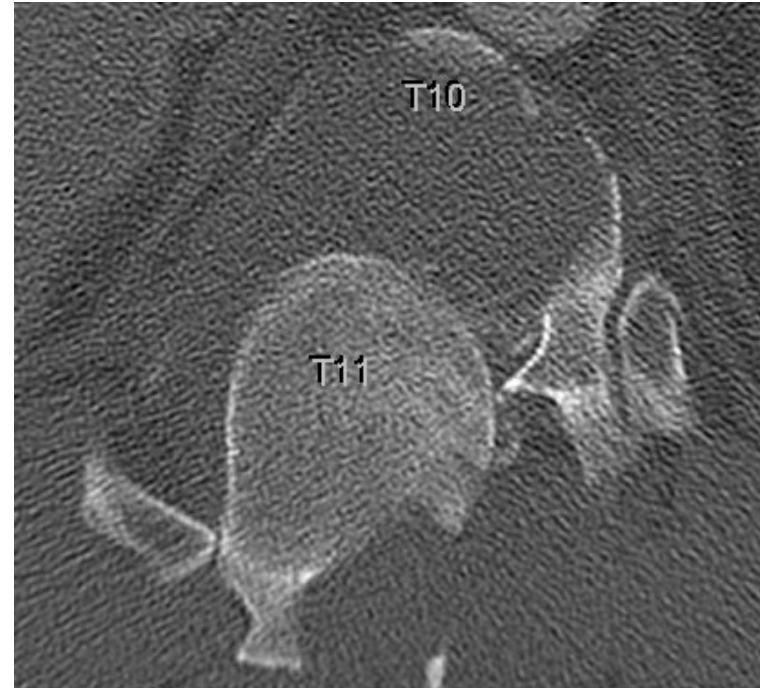
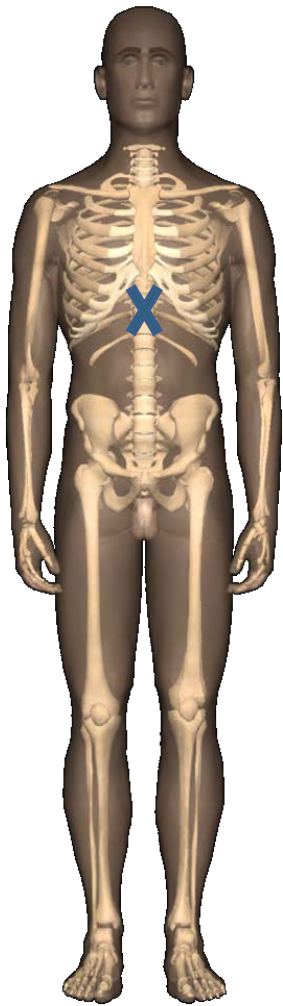
Hemorrhage = 

Laceration = 

AISCODE	Version	Description	Aspect	Rank
6404685	1998	Thoracic Spine cord laceration complete cord syndrome with fracture and dislocation	T10T11;Superior/Upper	1
4502324	1998	Rib cage fracture >3 ribs on one side and <=3 ribs on other side, stable chest or NFS	Bilateral;R Rib 4;R Rib 5;L Rib 11;R Rib 7	2
6506202	1998	Lumbar Spine fracture transverse process	L1;Inferior/Lower	3
6506202	1998	Lumbar Spine fracture transverse process	L2;Inferior/Lower	4
7530002	1998	Scapula fracture (OIS Grade II)	Left	5
7902021	1998	Upper Extremity Skin abrasion	Hand/Digits;Left	6

Rank Occupant Injury

(attributed to planar event)



T10-11 FRACTURE DISLOCATION WITH COMPLETE CORD TRANSECTION, NO SENSATION OR MOTOR FUNCTION UMBILICUS DOWN; FRACTURE THROUGH VERTEBRAL BODY.

AISCODE	Version	Description	Aspect	Rank
6404685	1998	Thoracic Spine cord laceration complete cord syndrome with fracture and dislocation	T10T11;Superior/Upper	1
4502324	1998	Rib cage fracture >3 ribs on one side and <=3 ribs on other side, stable chest or NFS	Bilateral;R Rib 4;R Rib 5;L Rib 11;R Rib 7	2
6506202	1998	Lumbar Spine fracture transverse process	L1;Inferior/Lower	3
6506202	1998	Lumbar Spine fracture transverse process	L2;Inferior/Lower	4
7530002	1998	Scapula fracture (OIS Grade II)	Left	5
7902021	1998	Upper Extremity Skin abrasion	Hand/Digits;Left	6

CIREN RO Cases

Variable	Criteria
Occupant age	≥ 16 years
Occupant role	Driver
Rollover	$1 \leq \text{Quarter turns} \leq 16$
Restraint usage	Lap and shoulder belt used
No. of events	≤ 5

CIREN query yielded 217
cases

Distribution of CIREN Cases

All rollovers: 217 cases
(belted adult drivers)

Single Event

48 cases

(belted adult drivers)

All object class= non-collision

Multiple Event Rollovers

169 cases

(belted adult drivers)

SVME

MVME

Object class=
Non-collision

51 cases

(belted adult
drivers)

Object class=
collision w/ fixed
objects

60* cases

(belted adult drivers)

Object class=
collision w/ non-
fixed object

3 cases

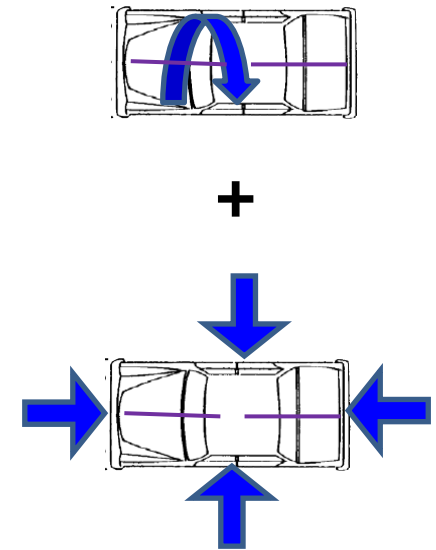
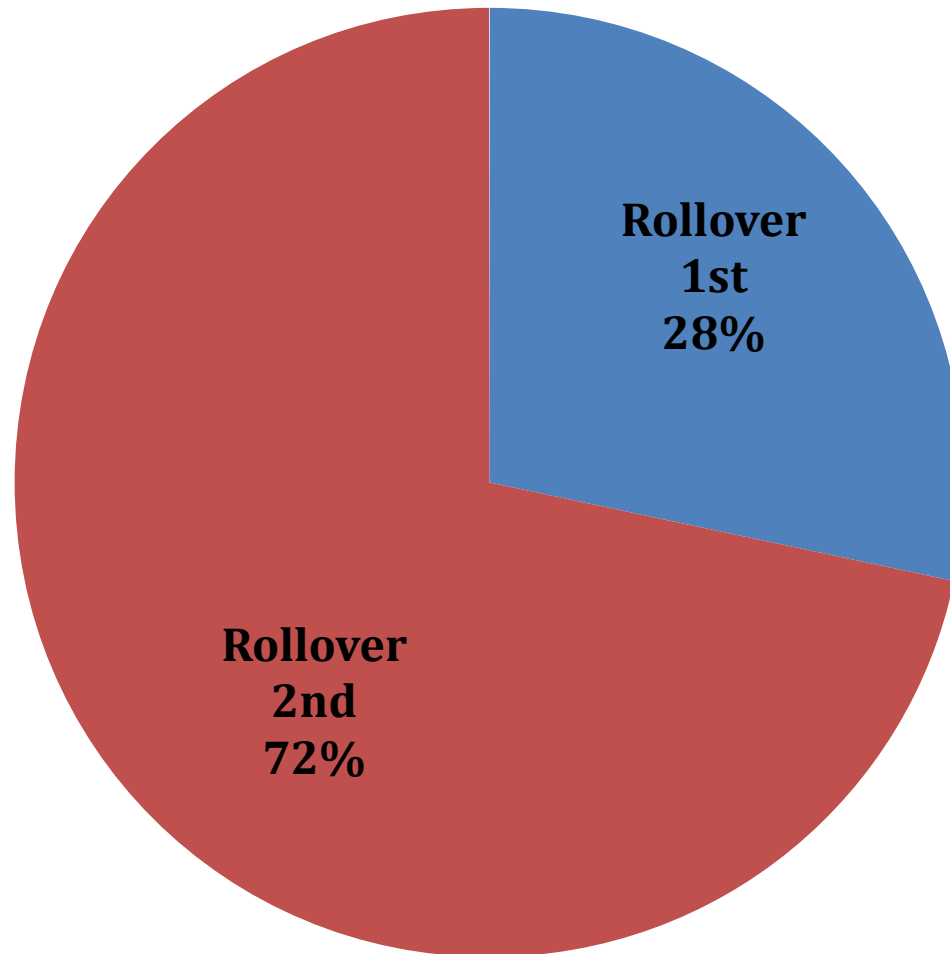
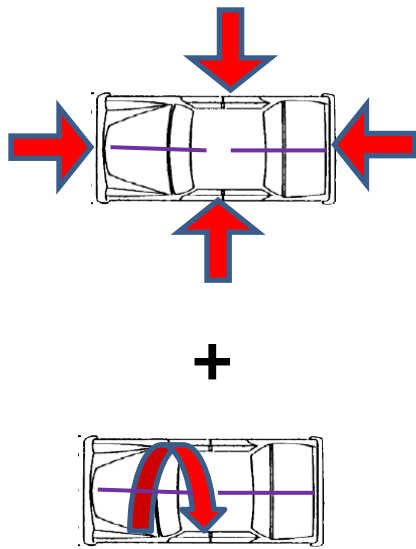
(belted adult drivers)

Object class=
collision w/ vehicle

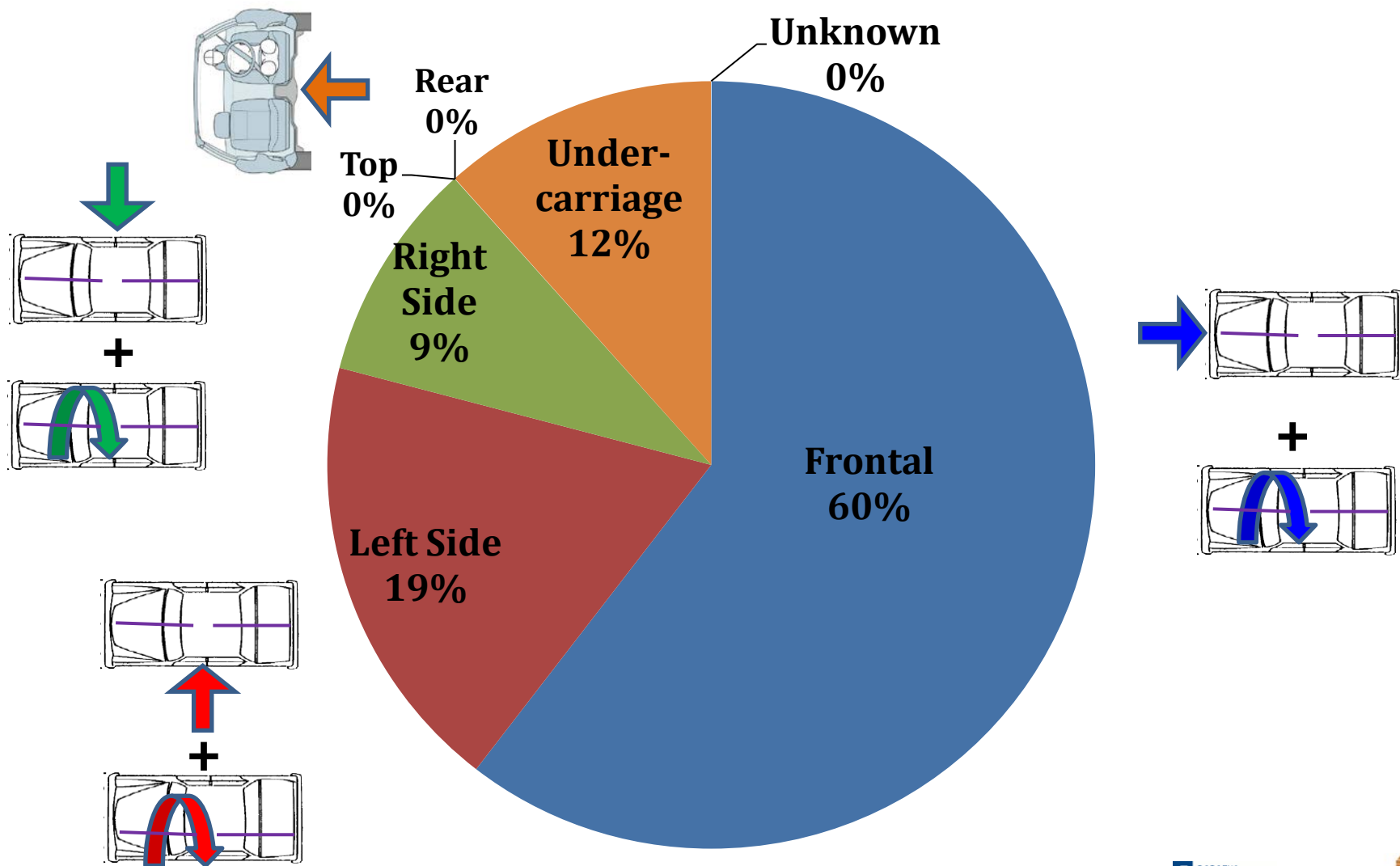
51 cases

(belted adult drivers)

