

Analysis & Reconstruction of Bicycle Accident Fatalities

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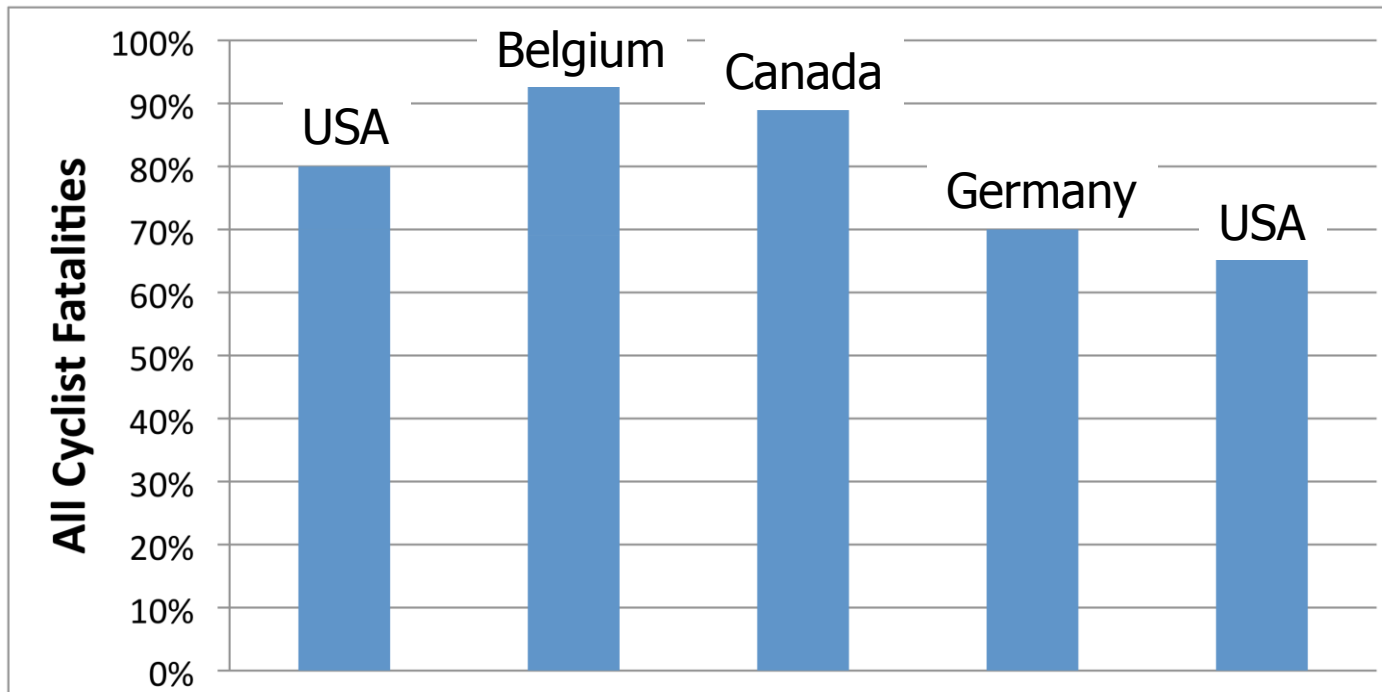


Údarás Um Shábháilteacht Ar Bhóithre
Road Safety Authority



Background

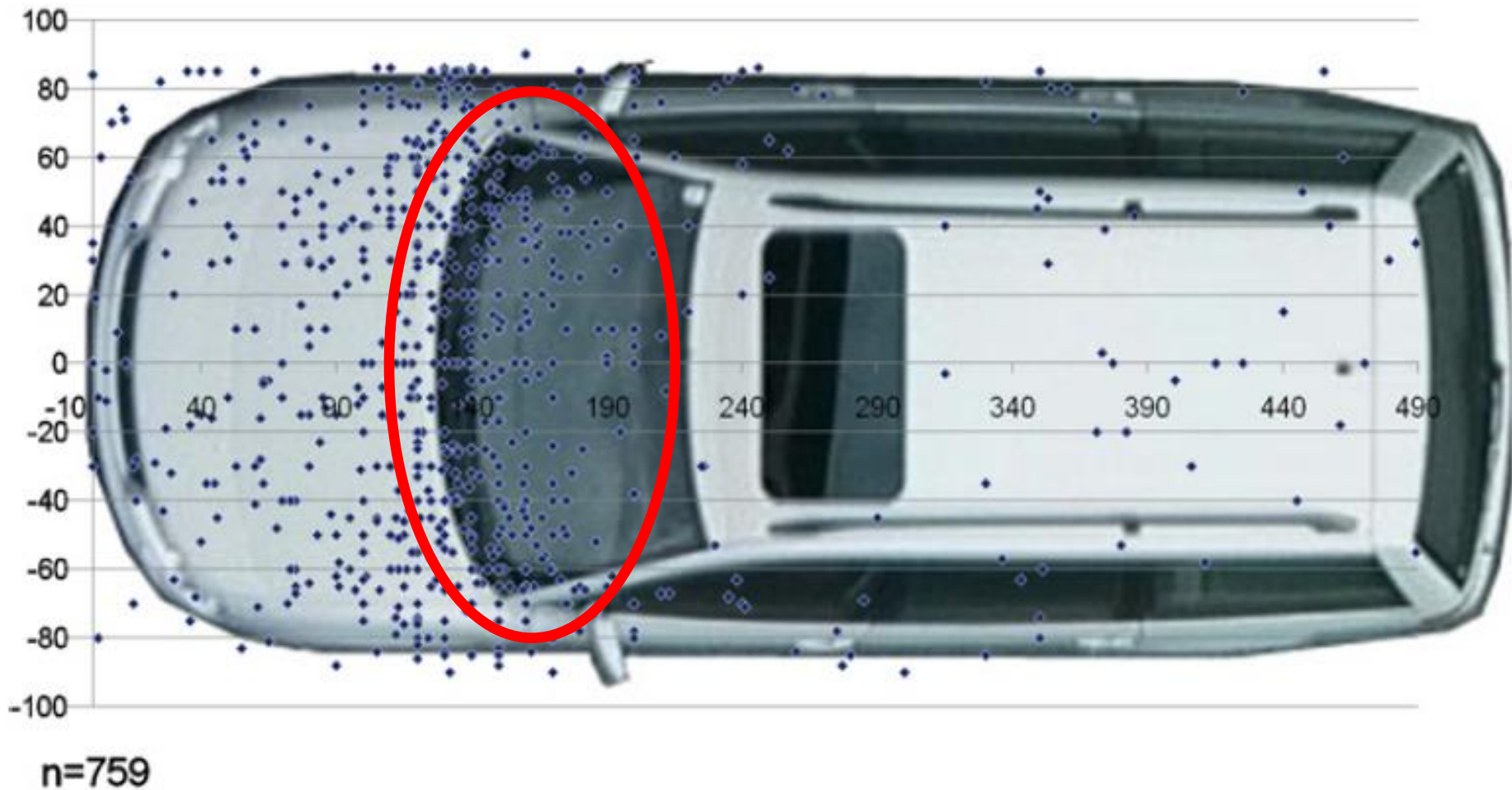
- The majority of cyclist fatalities are a result of collisions with motor vehicles
- Traumatic head injuries are the primary injury mechanism in cyclist fatalities



