NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

PUBLIC MEETING FOR ADVANCED GLAZING RESEARCH

Holiday Inn Capitol

550 C Street, S.W.

Washington, D.C.

FEBRUARY 1, 1996

9:00 a.m.

A G E N D A

NHTSA

People Saving People

On the Road for a Healthier Future

TEAM GLAZING

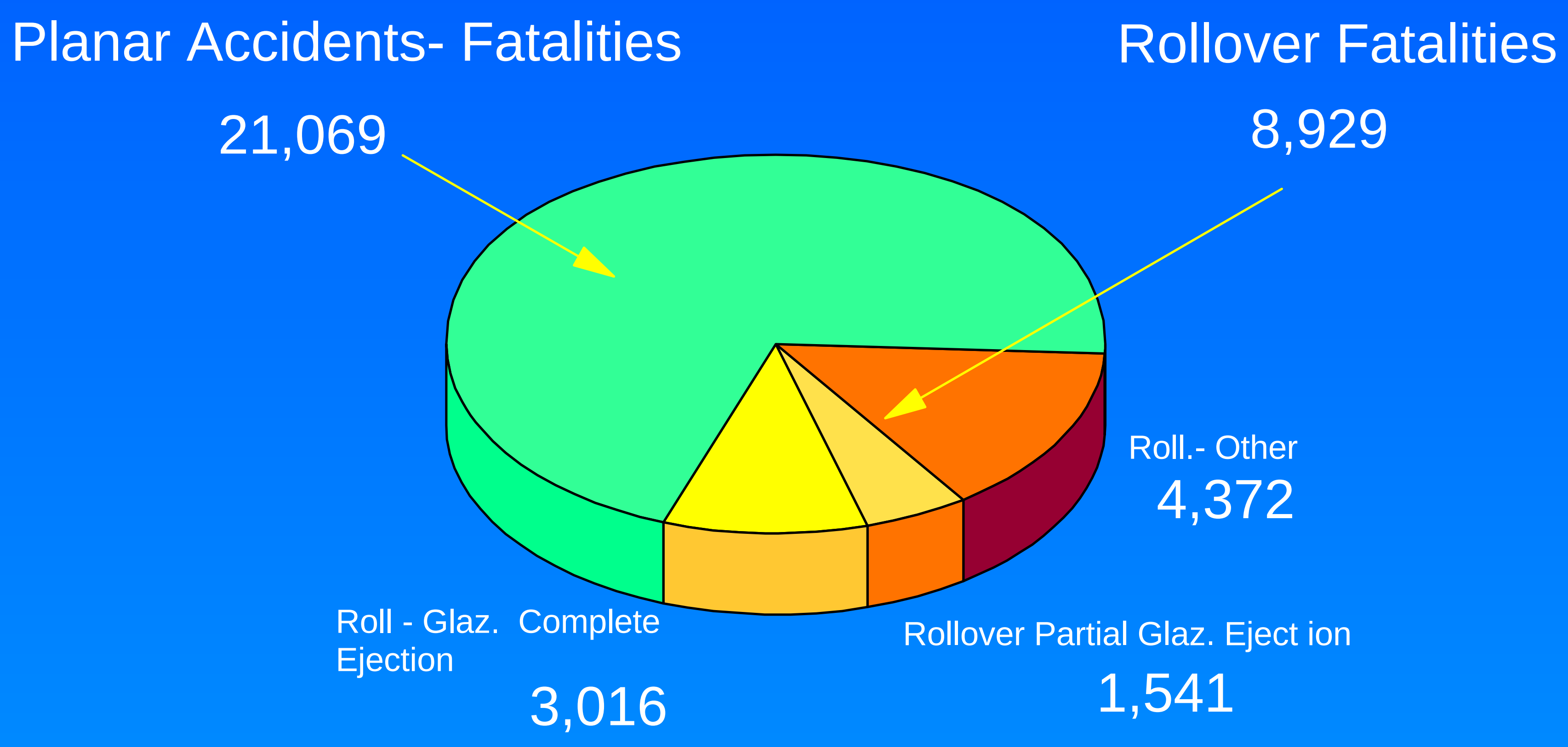
Advanced Glazing Research Team

Glazing Team Goal

- "To develop a recommendation on whether the agency should regulate occupant retention through side-window glazing, and if so, details on how to regulate the industry. Work with the glazing industry to assess and encourage research on the alternative glazing system.

Rollover Fatalities

1993 F.A.R.S,
distributed by '88-93 NASS Averages

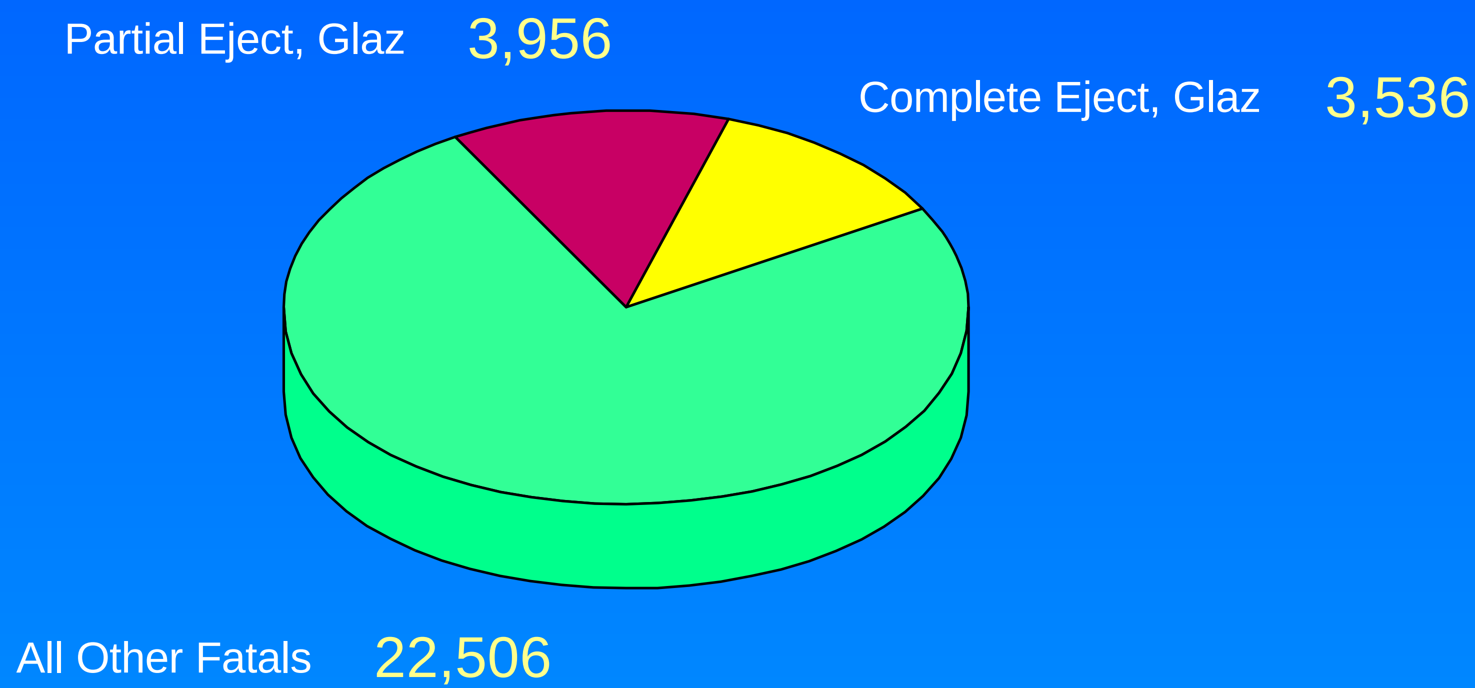


Ejection Status for Involved Occupants All Portals, In light Passenger Vehicles, Annual Average for 1988-1993 NASS Adjusted to 1993 FARS

	Fatalities		
	Cases	Estimate	Percentage
Not Ejected	1,867	19,079	63%
Completely Ejected	583	6,205	21%
Partially Ejected	303	4,714	16%
Unknown	88	distributed	distributed
Total	2,841	29,998	100%