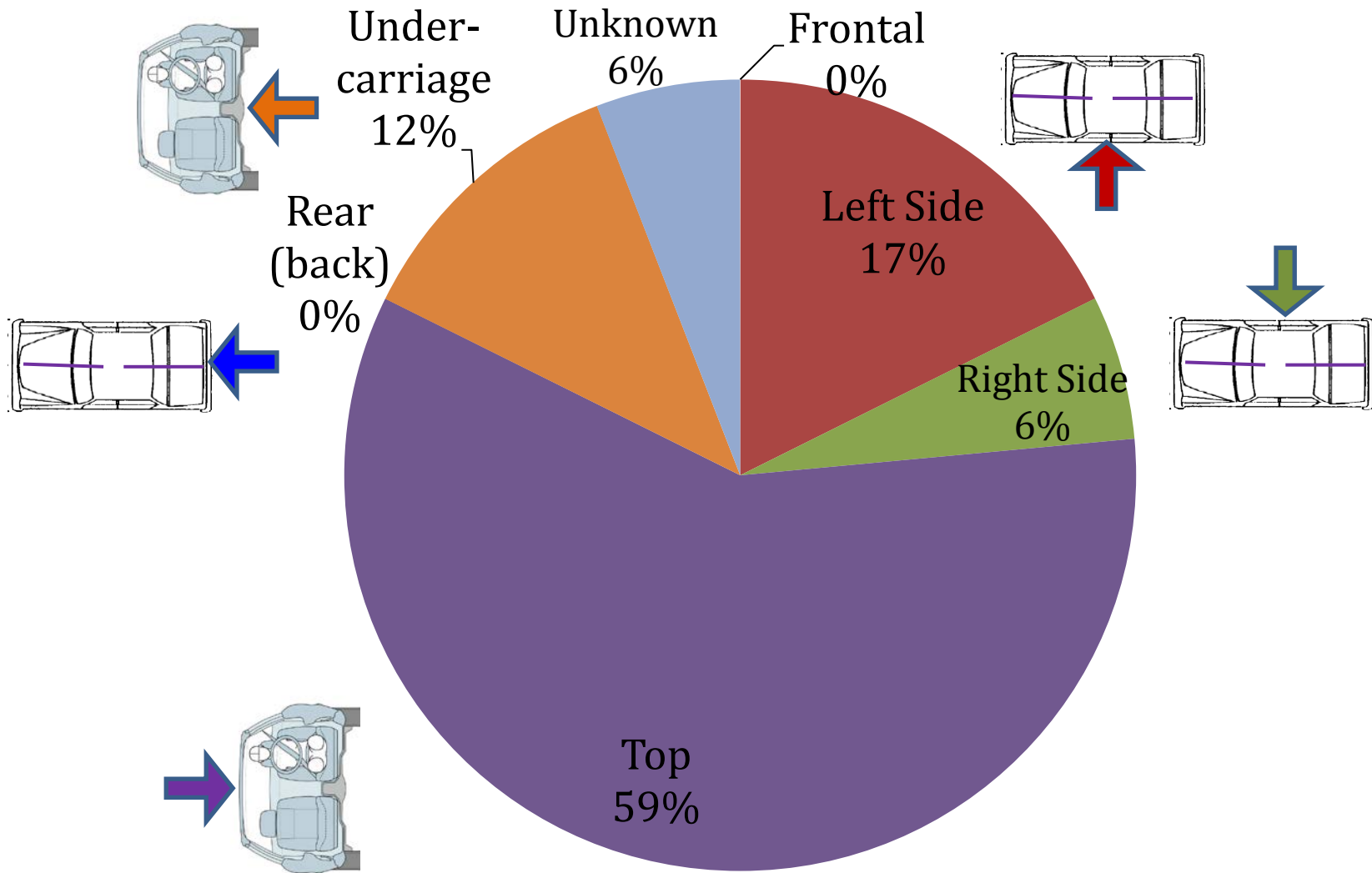
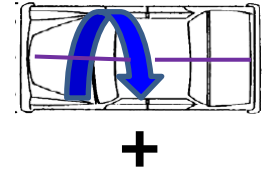
60 SVME Planar Rank 1 RO Cases – Event Sequence



SVME Planar Rank 1 RO Cases – Planar Impact then Rollover (43)

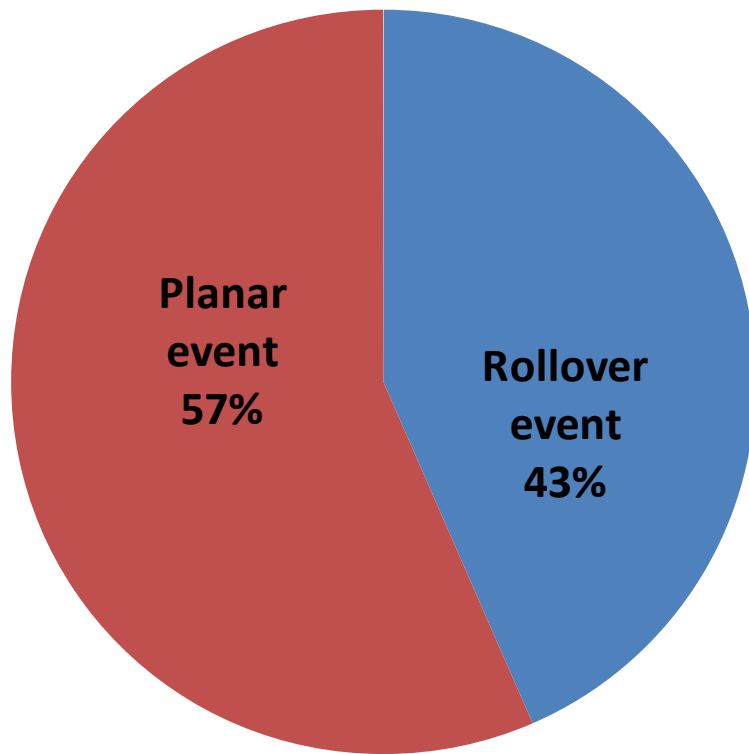


SVME Planar Rank 1 RO Cases – Rollover then Planar Impact (17)



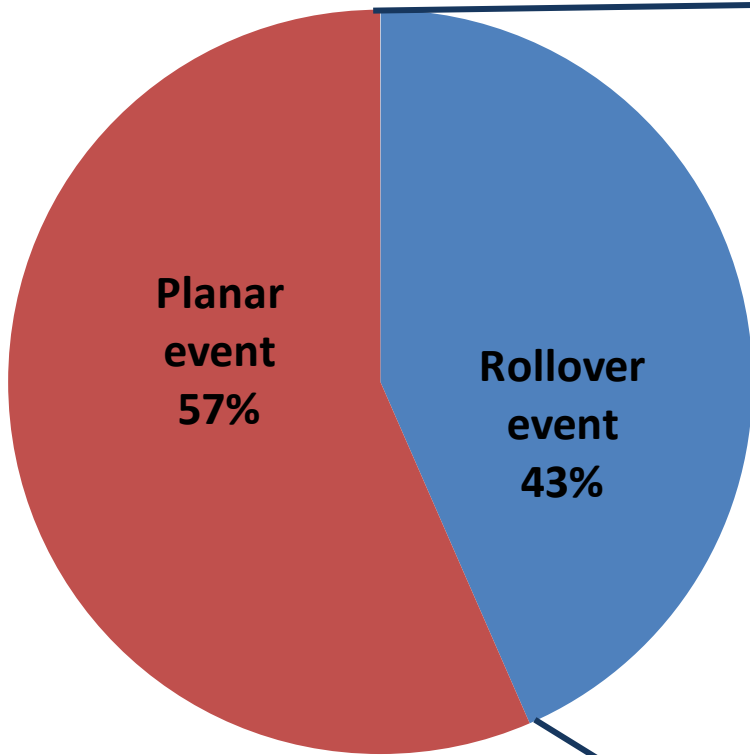
All CIREN SVME rollover cases (n=118)

Most severe vehicle damage

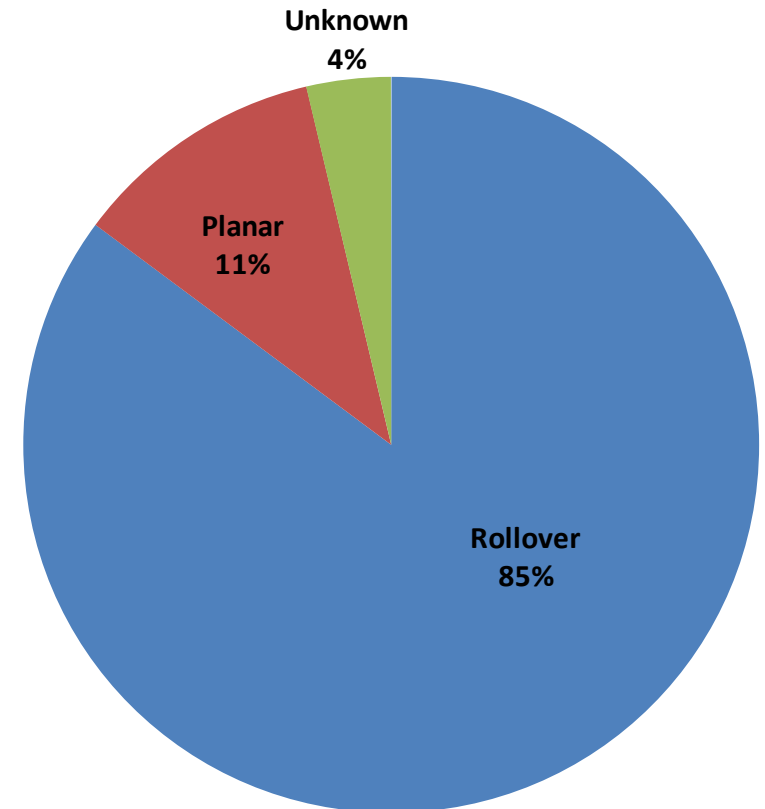


All CIREN SVME rollover cases (n=118)

Most severe vehicle damage



Attribution of rank 1 injury in primary rollover SVME cases



*attribution based on biomechanics tab when available (n=23)

CIREN Case Reviews

Median=3, mode=2

30 Single Vehicle –
Multiple Event Cases
Reviewed in Detail

SVME
(30)

Rank 1 Vehicle Damage

Planar
(21)

Rollover
(9)

Rank 1 Occupant Injury

Planar
(16)

Rollover
(5)

Planar
(1)

Rollover
(8)

CIREN Case Reviews

30 Single Vehicle –
Multiple Event Cases
Reviewed in Detail

SVME
(30)

Rank 1 Vehicle Damage

Planar
(21)

Rollover
(9)

MAIS Occupant Injury

Planar
(16)

Rollover
(5)

Planar
(1)

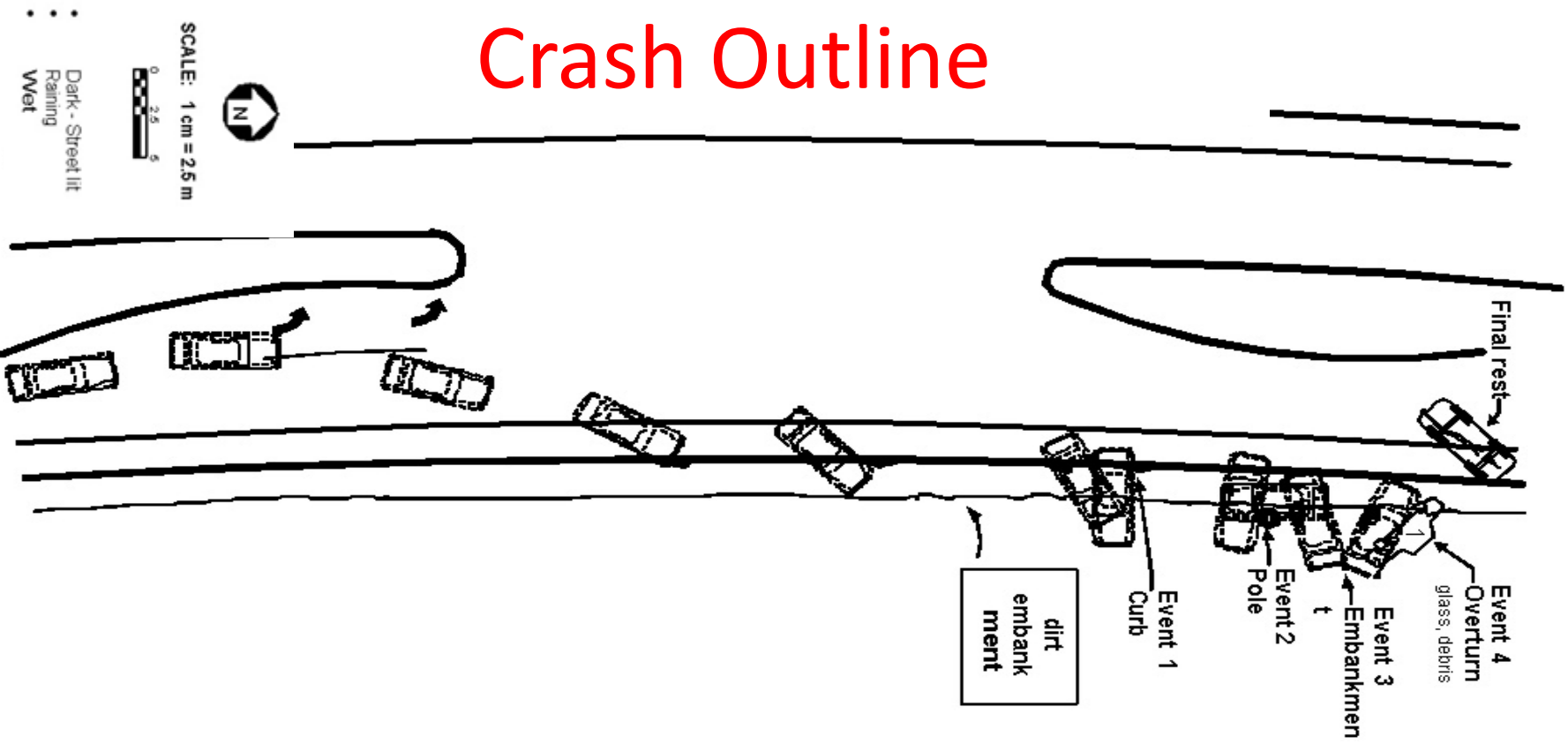
Rollover
(8)