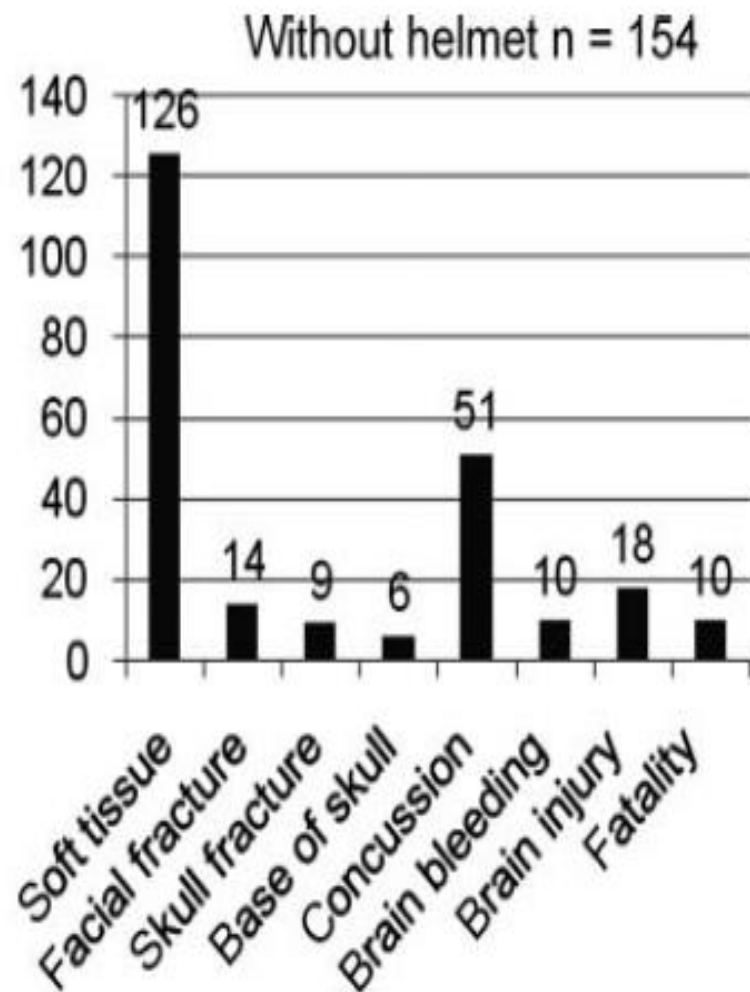
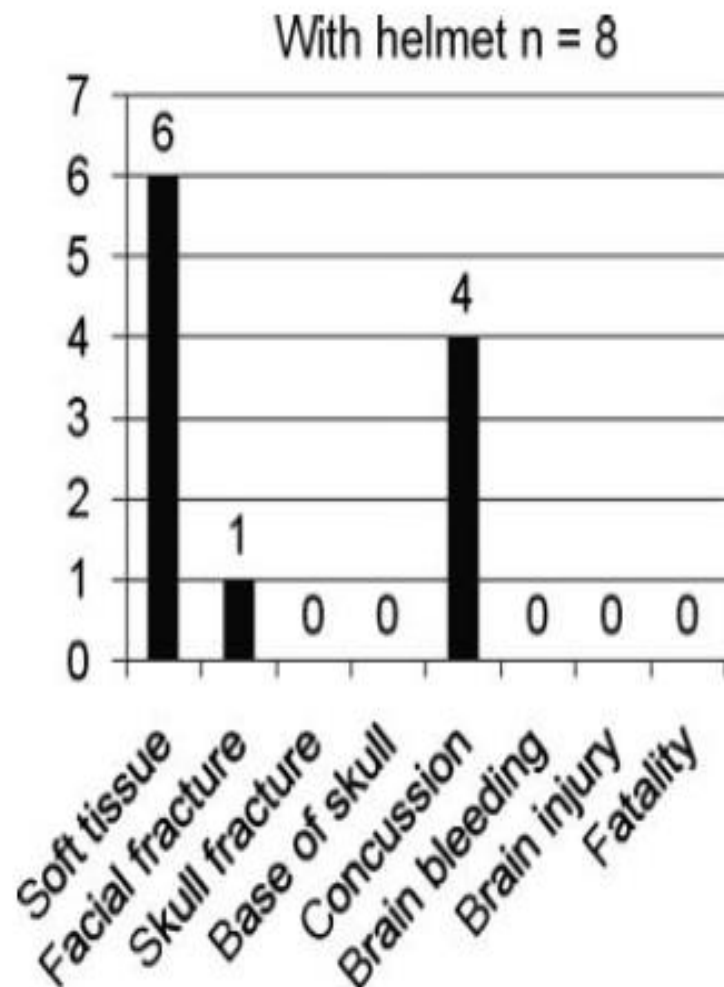
GIDAS: German In-Depth Accident Study

- Otte (Hannover) examined relationship between motor vehicle collisions and resulting head injuries
- Database of all traffic accidents in Germany from 1999 to 2008
- Consists of accidents/collisions involving 8204 Vulnerable Road Users (VRUs)
- Includes Pedestrians (25%), Cyclists (48%) and Motorcyclists (27%)

Head Impact Points of Vulnerable Road Users (AIS Head 3+)



Cyclists' head injuries following collision with motor vehicles



Bicycle Helmets

- Only direct head protection available to cyclists
- Typically composed of Expanded Polystyrene (EPS) liner, shell, restraint system and padding
- Must satisfy European Standards EN 1078 and EN 1080 in drop tower tests:
 - Linear drop with a 5kg headform
 - Withstand 250g to “pass”

UCD's RSA Project

- Analyse kinematics of cyclist-motor vehicle collisions: Helmeted Vs Non-helmeted
- Investigate effects of primary and secondary impacts:
 - 1: against vehicle
 - 2: subsequently against ground
- To examine how the velocity and orientation of the collision affect helmet performance

Case Database

- 37 cases provided by An Garda Síochána ('98—'08)
- All cyclists sustained fatal injuries as a result of the motor vehicle collision
- 25 males and 12 female cyclists
- 21 cyclists were ≥ 55 years old
- 8 cyclists were ≤ 18 years old
- 8 other cyclists were aged between 19-54

Case Information

- Information as per Accident Investigation Reports
- This was used to reconstruct cases using Madymo software
- Information included:
 - Eye witness testimonies from drivers and bystanders
 - Vehicle damage reports for bike and motor-vehicle
 - Medical Examiner post-mortem reports
 - On site sketches, measurements and photographs

General Circumstances of Accident

Mr. [REDACTED] was cycling his black Raleigh Bicycle from [REDACTED] towards [REDACTED] to his home at [REDACTED]. It was a **wet** very windy evening and Mr. [REDACTED] was cycling in to a very strong headwind. Witnesses have stated seeing Mr. [REDACTED] a short distance from the accident site struggling against the wind and **cycling in the middle of the road**

Mr. [REDACTED] was wearing a black coat, cap and dark pants and wellingtons at the time of the accident. Tests have shown that he had no working lights on his bicycle and only a small circular red reflector on the rear mudguard of the bicycle. The road was black tarmac with no road Markings. Mr. [REDACTED] was travelling home from work in his van, **Caddy Van 97** [REDACTED] and [REDACTED], [REDACTED] was his passenger. He was also travelling in the direction of [REDACTED]. He was travelling on his correct side of the road. He failed to see Mr. [REDACTED] on his bicycle and he **struck him with the front centre of the** [REDACTED]. He

struck the back of the bicycle and Mr. [REDACTED] **thrown up onto the bonnet and roof** and roof and when [REDACTED] **braked he fell down again in front of the van**

Mr. [REDACTED] left a **brake mark of 49 ft. from when he started breaking until his**

vehicle stopped [REDACTED] and his passenger have stated that there was no vehicle coming towards them at the time of the accident. It was **raining slightly**

Autopsy Report

HISTORY:

He was hit by a car while cycling on a dark morning at 6:00 am approximately on the 18th of September, [REDACTED]. He was brought in dead to [REDACTED] Mortuary.

EXTERNAL EXAMINATION:

The body was that of a bearded middle aged caucasian male 5' 7" height and weighing an estimated 14 stone. There was a closed fracture of the lower left leg (tibia and fibula). A skin wound on left forehead 5cm in length lacerated wound on the occiput of the scalp 5cm

SEAN CANNON DECEASED
Sections of the internal organs, heart, lungs, spleen and both kidneys were within normal.