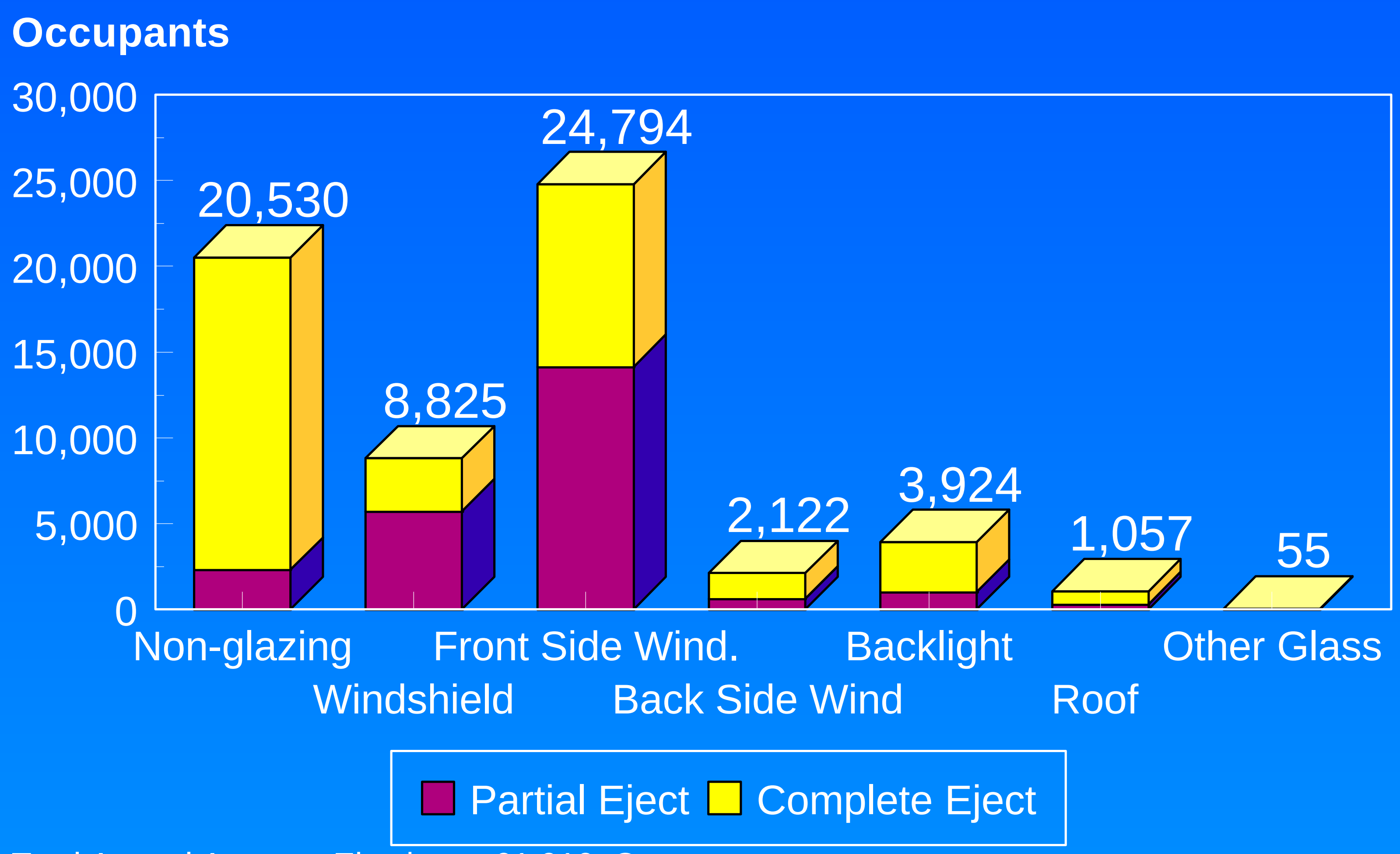
Glazing Related Fatalities

1988-1993 NASS Averaged
Adjusted to 1993 FARS



Ejection Paths

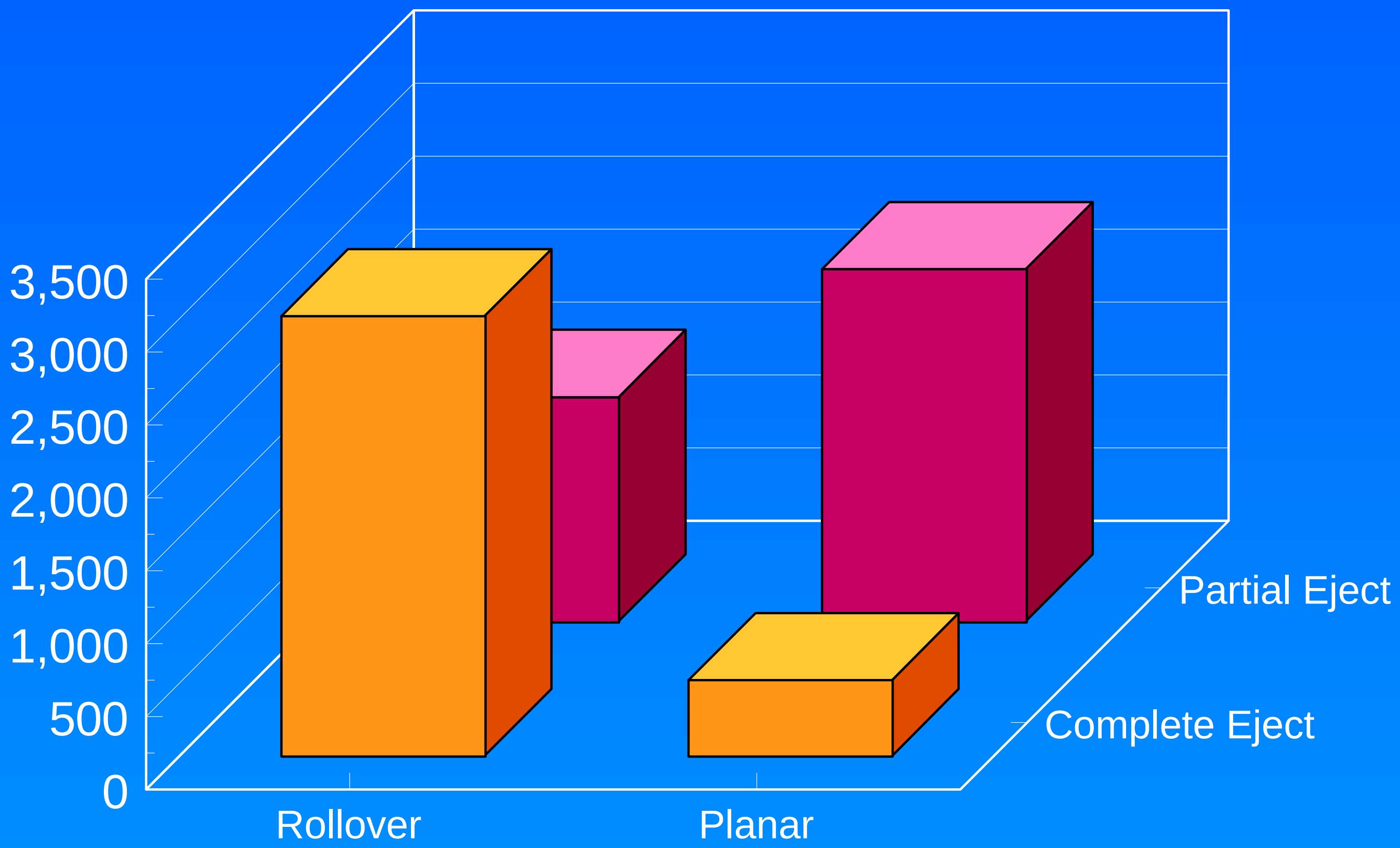
Annual Average, 1988-1993 NASS



Total Annual Average Ejections: 61,010 Occupants

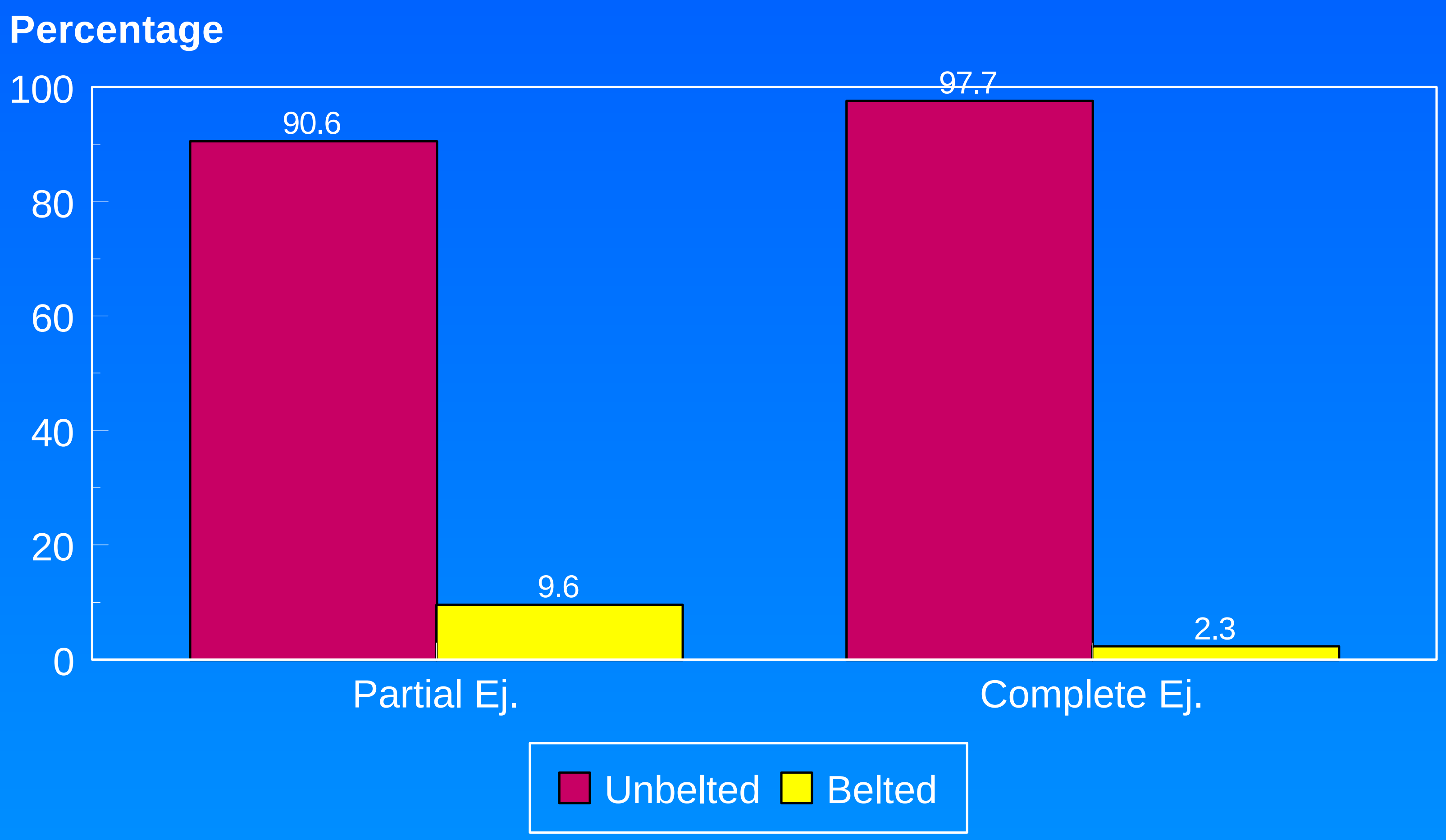
Fatal Glazing Ejections

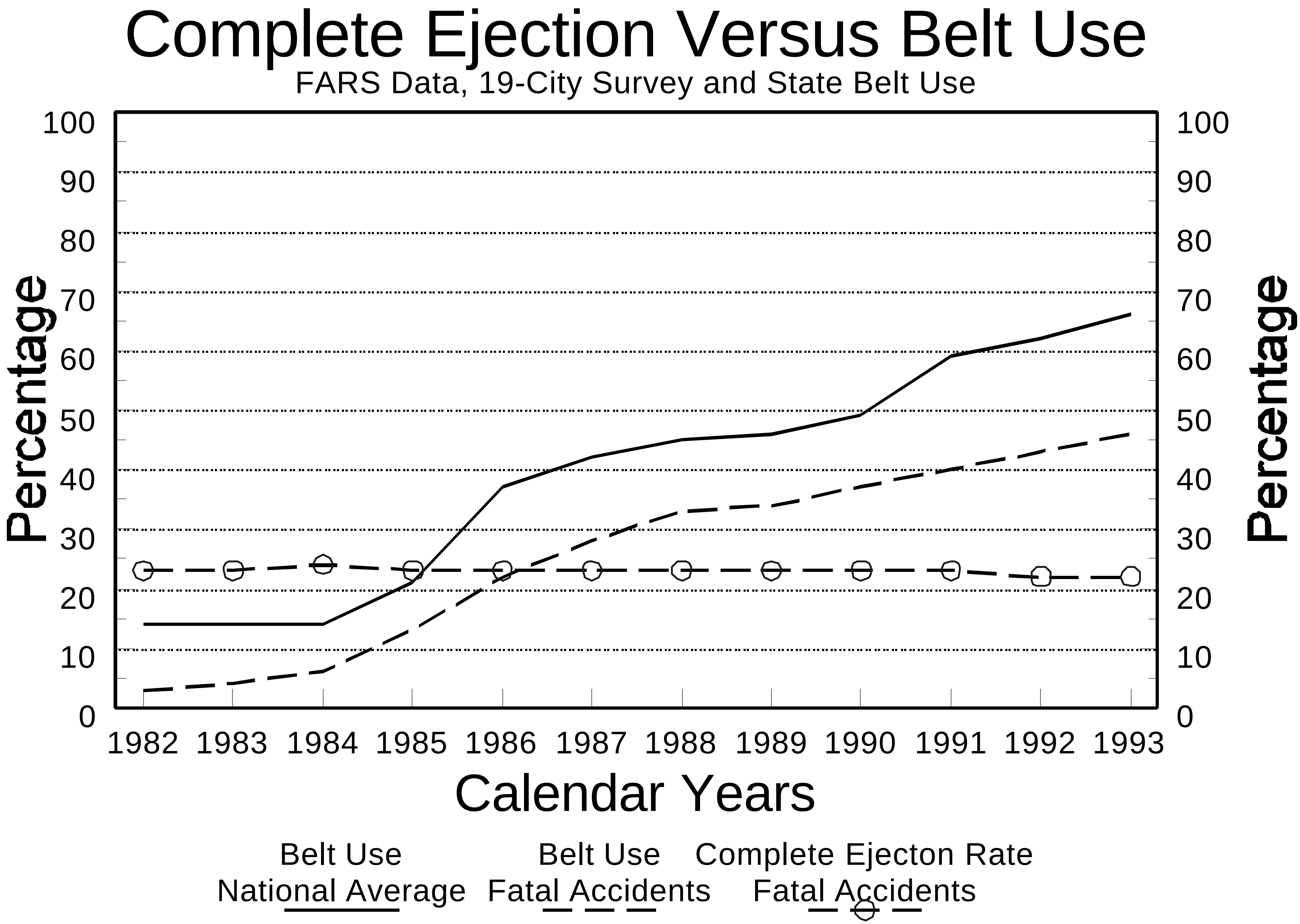
Annual Average for 1988-1993
Adjusted to 1993 FARS



Belt Use For Ejection-Related Fatalities

Police-reported Use, 1989 FARS




Complete Ejection Versus Belt Use
FARS Data, 19-City Survey and State Belt Use
Percentage
100
90
80
70
60
50
40
30
20
10
0
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
Calendar Years
Belt Use National Average