Scene/Occupant

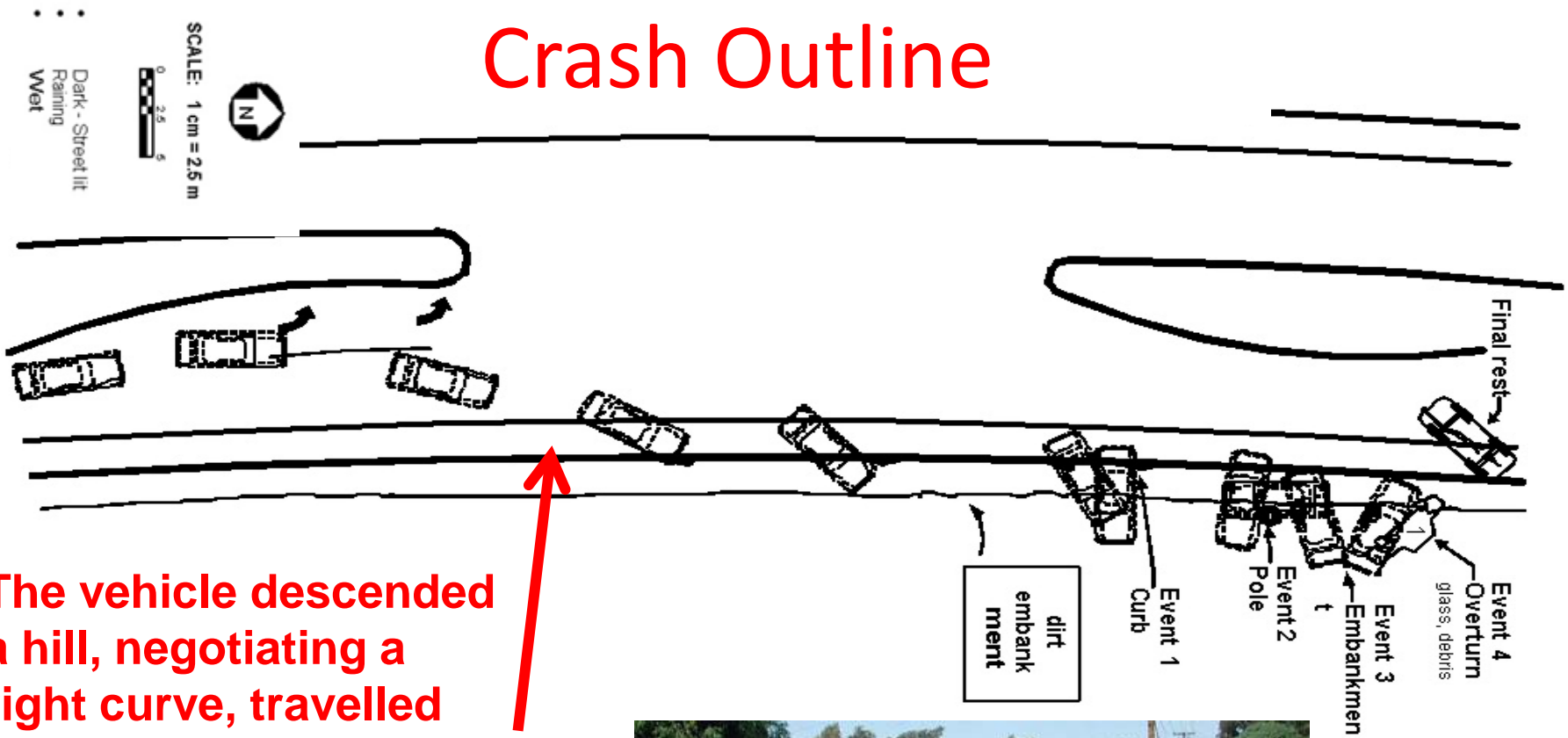
- Case vehicle
 - 1999 VW Jetta
- General crash type
 - Left side impact, Non-horizontal rollover collision
- Gender
 - Male
- Age
 - 16 years
- Seat position
 - Front left (driver)
- HT/WT
 - 183 cm, 70 kg



Crash Outline



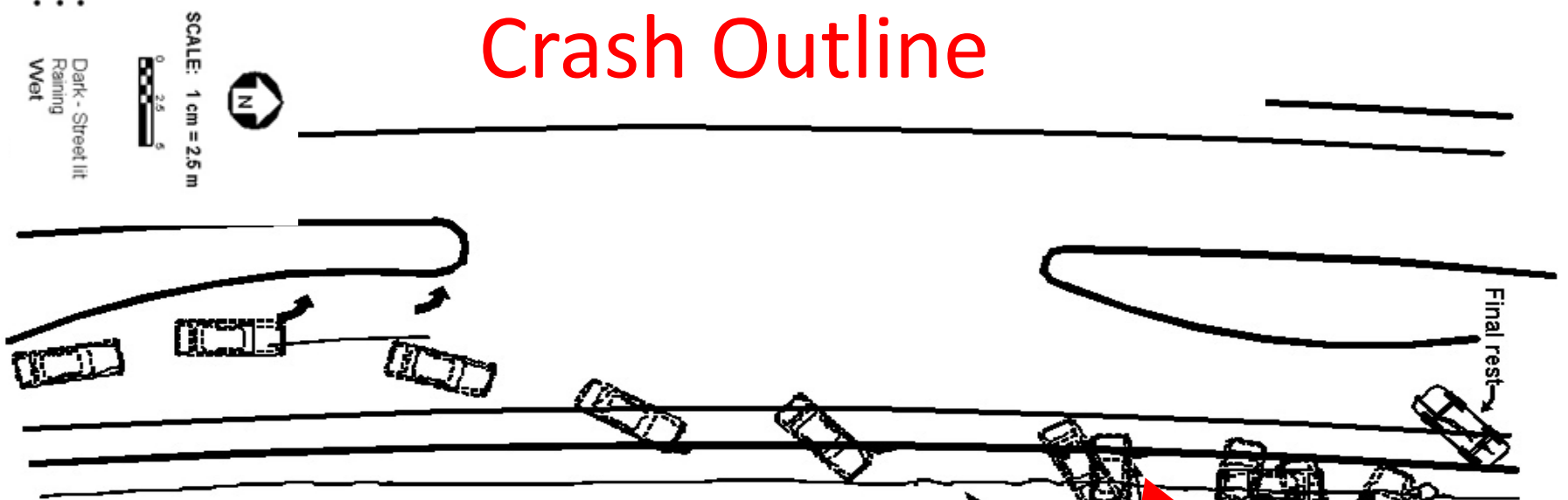
Crash Outline



The vehicle descended a hill, negotiating a right curve, travelled into the left lane, was about to hit the median, overcorrected to right, began a clockwise yaw and slid right.



Crash Outline



dirt
embankment

Event 1
Curb

Event 2
Pole

Event 3
Embankment

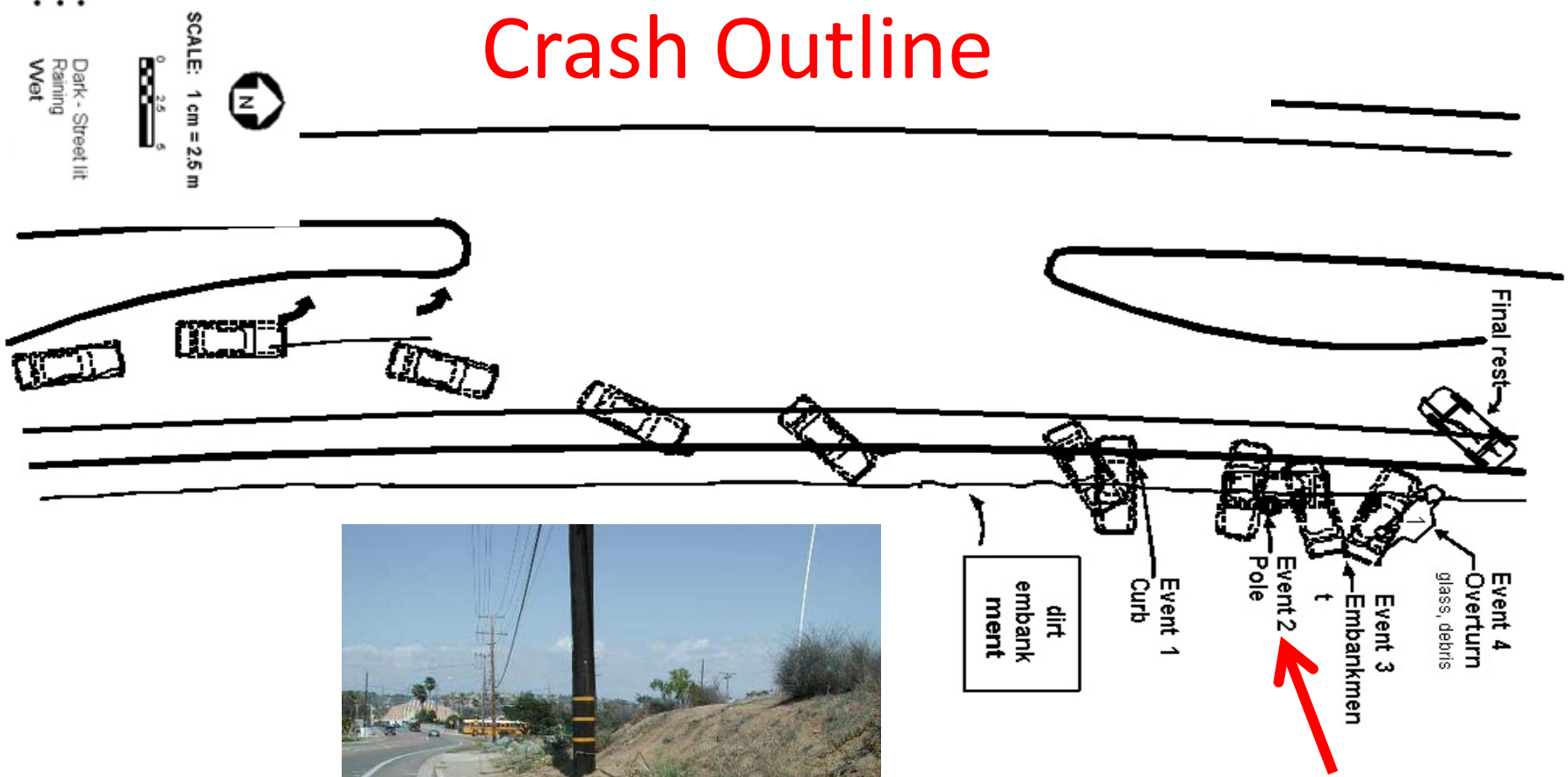
Event 4
Overtake
glass, debris

Final rest

Vehicle hit the curb with rear wheel.

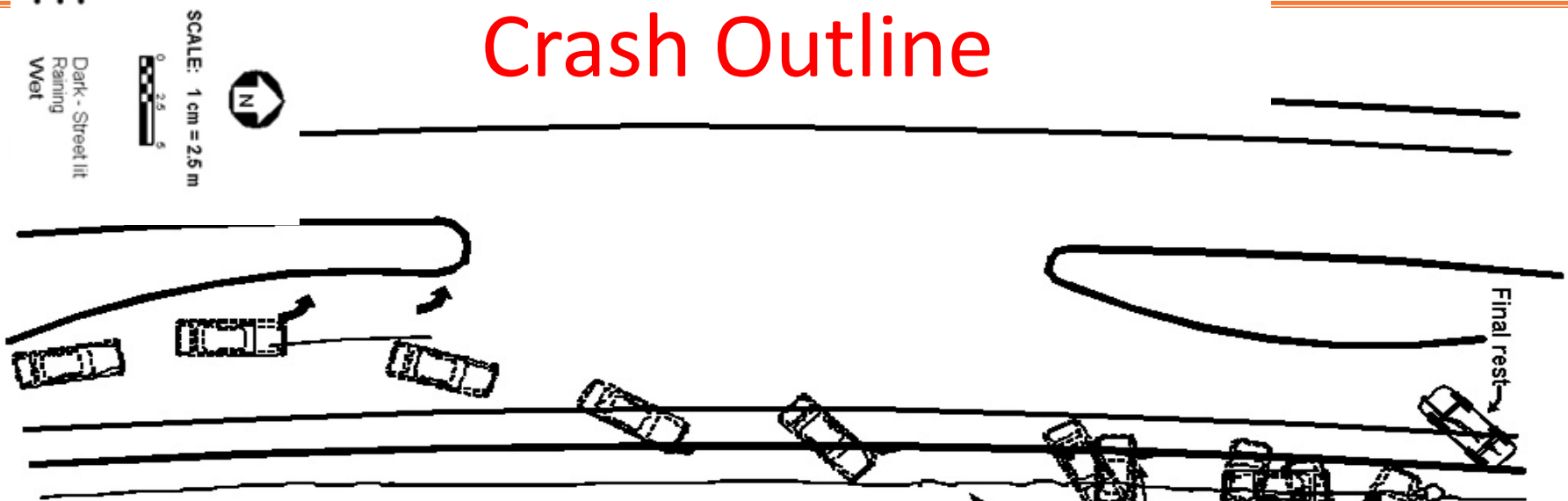


Crash Outline

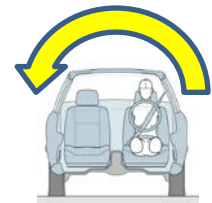


Scenario 1: Vehicle struck a utility pole with left side driver door, rotated 180 deg CW around the pole

