CPSC Comments to ANSI/ROHVA 1-2011

Question ANSI/ROHVA Occupant Retention Standards

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

DESIGN RESEARCH ENGINEERING

Chris A. Van Ee, Ph.D., P.E.
Daniel E. Toomey, M.S.E., P.E.

ROHVA Engaged DRE to Evaluate Occupant Retention Standards

Introduction

DRE Task

- Evaluate the effectiveness of the ROV Occupant Retention Systems (ORS) in rollover accident events.
- Evaluate the current ANSI-ROHVA standard with respect to occupant protection including kinematics and retention in 90 degree rollover events.

Background

Active Versus Passive Occupants

(Carhart and Newberry, 2010)

- ROV occupants are active riders that counter-posture and brace against inertial forces.
- Active muscle response combined with three point seat belts have been shown to keep occupants within ROVs in static 90 degree roll evaluations.

An example of a ROV passenger counter-posturing in a left-hand turn

Carhart M, Newberry W, Biomechanical Analysis of Passive and Active Occupant Responses During Rhino Riding and 90-Degree Tip-Over Events, 3:09-MD-2016-JBC, MDL No. 2016, 2010)

Background

Active Versus Passive Near Side Occupants

- During pre-trip vehicle dynamics near side surrogate occupants bend their necks away from the vehicle periphery resisting inertial head motions. *(Yamaguchi et al., SAE Paper 2005-01-0302)*
- Anthropomorphic Test Devices (ATDs) are passive occupants
- Leading up to 90 degree rollover events ATDs are…
  - reasonable estimate of near side occupant lateral motions
  - likely overestimate head excursion.

From Yamaguchi et al., 2005 (SAE Paper 2005-01-0302)

Background

Seat Belt

- Seat belts are the most effective injury mitigating safety device in rollover accidents.
- Seat belts offer effective protection against ejection and injury in rollover accidents.
  - Risk of ejection *(NHTSA DOT HS 810 741)*
    - 33% for unrestrained SUV occupants
    - Less than 1% (0.33%) for SUV restrained occupants
  - 98.6% of all seat belted occupants in SUV rollover crashes do not receive serious or fatal injuries *(Malliaris and Diggs, SAE Paper 1999-01-0063)*

Background
Seat Belts

- Seat belted ATDs (passive occupants) remain within ROVs during dynamic lateral deceleration sled tests inducing a 90 degree roll event.

From Carhart and Newberry, 2010

ANSI – ROHVA ORS Evaluation

DRE Approach

- ROPS / Seat belt system performance evaluation
  - ROPS Geometry
  - Rollover simulations
  - Computer modeling of belted/zone 1 retention
- Performance based requirement evaluation
  - Acceleration environment comparison
  - Hand grip force evaluation
- Zones 1, 2, and 3 barrier requirement evaluations
  - Barrier geometry
    - Occupant anthropometry
    - Computer simulation
  - Barrier strength
    - Computer simulation