Belt Use Fatal Accidents
Complete Ejecton Rate Fatal Accidents

Injury Severity, by Ejection Type out of Glazing Annual Average for 1988-1993 NASS, Adjusted to 1993 FARS

	Fatality	Severe Injury
Complete Ejection	3,536	3,717
Partial Ejection	3,956	4,265
Total	7,492	7,982

EJECTION MITIGATION:

NHTSA
ADVANCED GLAZING
RESEARCH PROGRAM

Research Objectives

- Identify Countermeasures to Occupant Ejection Through Side Windows
- Show Feasibility
- Limit Increased Head and Neck Injuries by Glazing Contact and Laceration Potential by Broken Glass

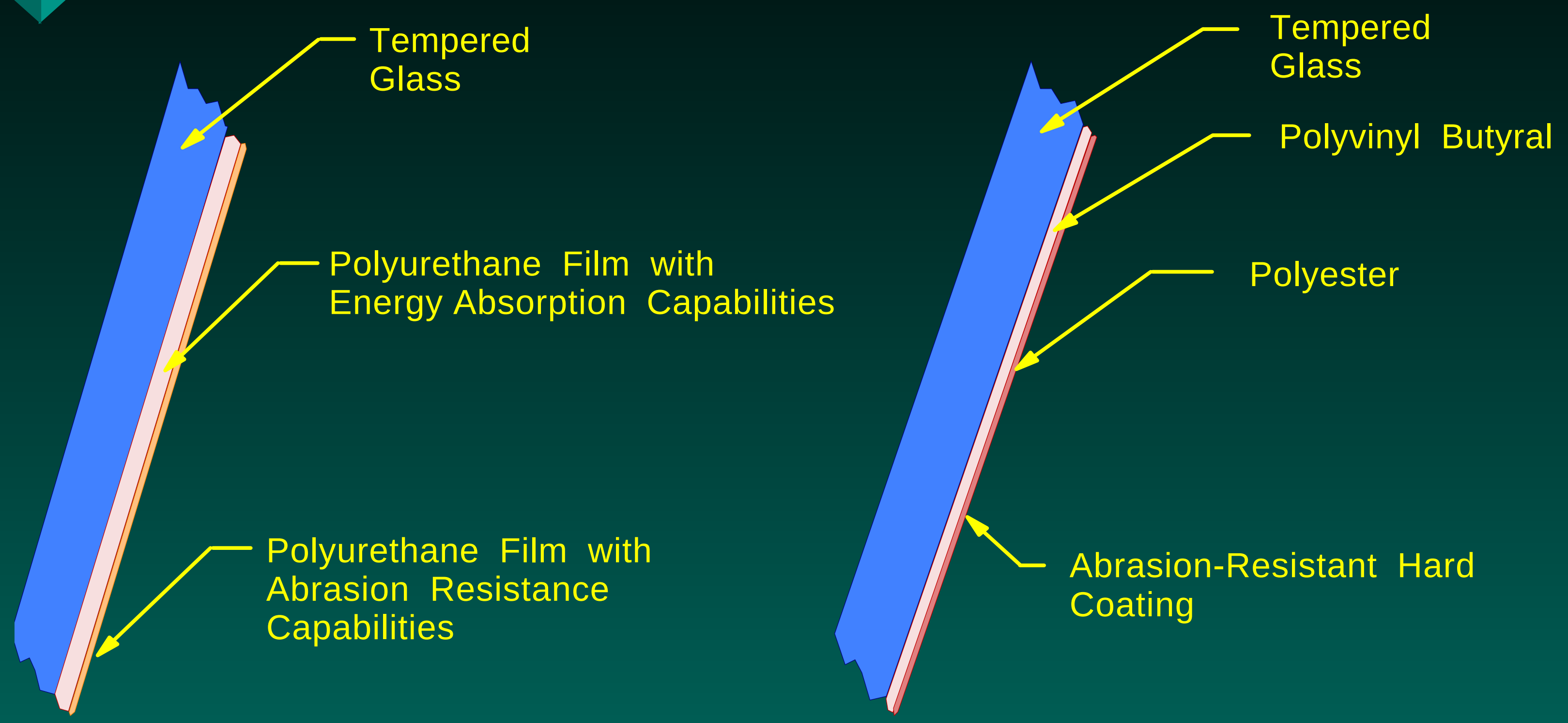
Approach

- Identify Countermeasures
- Develop Certification Test(s)
  - retention
  - injury potential
- Evaluate Countermeasures