Crash Outline

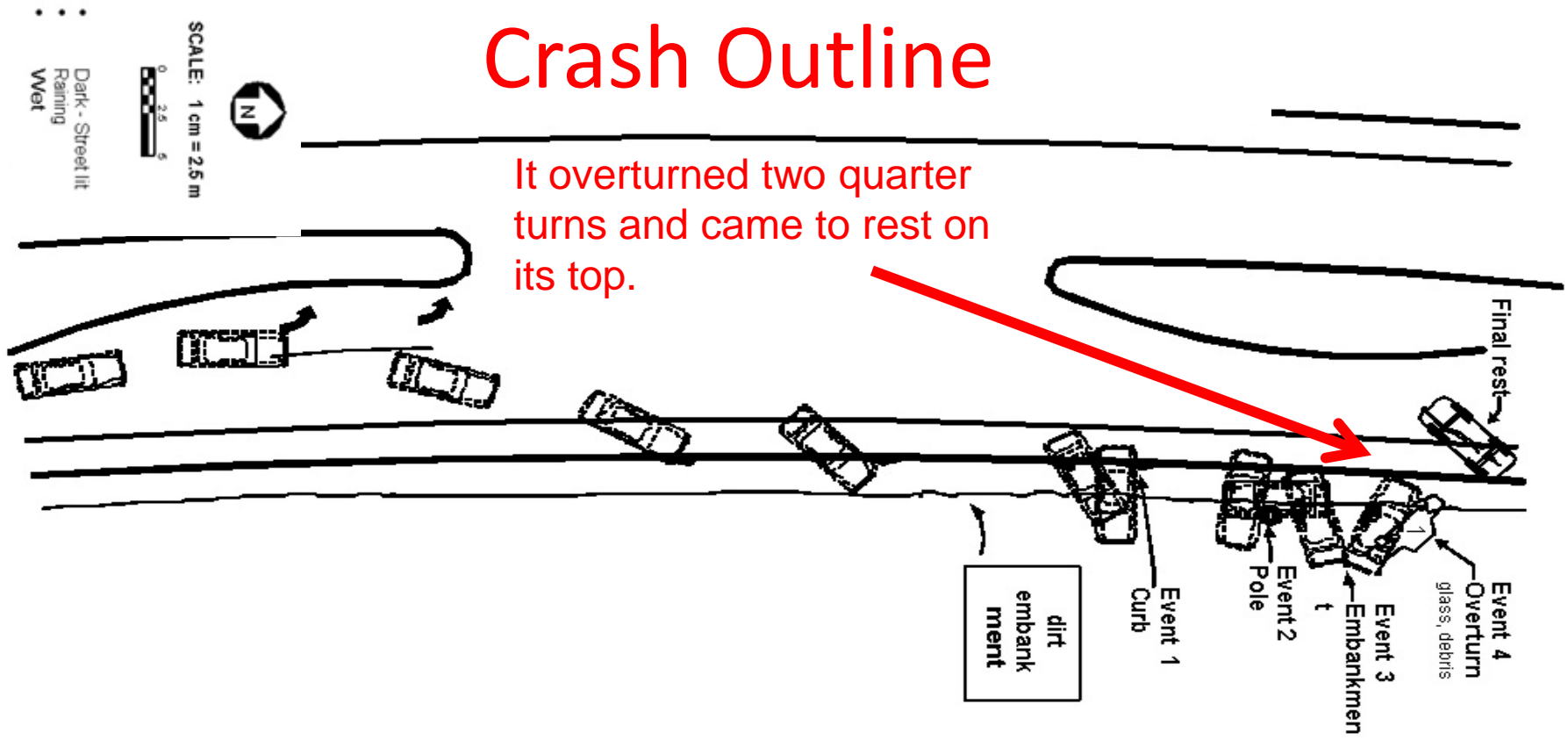


Final rest
Event 4
Overturn
glass, debris
Event 3
Embankment
Event 2
Pole
Event 1
Curb
dirt embankment



Scenario 1: When it disengaged the pole the rear undercarriage struck the embankment.

Crash Outline



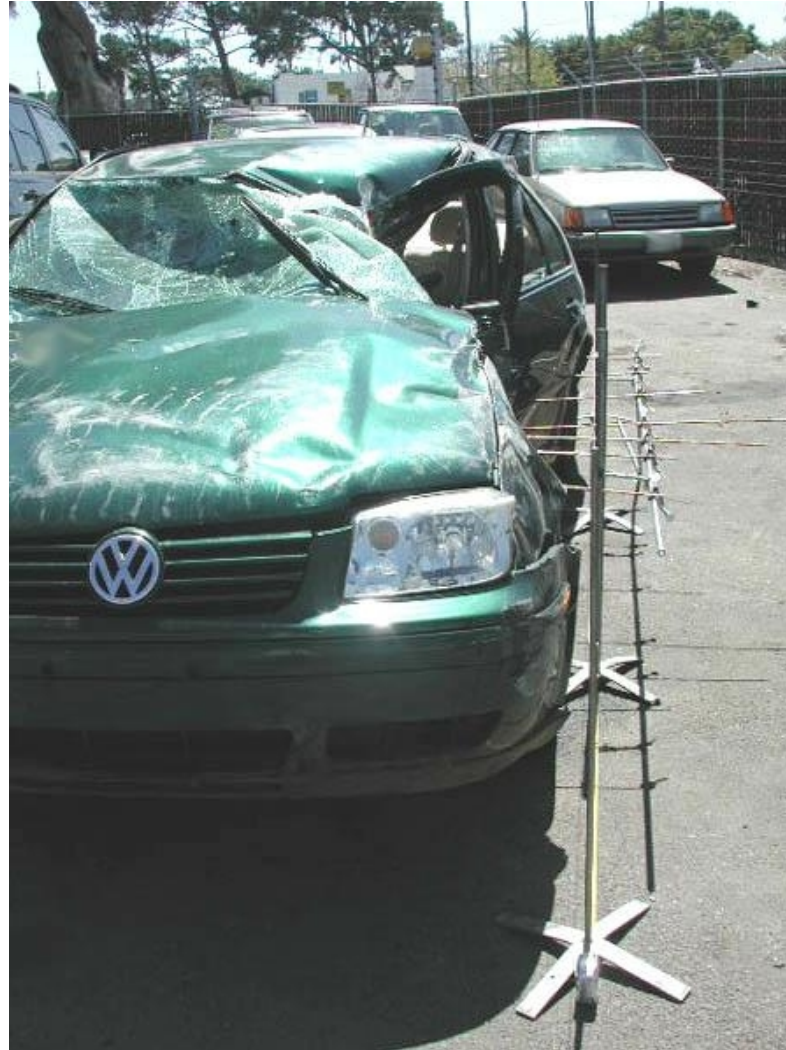
Event	Object Contacted	Force Dir	Location	Total	Long	Lateral	Energy	Impact	Barrier	Est	Rank
1	Curb	290	10LBW01	999	999	999	-9999	999	999	7	3
2	Nonbreakaway pole or post(>30 cm in	270	89LPAW05	42	0	42	92116	998	42	1	1
3	Embankment	Horizontal	00UBLW02	999	999	999	-9999	999	999	7	4
4	Overturn->rollover(excludes end-ove	Horizontal	00TYD002	999	999	999	-9999	999	999	7	2

Impact

- PDOF (degree) Rank 1 Event
 - 270
- CDC Rank 1 Event
 - 89LPAW05
- Delta V Rank 1 Event
 - 42 km/h
- Restraint status
 - Manual Lap/Shoulder
- Airbag status
 - Frontal (no deploy)
 - No side airbag



Vehicle Photographs









Left front



Left rear



Right front



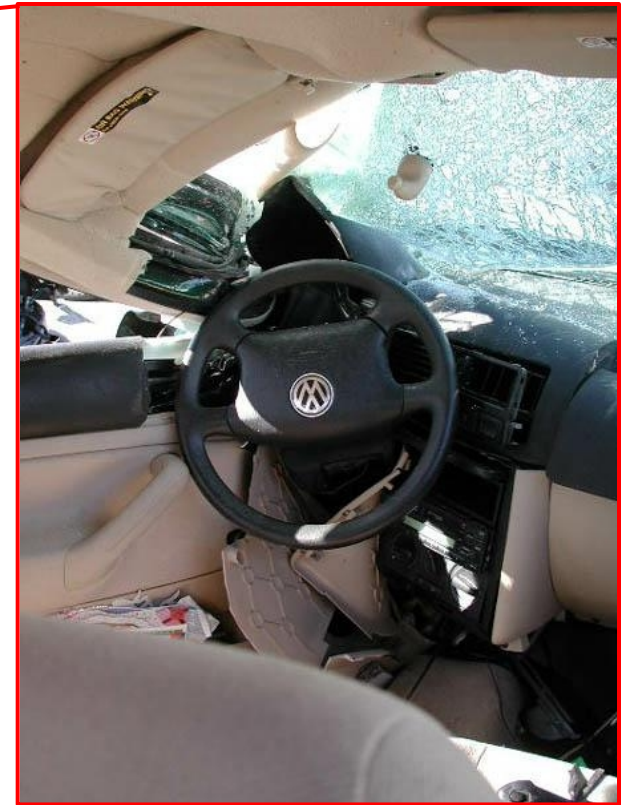
Right rear

Right Side



Right Side



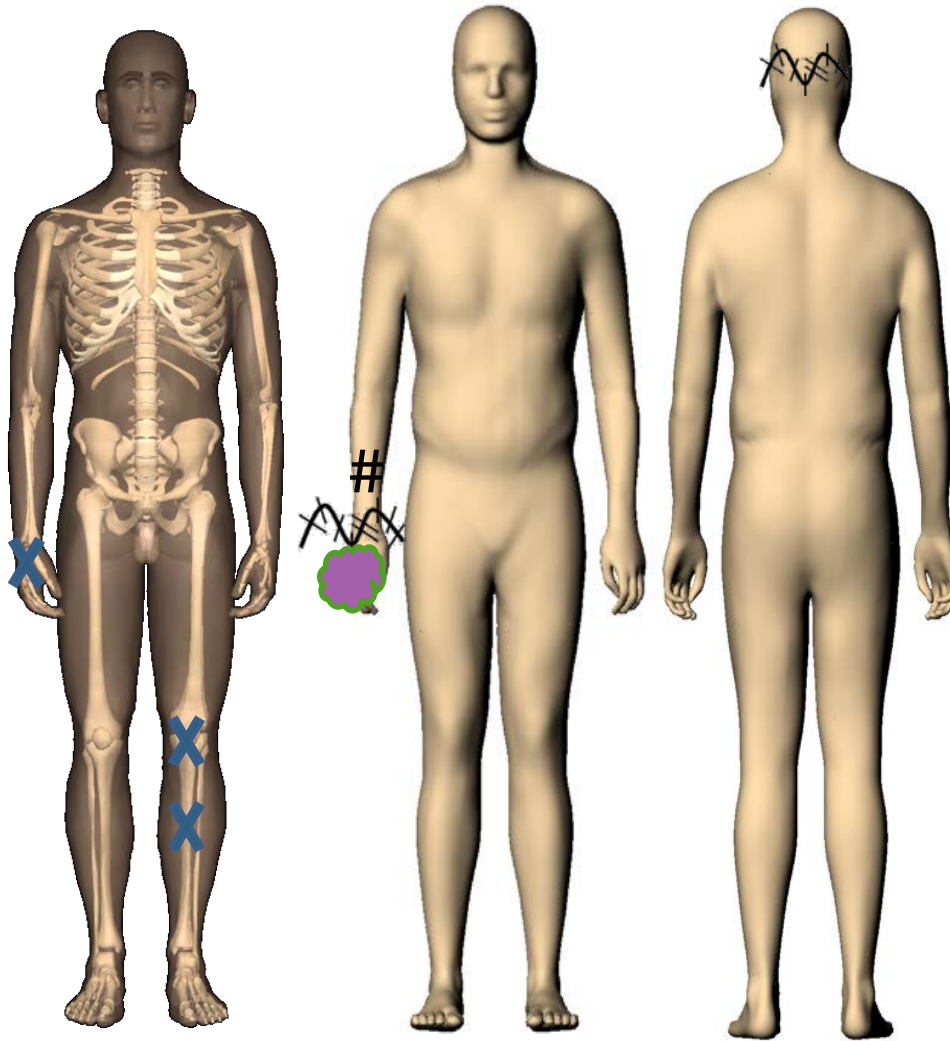


Row	Position	Area	Intruded Component	Comparison	Intruded	Intrusion	Magnitude	Crush Direction
Front Seat	Left	Interior	Door panel (side)	68	12	56	>= 46 to < 61 cms	Lateral
Front Seat	Left	Interior	Floor pan (includes sill)	68	21	47	>= 46 to < 61 cms	Lateral
Front Seat	Left	Interior	Side panel - forward of	64	8	56	>= 46 to < 61 cms	Lateral
Second Seat	Left	Interior	Front seat back	0	55	55	>= 46 to < 61 cms	Longitudinal
Front Seat	Left	Interior	A (A1/A2)-pillar	65	29	36	>= 30 to < 46 cms	Lateral
Front Seat	Left	Interior	Windshield header	29	6	23	>= 15 to < 30 cms	Vertical
Front Seat	Left	Interior	Roof (or convertible top)	33	7	26	>= 15 to < 30 cms	Vertical
Front Seat	Left	Interior	Roof side rail	59	33	26	>= 15 to < 30 cms	Lateral
Second Seat	Left	Interior	Door panel (side)	136	129	7	>= 3 to < 8 cms	Lateral



Row	Position	Area	Intruded Component	Comparison	Intruded	Intrusion	Magnitude	Crush Direction
Front Seat	Left	Interior	Door panel (side)	68	12	56	>= 46 to < 61 cms	Lateral
Front Seat	Left	Interior	Floor pan (includes sill)	68	21	47	>= 46 to < 61 cms	Lateral
Front Seat	Left	Interior	Side panel - forward of	64	8	56	>= 46 to < 61 cms	Lateral
Second Seat	Left	Interior	Front seat back	0	55	55	>= 46 to < 61 cms	Longitudinal
Front Seat	Left	Interior	A (A1/A2)-pillar	65	29	36	>= 30 to < 46 cms	Lateral
Front Seat	Left	Interior	Windshield header	29	6	23	>= 15 to < 30 cms	Vertical
Front Seat	Left	Interior	Roof (or convertible top)	33	7	26	>= 15 to < 30 cms	Vertical
Front Seat	Left	Interior	Roof side rail	59	33	26	>= 15 to < 30 cms	Lateral
Second Seat	Left	Interior	Door panel (side)	136	129	7	>= 3 to < 8 cms	Lateral

