

Golf Car Ejection

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1

Golf Car Ejection

Golf car Type

- Golf car
- LSV - Low Speed Vehicle (Top speed 20-25 mph)
- PNV - Personal Neighborhood Vehicle
- NEV - Neighborhood Electric Vehicle

Golf Car – Maximum speed below 20[mph]

LSV – Maximum speed 20-25[mph]

2

Golf Car Ejection

Golf cars come in different styles



Golf Car Ejection

Accidents Statistics

- 1990-2006 almost 150,000 accidents
- Ejection counts to more than 45% of the injuries
- More than 25% injuries to head and neck
- Accident location
 - 70% at sports or recreational facilities
 - 15% on streets
 - 15% around homes or farms

Golf Car Ejection

Regulations/Standard

- SAE J2358 – Low Speed Vehicles
- ANSI Z130.1 – Safety Requirements for Golf Cars
- 49 CFR 571.500 - Low Speed Vehicles

5

Golf Car Ejection

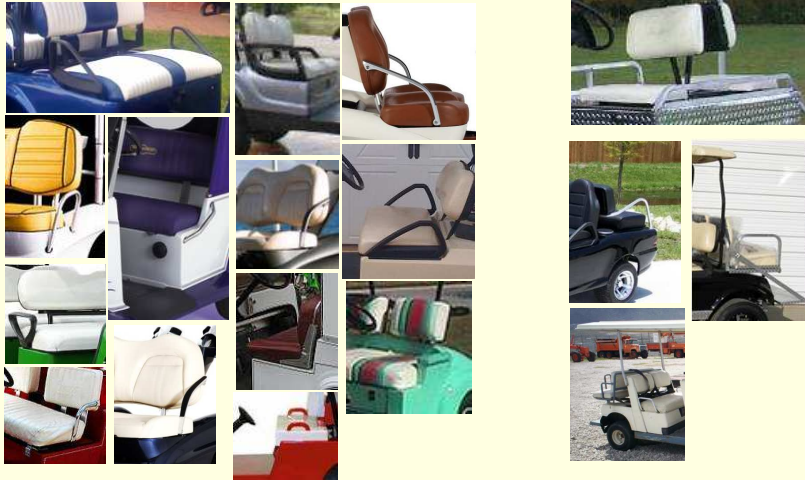
Safety Requirements - LSV

- Headlamps
- Stop lamps
- Turn signal lamps
- Tail lamps
- Reflex reflectors
- Parking brake
- Windshields of either type AS-1 or type AS-5 glazing
- Rearview mirrors
- **Seat belts**
- Vehicle identification

6

Golf Car Ejection

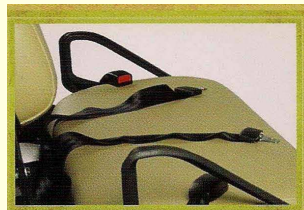
Golf cars restraints



7

Golf Car Ejection

Golf cars restraints



Many after market products

8

Golf Car Ejection

Golf cars accidents: Tip over



9

Golf Car Ejection

Golf cars accidents: Tip over



10

Golf Car Ejection

Golf cars accidents: with other cars



Golf Car Ejection

Golf cars accidents: Self – into the woods



Golf Car Ejection

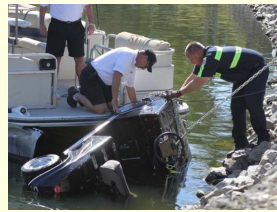
Golf cars accidents: Stupid



13

Golf Car Ejection

Golf cars accidents: Into the water



14

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Future Problems

- Number of Golf Cars increasing
- LSV can be used on city streets
- No need for license
- No enforcement to use seatbelt

15

Golf Car Ejection

Ejection is caused due to acceleration exerted on the driver and passengers during maneuvering of the car:

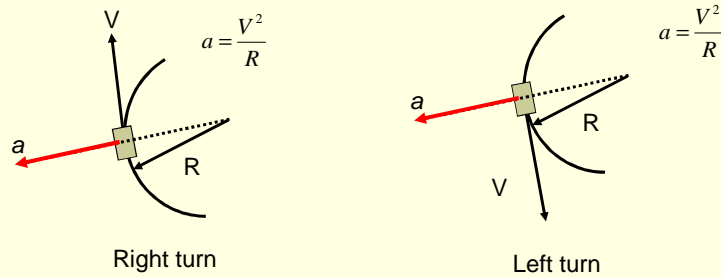
- a. High speed turning
- b. High acceleration
- c. High deceleration (hard stop)
- d. Resultant of High speed turning and High Acceleration or Deceleration