Glazing Types

- Tempered Glass
- Glass-Plastics (Bilaminates)
- Trilaminates
- Rigid Plastics

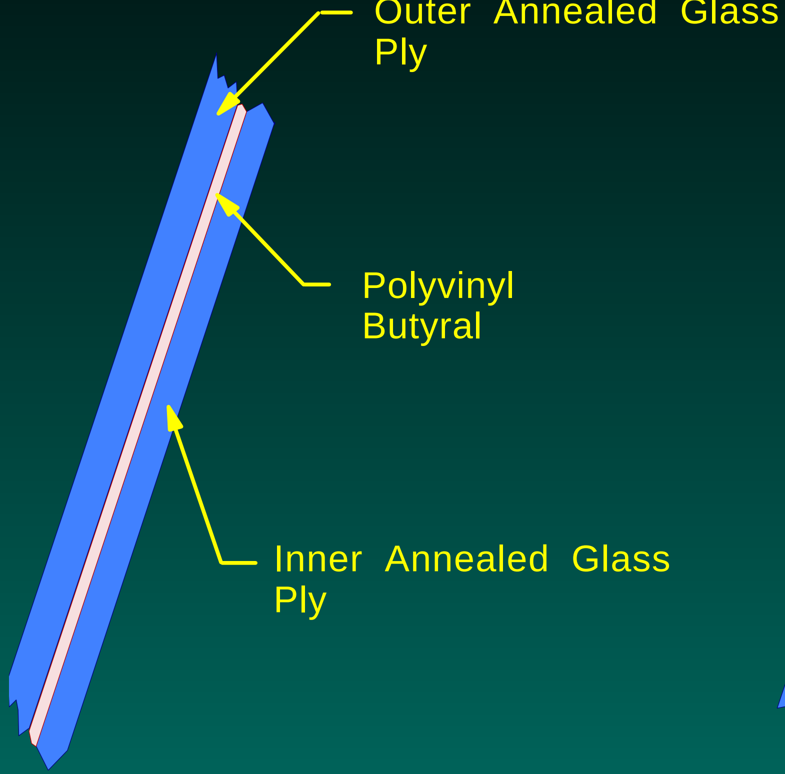
Glass-Plastic (Bilaminate) Glazing



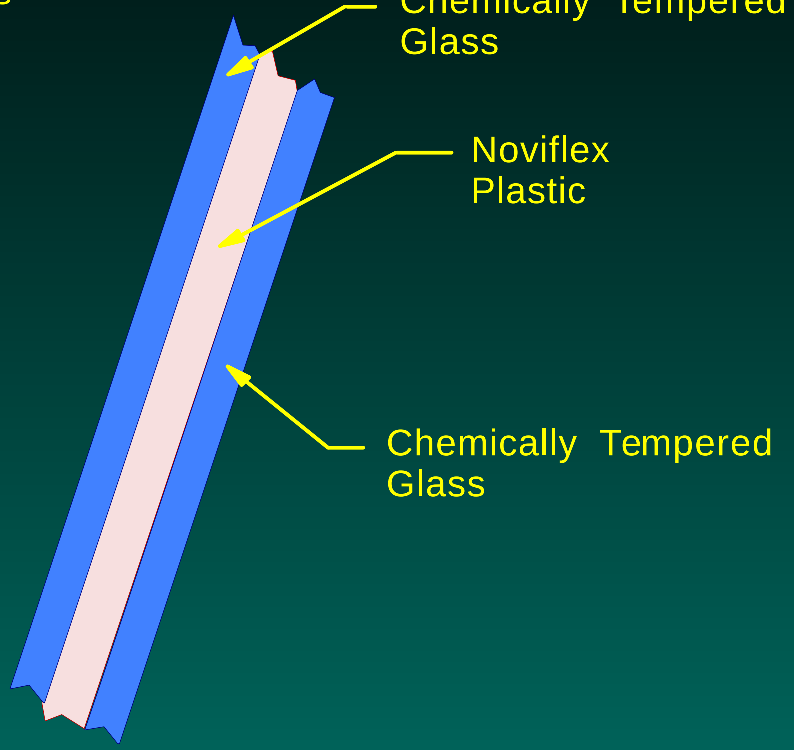
Total Thickness = 4.2 mm

Total Thickness = 5.1 mm

Tri-laminates



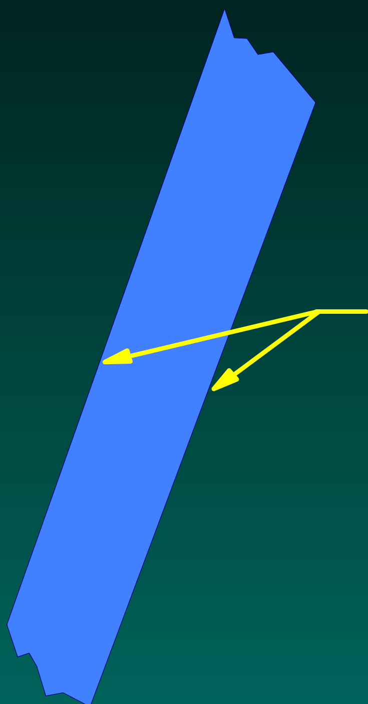
Total Thickness = 4.46 mm



Total Thickness = 5.33 mm

Polycarbonates

LEXAN



Thermosetting Silicone Resin Coating, both surfaces

Thickness = 4.5 mm

MAKROLON

Thickness = 4.4 mm

Establish Impact Conditions (Mass & Speed)

- Accident/Crash Test Data
- Pendulum/Sled Test Data
- Windshield Test Data

Impact Speed

- Rollover Test Film Analysis
  - range: 2.4 to 31.4 kmph (1.5 to 19.5 mph)
  - average: 11.3 kmph (7.0 mph)

- Accident Data Analysis (ΔV)
  - range: 0 to 56 kmph (35 mph)
  - average: 18 kmph (11.2 mph)
  - most frequent: 30.6 kmph (19 mph)

Impacting Mass

- Pendulum Tests (BioSID)
  - Head
  - Shoulder
- Sled Tests (BioSID)
  - “rollover” configuration
  - “side Impact” configuration

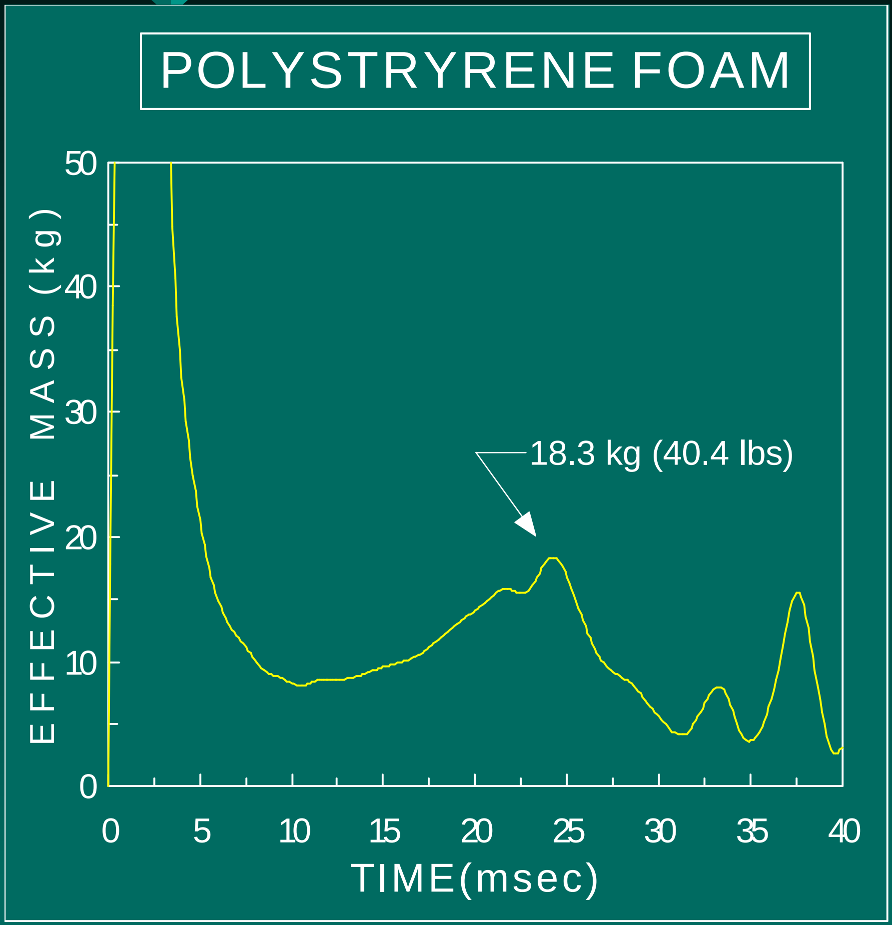
Effective Mass
(Pendulum Tests)

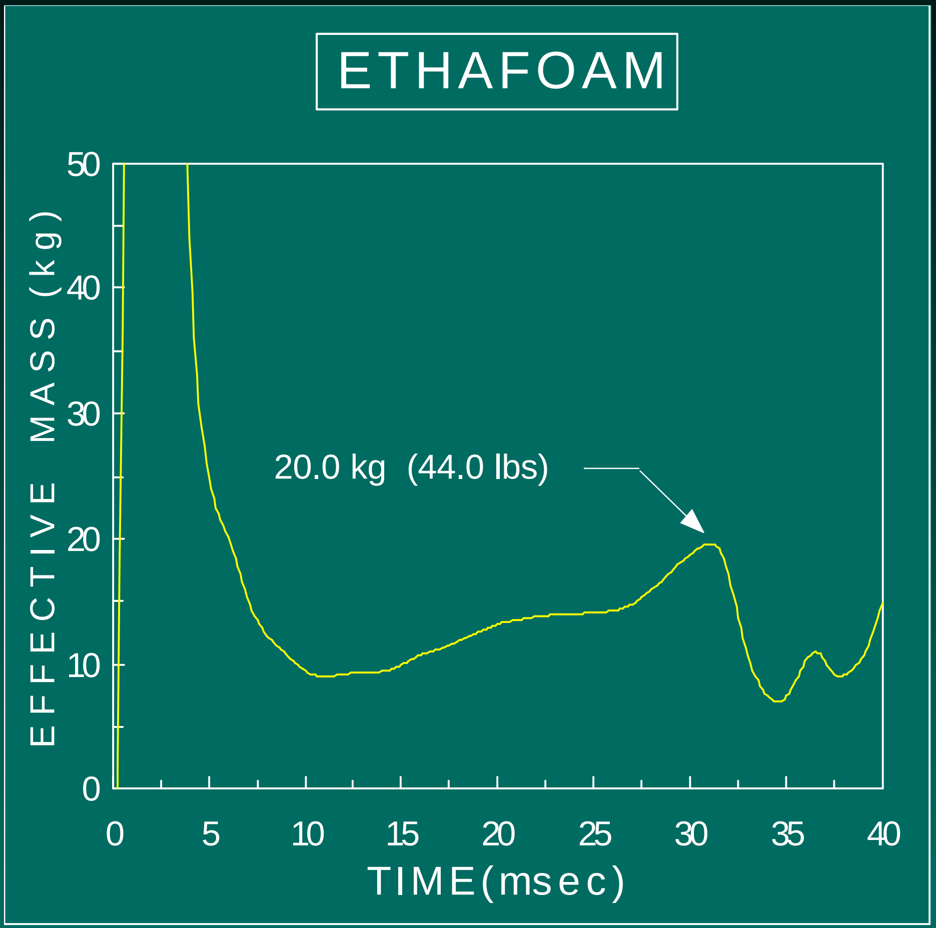
- Head
  - initially 4.5 kg (9.9 lbs)
  - rises to 10-18 kg (22-40 lbs)
- Shoulder
  - initially 16-18 kg (35-40 lbs)
  - rises gradually to 25-27 kg (55-60 lbs)