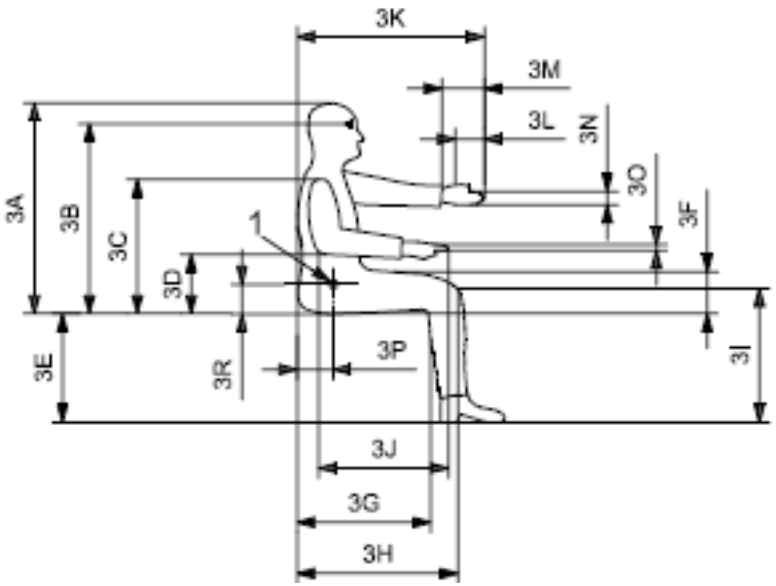
ROPS Geometry Analysis

Exemplar Scanning

ROPS Geometry Analysis

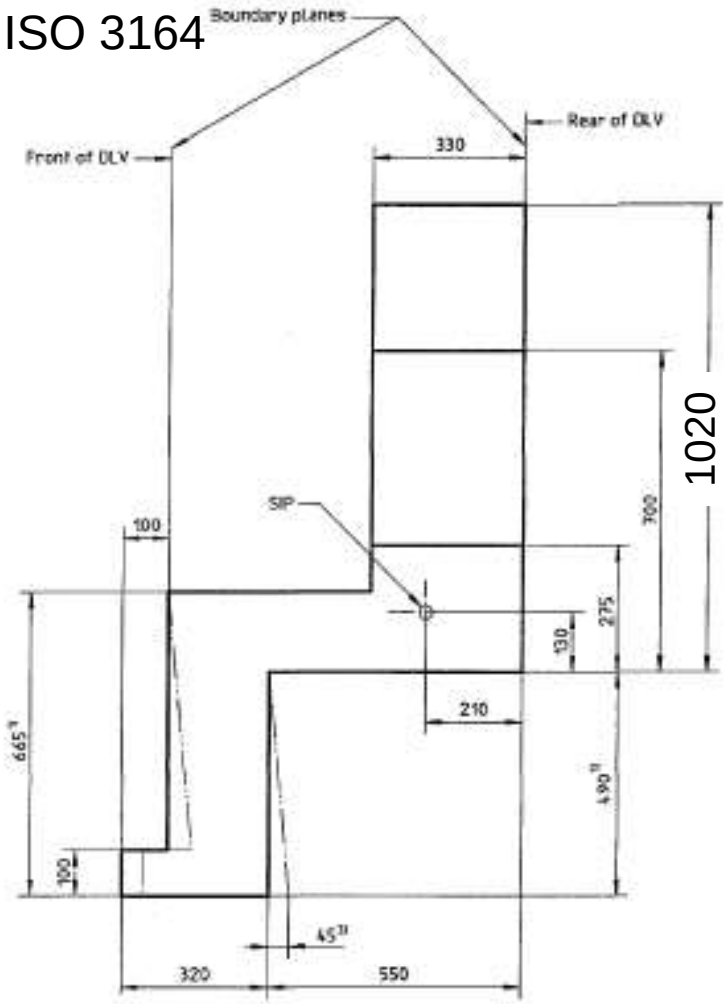
Methodology

ISO 3411



95th % Seated Height
976 + 50 (helmet) = 1026 mm

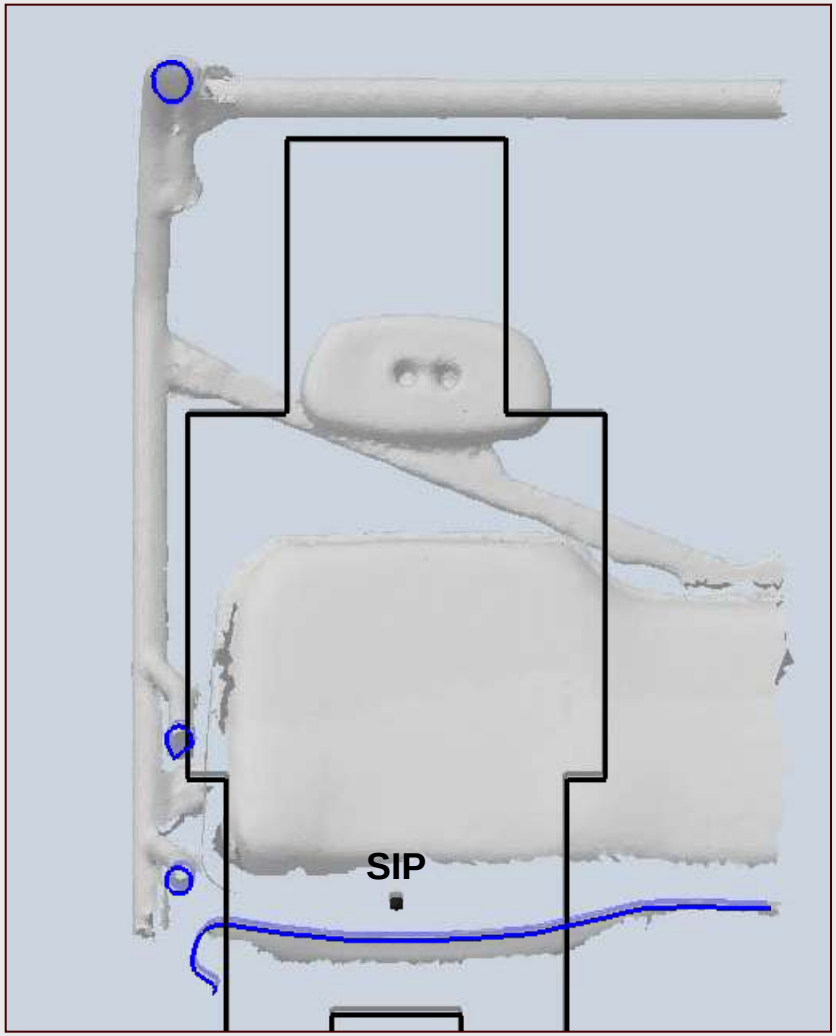
ISO 3164



Seated Height
1020 mm

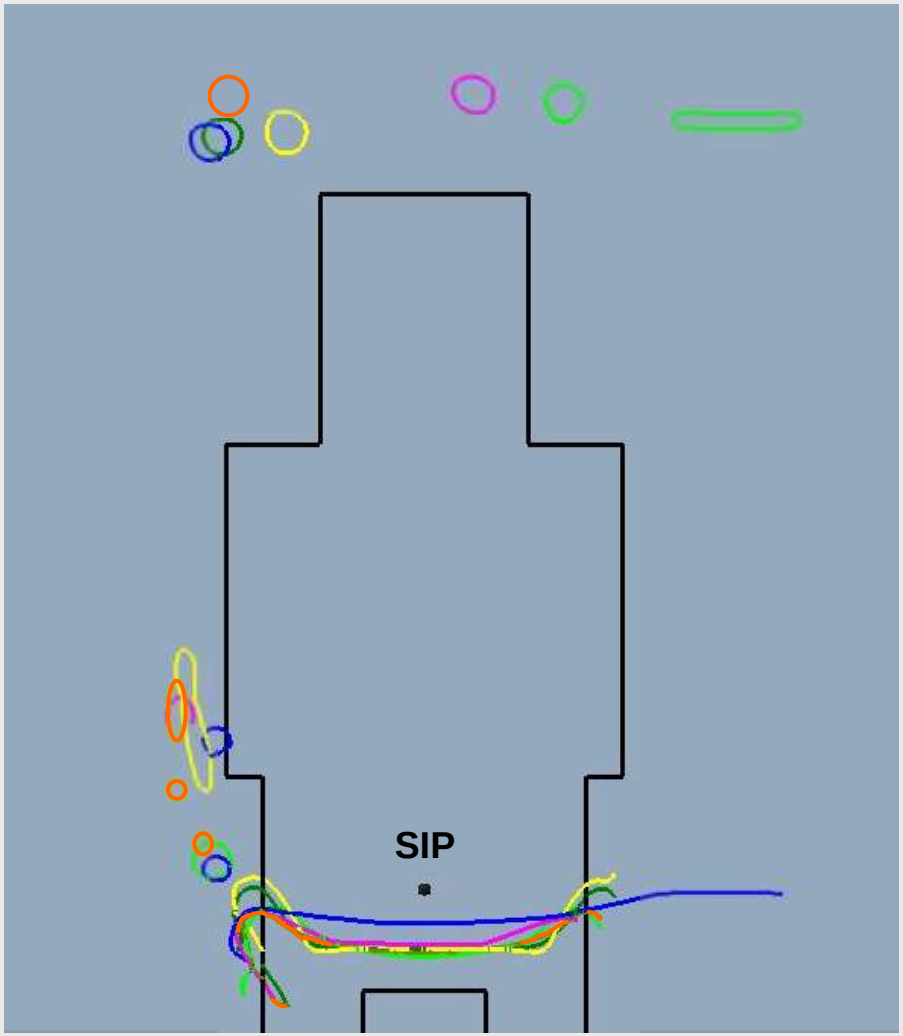
ROPS Geometry Analysis

Cross Section Through Seat Index Point



ROPS Geometry Analysis

Summary



ANSI-ROHVA standard specifies ROPS force and energy performance requirements. This has resulted in ROPS initial geometries well outside the Deflection Limiting Volume (DLV).

Quasi-Static Rollover Simulations

Setup

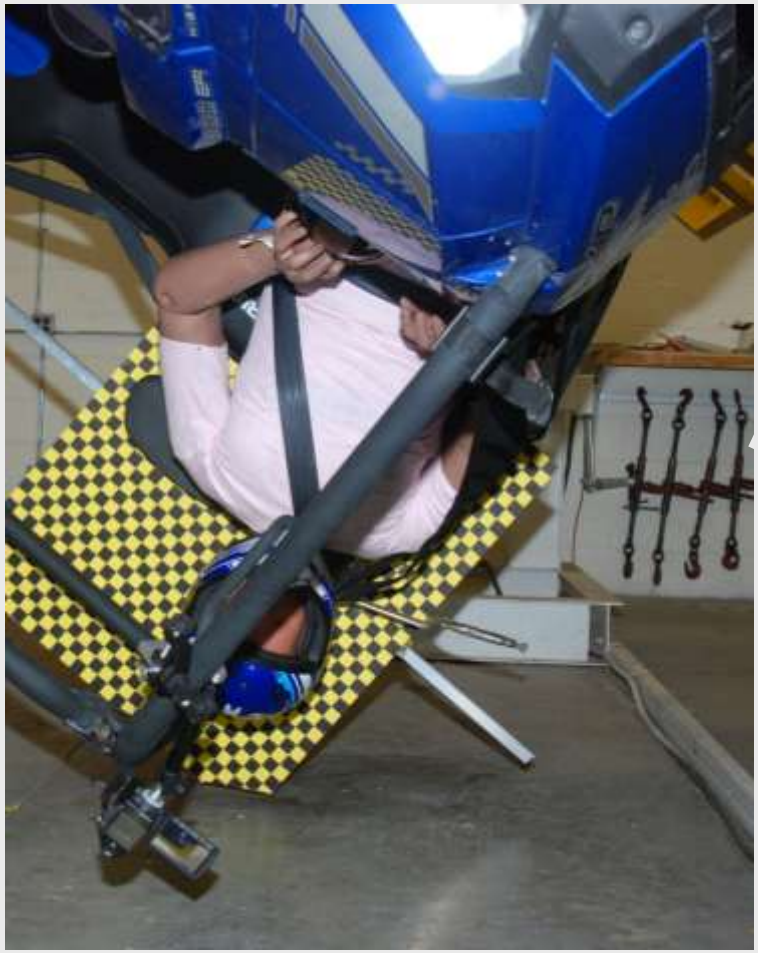
- Centered ATD hips and buttocks against seat back
- Route available seat belt and adjust lap belt loop with fingers between ATD pelvis and belt
- ATD hands secured to knees
- Rotate table to potential head-ROPS interaction angle.
- Allow seat belt retractor to lock via table tilt angle.
- Repeat above process three times