16

Golf Car Ejection

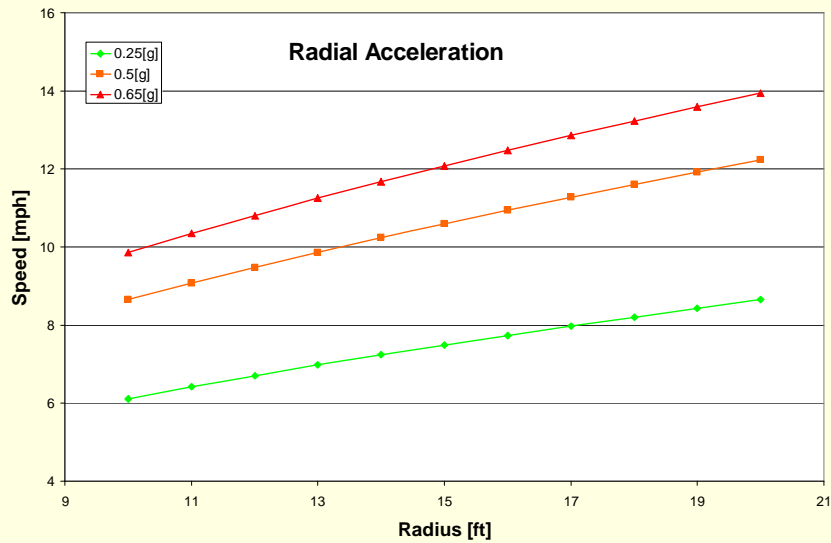
High speed turning

The maximum acceleration is limited by the coefficient of friction between the car's tires and the road (about 0.65g). If the acceleration is higher the car will skid laterally.



17

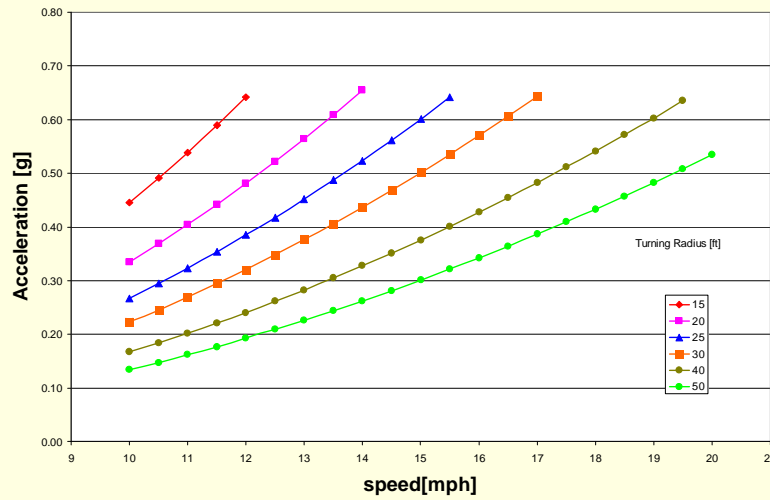
Golf Car Ejection



18

Golf Car Ejection

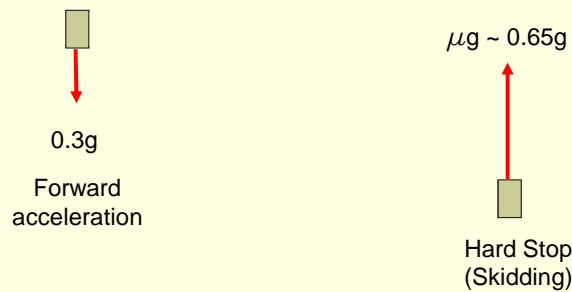
Lateral acceleration versus speed and turning radius



19

Golf Car Ejection

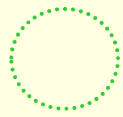
High acceleration or high deceleration (hard stop)



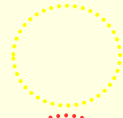
20

Golf Car Ejection

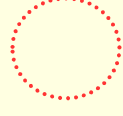
In the following the circles convey:



Low risk



Moderate risk



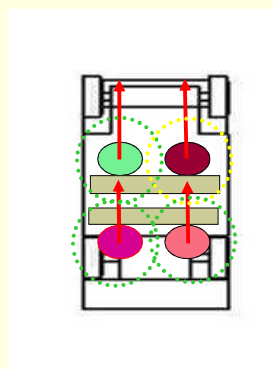
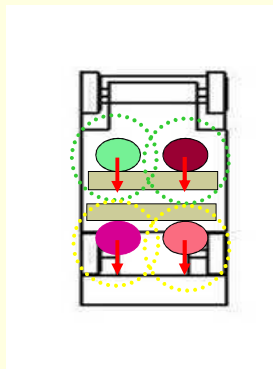
High risk

21

Golf Car Ejection

Forward
Acceleration

Forward
Deceleration

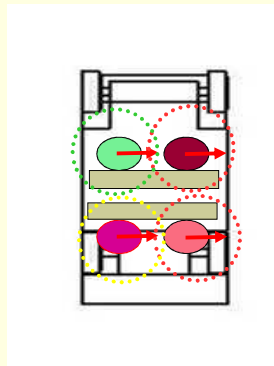
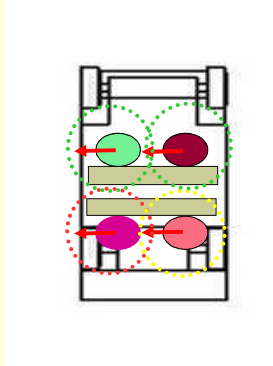


22

Golf Car Ejection

Right Turn

Left Turn

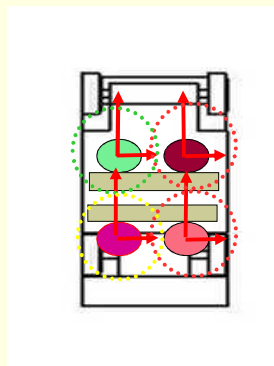
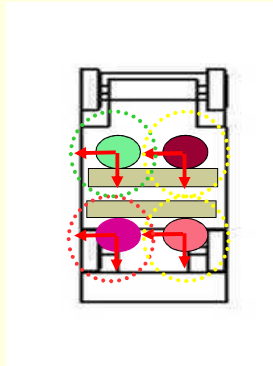