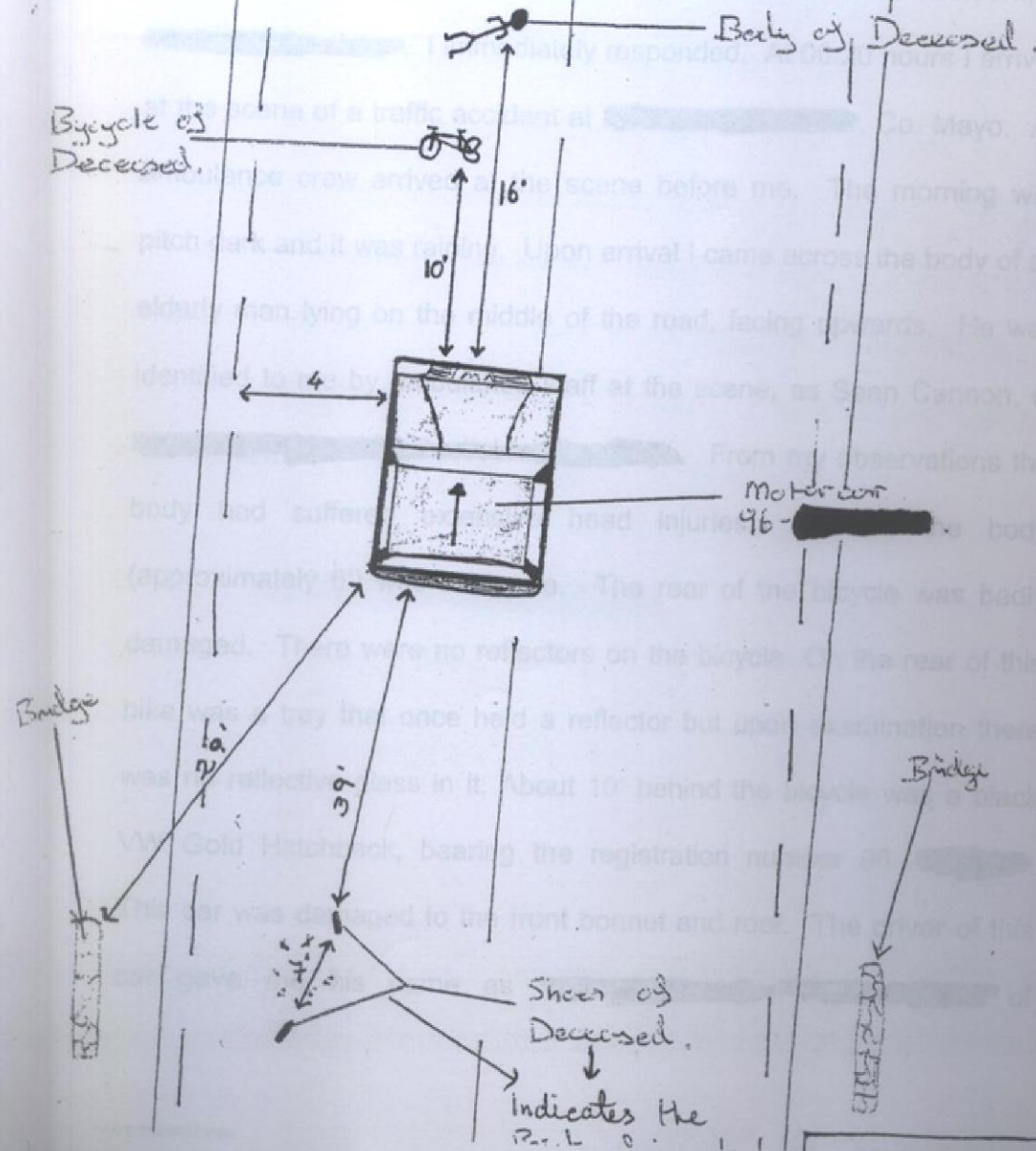
Liver: Sections of the liver showed in addition to the macerated area extensive parenchymal haemorrhages.

CONCLUSION AND CAUSE OF DEATH:

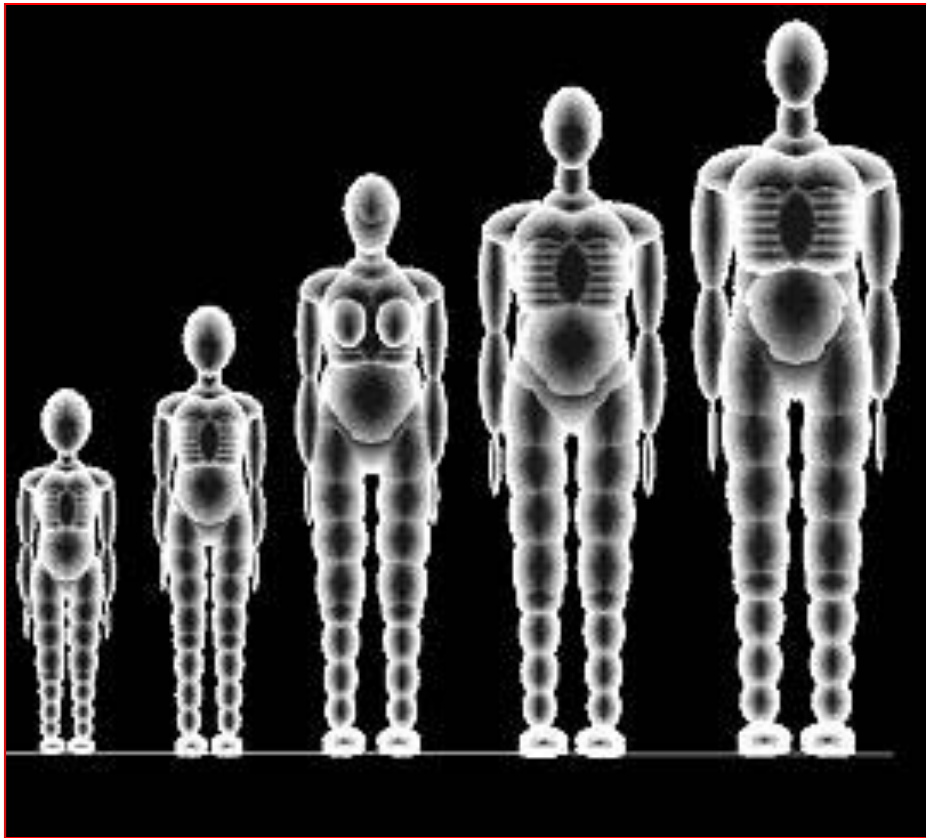
Death was due, in my opinion, to multiple injuries and profuse blood loss, consistent with a road traffic accident



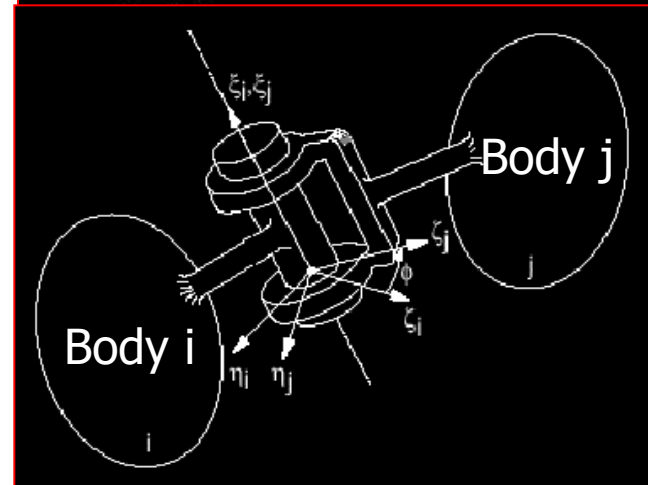
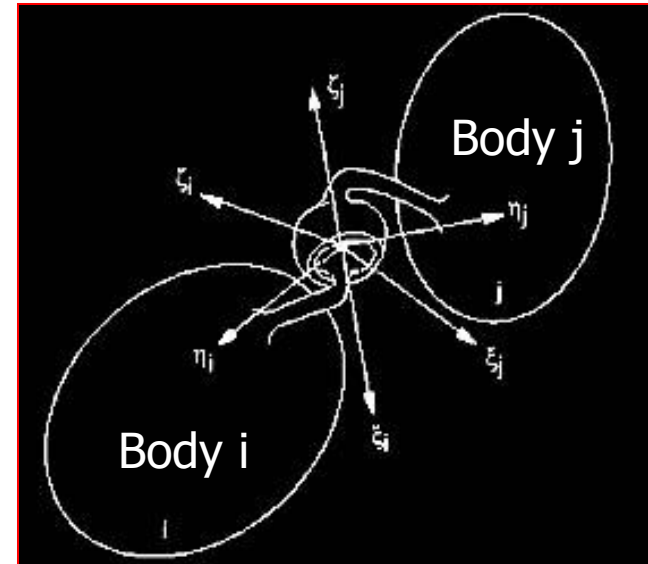