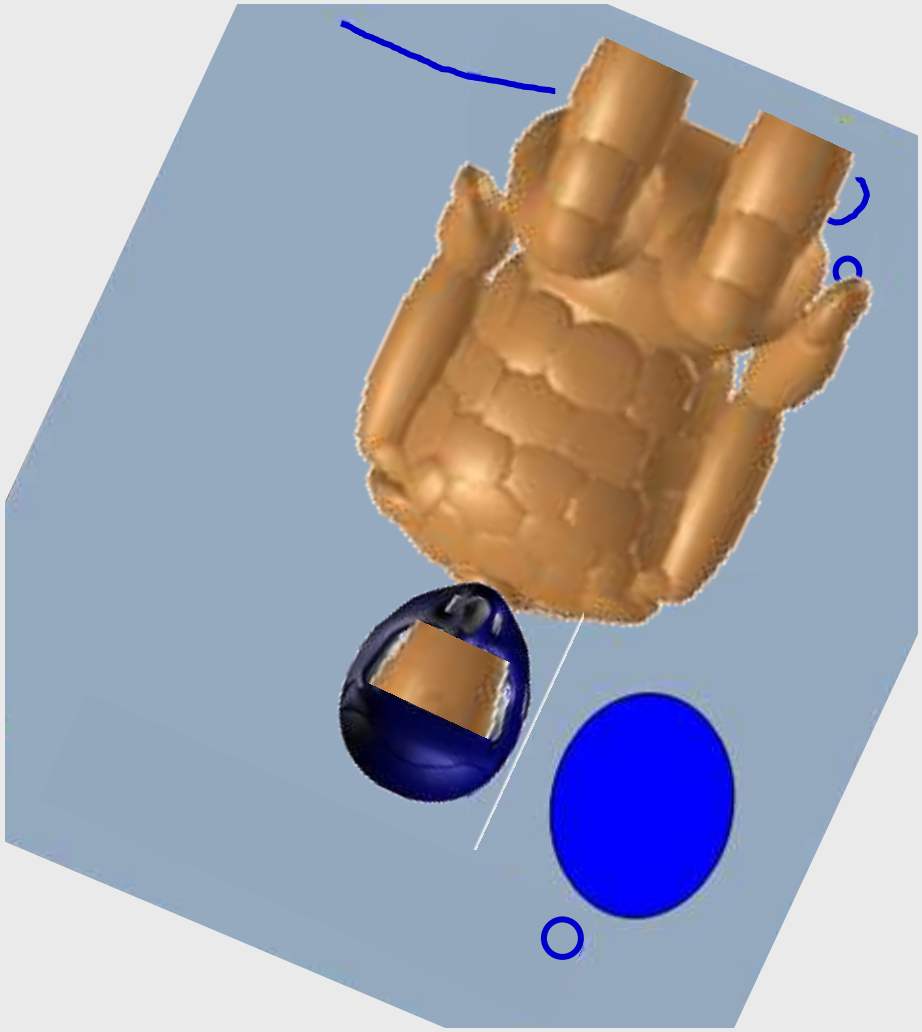
Quasi-Static Rollover Simulations

Results – Sample Inverted Position

Quasi-Static Rollover Simulations

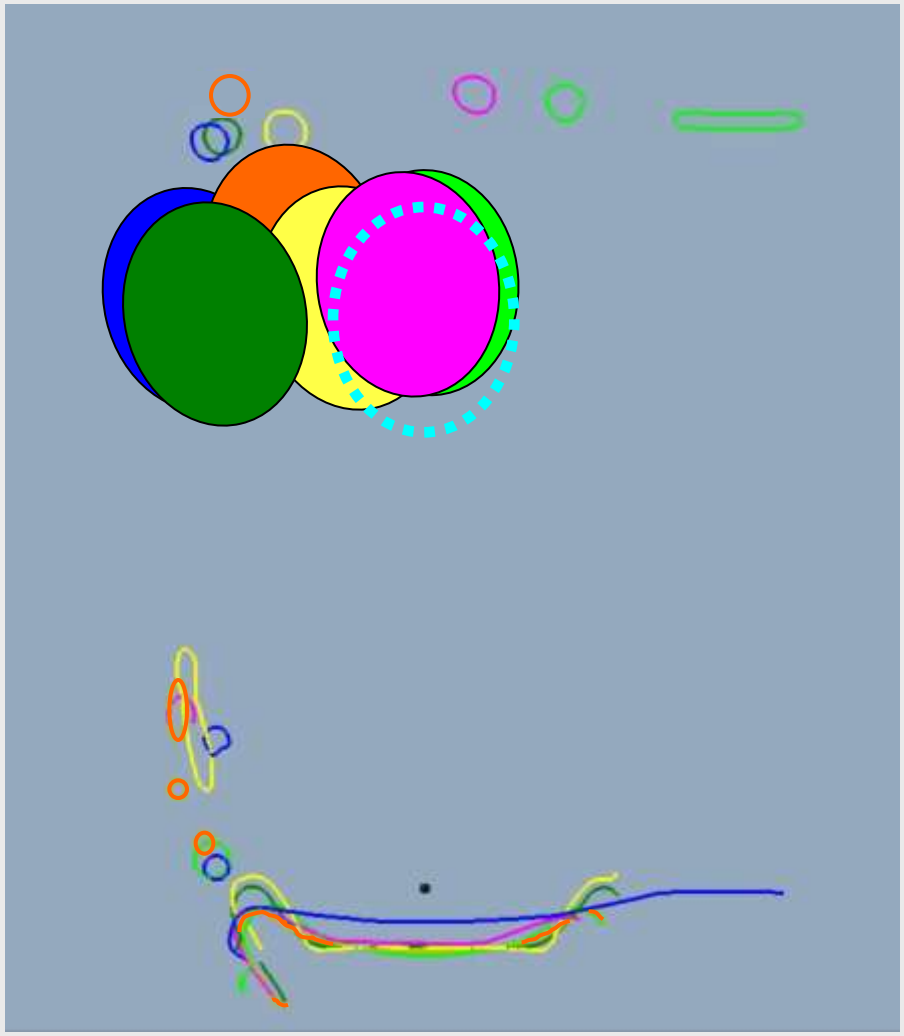
Results – Inverted Head Position

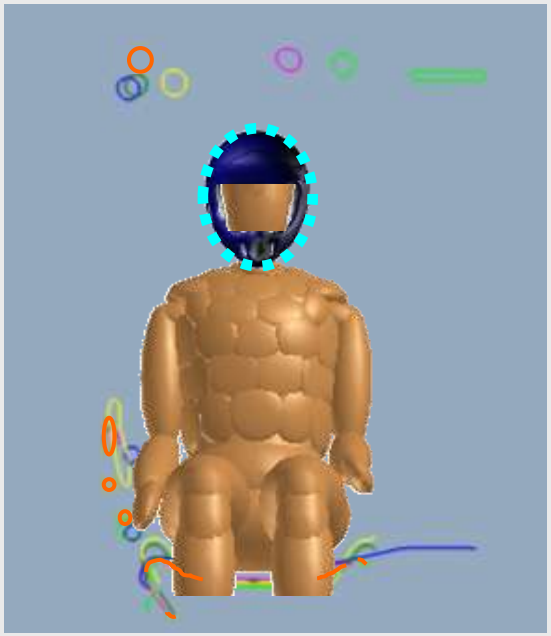




Quasi-Static Rollover Simulations

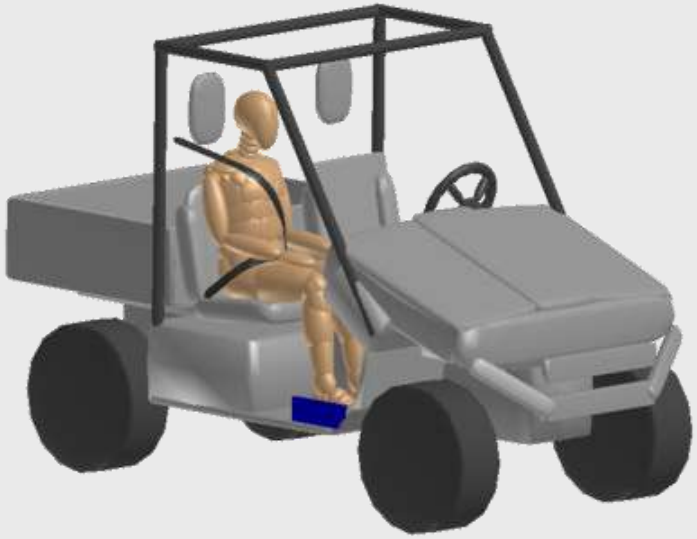
Results – Inverted Head Positions





MADYMO

Modeling Setup

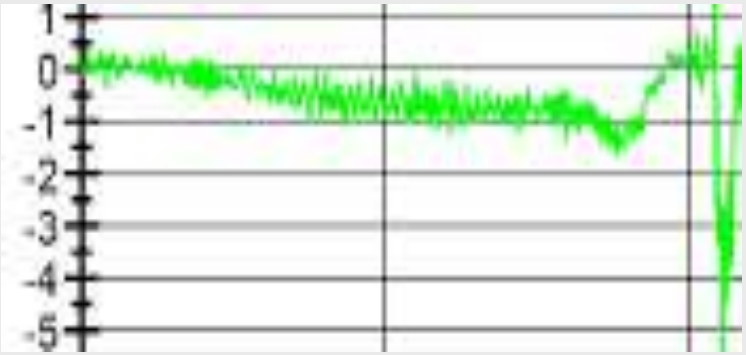


- MADYMO Version 7.3
- Generic vehicle model from scans
- Hybrid III Series ATDs
  - 95% Male (6’2” 223 lbs)
  - 50% Male (5’9” 171 lbs)
- Sliding Friction (μ) = 0.5
- Generic belt restraint properties
- Seat has modest contour/sculpting

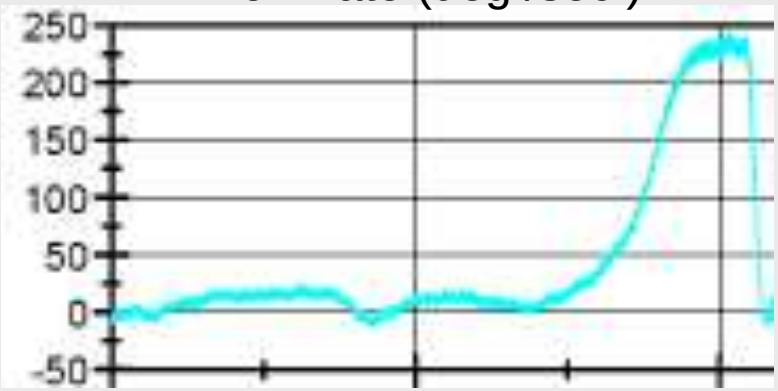
MADYMO

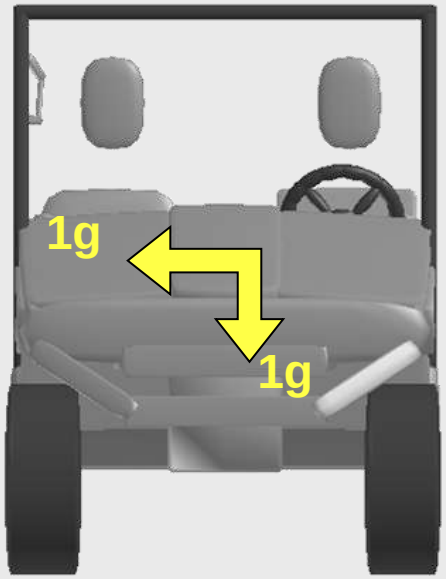
Acceleration Environment

Lateral Acceleration (g)



Roll Rate (deg./sec.)





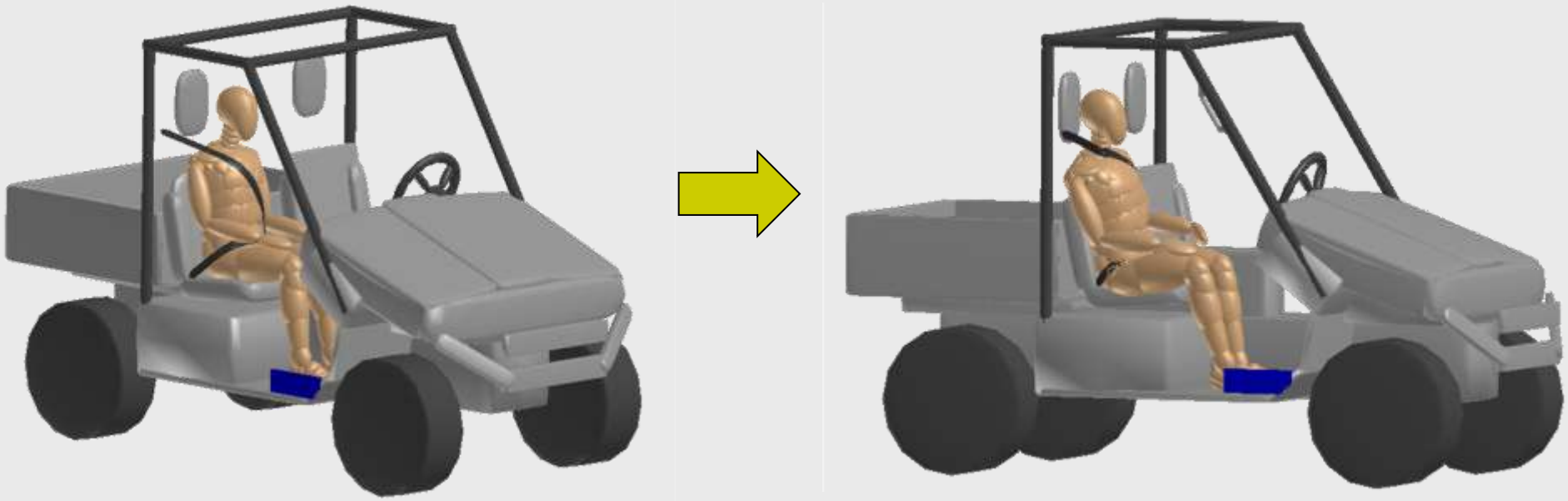
Gravitational and lateral accelerations are step inputs in MADYMO simulation

Change in body roll angle is not simulated in MADYMO increasing the relative lateral motion between the occupant and ROV

Test 2 From Warner and Bready, SAE Paper 2011-01-1117

MADYMO

Restrained 50th % Male ATD

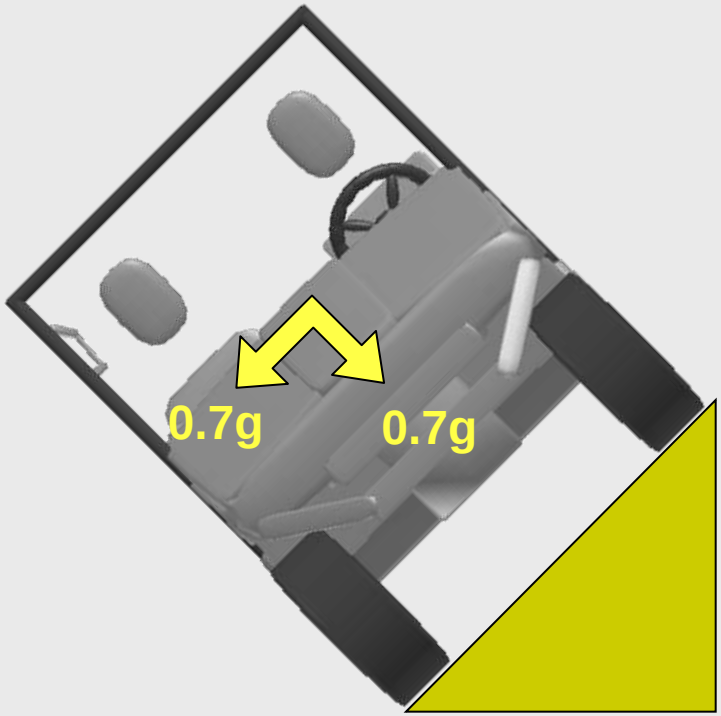


Steady state zone 1 force is 85 N (~19 lbs.)

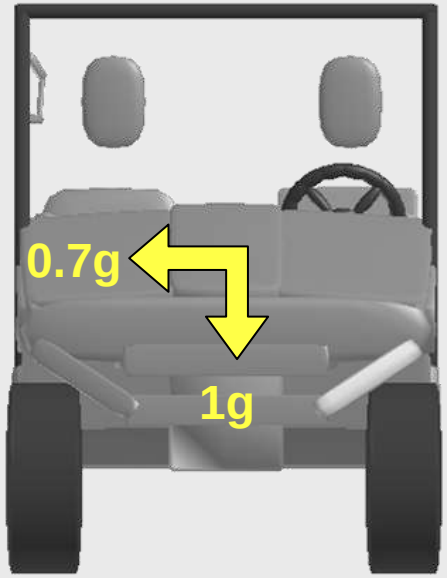
Hand maintained on right thigh with a steady state force of 50 N (~11 lbs.)