23

Golf Car Ejection

Right Turn &
Forward
Acceleration

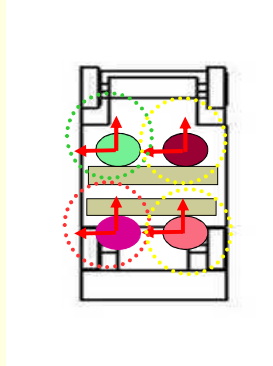
Left Turn &
Forward
Deceleration



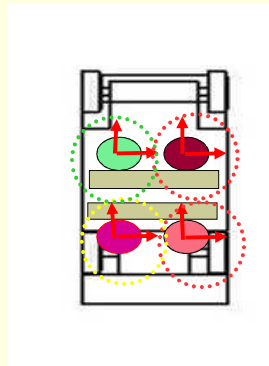
24

Golf Car Ejection

Right Turn &
Forward
Deceleration



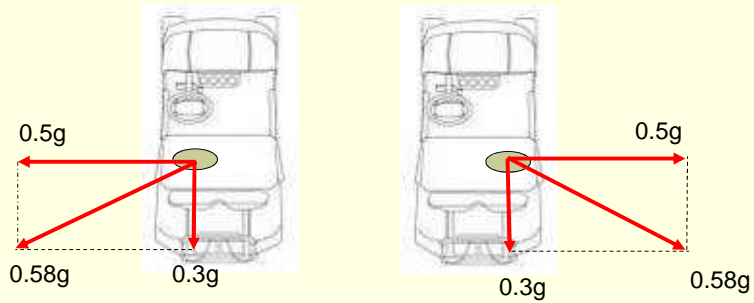
Left Turn &
Forward
Deceleration



25

Golf Car Ejection

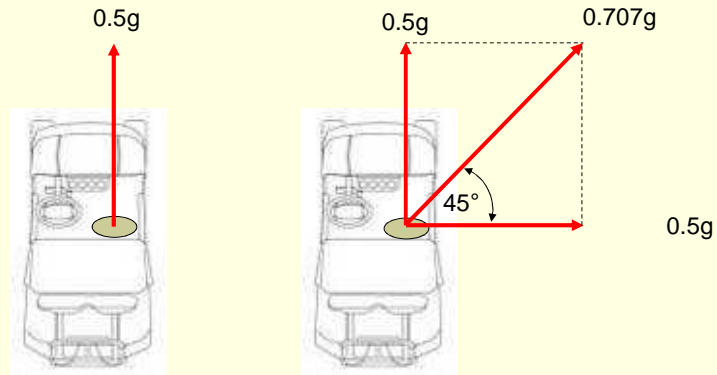
Worst cases – Rear seated passengers



26

Golf Car Ejection

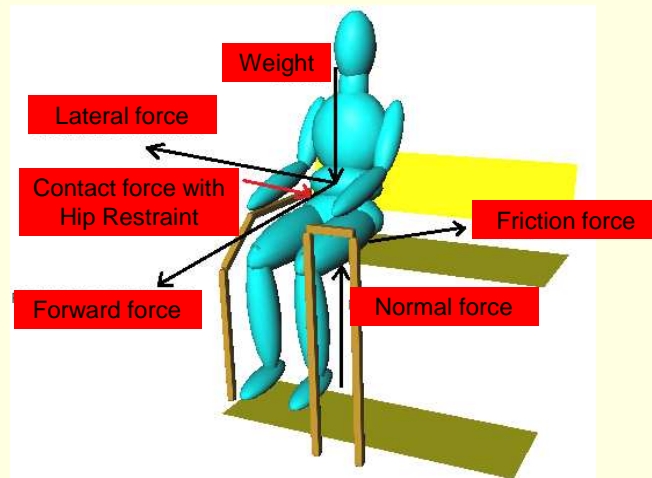
Worst cases – Front seated passenger



27

Golf Car Ejection

Forces acting on a rear seated passenger during turning and stopping



28

Golf Car Ejection

Ejection Accidents Reconstruction:

Following these steps:

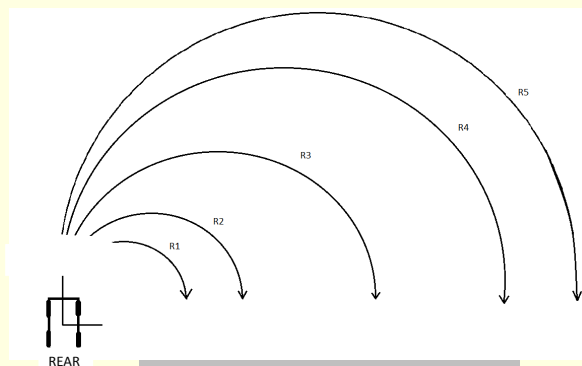
- Perform a set of experiments with the incident golf car or exemplar in which the acceleration, acting on the occupant, are measured during the same maneuvers
- Construct a three dimensional model of the golf car (ATB*)
- Construct a model of the occupants sitting in the car (GEBOD*)
- Determine the angular velocity and angular acceleration of the car.
- Apply these accelerations to the ATB+GEBOD model
- Perform the simulation and determine whether or not ejection occurs

* ATB – Articulated Total Body program

29

Golf Car Ejection

Car performance – Turning Radius



Label	Steering Wheel Turn	Turning Radius (m)
R1	540°	1.73
R2	360°	3.46
R3	270°	5.08
R4	180°	7.87
R5	90°	8.36

30

Golf Car Ejection

Car Performance – Maximum Speed

$$V = \frac{D}{T_2 - T_1}$$

31

Golf Car Ejection

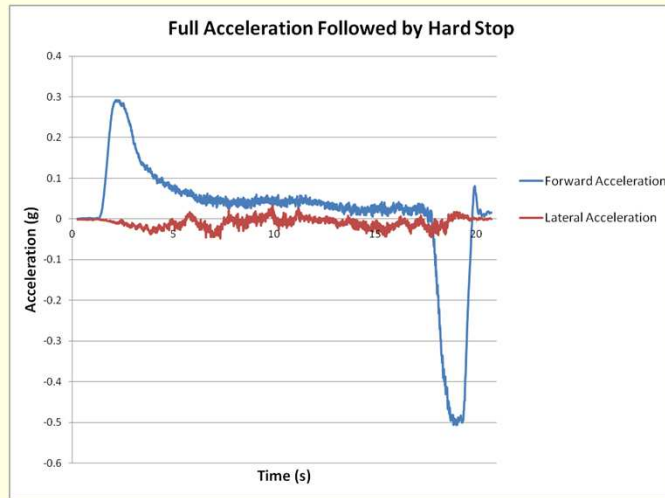
Car Performance – Maximum Forward Acceleration