Computational Multibody Dynamics



MADYMO pedestrian models: 64 ellipsoidal bodies



Spherical Vs rotational joints
kinematic stiffnesses

Linear Vs Angular Motion

Force:
causes
translational
motion

$$F = m a$$

Mass

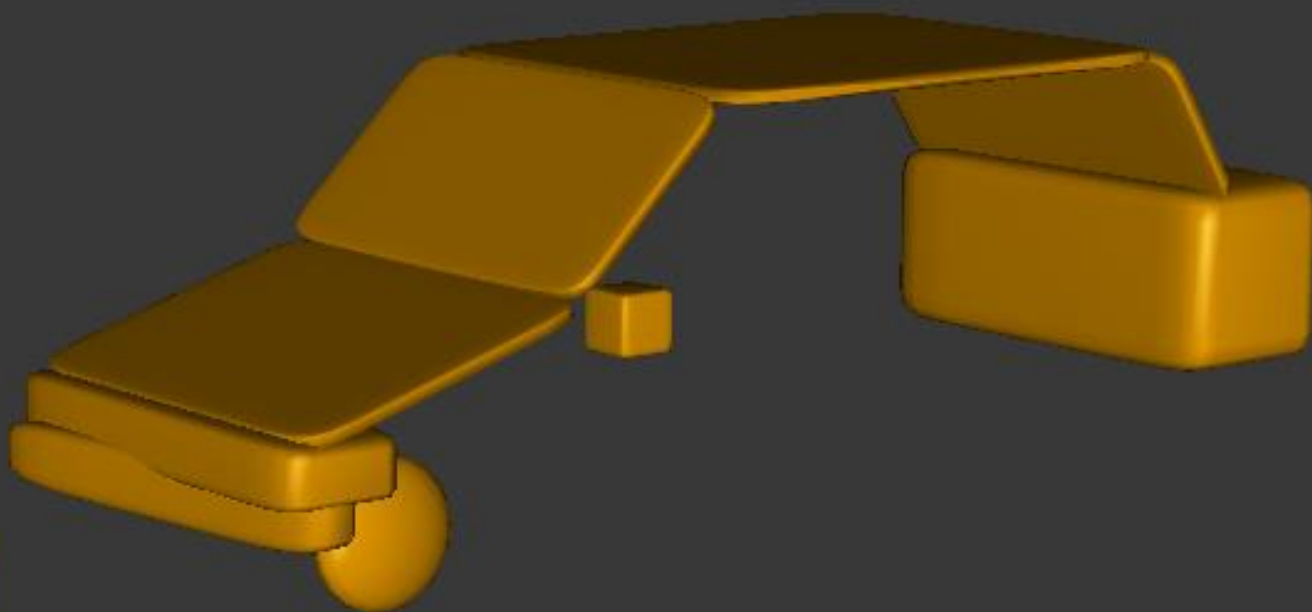
Linear
acceleration