Occupant Injuries




Abrasion = #

Contusion/hematoma = 

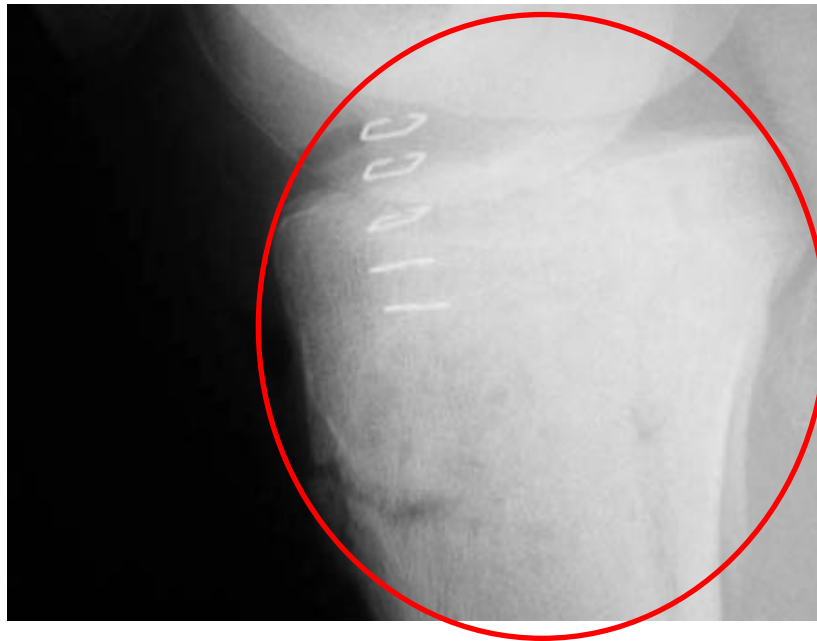
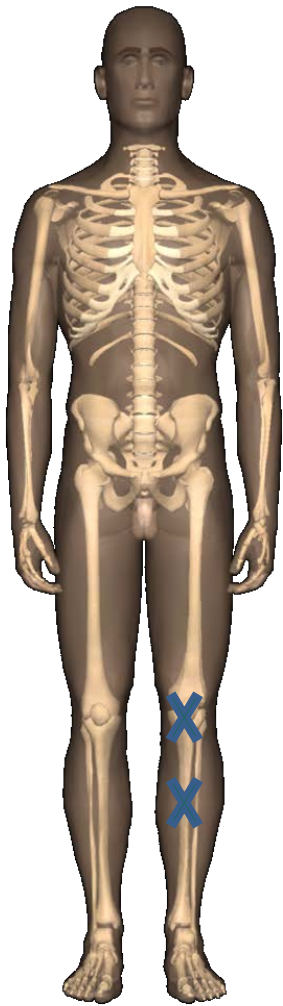
Fracture = X

Hemorrhage = 

Laceration = 

AISCODE	Description	Aspect	Injury Source	Confidence	Rank
8534083	Tibia fracture condyles open/displaced/comminuted	Left	Left side interior surface, excluding hardware or a	Probable	1
8534223	Tibia fracture shaft open/displaced/comminuted	Left	Left side interior surface, excluding hardware or a	Probable	1
7520022	Carpus or metacarpus fracture	Right	Steering wheel rim	Possible	2
1906021	Scalp laceration minor	Posterior/Back/Dorsal	Flying glass	Possible	3
7904021	Upper Extremity Skin contusion	Hand/Digits;Right	Steering wheel rim	Possible	3
7906021	Upper Extremity Skin laceration minor	Hand/Digits;Right	Flying glass	Possible	3
7906021	Upper Extremity Skin laceration minor	Hand/Digits;Left	Left side interior surface, excluding hardware or a	Probable	3
8902021	Lower Extremity Skin abrasion	Thigh;Right	Same occupant contact (specify) [ex- knee]	Probable	3

Occupant Injuries



AISCODE	Description	Aspect	Injury Source	Confidence	Rank
8534083	Tibia fracture condyles open/displaced/comminuted	Left	Left side interior surface, excluding hardware or a	Probable	1
8534223	Tibia fracture shaft open/displaced/comminuted	Left	Left side interior surface, excluding hardware or a	Probable	1
7520022	Carpus or metacarpus fracture	Right	Steering wheel rim	Possible	2
1906021	Scalp laceration minor	Posterior/Back/Dorsal	Flying glass	Possible	3
7904021	Upper Extremity Skin contusion	Hand/Digits;Right	Steering wheel rim	Possible	3
7906021	Upper Extremity Skin laceration minor	Hand/Digits;Right	Flying glass	Possible	3
7906021	Upper Extremity Skin laceration minor	Hand/Digits;Left	Left side interior surface, excluding hardware or a	Probable	3
8902021	Lower Extremity Skin abrasion	Thigh;Right	Same occupant contact (specify) [ex- knee]	Probable	3

CIREN Case Reviews

30 Single Vehicle –
Multiple Event Cases
Reviewed in Detail

SVME
(30)

Rank 1 Vehicle Damage

Planar
(21)

Rollover
(9)

MAIS Occupant Injury

Planar
(16)

Rollover
(5)

Planar
(1)

Rollover
(8)

Partial
Ejections
Included

Scene/Occupant

- Case vehicle
 - 1999 Dodge Ram
- General crash type
 - Frontal and Non-horizontal rollover collision
- Gender
 - Male
- Age
 - 35
- Seat position
 - Front left (driver)
- HT/WT
 - 178 cm, 73 kg



planar(vehicle damage) and Rollover (injury)]

Impact

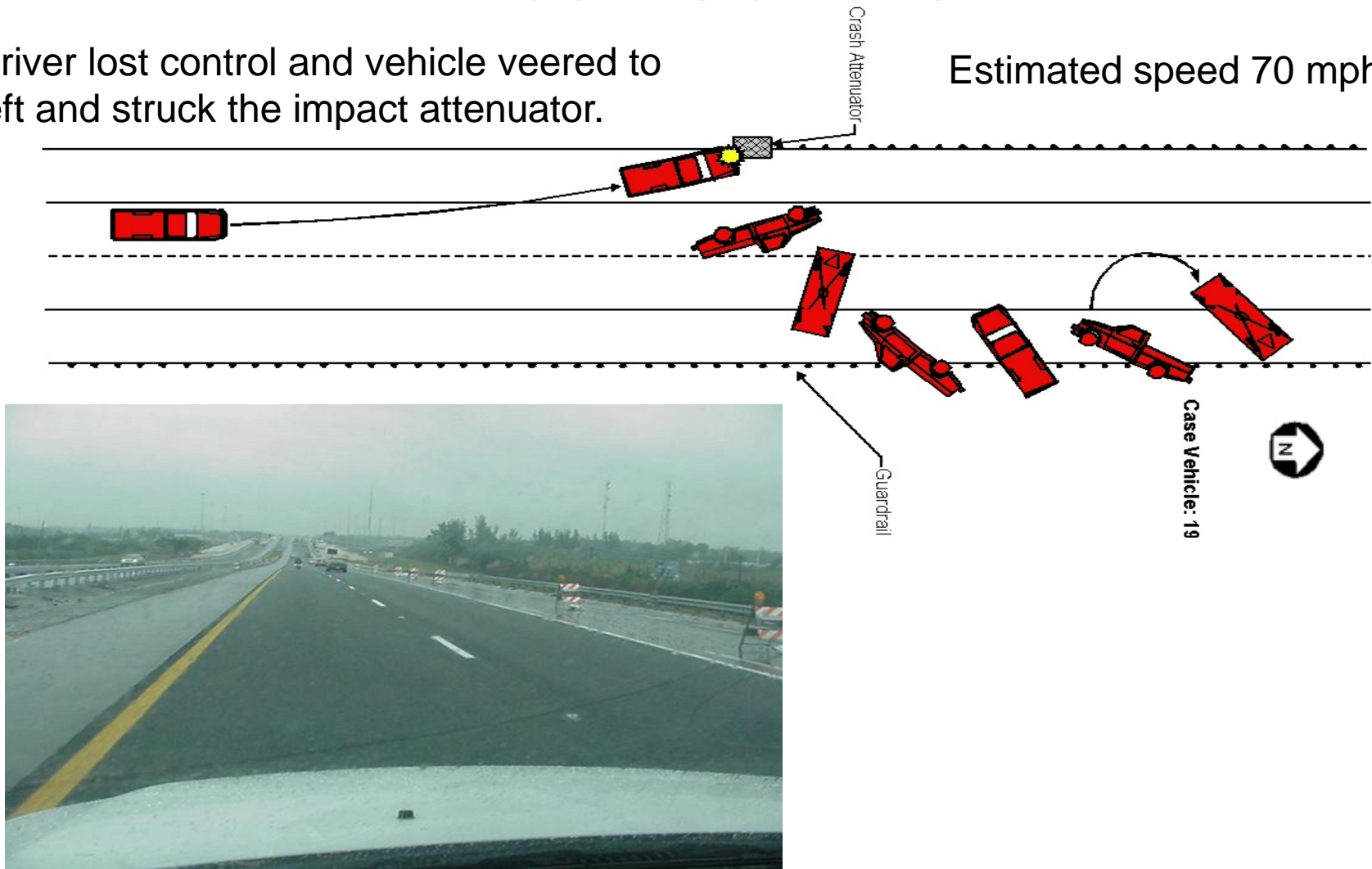
- PDOF (degree)
 - 0
- CDC
 - 12FLEW2
- Delta V
 - 35 km/h
- Restraint status
 - Manual Lap/Shoulder
- Airbag status
 - Frontal (deployed)



Crash Outline

Driver lost control and vehicle veered to left and struck the impact attenuator.

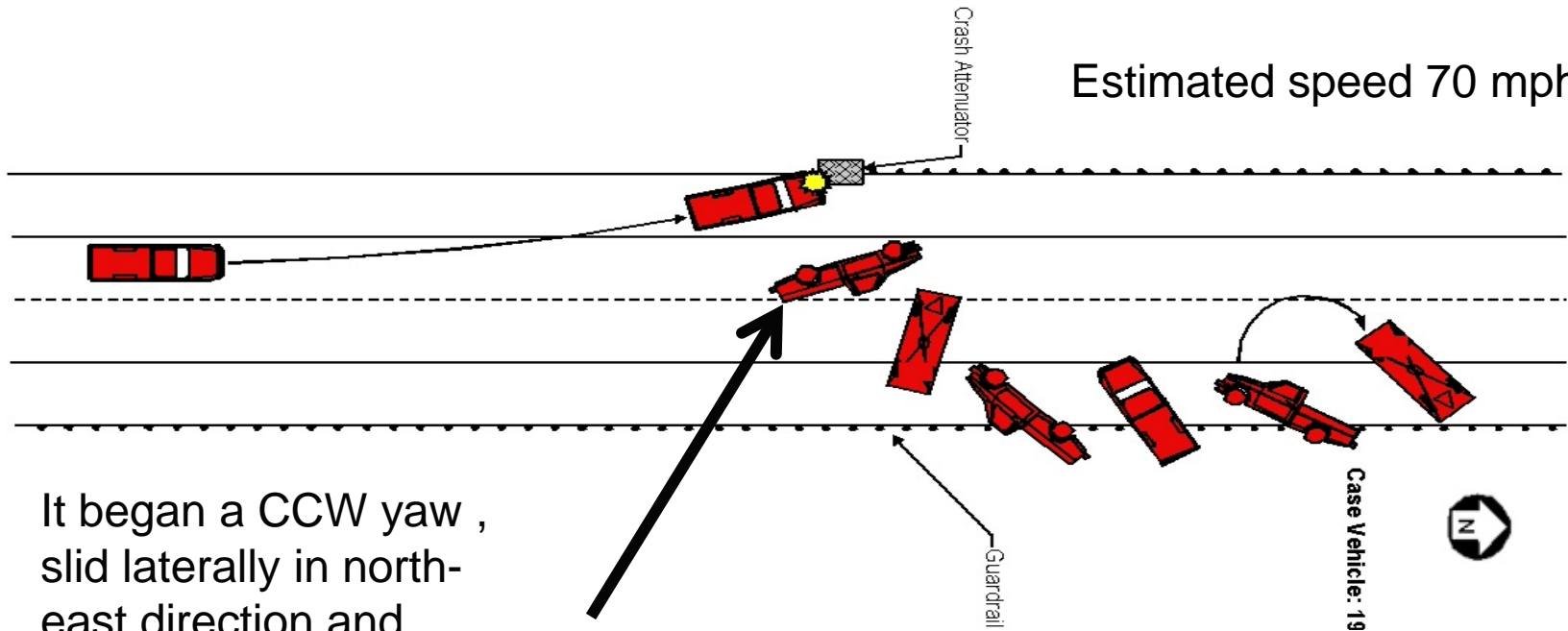
Estimated speed 70 mph



Event	Object Contacted	Force Dir	Location	Total	Long	Lateral	Energy	Impact	Barrier	Est	Rank
1	Impact attenuator	0	12FLEW02	35	-35	0	67707	998	35	1	1