Time (s)	Forward Acceleration (g)	Lateral Acceleration (g)
0	0.00	0.00
1	0.00	0.00
2	0.30	0.01
3	0.15	0.01
4	0.08	0.01
5	0.05	0.01
6	0.04	0.01
7	0.04	0.01
8	0.04	0.01

32

Golf Car Ejection

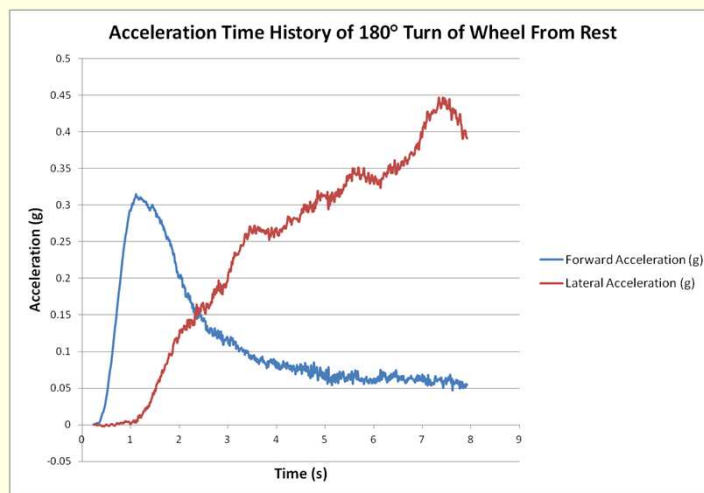
Car performance – Maximum Stopping Deceleration



33

Golf Car Ejection

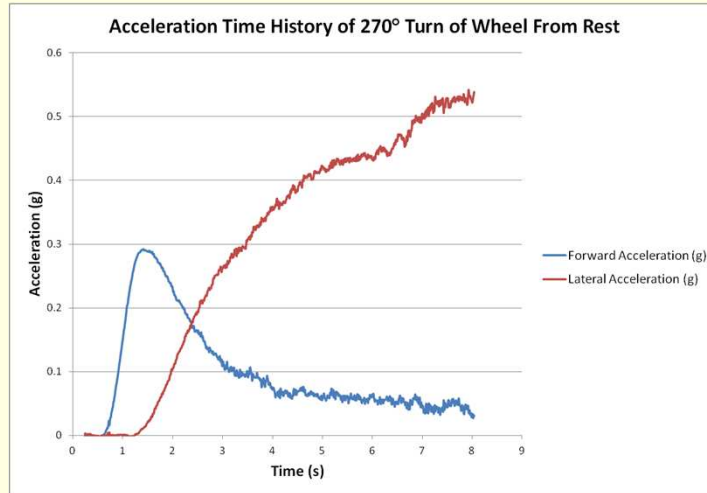
Car performance – Accelerations in turning



34

Golf Car Ejection

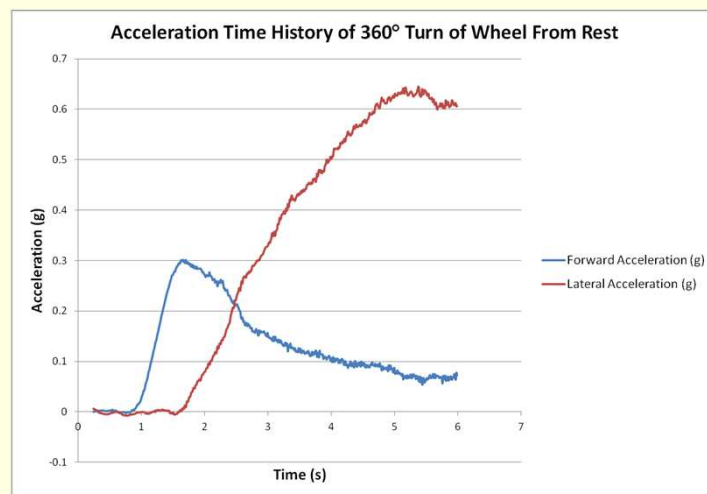
Car performance – Accelerations in turning