$$M = I \ddot{\theta}$$

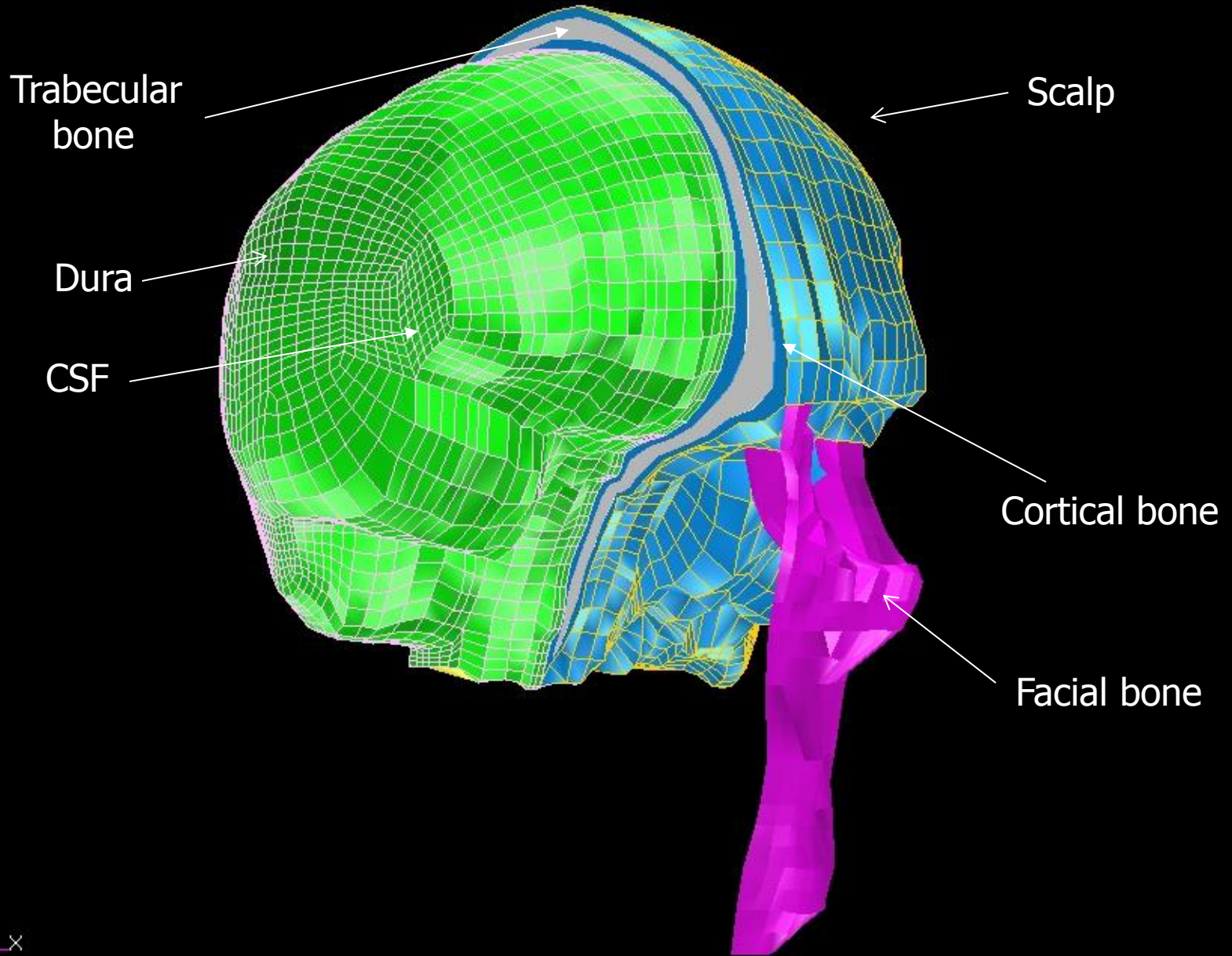
Moment:
causes
rotational
motion

Moment of
Inertia of a
mass

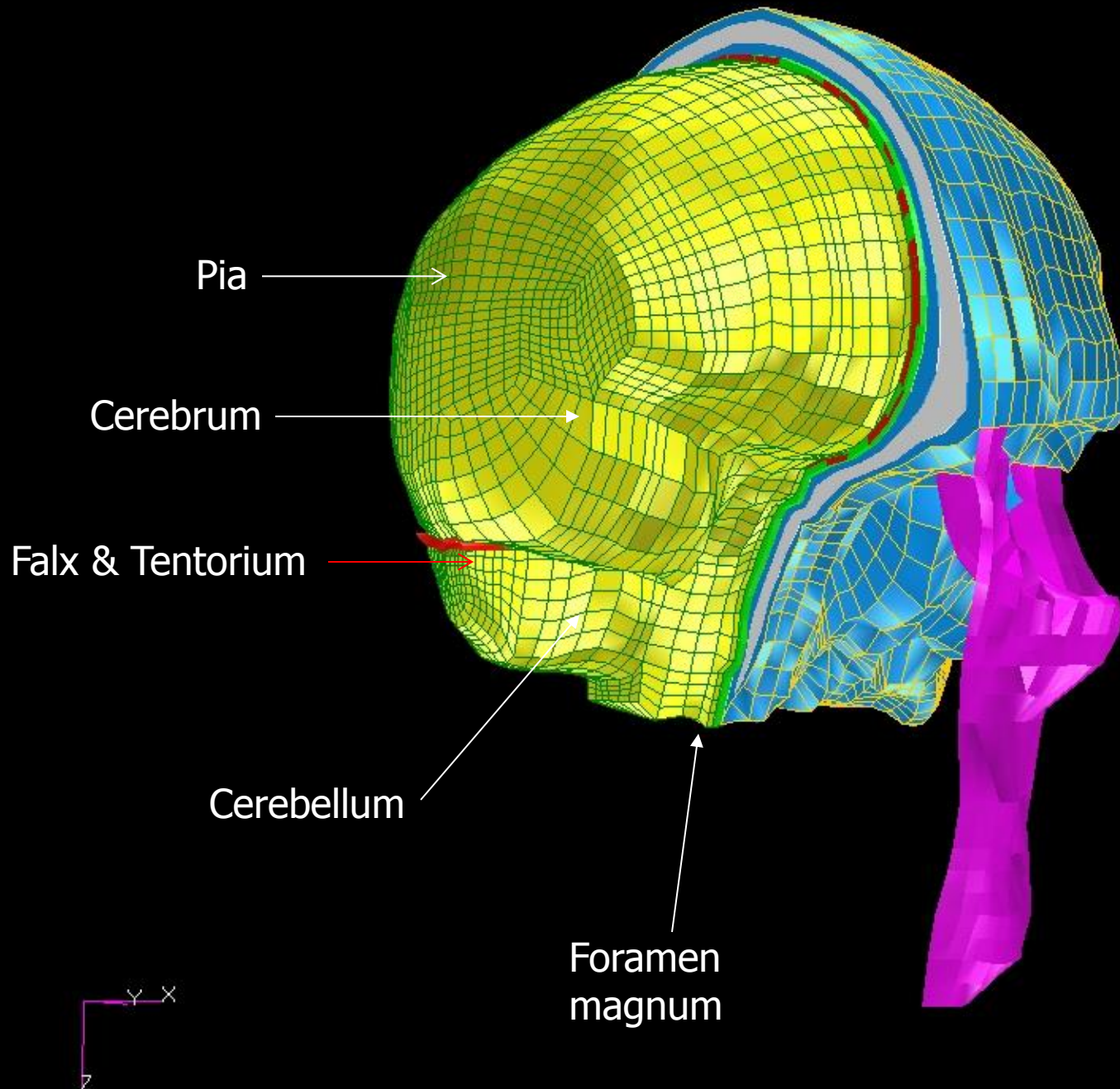
Angular
acceleration



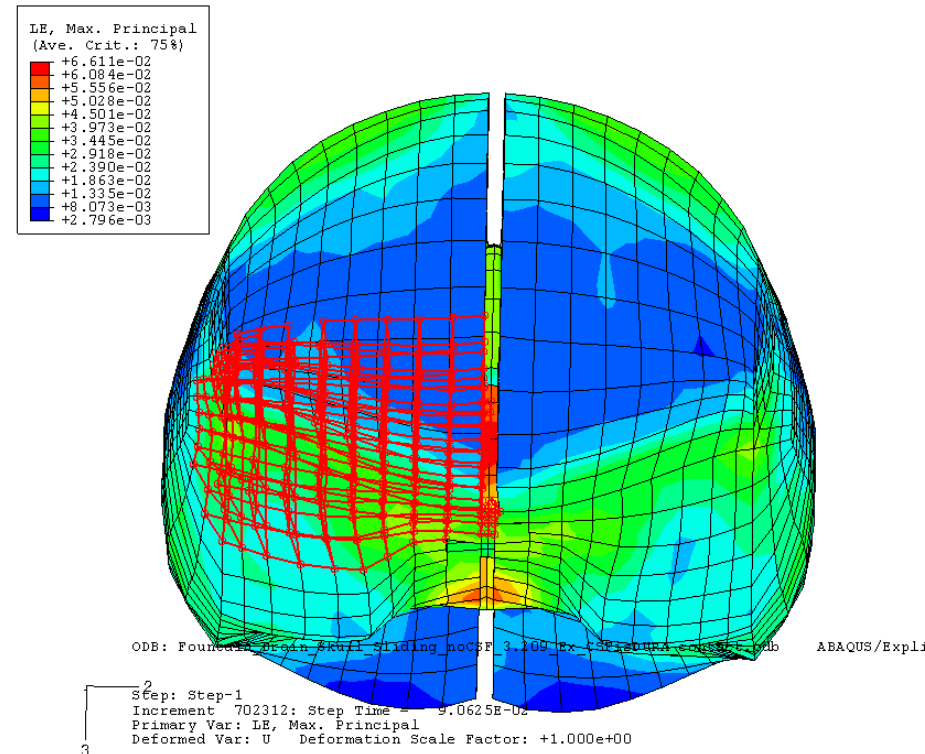
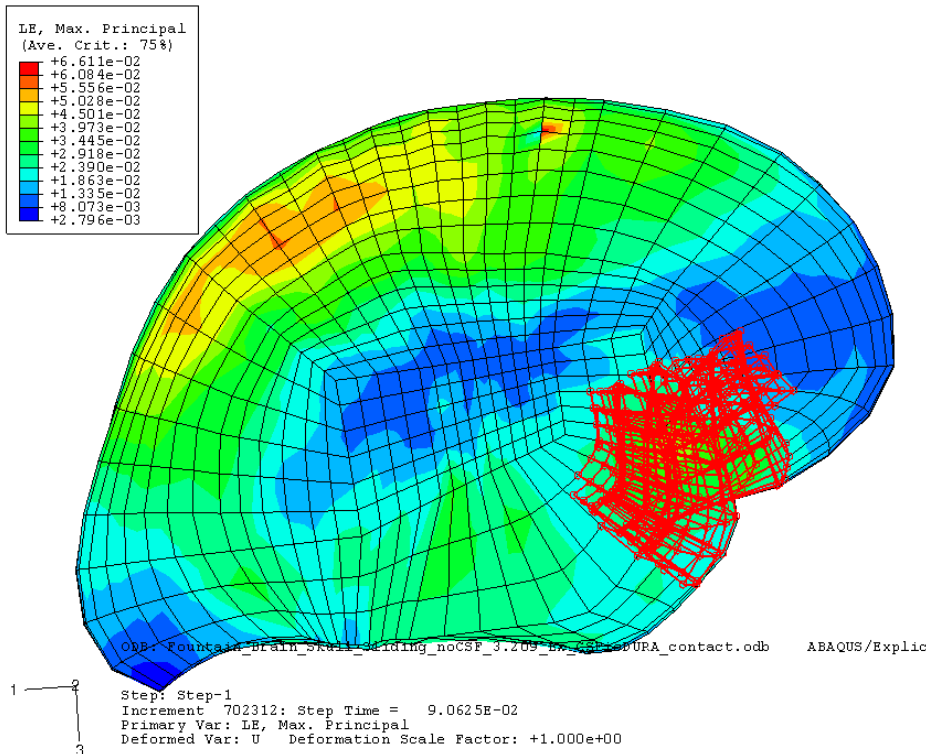
UCD Brain Trauma Model