Impacting Mass

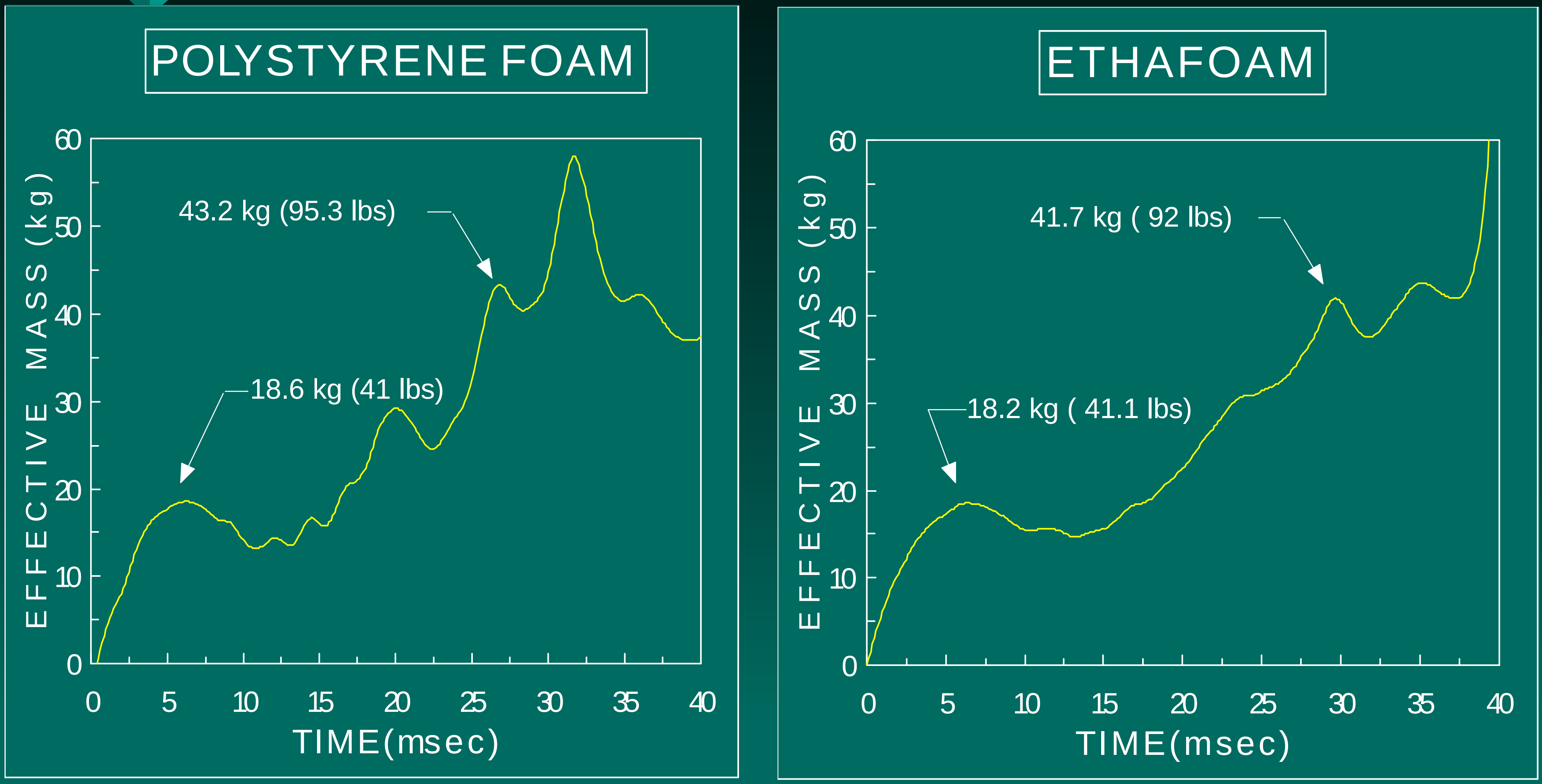
- Sled Tests (BioSID)
  - "rollover" configuration
  - "side impact"configuration

Effective Mass Measurement in Side Impact Simulation





Effective Mass Measurement in Rollover Impact Simulation



Effective Mass
(Sled Tests Summary)

- "Rollover" = 16.1 kmph (10 mph)
  - initially 18-20 kg
  - rises gradually to 41-43 kg
- "Side Impact" = 24.1 kmph (15 mph)
  - initially 9 kg
  - rises to 16-20 kg

- 9 kg at 24.1 kmph = 200 N-m (150 ft-lb)
- 18 kg at 16.1 kmph = 180 N-m (135 ft-lb)

Impact Conditions

Preliminary Selection

- 18 kg (40 lbs)
- 16.1 to 24.1 kmph (10 - 15 mph)

Windshield Testing

- Hemi-Spherical Impactor (18 kg)
- Resists Penetration Up To 22.7 kmph (14.1 mph)
- Windshield Reasonable Upper Bound

Impacting Mass

Preliminary Selection 18 kg

- Similar Energy Levels
- High Mass/Low Speed More Severe
- Ejection Largely Rollover Problem

Establish Performance Criteria

- Decide which criteria must be addressed in component test
  - Retention
  - Head Injury
  - Neck Injury
  - Laceration (minor injuries but disfiguring)

Establish Performance Criteria (Continued)

- Decide what type of measurement must be made for each criterion and establish pass/fail limits
  - Retention: max. dynamic deflection, energy containment, etc.
  - Head Injury: HIC, Mean Strain Criterion, etc.
  - Neck Injury: neck rotation, neck loading, etc.
  - Laceration: chamois cuts, developmental polymer face mask, etc.

Establish Performance Criteria (Continued)

- Decide what type of measurement must be made for each criterion and establish pass/fail limits
  - Retention: max. dynamic deflection, energy containment, etc.
  - Head Injury: HIC, Mean Strain Criterion, etc.
  - Neck Injury: neck rotation, neck loading, etc.
  - Laceration: chamois cuts, developmental polymer face mask, etc.

Select and Develop Impactor

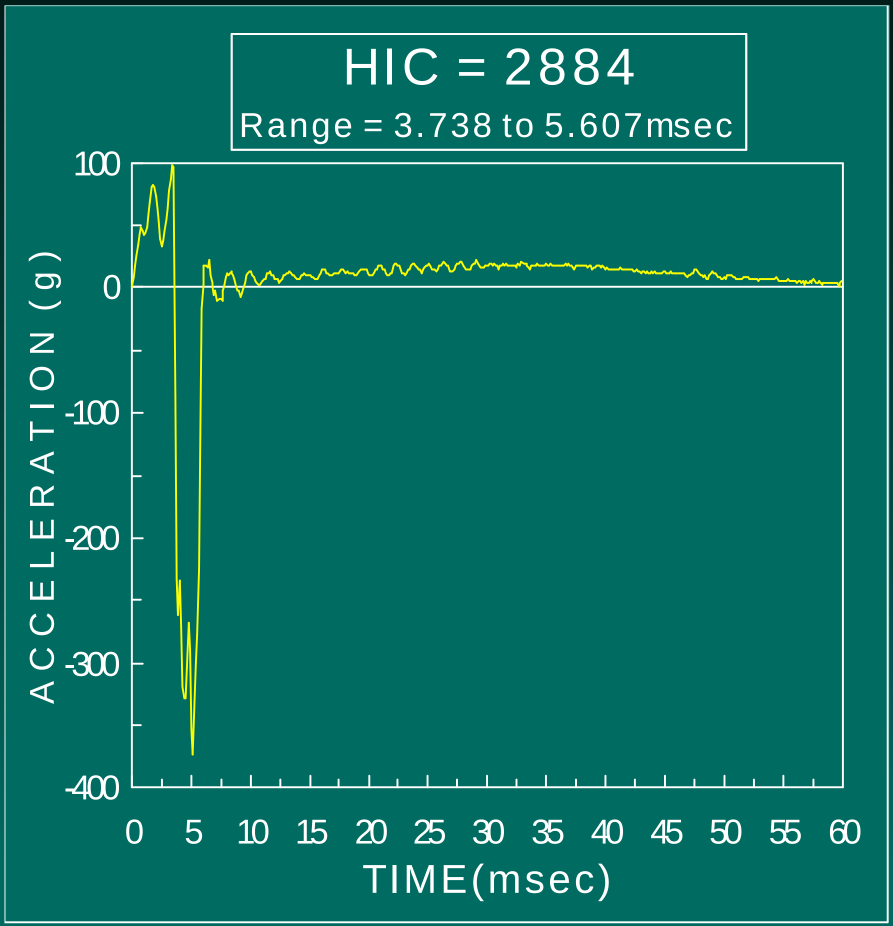
- Guided
  - measure acceleration & displacement
- Adjustable Mass
- Changeable Faces
- Usable In Vehicles