Performance Based Tilt Test

45 Degrees Static Evaluation



Static Tilt



Pre – Roll Dynamics

45 degree static tilt is conservatively comparable to 0.7 g pre-roll dynamics

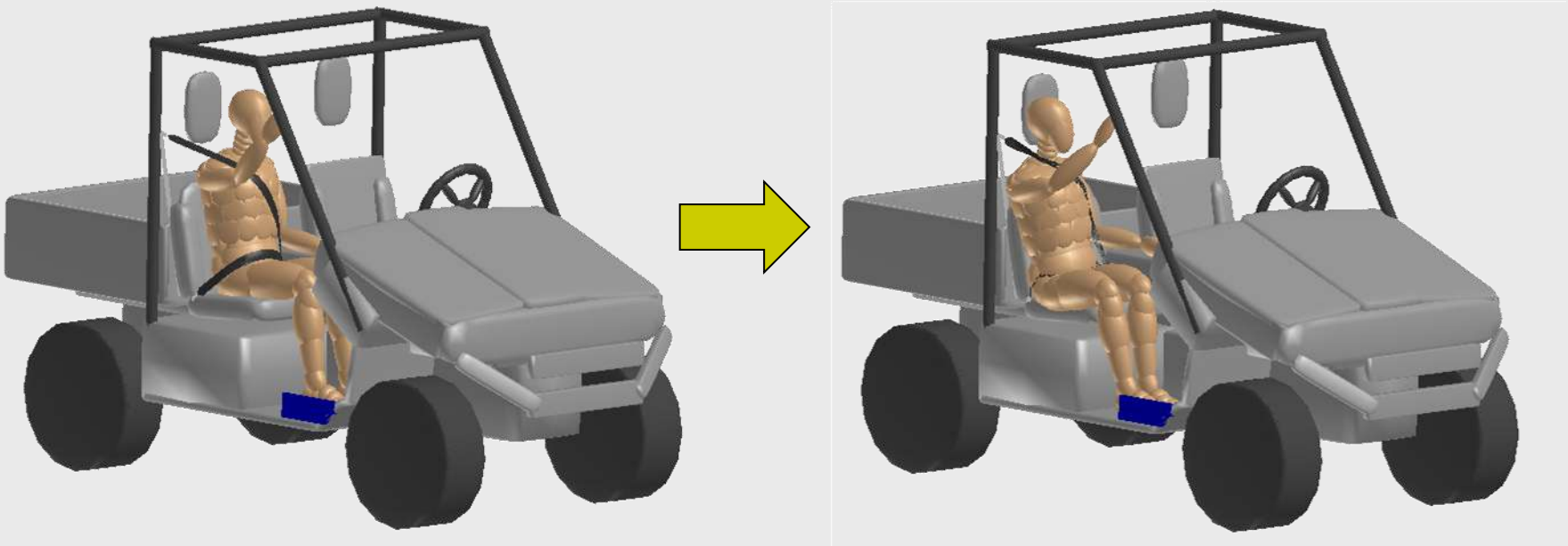
Tilt Test – Reasonable Grip Force

MADYMO - Restrained 50th % Male ATD

- Outboard hand connected to hand hold using a Kelvin (spring/dashpot) element.
- Hand hold location accentuates arm tensile loading.
- Zone 1 barrier included.

Tilt Test – Reasonable Grip Force

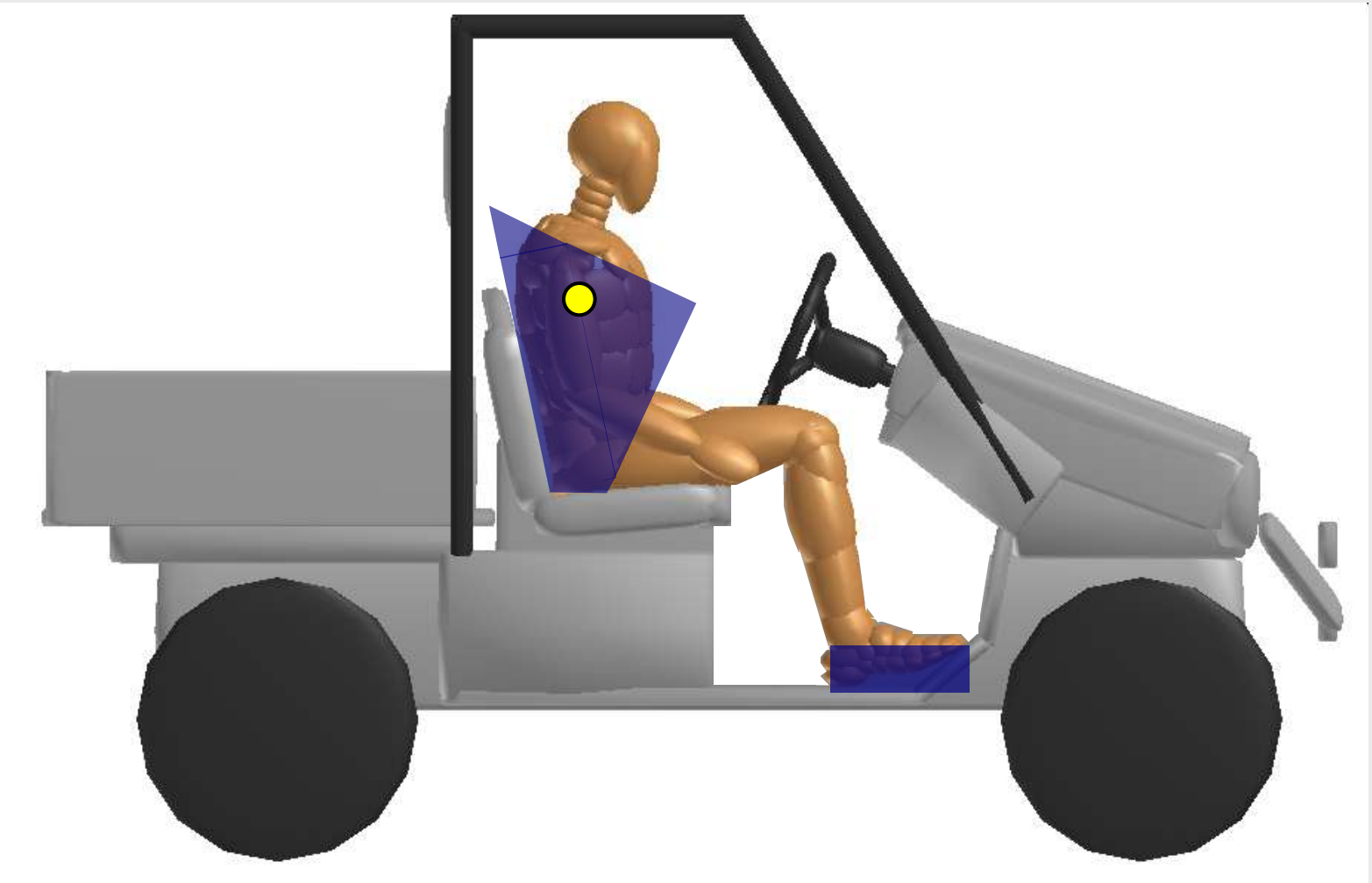
MADYMO - Restrained 50th % Male ATD



Steady state hand hold force 150 N (~34 lbs.) or 20% of body weight. This is well within occupant capability and consistent with findings of Carhart and Newberry (2010).
Steady state zone 1 force is 100 N (~22 lbs.).

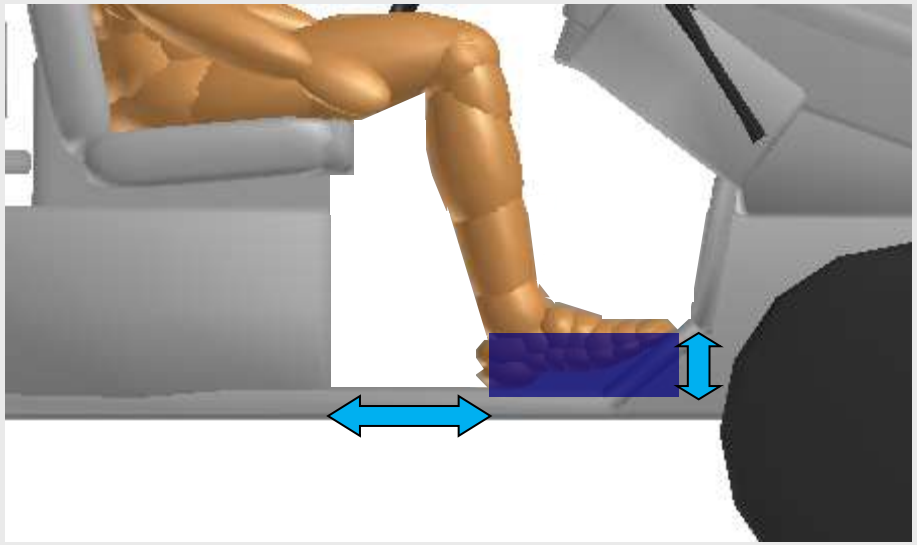
Construction Based Barriers

95th % Male ATD – Generic Vehicle Model



Barrier Dimensions

Zone 1 Geometry



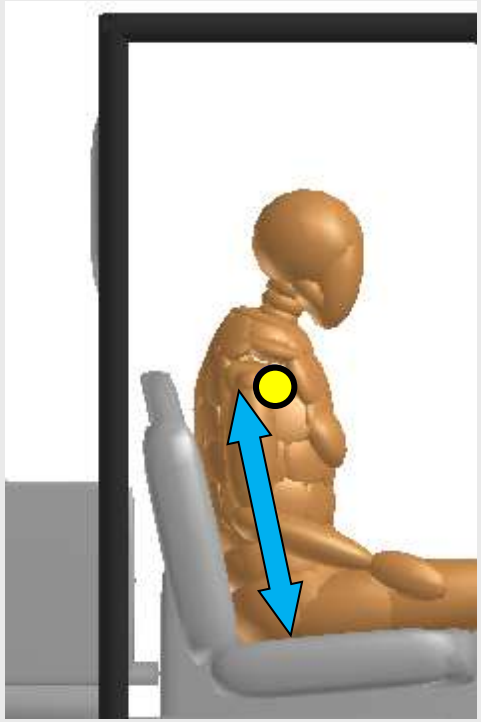
4” Height
- Ankle height
  - 3.9 – 4.7 in. (ISO 3411)
  - 2.5 – 3.7 in. (Tilley)

9” Opening
- Foot length
  - 9.8 – 12.2 in. (ISO 3411)
  - 9.9 – 13.2 in. (Tilley)

ISO 3411. Earth-moving machinery — Physical dimensions of operators and minimum operator space envelope (5th-95th % Operators)
Tilley AR. The Measure of Man and Woman, Henry Dryfus and Associates, New York, 1993 (1st % female to 99th % male)