UCD Brain Trauma Model

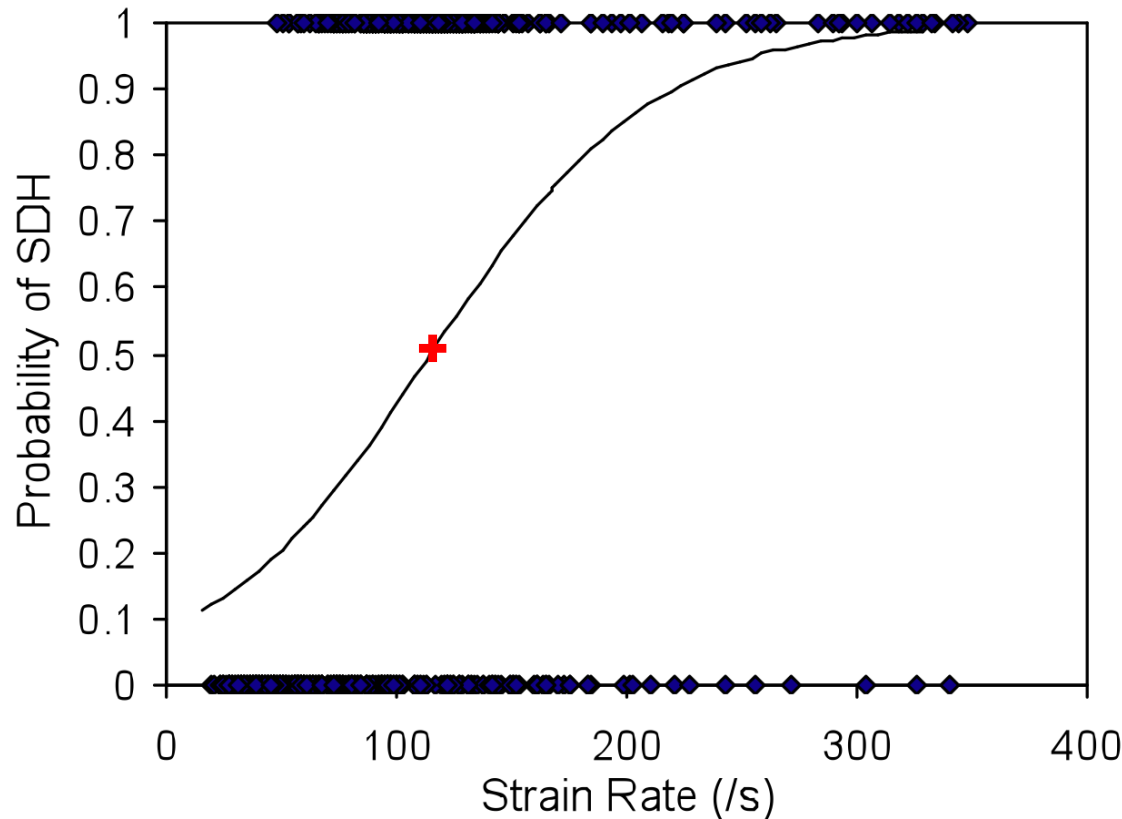


UCD Brain Trauma Model



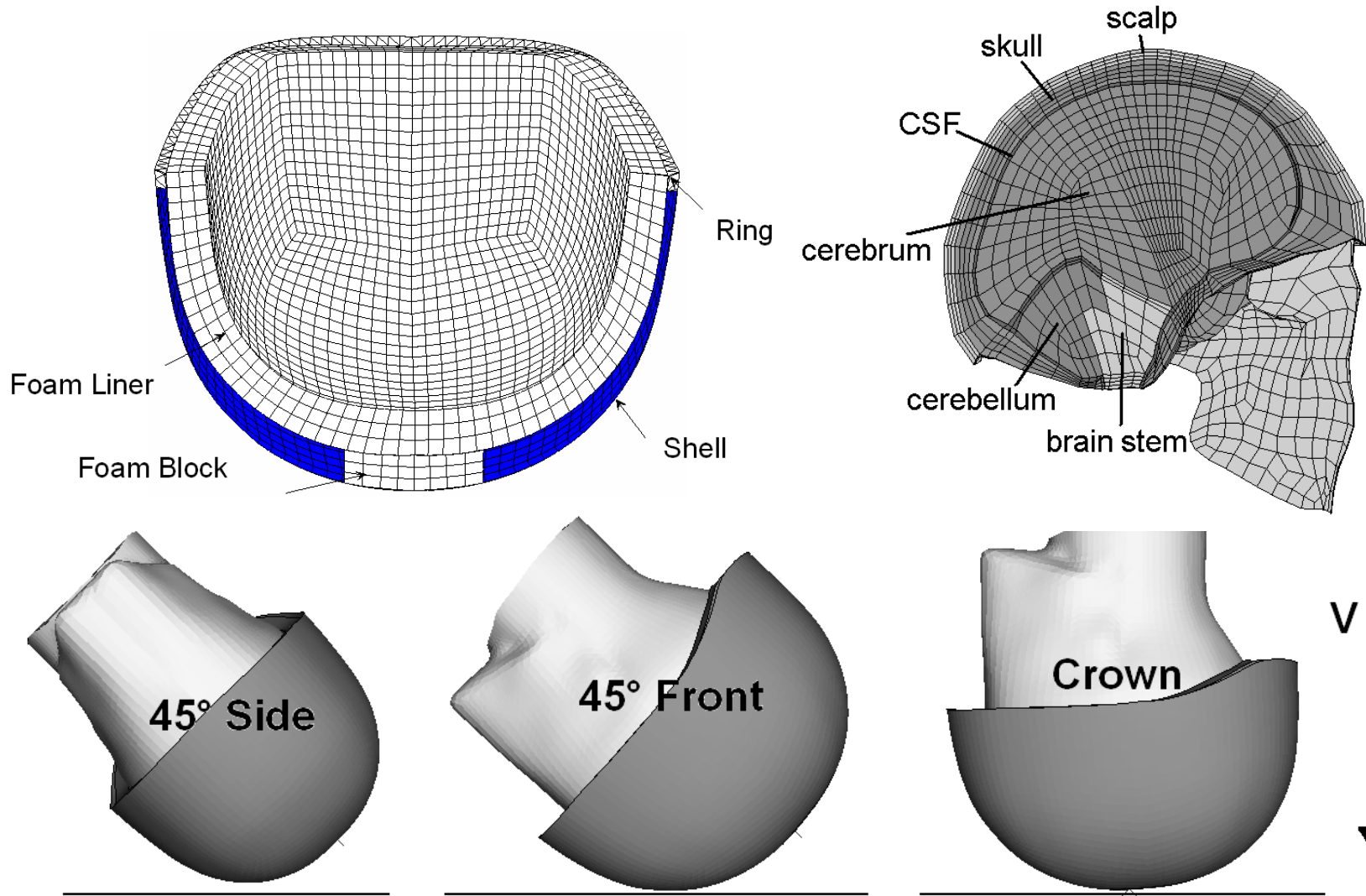
Case: Boy Fainting (Haemorrhage)

Injury Risk Curves: SDH (8x)



Parameter	50% Prob
Von Mises (kPa)	11
Strain	0.226
Strain Rate (s ⁻¹)	115
Product (s ⁻¹)	24.2

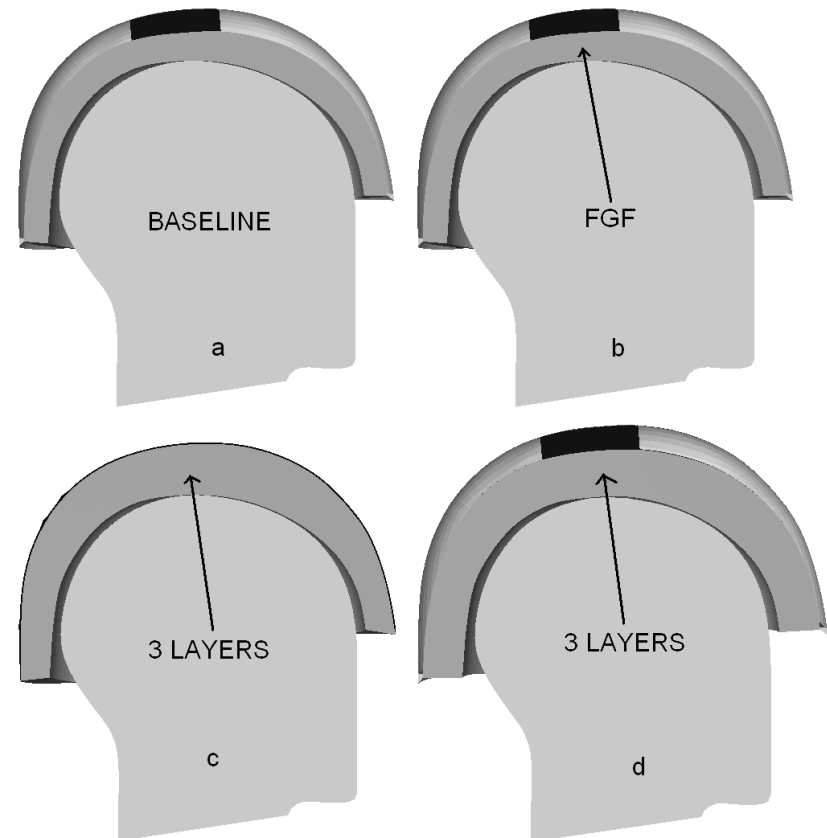
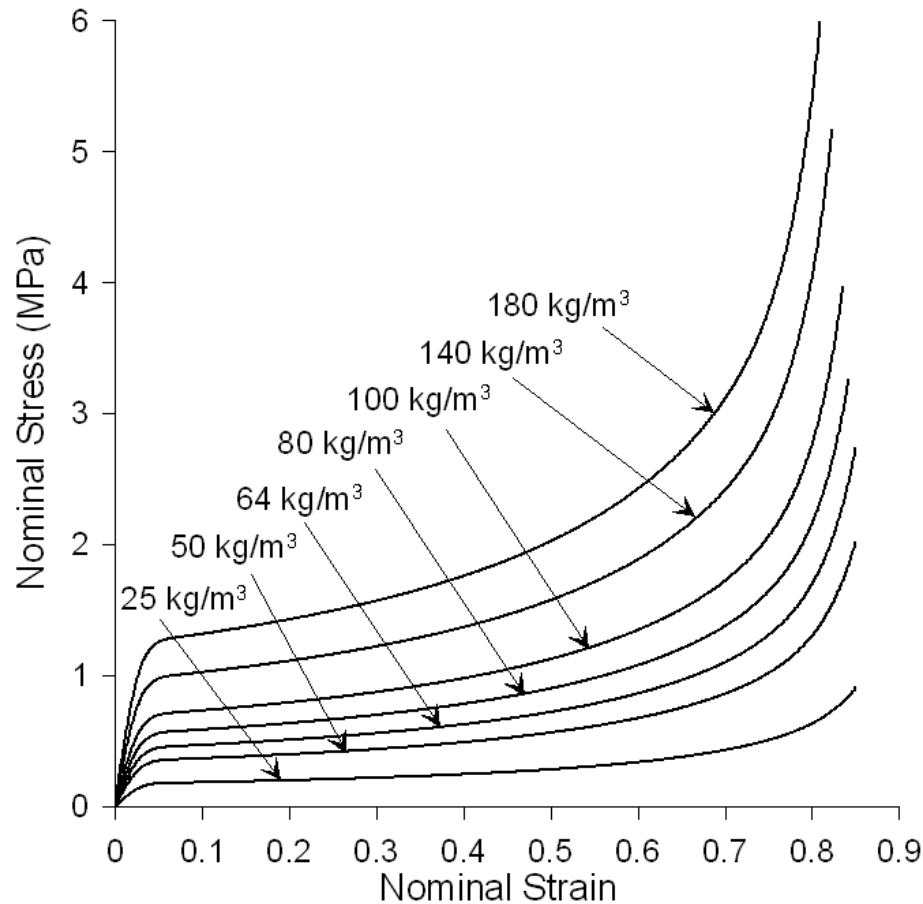
Aspects of Helmet Design