35

Golf Car Ejection

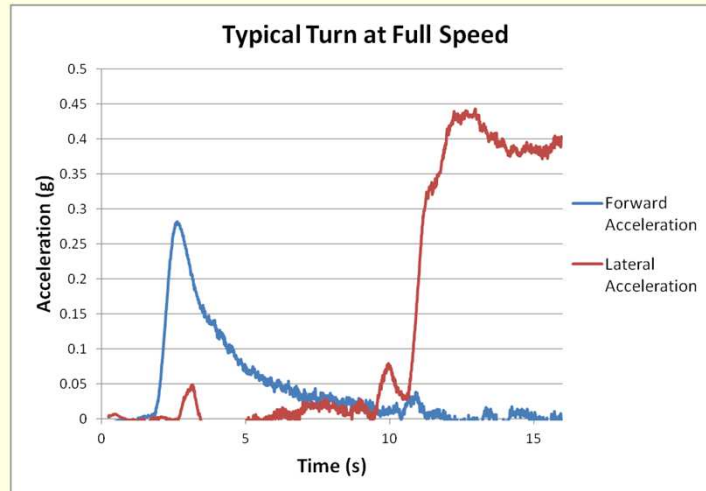
Car performance – Accelerations in turning



36

Golf Car Ejection

Car performance – Acceleration during typical turn

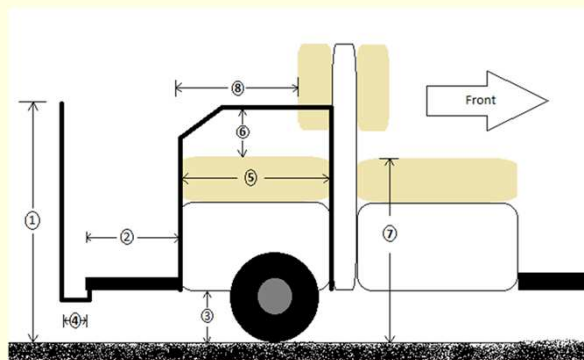


37

Golf Car Ejection

Vehicle Model

- Use measure dimensions of the incident car
- No need to model the whole car
- Properties of the seat are important:
 - Coefficient of friction
 - Seat stiffness

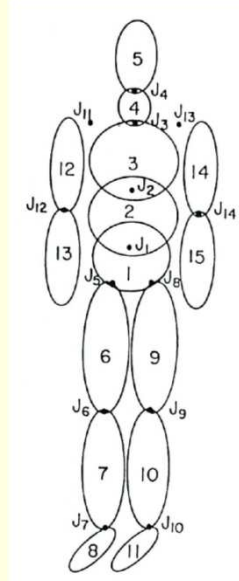


38

Golf Car Ejection

Occupant Model

- Use Generator of Body Data Manual (GEBOD)
- Input: Gender, Weight and Height
- Program generates all properties of a human model consists of 15 ellipsoids and 14 joints (better model will include hands)
- Properties include: Weight, Inertia, Joints properties

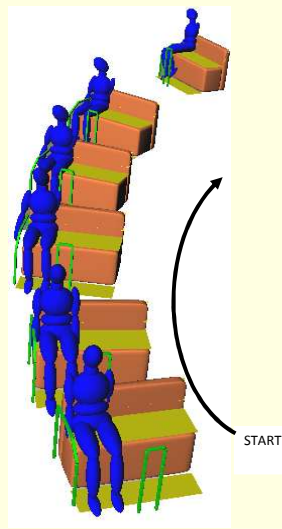


39

Golf Car Ejection

Example - I

Moderate Turning
 $R=8.36[m]$ (27.4[ft])