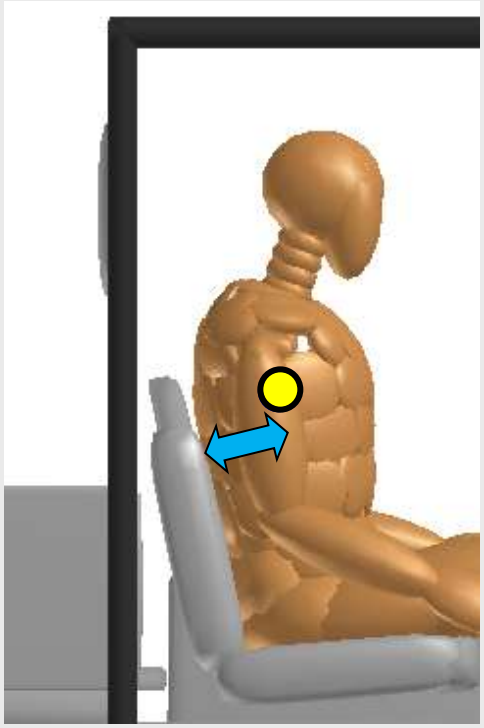
Barrier Dimensions

Zone 2 Geometry



17” along Seat Back

- Shoulder Height
  - 20.9 – 25.6 in. (ISO 3411)
  - 20.8 – 26.6 in. (Tilley)

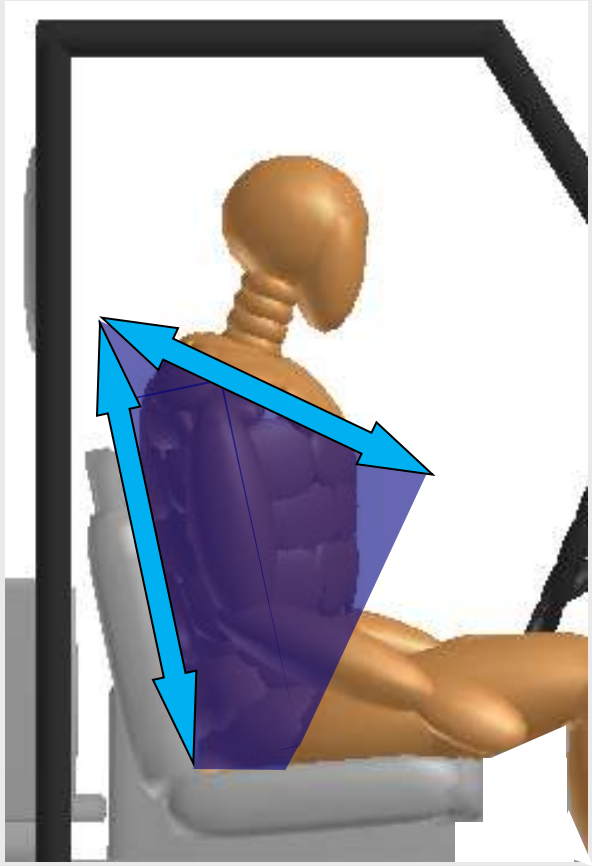


6” Perpendicular from Seat Back

- Chest Depth
  - 8.3 – 11 in. (ISO 3411)
  - 7.5 – 12 in. (Tilley)

Barrier Dimensions

Zone 3 Geometry



26” Along Seat Back

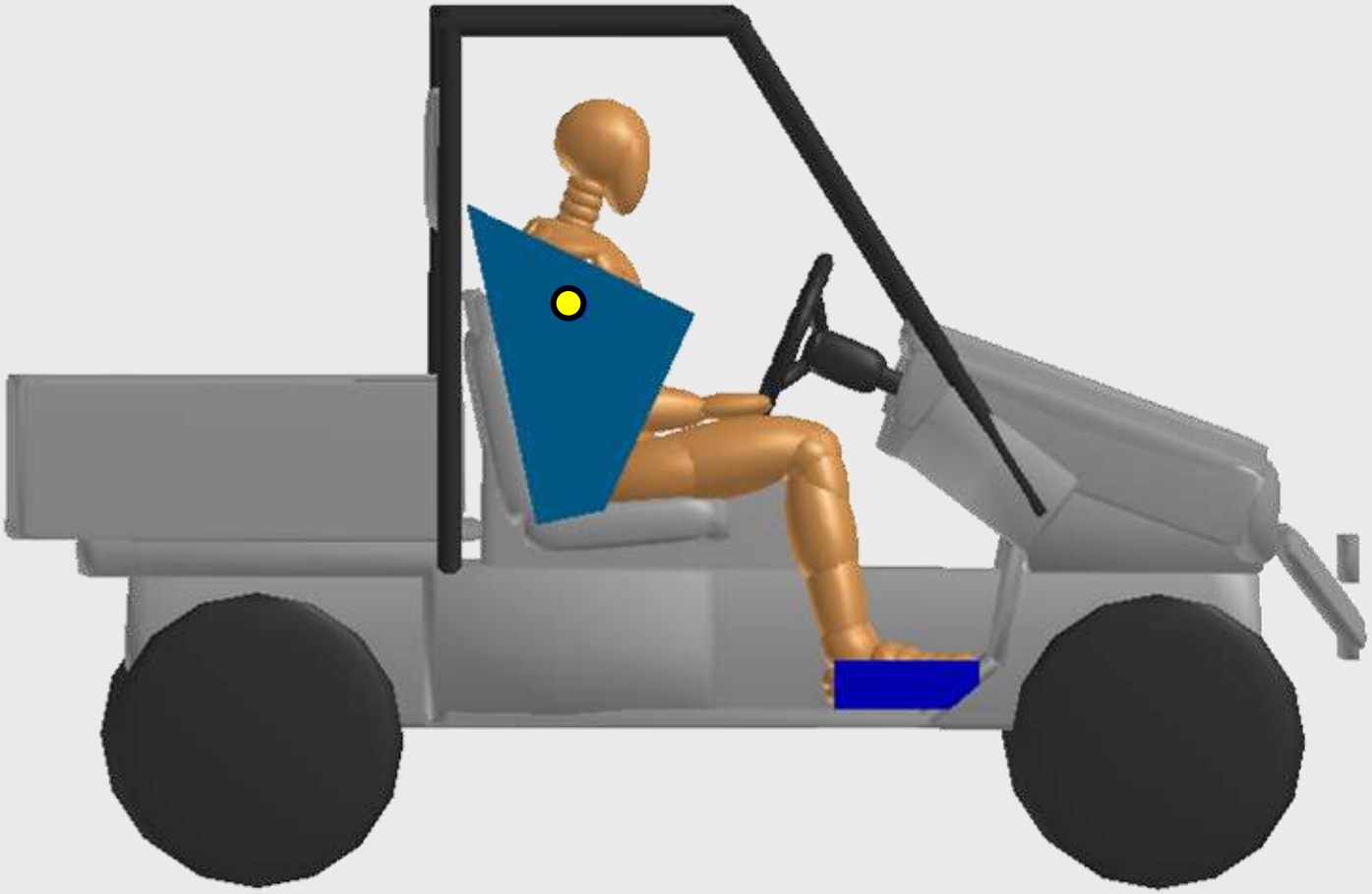
- Shoulder Height
  - 20.9 – 25.6 in. (ISO 3411)
  - 20.8 – 26.6 in. (Tilley)

19.7” @ 25 deg. from Horizontal

- Upper Arm Length
  - 9.2– 12.3 in. (Tilley)
- Buttock to Shoulder Joint Depth
  - 4 – 5.3 in. (Tilley)