Crash Outline

Estimated speed 70 mph

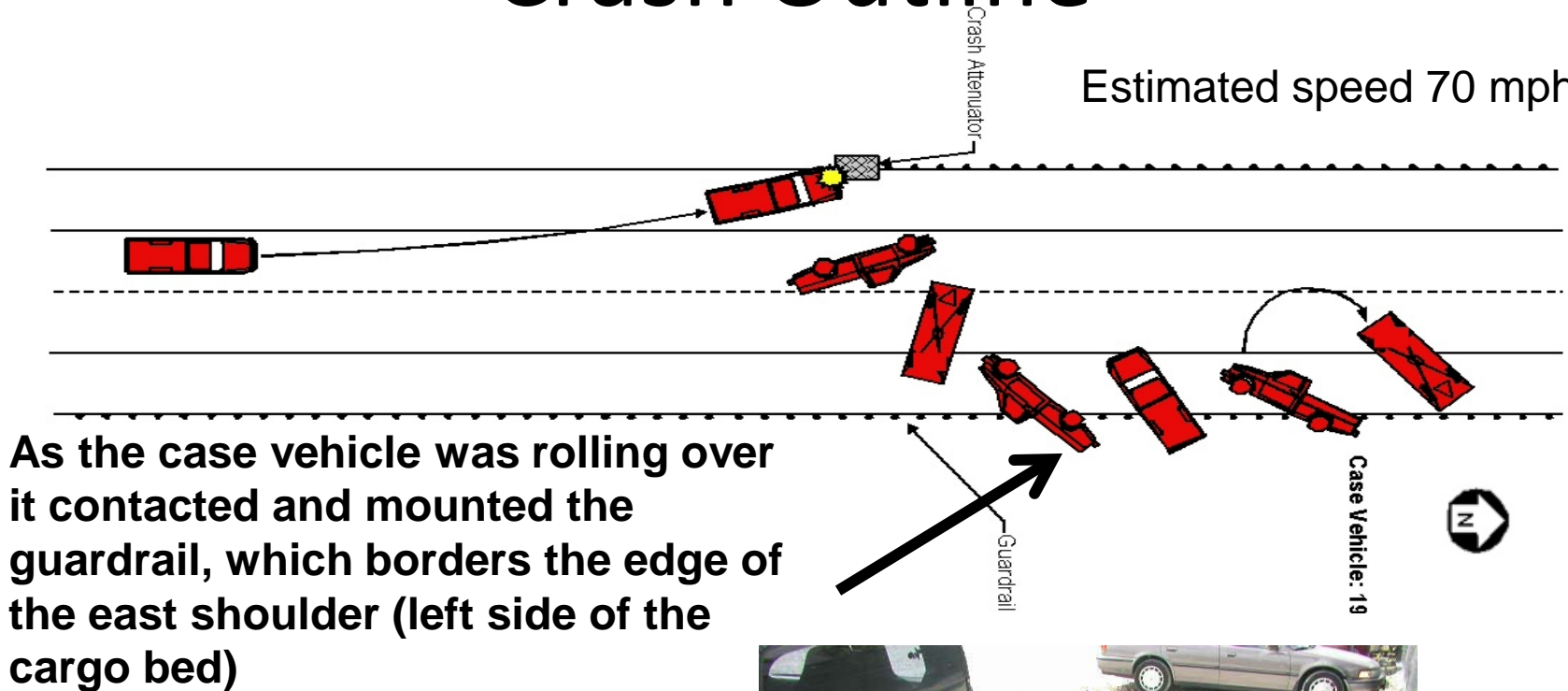


It began a CCW yaw ,
slid laterally in north-
east direction and
began to roll over to the
right.



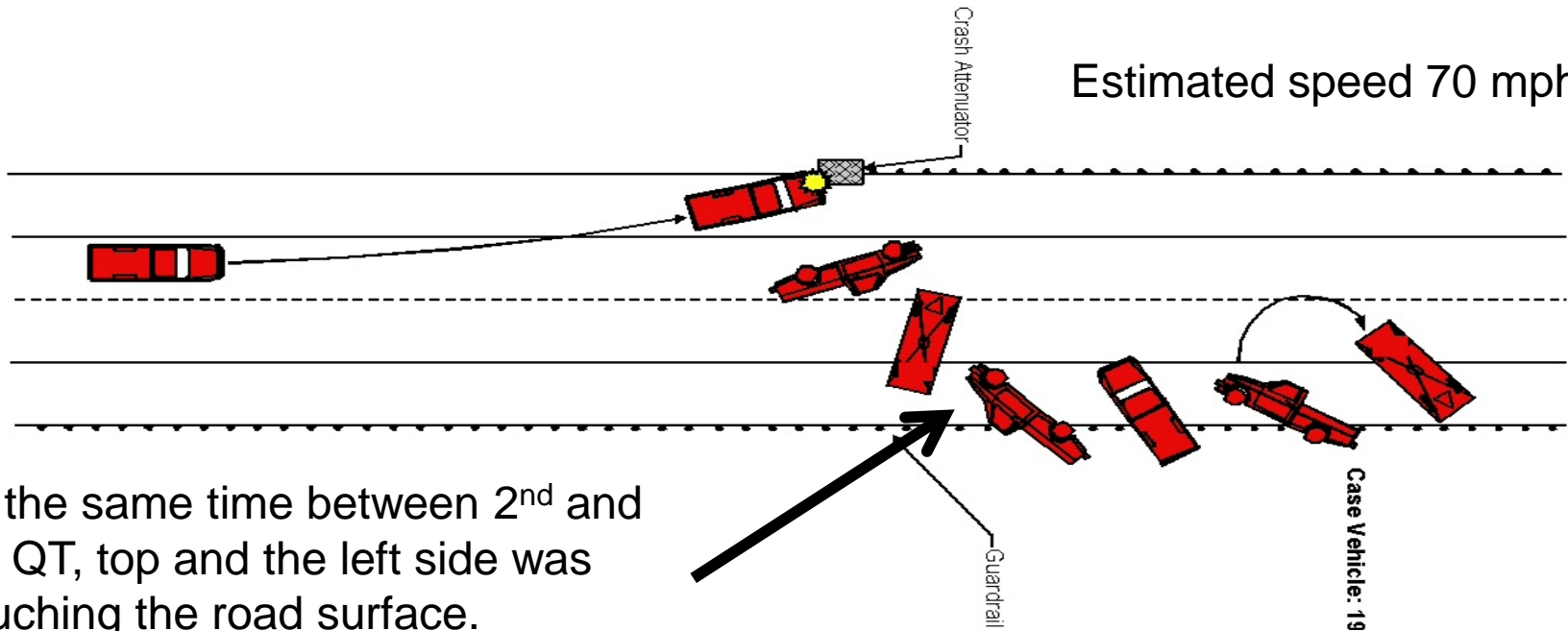
Crash Outline

Estimated speed 70 mph



Crash Outline

Estimated speed 70 mph

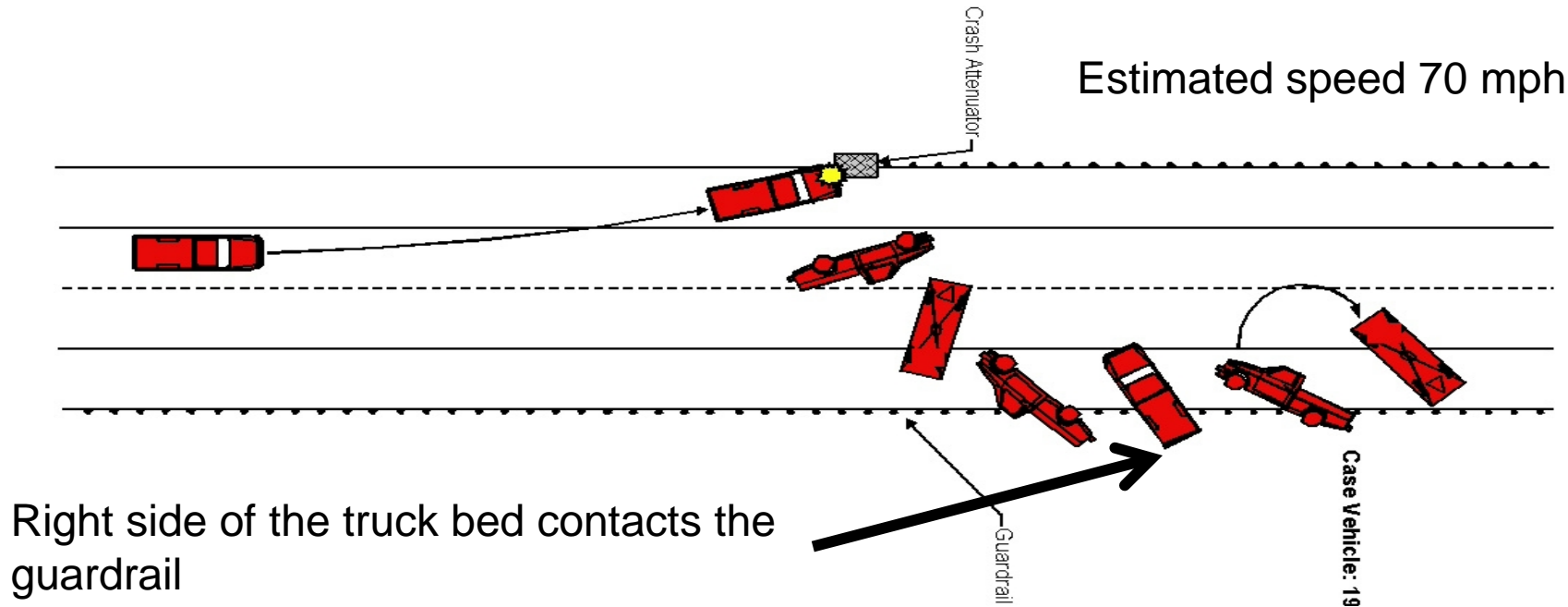


At the same time between 2nd and 4th QT, top and the left side was touching the road surface.



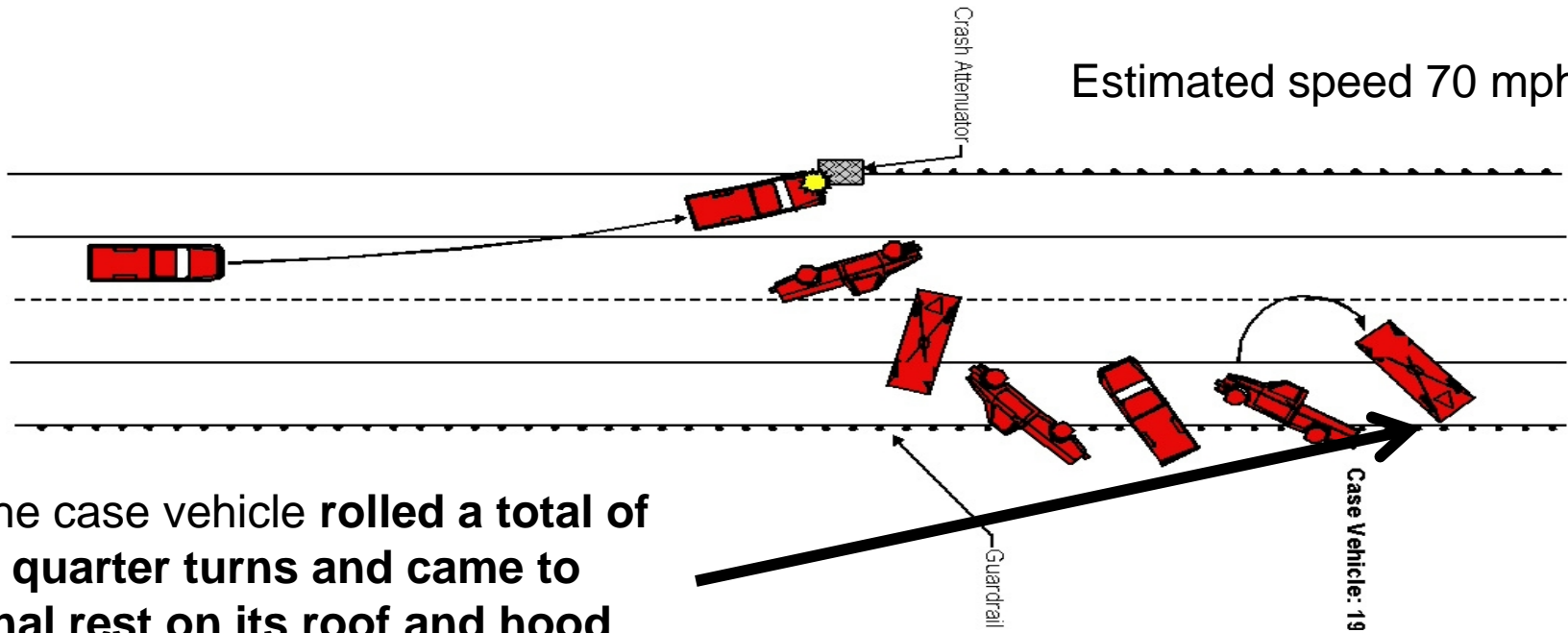
Crash Outline

Estimated speed 70 mph



Crash Outline

Estimated speed 70 mph



The case vehicle rolled a total of 6, quarter turns and came to final rest on its roof and hood,