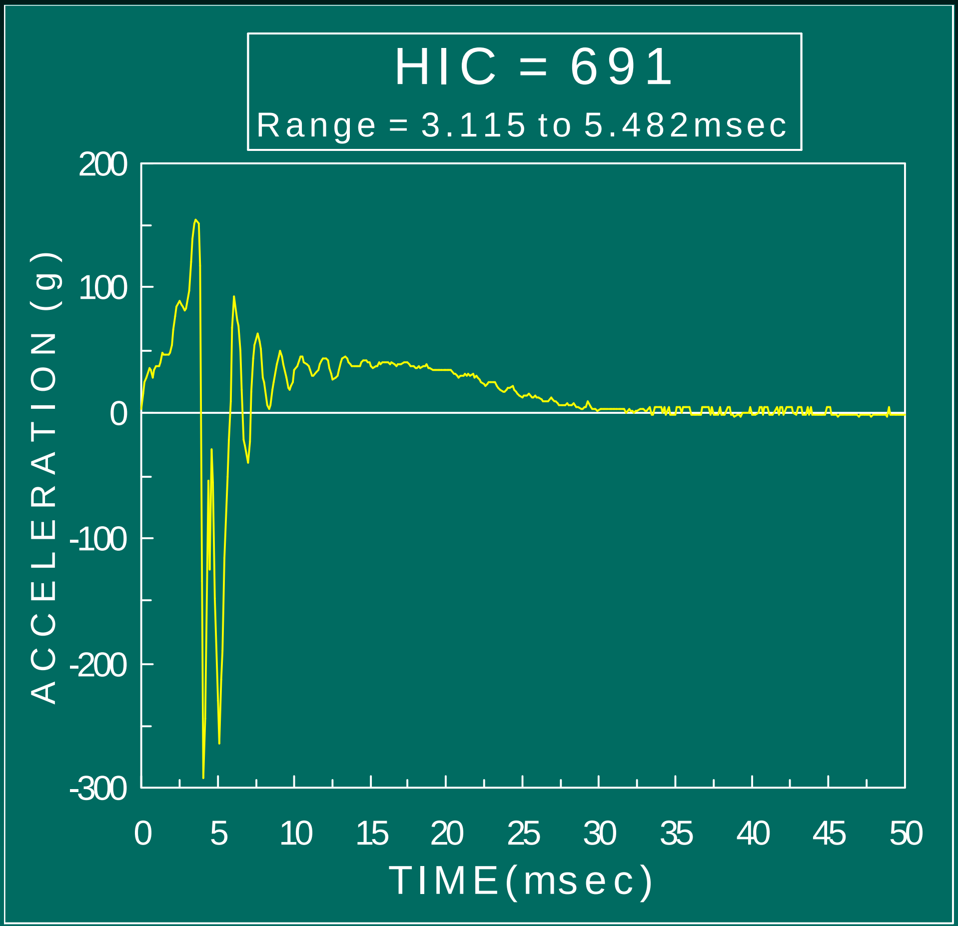
Establish Test Procedures

Initial Testing

- 5 Alternative Glazings
- Rigidly Mounted
- 10 - 15 mph Range

Erroneous Accelerometer Output

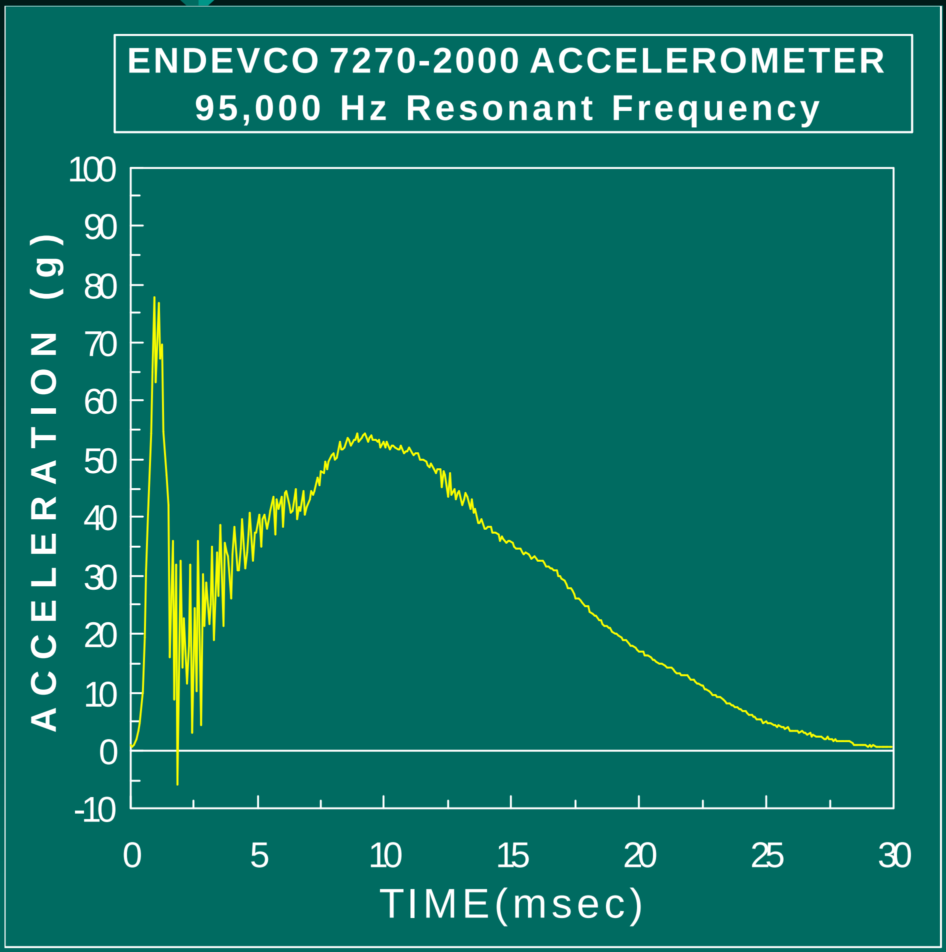


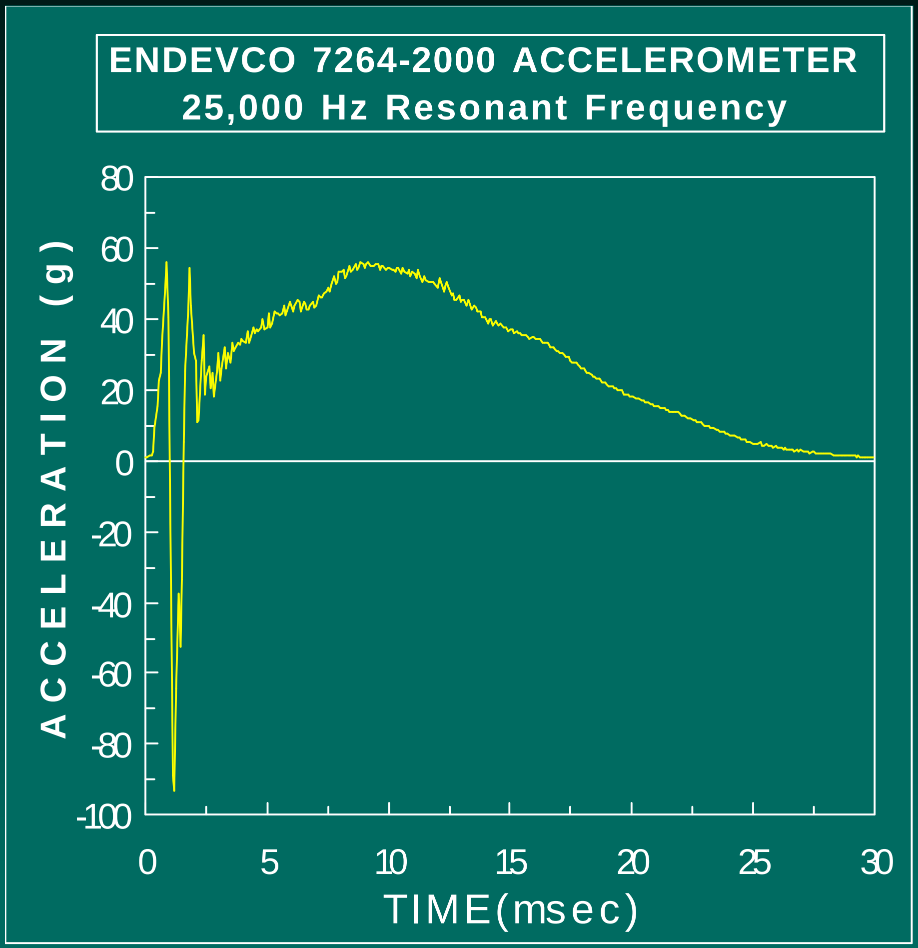


Solution to Erroneous Output

- High Frequency Accelerometers
- Free-Motion Headform (FMVSS 201)

FMH Response





Certification Test Development Summary

- Retention Test
  - guided impactor
  - 18 kg (40 lbs)
  - 16.1 to 24.1 kmph (10 to 15 mph)
- Head Injury
  - FMH
  - 24.1 kmph

Other Certification Test Issues

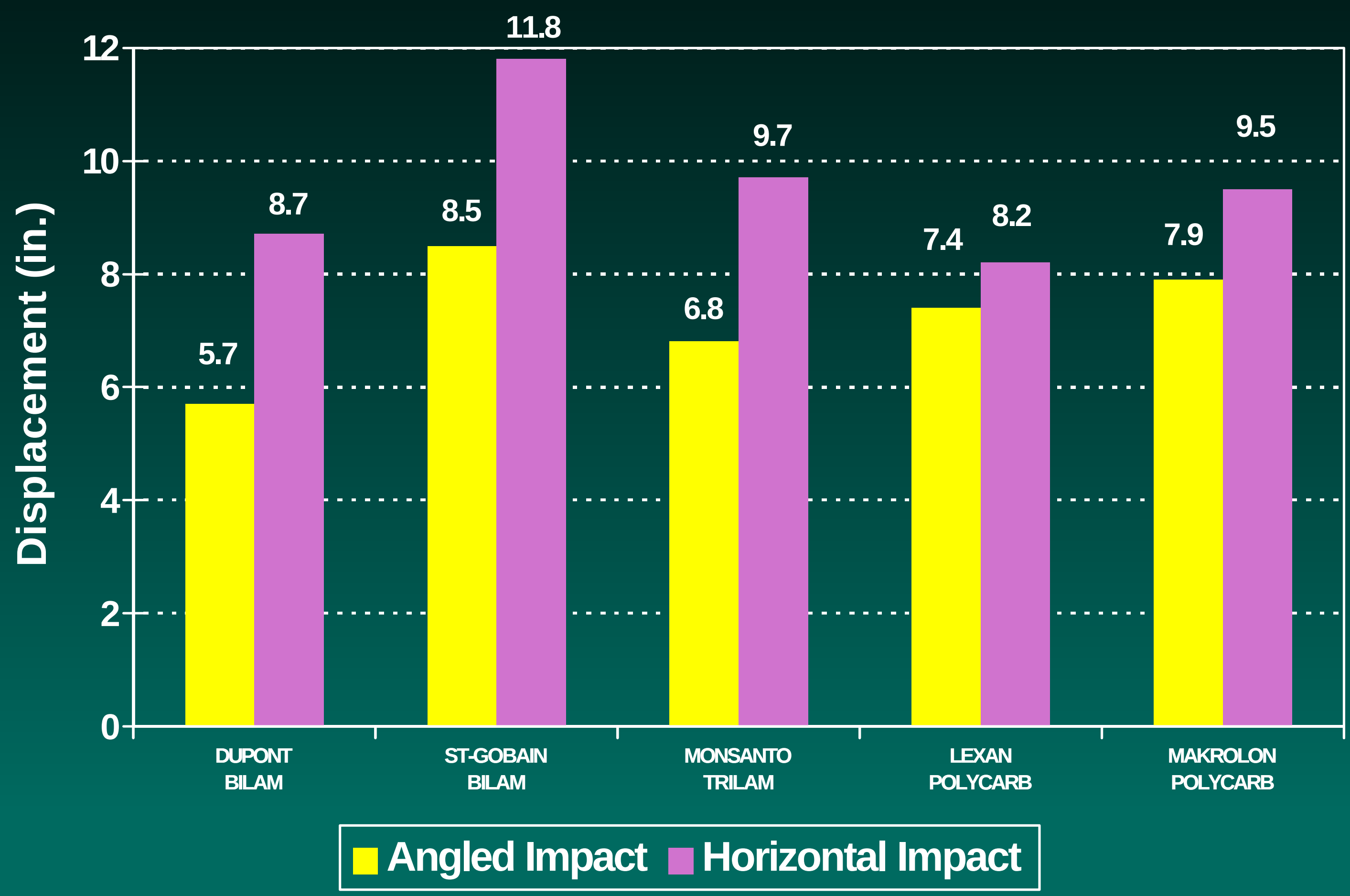
- Impactor Orientation
- Impact Location
- Window Position
- Pass/Fail Limits