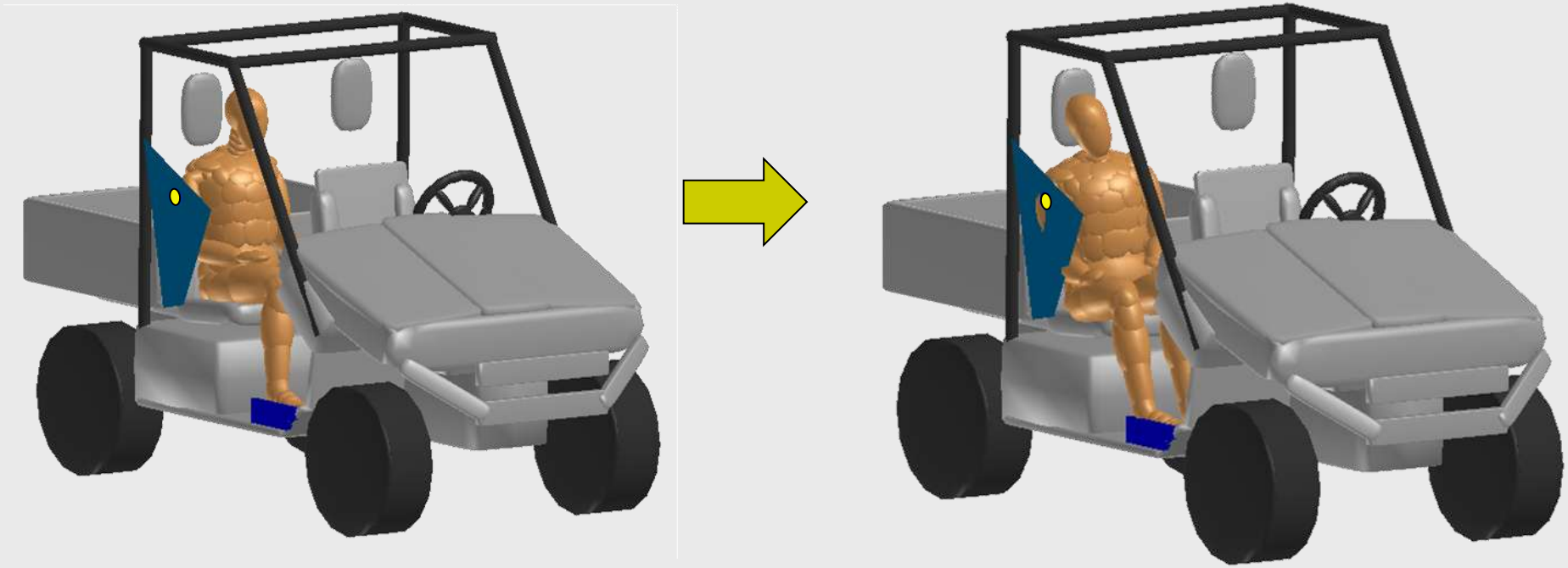
Barrier Force Requirements

MADYMO - 95th % Male ATD Not Seat Belted



Barrier Force Requirements

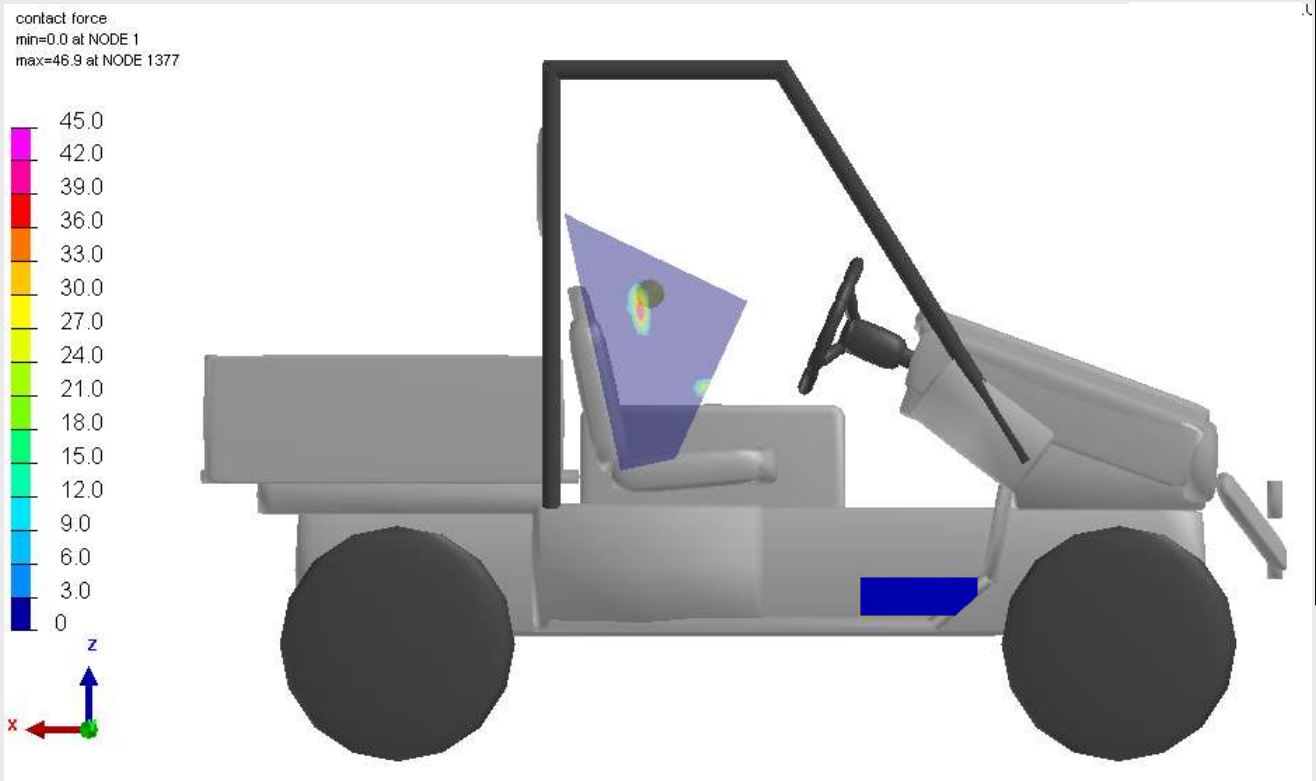
MADYMO - 95th % Male ATD Not Seat Belted

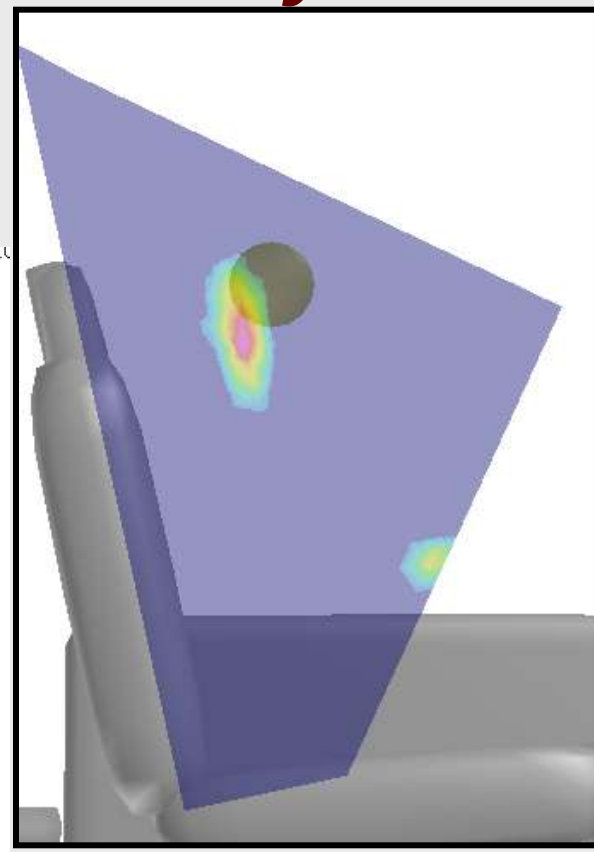


Steady State Zone 1 Contact Force 225 N (~50 lbs)
Steady State Zone 2/3 Contact Force 700 N (~157 lbs)
Barrier force requirements are sufficient to retain 95th male ATD

Zone 2 Barrier Location

MADYMO - Pressure Contour Analysis





Mandatory Standards Are Not Necessary

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

- **Significant evolution of voluntary standards**
- **ROHVA has been responsive to CPSC's areas of concern (dynamic stability; occupant retention)**
- **Chairman: CPSC has "an active partner in addressing safety concerns with" ROHVA members. Mandatory standards necessary if:**

1. **Insufficient compliance with voluntary standard** → **All ROHVA members comply/will comply with ANSI/ROHVA 1-2011**
2. **Voluntary standard does not adequately protect consumers from unreasonable risk of death and injury** → ***The data show that vehicles meeting ANSI/ROHVA 1-2011 do not present an unreasonable risk of death and injury***

Analyzed Incident Data For True Causes

Relevance of Vehicle Design in Incidents

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

- **In 1989, CPSC conducted a multi-disciplinary qualitative analysis of 162 fatality incidents in order to address crash avoidance issues for ATVs** (A. Corley, Analysis of Causative Factors in All-Terrain Vehicle-Related Deaths – 1989 (Jan. 1991))

- **Conclusion: Vehicle design (i.e stability, steering/handling) not the primary factor in 94% of the incidents; "overwhelming number" attributed to actions of the operator**

- **CPSC has not conducted such a multi-disciplinary qualitative analysis of ROV IDIs**

ROHVA Commissioned a Similar Multi-disciplinary Qualitative Analysis

Qualitative Analysis of ROV IDIs

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

Carr Engineering, Inc.

APPLIED SAFETY AND ERGONOMICS, INC.

J. Paul Frantz, Ph.D., C.P.S.M., CPE
Applied Safety and Ergonomics

Dual independent analyses: Human factors and vehicle dynamics

- Two teams of human factors and vehicle dynamics experts:
  - Applied Safety and Ergonomics
  - Carr Engineering
- Hundreds of hours of analysis
- Independent assessment followed by joint analysis

In-Depth investigations

- Analysis of 171 complete IDIs
  - Examined IDIs to assess potential effects of changes in crash avoidance features
  - Did not include duplicates or terminated incomplete IDIs
- Range of incident dates: April 2004 to September 2010
- Vehicle model years: 1999 to 2010

Sample Circumstances Before Loss of Control

- Drivers and passengers with alcohol
- Youngsters in groups without adults present
- Ride areas with obstacles/extreme terrain
- Driving on roads: collisions, impaired or without license
- Recognition of risky behaviors or potential concerns
- Unsupervised or unauthorized use or location of use

Criteria for crash avoidance categories

- **Highly Unlikely or Unlikely Per Investigation**
  - The circumstances of the crash were unrelated to the crash avoidance capacities of the machine, the operator was intentionally engaging in risk-taking behavior or stunts, or the authority or agency investigating the incident concluded that the operator was making unreasonable and/or inappropriate driving decisions.
- **Inconclusive**
  - It is possible, but unclear, that different design attributes could have mitigated the crash.
- **Insufficient Information**
  - Not enough is known about the crash scenario to draw a definitive conclusion.

Examples of crash circumstances highly unlikely or unlikely per investigation to be related to crash avoidance

Launching:

"At that time, he approached the truck stop and a 30 to 40 foot raised dirt embankment. The victim failed to apply the brakes or stop causing all four wheel to leave the ground and the vehicle became airborne. The victim's vehicle impacted the upper rear portion of a parked tractor-trailer and fell to the ground." - 091118HWE8524

Struck by other on-road vehicle:

"Utility vehicle that was struck by an oncoming truck" - 100113HCC2316

Examples of crash circumstances highly unlikely or unlikely per investigation to be related to crash avoidance

Collision with fixed object:

"The [vehicle] approached the gate and crashed into the portion which was extended into the road." - 080415HWE7319

Intentional stunt:

"The father was attempting to spin the UTV to make donuts in the dirt when one of the UTV wheels caught in a rut and the UTV tipped over toward the passenger side." – 091123HWE8536

Examples of crash circumstances highly unlikely or unlikely per investigation to be related to crash avoidance

Loss of control leading to rollover in a ditch:

"…a one vehicle Off-Road/ATV accident on County Road…[redacted] was distracted by handing a can of root beer to [redacted] then looked back to the road and saw that they were going off of the road. She yelled, [redacted] to get her attention, but they were already off of the roadway and in the ditch." - 100601HNE0366

Use on extreme terrain:

"At some point, the decedent attempted to climb a hill which was approximately 70-degrees incline. The OHV tipped rearward and to the right then rolled over." - 090728HCC3816

Examples of crashes circumstances where there was insufficient information to make a determination

Insufficient information:

"[Driver] attempted to pass the van traveling in front of him, [and] the UTV which he was driving flipped." – 090126CCC2285

"The Witness states that the victim went to turn around and the vehicle overturned" – r070430HNE2274

"For unknown reasons (possibly due to the rough terrain) P1 lost control of V1" – 081030CCC3081

Examples of crash circumstances where the effect of additional crash avoidance features is inconclusive

Description of operation causing a crash:

"While riding as a passenger in a [UTV], side by side ATV, a slow gradual turn to the left causing the vehicle to roll over on the passenger side." – 080905CNE3738

"The driver and two passengers were traveling on "a slight uphill grade" when the driver "initiated a slight right hand turn." The vehicle "tipped over a quarter turn onto its driver's side."" – 090508CCC1699

Examples of crash circumstances where the effect of additional crash avoidance features is inconclusive

Description of operation causing a crash:

…had been creeping along at about 2-5 mph when he overturned. He was braking at the time and believes that his back wheels lock (sic) up, but he does not know if his front wheels may have been turned to the left or right. He stated that as the back wheels locked up, the back end of the vehicle began to slide sideways and within one flow the vehicle overturned onto the passenger side. – 0905057CCC2610

Joint analysis results: Additional Crash Avoidance Features

* 1% not applicable (2/171)

Inconclusive:

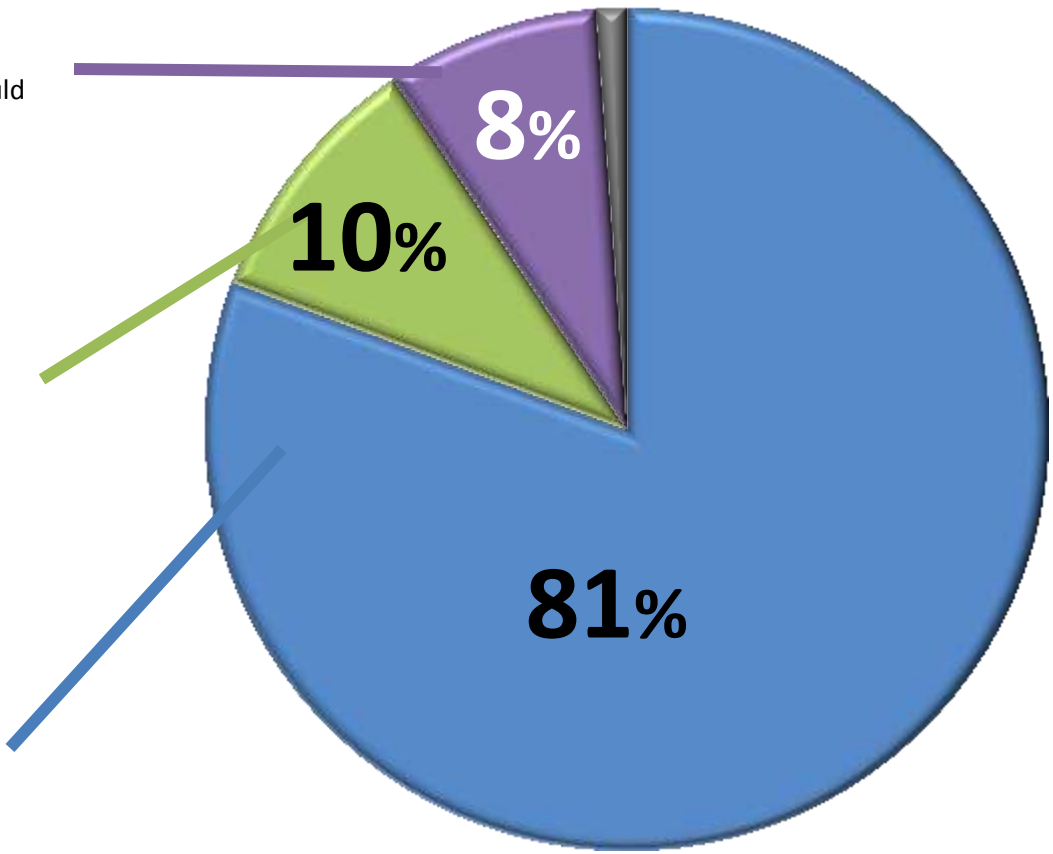
It is possible, but unclear, that different design attributes could have mitigated the crash

Insufficient Information:

There is insufficient information known about the crash scenario to draw a conclusion about the effect of different crash avoidance attributes

Highly Unlikely/Unlikely:

The circumstances of the crash were unrelated to the crash avoidance capacities of the machine, the operator was intentionally engaging in risk-taking behavior or stunts, or the authority or agency investigating the accident concluded that the operator was making unreasonable and/or inappropriate driving decisions

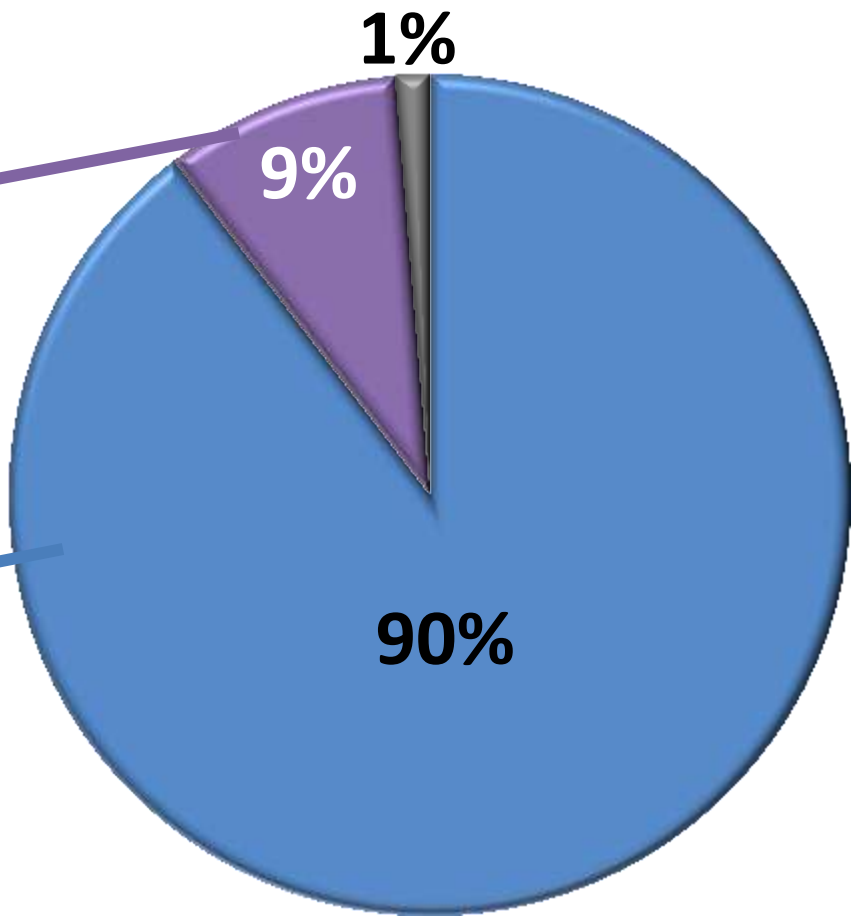


Joint analysis results: Effect of additional crash avoidance features

Proportionally distributed insufficient information IDIs

Inconclusive

Highly unlikely or unlikely per investigation



* 1% not applicable

SUMMARY STATISTICS

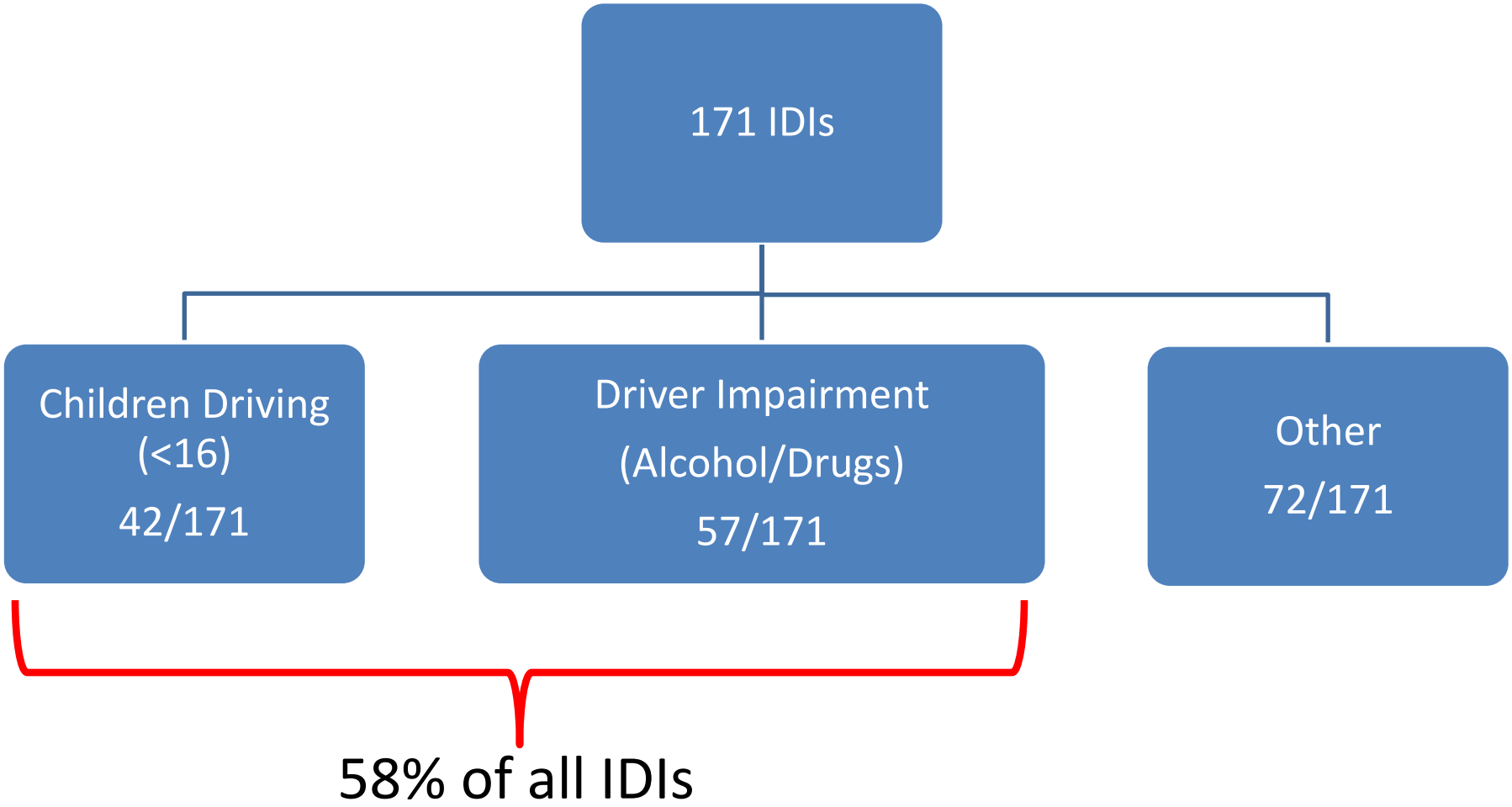
Crash Avoidance	Percent
Unlikely/Highly unlikely	90
Inconclusive	9
Not applicable	1