Contacts

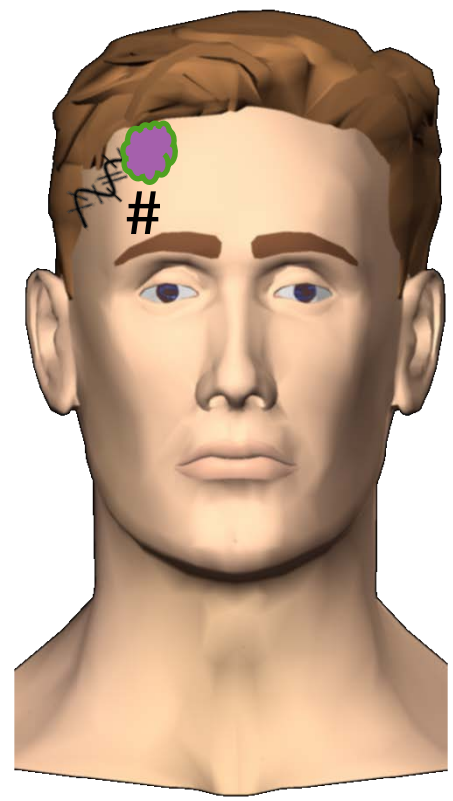
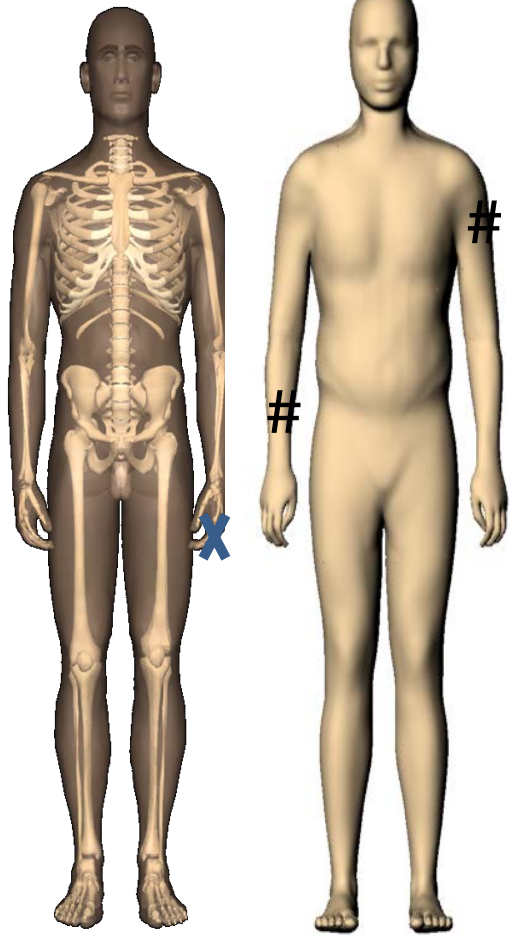
Contact	Area	Component	Occ #	Body Region	Evidence	Confidence
A	Front	Windshield	1	Lower Arm - Left	Transfer (Specify)	Certain
B	Air Bag	Air bag-driver side	1	Face	Scuffed	Certain
C	Front	Left instrument panel and below	1	Hand - Left	Cracked	Certain
D	Roof	Roof or convertible top	1	Shoulder - Right	Scuffed	Probable
E	Interior	Center console first row	1	Hip - Right	Bent	Probable
F	Front	Knee bolster	1	Knee - Left	Scuffed	Certain
G	Front	Knee bolster	1	Knee - Right	Scuffed	Certain



Intrusion

Row	Position	Area	Intruded Component	Comparison	Intruded	Intrusion	Magnitude	Crush Direction
Front Seat	Left	Interior	Instrument panel left	86	82	4	≥ 3 to < 8 cms	Longitudinal
Front Seat	Left	Interior	Toe pan	127	124	3	≥ 3 to < 8 cms	Longitudinal
Front Seat	Middle	Interior	Instrument panel center	86	84	2	≤ 2 cms	Longitudinal

Occupant Injuries




Abrasion = #

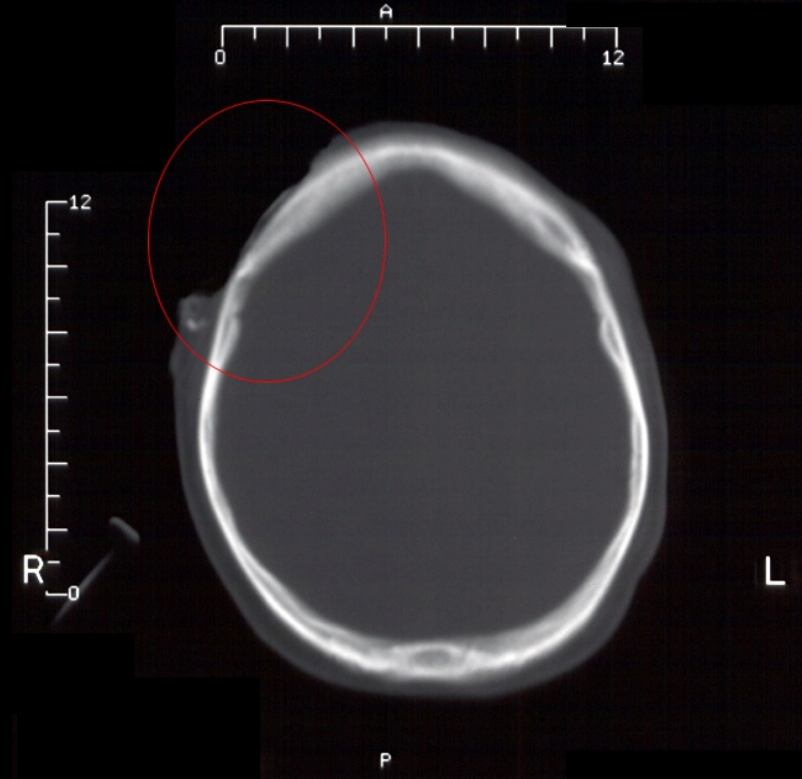
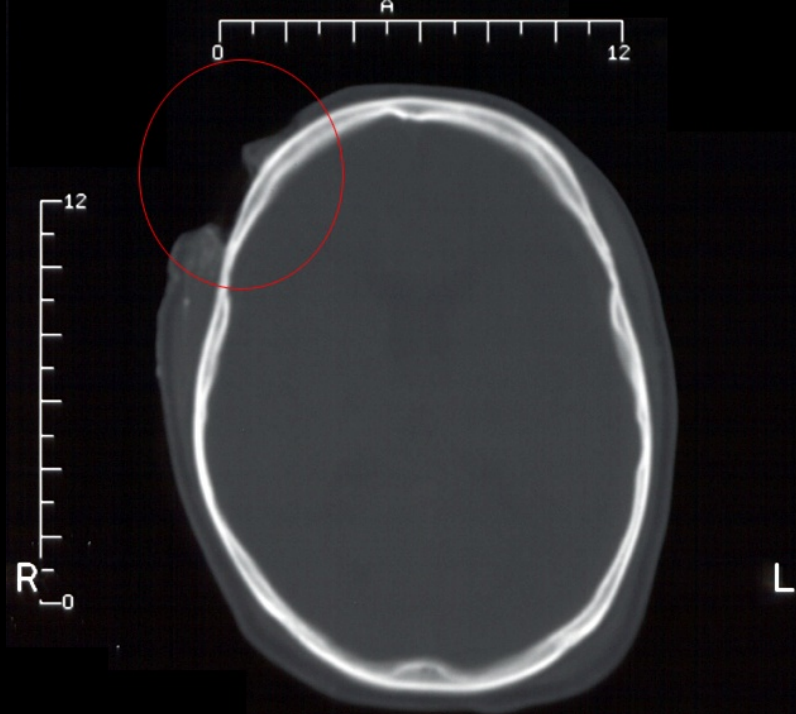
Contusion/hematoma = 

Fracture = X

Hemorrhage = 

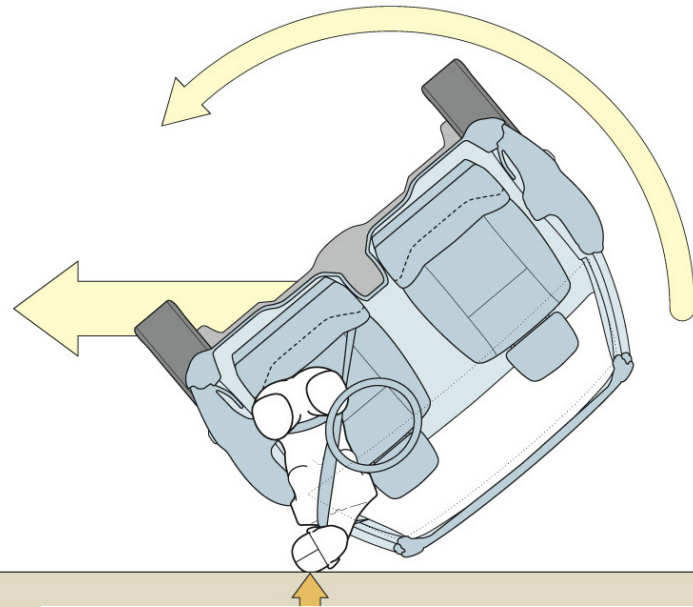
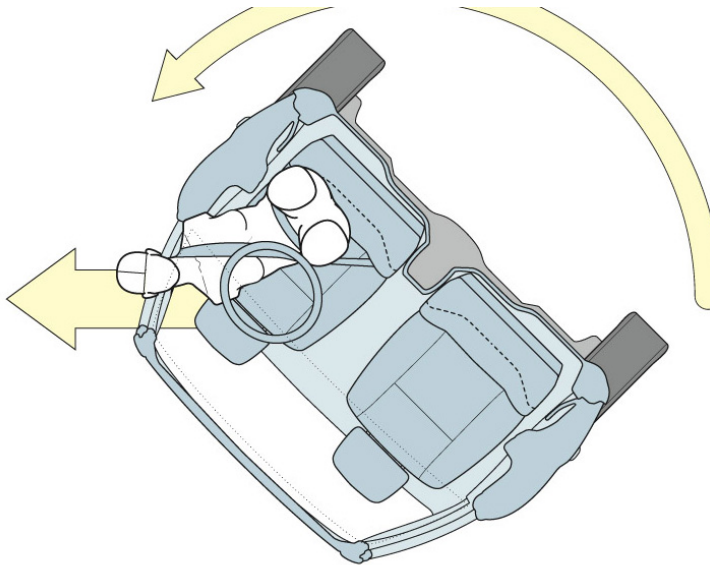
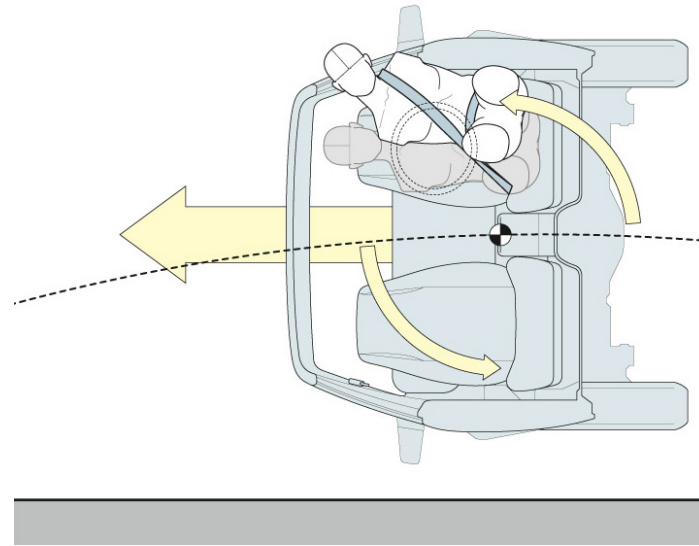
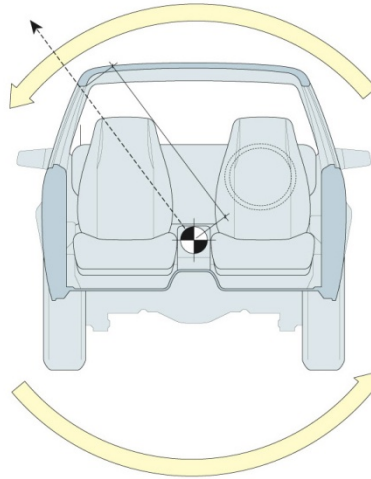
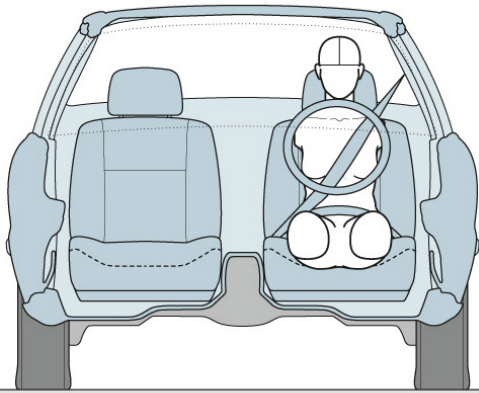
Laceration = 

AISCODE	Description	Aspect	Injury Source	Confidence	Rank
1908042	Scalp avulsion major	Anterior/Front/Ventral	Ground	Certain	1
2902021	Facial Skin abrasion	Right	Air bag-driver side	Probable	2
2904021	Facial Skin contusion	Right	Air bag-driver side	Certain	2
7524041	Finger fracture	Left	Left instrument panel and below	Certain	2
7902021	Upper Extremity Skin abrasion	Upper Arm;Left	Flying glass	Certain	2
7904021	Upper Extremity Skin contusion	Right	Roof or convertible top	Certain	2
7906001	Upper Extremity Skin laceration NFS	Left	Windshield	Certain	2
2906021	Facial Skin laceration minor	Left	Flying glass	Probable	8



**LARGE
LACERATION IN
THE SKIN OVER
THE RIGHT
FRONTAL REGION
(INBOARD)**

radial acceleration = $\omega^2 r$



Conclusions

- **Cumulative injury** for **SVME RO** as function of **QT** showed **offset & slope increase** relative to **SVSE RO**
- **Overlap** in **injury frequency** and **distribution** among SVSE, primary RO, planar, and planar + rollover (**exceptions: c-spine primary RO** and **lower limb planar**)
- **Planar events + RO** resulted in considerably more **variation** in **RO initiation object** than SVSE RO
- **Frontal + RO** had higher **odds** of **MAIS 3+ injury** than other SVME RO (OR: 1 QT – 1.4, 1-3 roof inversions 1.69-1.95)

Conclusions

- **Planar event ending SVME RO** sequence **higher odds** of MAIS 3+ **injury** (**OR**: 1 QT – 6.5, 1-2 roof inversions 1.1-1.6)
- **SVME RO Rank 1 Event** associated with **Rank 1 Injury** in **75% -85%** of CIREN cases examined
- **Planar Event Rank 1** in **57%** CIREN SVME RO cases
- **SVME RO \neq SVSE RO + Planar**
- **SVME RO are complex!**
- **We will not propose MVME RO for next year's CIREN Research Project**