Countermeasure Evaluation
Previous Work

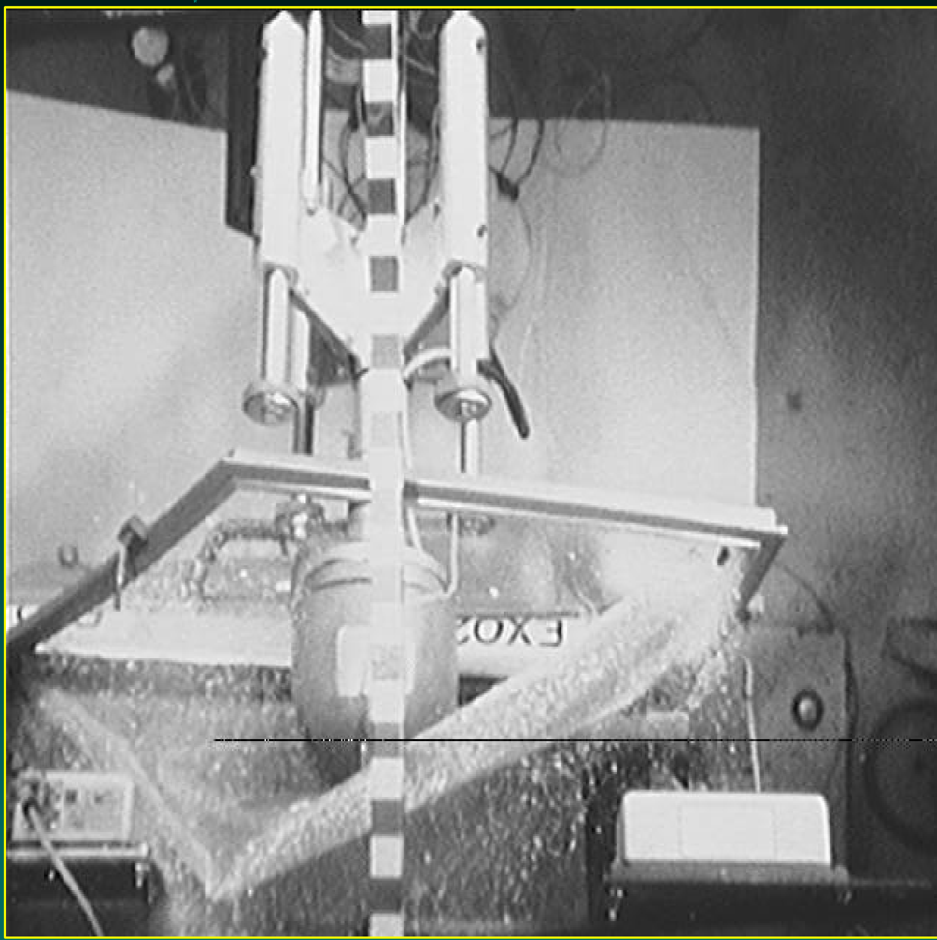
- T-Edge Encapsulation
- Modified LTD Door
  - clamped window frame
- Successful Retention
  - 40 lbs at 20 mph