Forero Rueda, M.A. et al., Optimisation of energy absorbing liner for equestrian helmets. Part I: Layered foam liner. *Journal of Materials & Design* **30** (9) pp. 3405-3413 (2009)

Forero Rueda, M.A. et al., Finite element modelling of equestrian helmet impacts exposes the need to address rotational kinematics in future helmet designs. *Computer Methods in Biomech and Biomed Engng* **14**(9) pp. 1021-1031 (2011)

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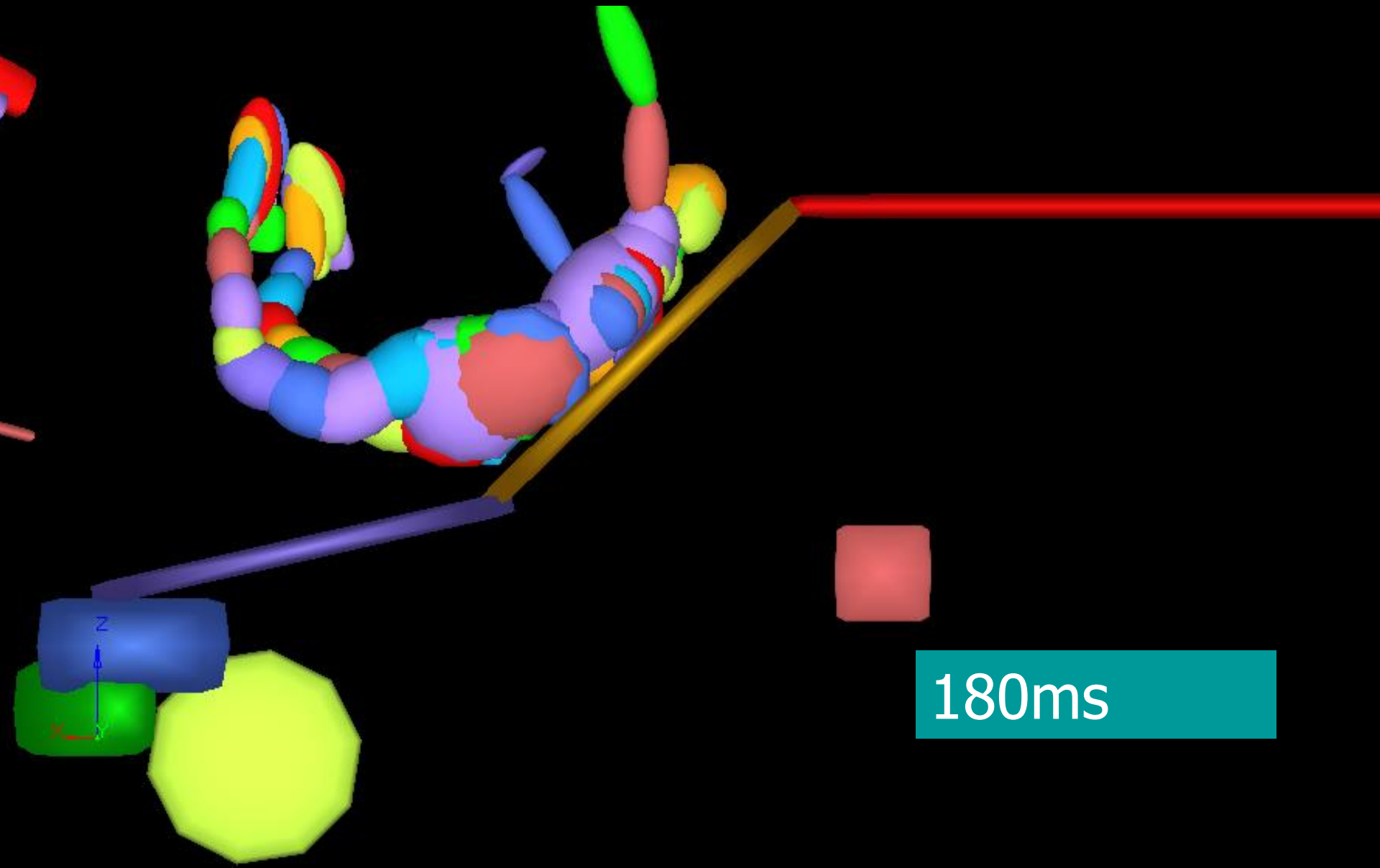