“Education is the path from cocky
ignorance to miserable uncertainty”

- Mark Twain

Single Vehicle Multiple Event Rollover Crashes: NASS and CIREN Analysis



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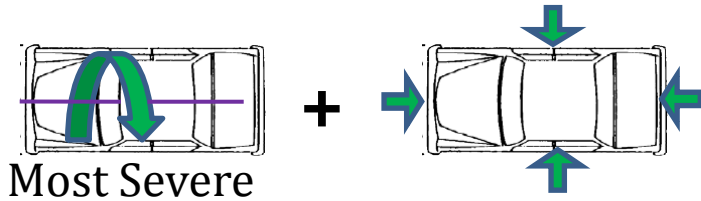
CIREN Center



Body-region Distribution (AIS 3+)

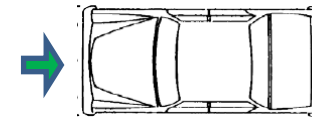
Primary Rollovers

(Object in most severe event=overturn)

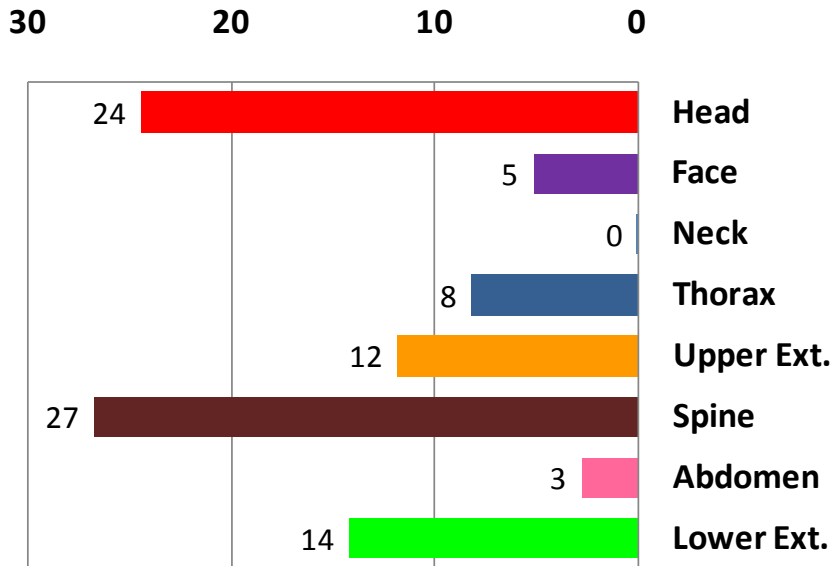


Frontal (no rollover)

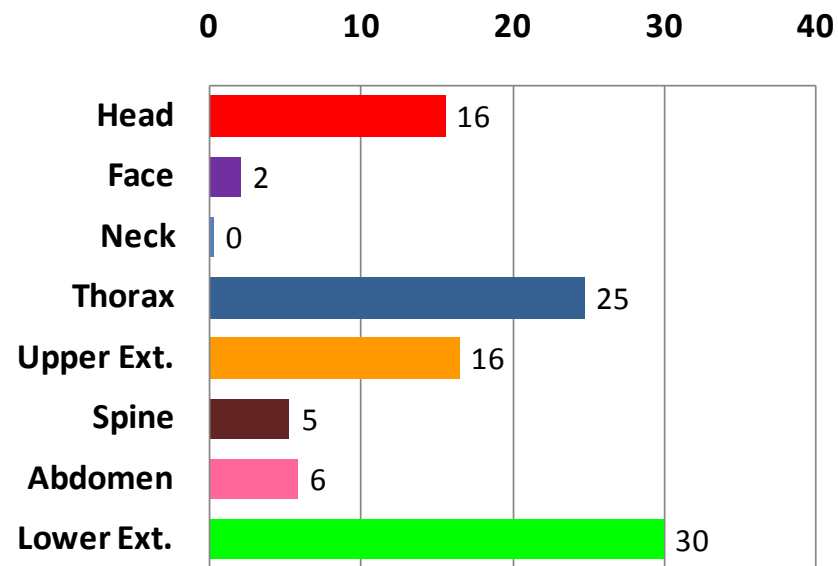
(by rank 1 general area of damage)



Percentage of all AIS 3+ injuries (%)



Percentage of all AIS 3+ injuries (%)



Top 10 AIS injury codes (AIS 3+)

Primary Rollovers

(Object in most severe event=overturn)

Frontal (no rollover)

(by rank 1 general area of damage)

AIS	Injury	Injury freq. %
3	Subarachnoid Hemorrhage	11
3	Unilateral lung contusion	7
3	C-spine facet fx.	5
4	Bilateral lung contusion	3
3	Open/displaced radius fx.	7
3	C-spine lamina fx.	3
3	Open/displaced ulna fx.	5
3	C-spine pedicle fx.	3
3	Closed humerus fx.	2
4	Small subdural hematoma	2

Cumulative freq. 48%

AIS	Injury	Injury freq. %
3	Femur shaft fx.	8
3	Open/displaced radius fx.	8
3	Open/displaced ulna fx.	5
	Tibia shaft	
3	fx.(Open/displaced)	5
3	Subarachnoid Hemorrhage	2
3	Unilateral lung contusion	5
3	Pelvis fx. (open/displaced)	3
4	Bilateral lung contusion	2
	Tibia condyle fx.	
3	(open/displaced)	4
	Thoracic cavity injury with	
3	hemo/pneumothorax	5

Cumulative freq. 47%

CIREN Case Reviews

Median=3, mode=2

30 Single Vehicle –
Multiple Event Cases
Reviewed in Detail

SVME
(30)

Rank 1 Vehicle Damage

Planar
(21)

Rollover
(9)

Rank 1 Occupant Injury

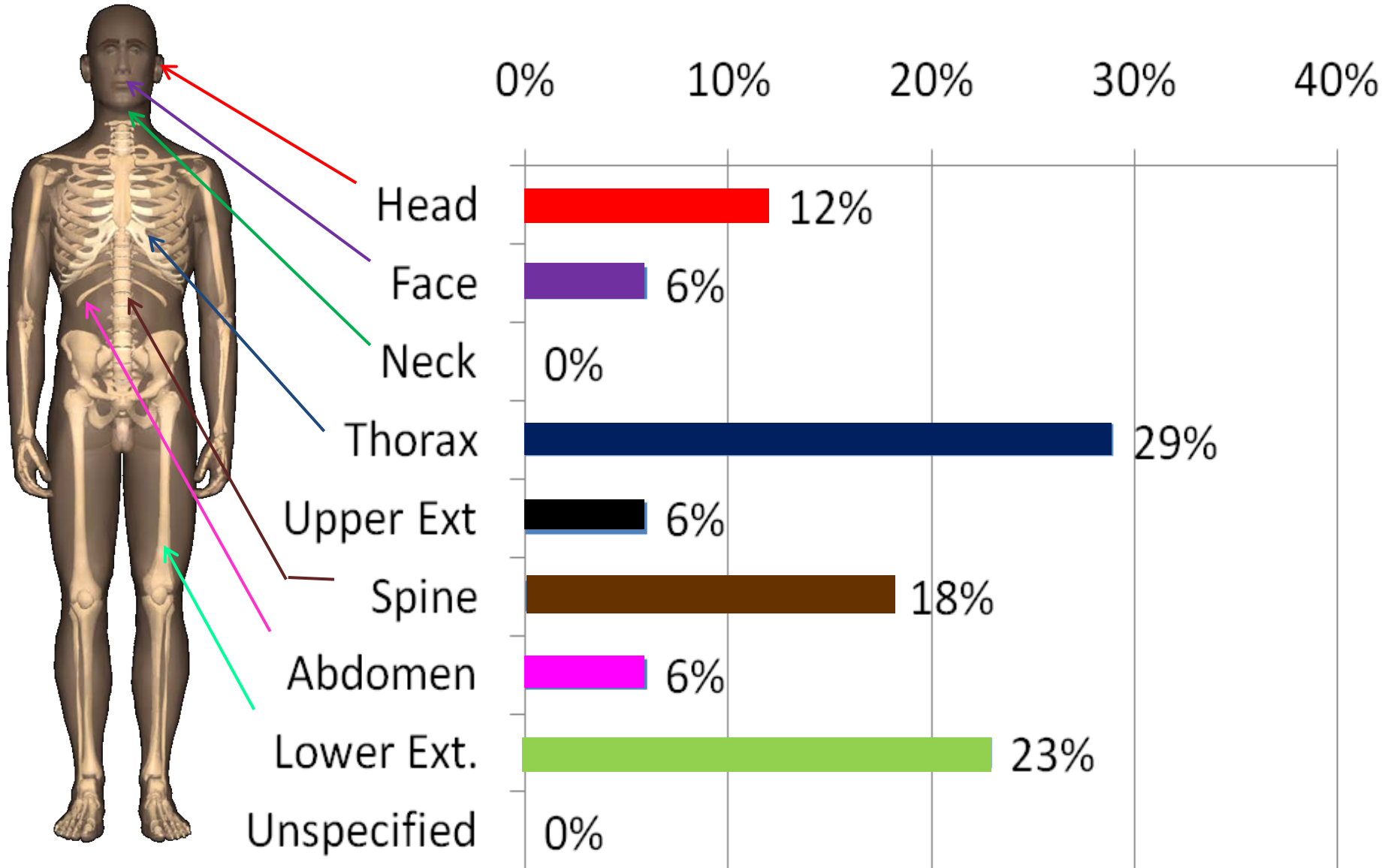
Planar
(16)

Rollover
(5)

Planar
(1)

Rollover
(8)

CIREN SVME Planar Injury (Rank 1)



* Includes partial ejections

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Median=3, mode=2

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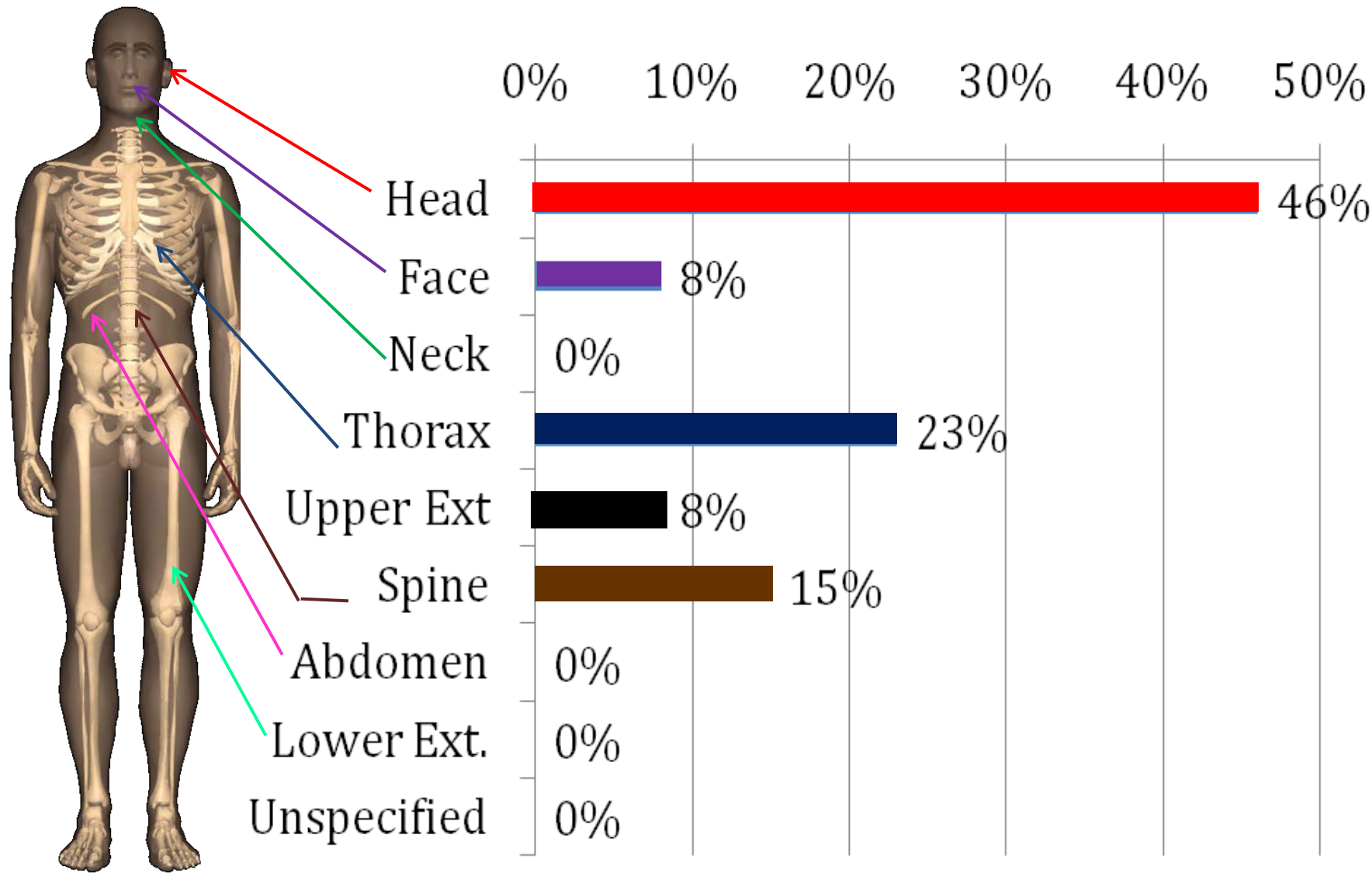
Planar
(16)

Rollover
(5)

Planar
(1)

Rollover
(8)

CIREN SVME Rollover Injury (Rank 1)



* Includes partial ejections