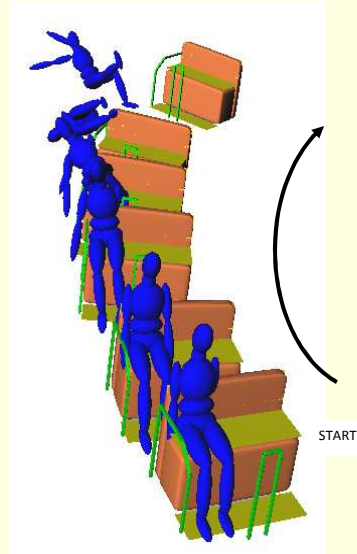


40

Golf Car Ejection

Example - II

Moderate Turning
 $R=8.36[m]$ (27.4[ft])

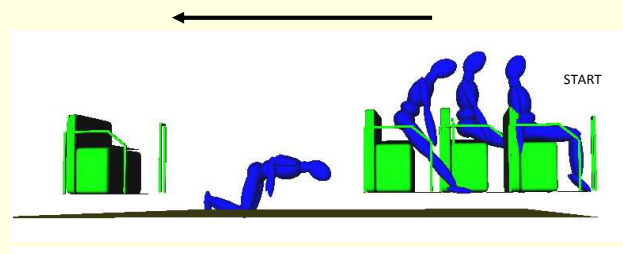


41

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Example - III

Forward Acceleration

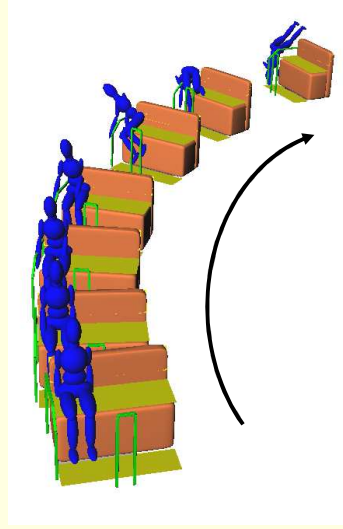


42

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Example - IV

12 year old child



43

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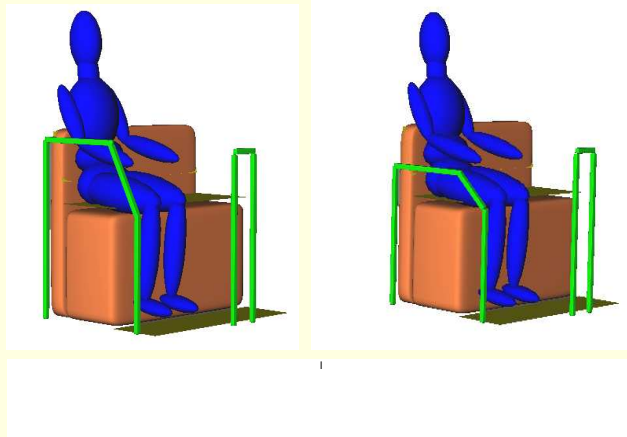
Simulation Results

Radius [ft]	Results	Time to Ejection (ms)
5.32	Ejected	950
10.65	Ejected	1200
15.64	Ejected	1450
24.24	Ejected	1500
25.75	Not Ejected	N/A

44

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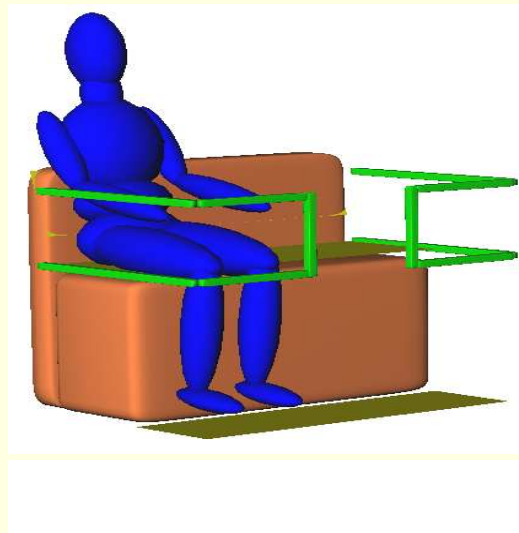
Hip Restraint Modification



45

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Rear Seats Restraints



46

Golf Car Ejection

Recommendations

- No Low Speed Vehicles on city streets
(Their crash resistant is inferior to smallest passenger car).
- Require licensing or minimum training
- Require seat belts and enforce their use in particular in neighborhoods and facilities.
- Improve restraints