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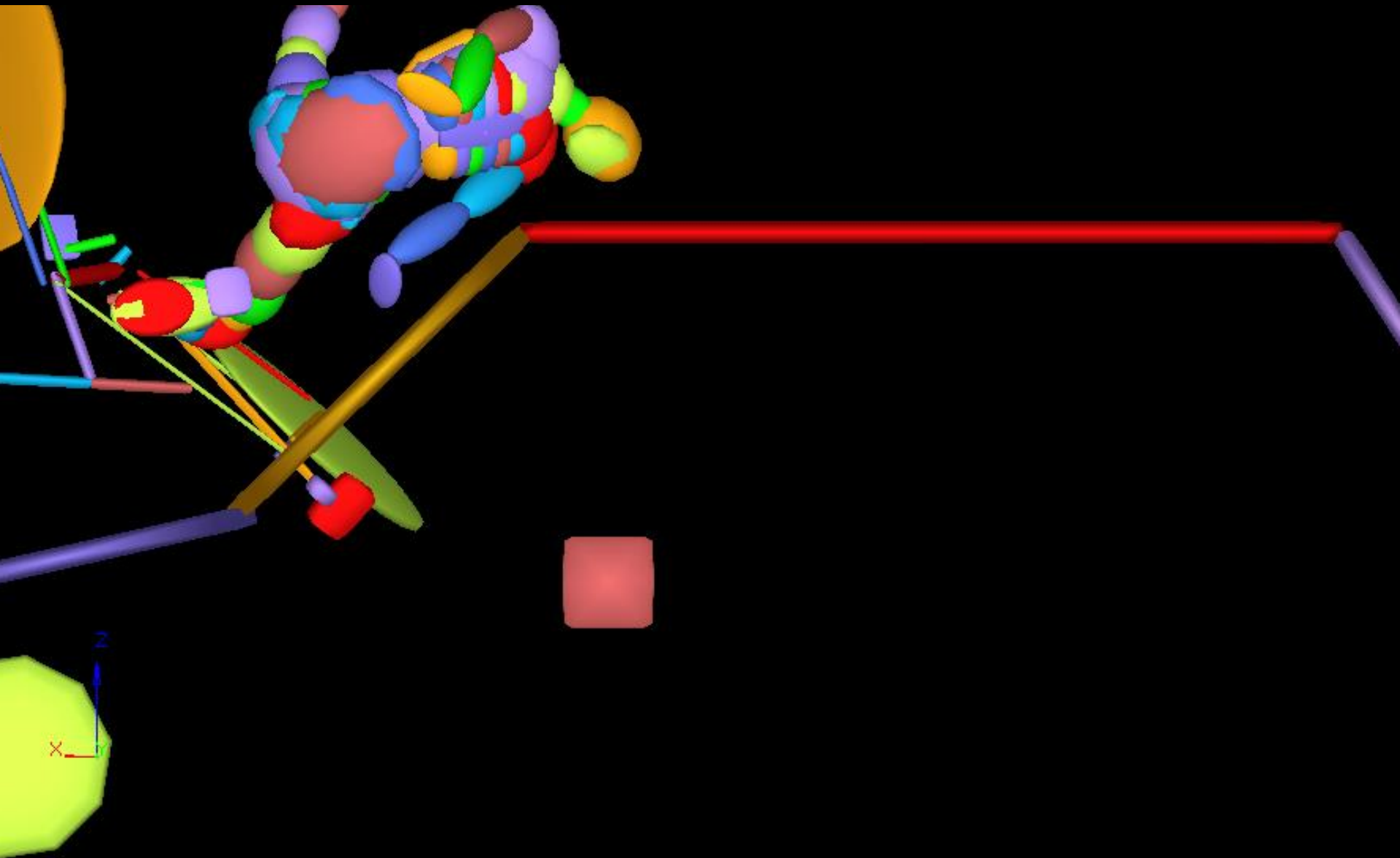
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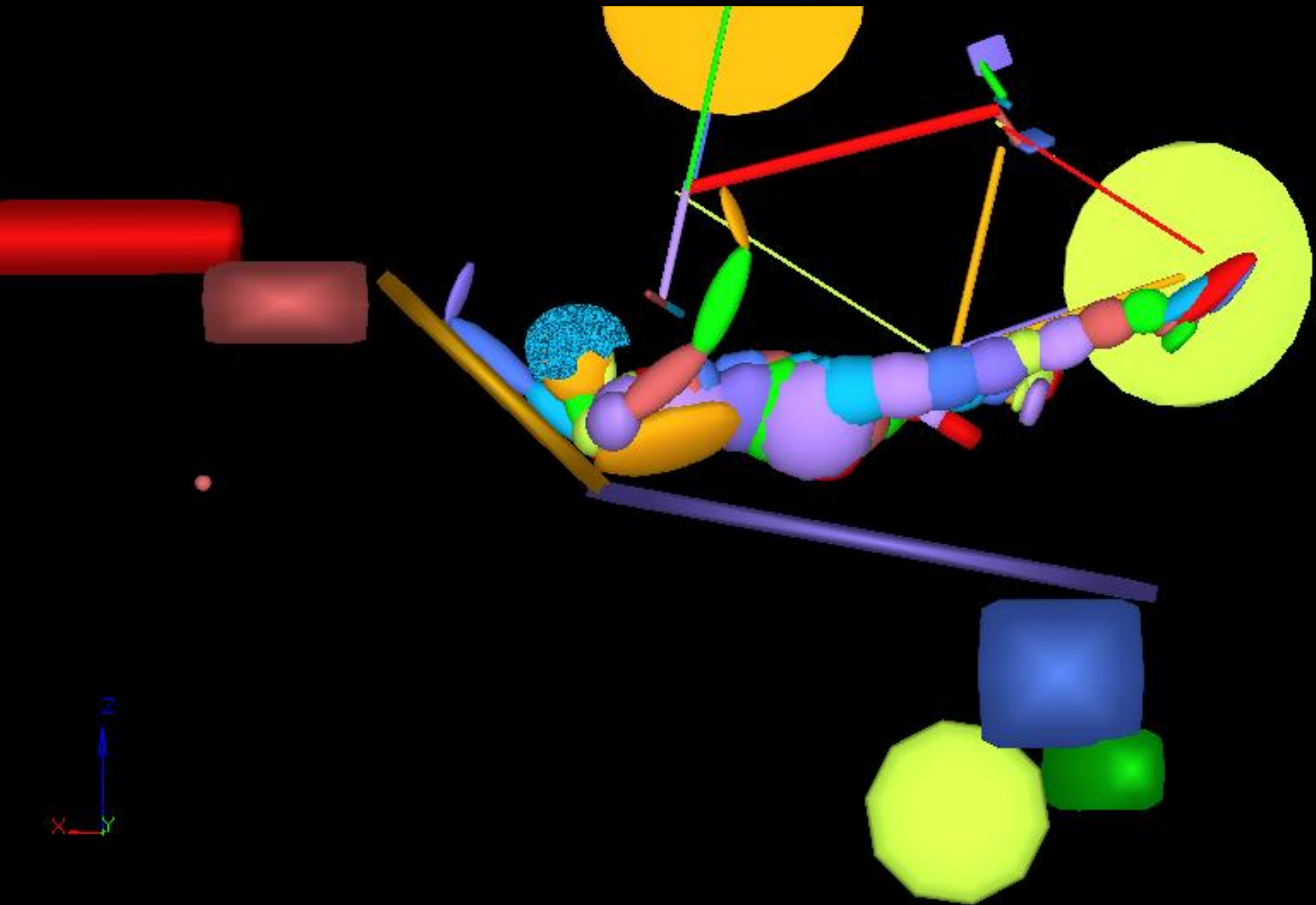
Primary Impact HIC Head-on Collisions



Primary Impact HIC Side-on Collisions



Primary Impact HIC Rear Collisions



Results and Findings

- Impact velocity not $>50\text{kph}$ for 12 of 37 cases. For almost all of these cases, primary HIC significantly greater w/out helmet
- For impact velocity $>50\text{kph}$, no consistently greater primary HIC score either with or w/out helmet
- Secondary HIC almost always greater w/out helmet, regardless of impact velocity
- Maximum linear and angular accelerations almost always greater w/out helmet, regardless of impact velocity

Conclusions

- Helmets offer protection in low velocity impacts and falls (up to 50kph)
- Protective capabilities of helmets in high velocity impacts ($>50\text{kph}$) with vehicles appear minimal
- Helmets offer protection against secondary impacts against ground
- Results indicate helmets should be worn as they do provide significant protection

Summary & Future Challenges

- Some fatalities can be prevented
- Seriousness of injuries can be reduced
- Better equipment can be designed and manufactured



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- Simulation tools exist (computational biomechanics)
- Generic & customised models are both feasible
- Appropriate material property data still required

Case No.	Sex	Age	Vehicle	Collision	Impact velocity (km/h)
C1	Male	64	Mercedes Cattle Lorry	Run Over	50
C2	Male	16	Mercedes saloon taxi.	Side On	50
C3	Female	12	Opel Vectra	Side On	70
C4	Male	27	Ford Escort	Rear Strike	55
C5	Male	55	Mitsubishi Shogun Jeep	Rear Strike	100
C6	Male	45	Ford Transit Van	Rear Strike	70
C7	Male	65	VW Caddy Van	Rear Strike	70
C8	Male	12	Mercedes Skip Truck	Rear Strike	85
C9	Female	50	Peugeot 306	Head on	50
C10	Female	9	Dump truck	Side On	45
C11	Female	64	Nissan Pickup Jeep	Fall	85
C12	Male	66	Daf 65 C- Oil truck	Rear Strike	85
C13	Male	55	Nissan Almera	Side On	70
C14	Male	83	BMW 520 saloon	Side On	15
C15	Male	71	DAF Box Lorry	Rear Strike	45
C16	Male	68	Nissan Cab Van	Rear Strike	70
C17	Male	47	Ford Focus	Run Over	55
C18	Male	83	Seat Arosa (4d)	Side On	55
C19	Male	35	Ford Maverick Jeep	Cyclist hit parked vehicle	20
C20	Male	71	Opel Astra Saloon	Side On	55
C21	Male	56	Iveco Ford Cattle Truck	Head On	30
C22	Female	68	Motor Lorry - Scania	Rear Strike	55
C23	Male	63	toyota hiace van	Rear Strike	85
C24	Female	14	Scania Tipper Lorry	Side On	85
C25	Male	65	VW Golf	Rear Strike	70
C26	Male	13	Ford Transit	Side On	85
C27	Female	68	Scania	Fall/Run over	10
C28	Male	61	Ford Fiesta	Head On	100
C29	Female	7	Citreon AX	Side On	55
C30	Female	16	Ford Escort	Side On	70
C31	Male	41	Hio ridig bodied truck	Run Over	15
C32	Female	36	Articulated lorry	Run Over	15
C33	Male	65	CZM	Rear Strike	60
C34	Male	70	Tractor & Trailer	Rear Strike	50
C35	Male	62	Renault Cleo	Rear Strike	55
C36	Male	64	Light Goods Vehicle	Side On	85
C37	Female	27	Sedan	Head on	70



Secondary Impact HIC

1545ms