Proportionally distributed Insufficient Information IDIs

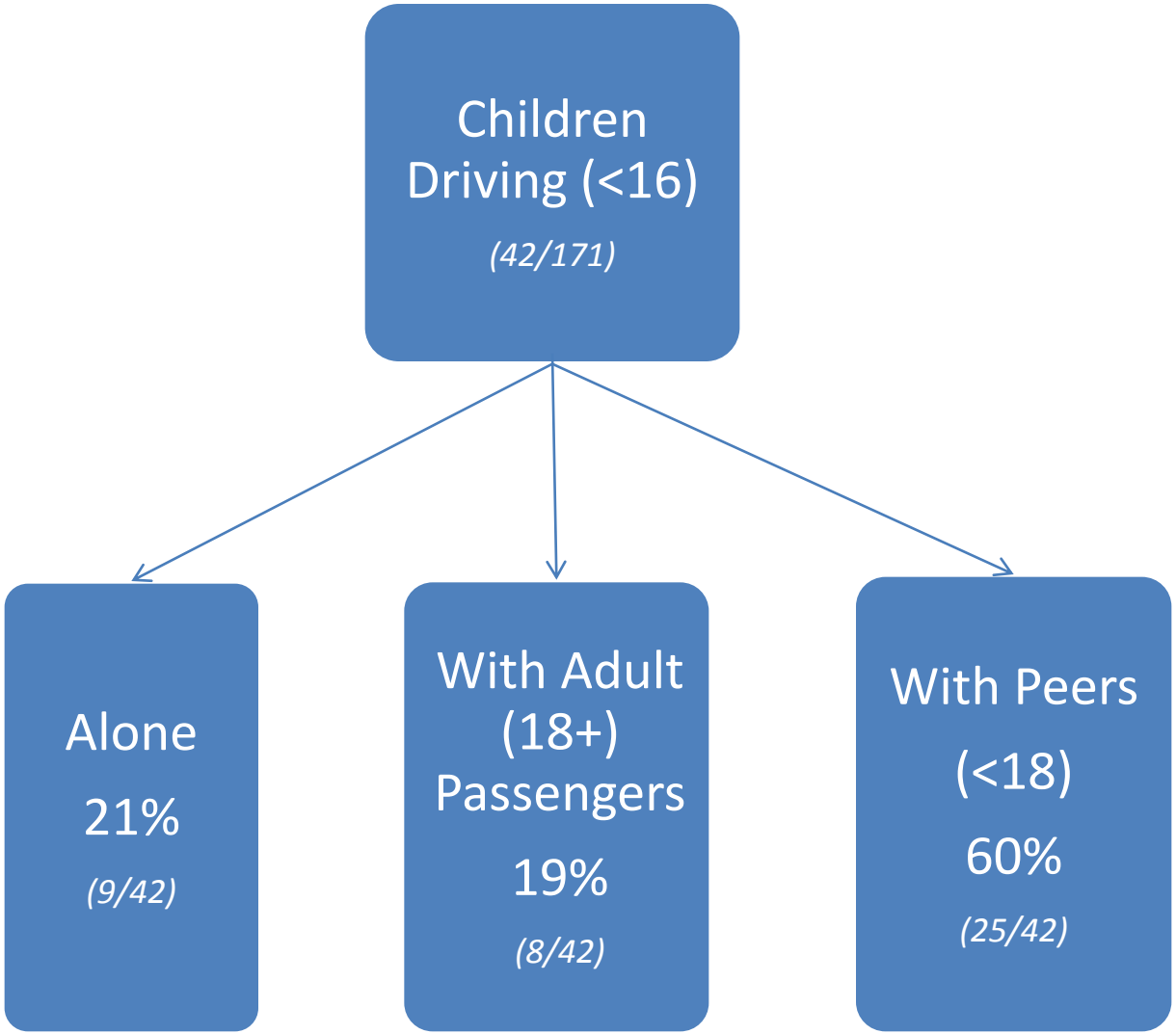
Additional Human Factors Analysis

- Review of over 70 factors associated with IDIs
- Examples factors include:
  - Indication of Legal Violations (Ex. Felonies and Misdemeanor offenses)
  - Driver & Passenger Age
  - Number of Passengers
  - Goal of Operation
  - Alcohol Use & Levels
  - Location of Passengers
  - Location of Use
  - Accident Terrain

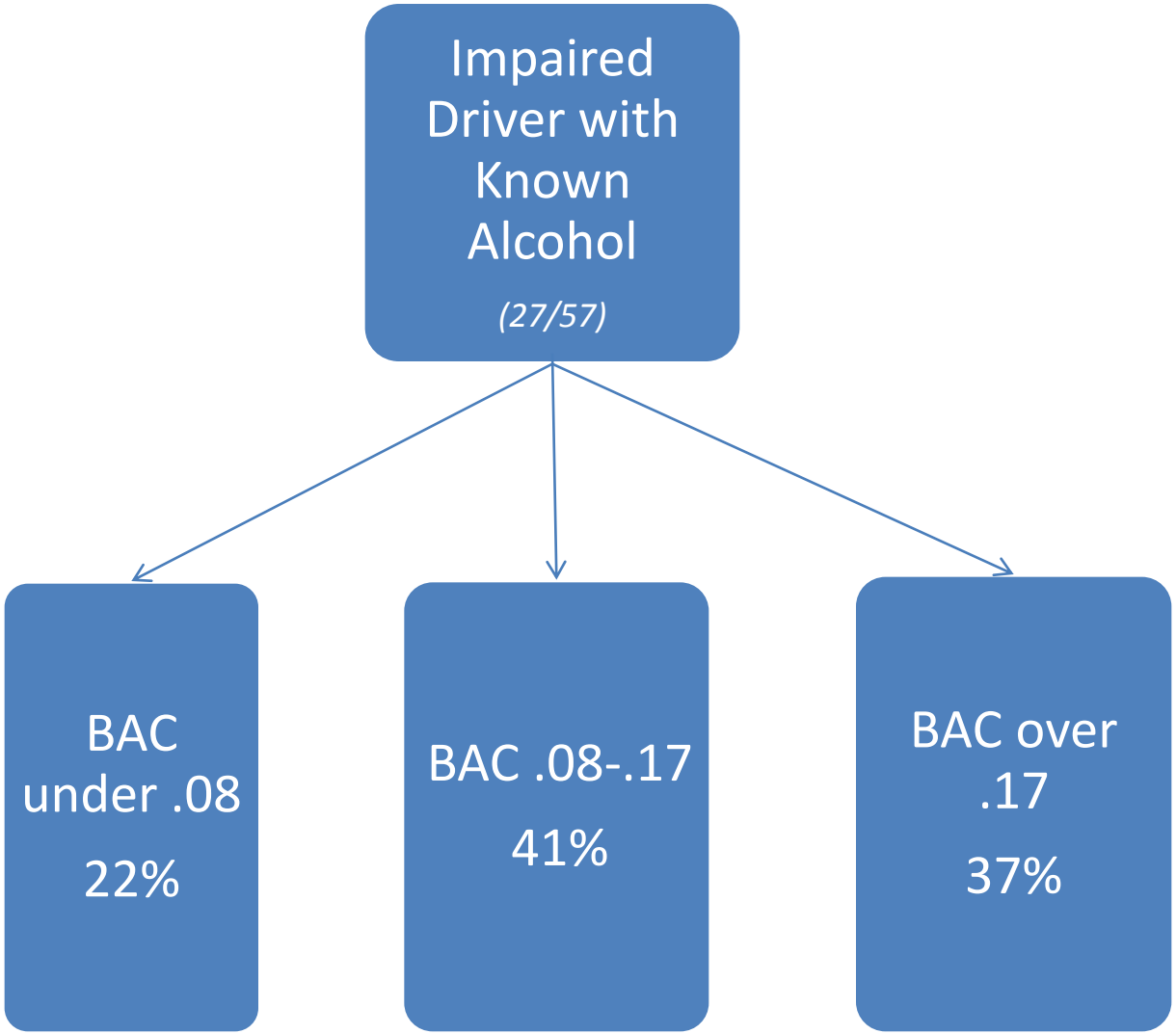
IDI Breakdown



When children under 16 drive, who is in the vehicle when they crash?



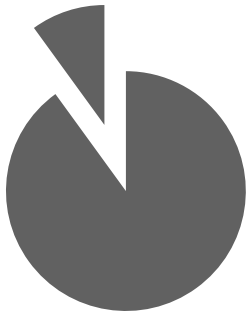
Incidents with Known Driver Blood Alcohol Content Level



Conclusions from Qualitative Analysis of IDIs

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

- **Portion of ROV incidents that <u>potentially</u> could be addressed by different stability & handling performance requirements is very small**
  - **90% of incidents would not have been prevented by different stability & handling performance requirements**
  - **10% of IDIs are inconclusive – It is not possible to conclude that different design attributes could have prevented the crash**



- **ROHVA's work on rules for behavior is addressing the primary**

Differences Between ROHVA & CPSC Approaches To Stability & Handling Not A Factor In At Least 90% of IDIs

Rules for Behavior

ROV Safety Rules

- Key messages to address hazard patterns
- Regularly promoted by ROHVA and others


Recreational Off-Highway Vehicle Association
Media Relations
949-255-2560, Ext. 3132

The Recreational Off-Highway Vehicle Association Promotes Safe Driving Tips for Memorial Day Weekend

IRVINE, Calif.,

Contact:
Recreational Off-Highway Vehicle Association
Media Relations
949-255-2560, Ext. 3132

Recreational Off-Highway Vehicle Association Calls for Safe Four-Wheeling this

IRVINE, Calif., J

Recreational Off-Highway Vehicle Association
Media Relations
949-255-2560, Ext. 3132

Recreational Off-Highway Vehicle Association Continues Pioneering Work In Support of Consensus Standards and Occupant Safety

NEWS from CPSC

U.S. Consumer Product Safety Commission

Office of Information and Public Affairs — Washington, DC 20207

FOR IMMEDIATE RELEASE
May 27, 2011
Release #11-233

CPSC Recall Hotline: (800) 638-2772
CPSC Media Contact: (301) 504-7908

CPSC Warns Memorial Day Weekend

"… CPSC encourages ROV riders & passengers to follow these guidelines from CPSC and the Recreational Off-highway Vehicle Association (ROHVA) …"

CPSC Support of ROHVA Safety Rules Important

Education And Training

ROV E-Course

- Over 2,800 enrolled in 2011
- Up 23% from 2010
- Supported by members
- Publicity via enthusiast, trade and government partners

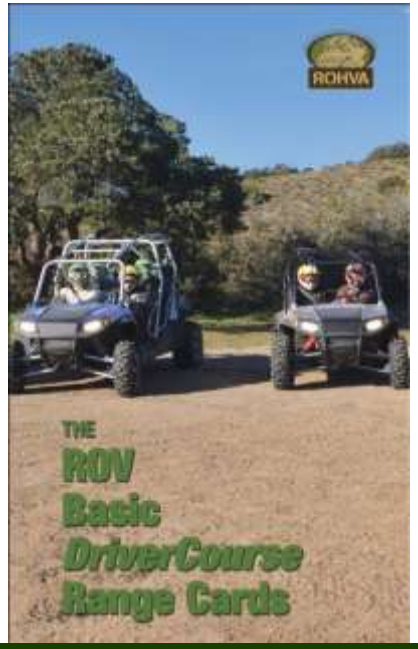
Demand for E-Course Building and Will Drive Hands-On Training

Education And Training

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

ROV Hands-On Training

- Incorporating best practices and leveraging resources from ASI & MSF
- ROV Basic *DriverCourse* and Open Trail Experience Suite – launch in early 2012
- Training available to customers of non-member companies



CALIFORNIA STATE PARKS
SINCE 1864
OHV

Public Health
Prevent. Promote. Protect.

Recreational and Occupational Users Excited About ROHVA Training

Next Steps

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

Continue to Promote Safe and Responsible Use

1. Demand building for ROV E-Course: appreciate more help from CPSC
2. Launch ROV Basic *DriverCourse* and Open Trail Experience Suite in early 2012
3. Promote education and training with media events (Locations TBD)

Continue Dialogue with CPSC regarding Vehicle Standards

1. Answer questions regarding ROHVA's work
2. Rely on a fact based approach to safety correlating standards development to real world risk
3. Request open communication with CPSC regarding its positions and the underlying data

ROHVA Is An Active Partner on Safety