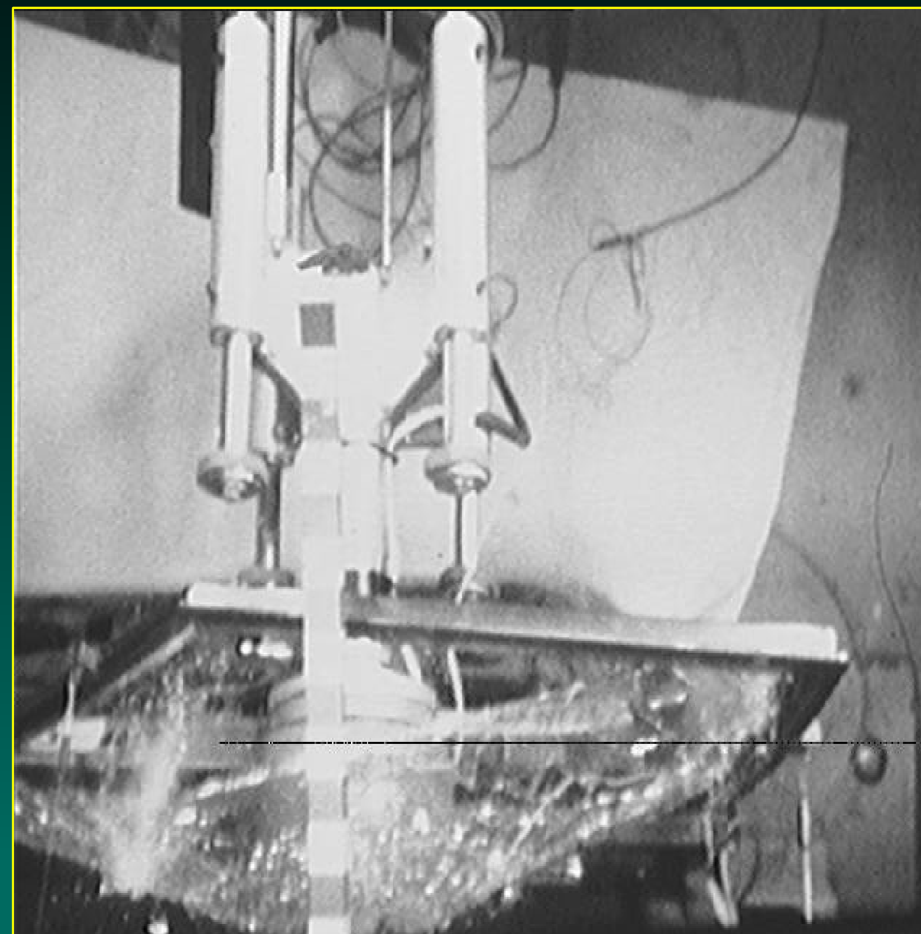
Encapsulated Edge Urethane Frame

Impactor Angle Effect



Dynamic Deflection



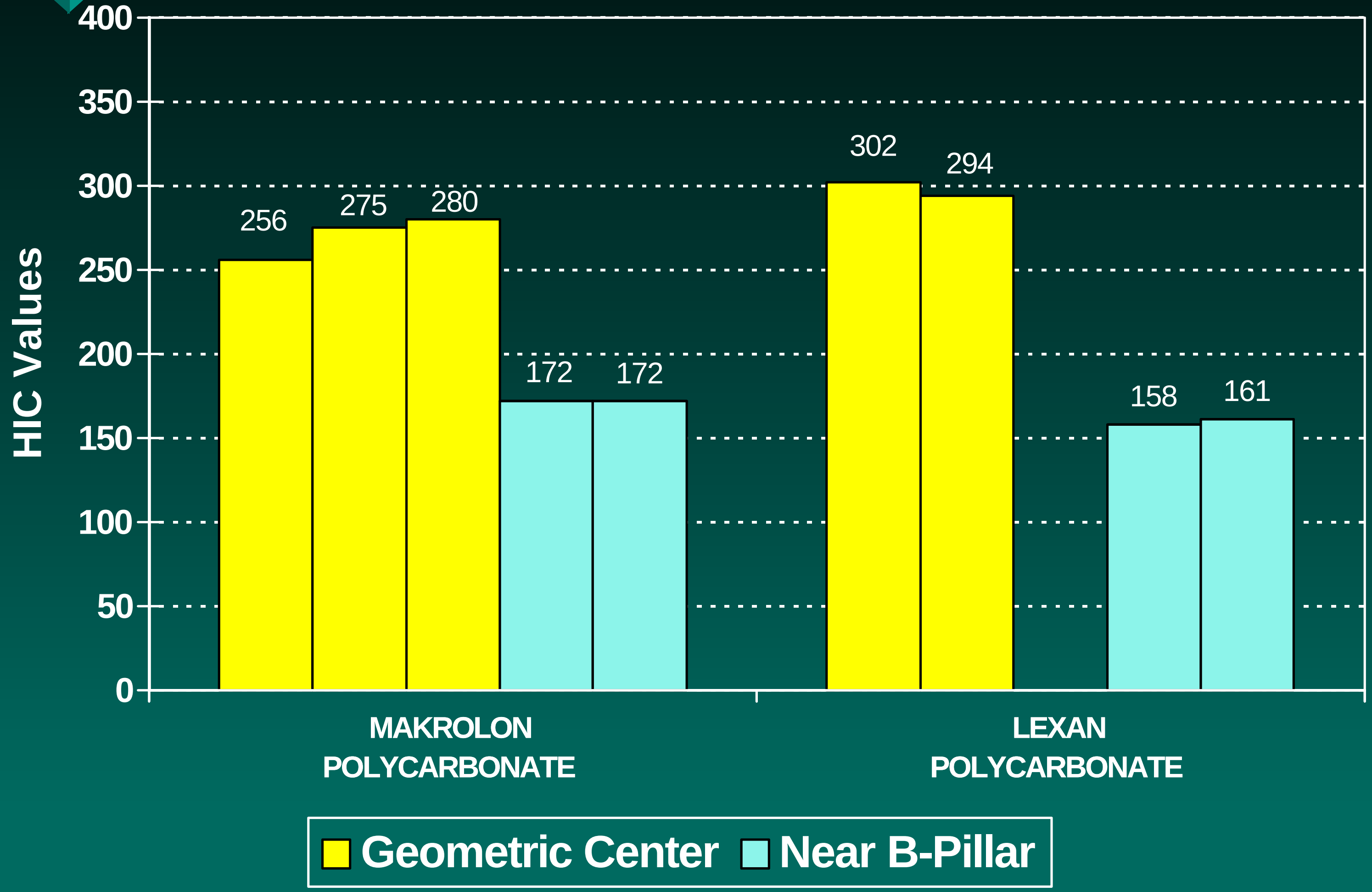


FMH Impact Test Data

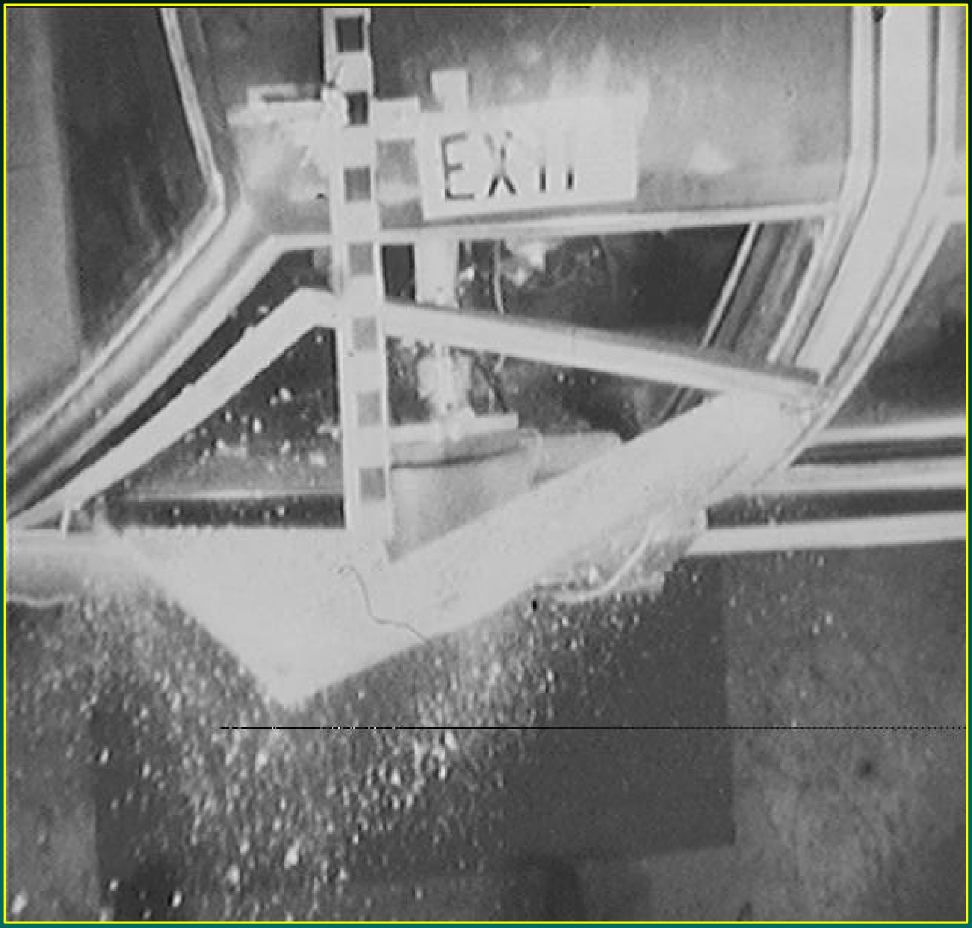
GLAZING MATERIAL	HEAD FORM IMPACT SPEED		HIC VALUE	MATERIAL BREAKAGE	DISENGAGED FROM WINDOW FRAME
	(km/h)	(mph)			
LTD Tempered Glass	25.4	15.2	27	Yes	Yes
LTD Tempered Glass	19.8	12.3	37	Yes	Yes
Dupont Bilaminate	24.6	15.3	137	Yes	Yes
Dupont Bilaminate	24.4	15.2	178	Yes	Yes
St-Gobain Bilaminate	24.9	15.5	106	Yes	Yes
St-Gobain Bilaminate	24.6	15.3	122	Yes	Yes
Monsanto Trilaminate	24.6	15.3	570	No	No
Monsanto Trilaminate	29.1	18.1	858	Yes	No
Monsanto Trilaminate	29.1	18.1	308	Yes	No

Impact Location Effect on HIC Values

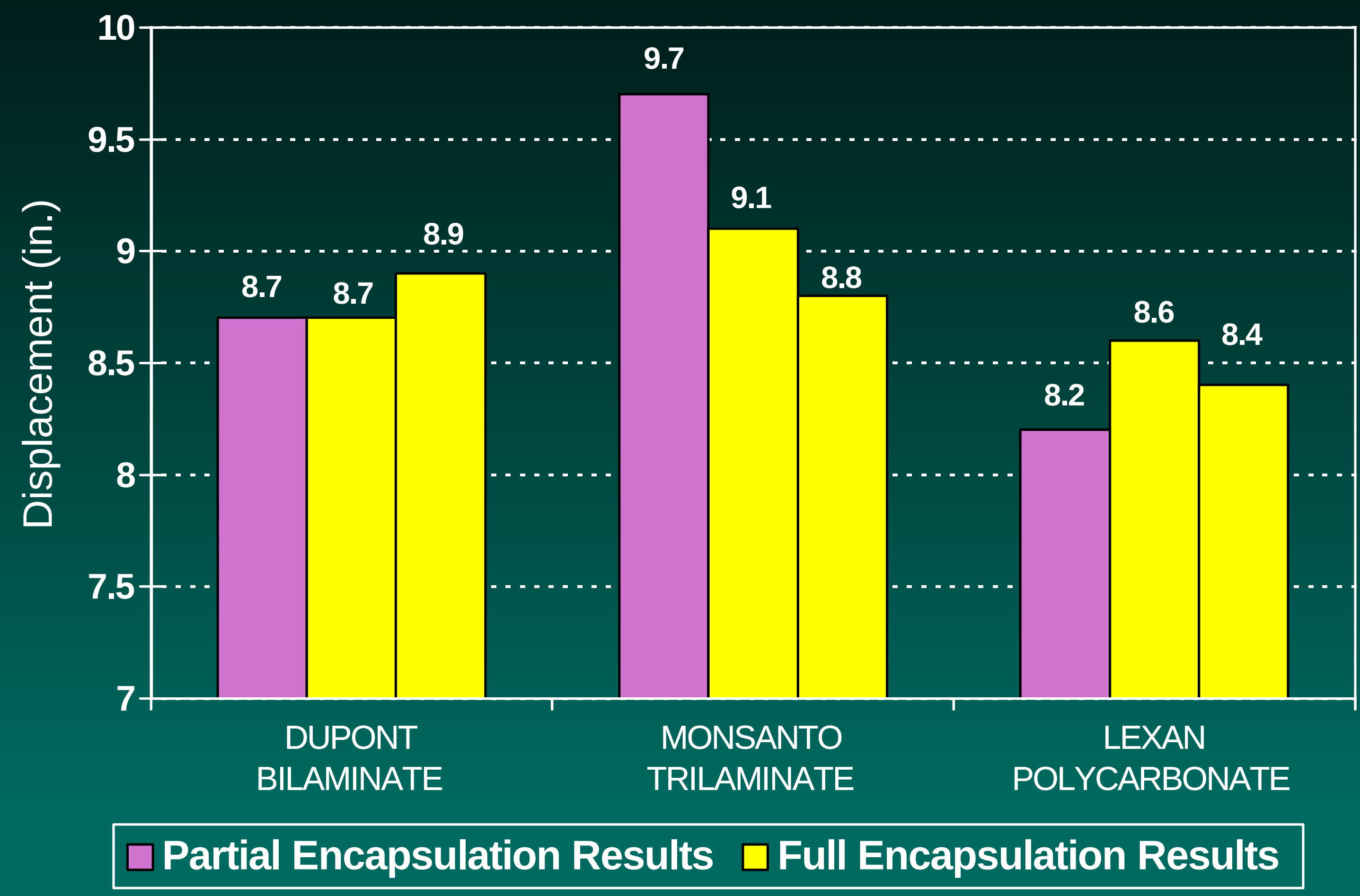
(Rigid Plastic Glazing)



Partial Vs. Full Encapsulation



Full Encapsulation Effect



Preliminary Test Observations

- Retention Test
  - guided impactor shows good repeatability
  - impact angle influence
  - top edge subject to large deflections
- FMH Test
  - good repeatability on some materials
  - impact location influence on HIC values

Future Research

- Further LTD Encapsulation Development
- Explore Encapsulation on Other Vehicles
- HIC Validation
- Neck Injury Potential
- Laceration Potential
- Other Certification Issues

Computer Modeling of Rollover Accidents

Objectives

- Simulate typical rollover accidents to
  - estimate the benefits of alternative glazing
  - estimate the occupant into glazing impact velocity

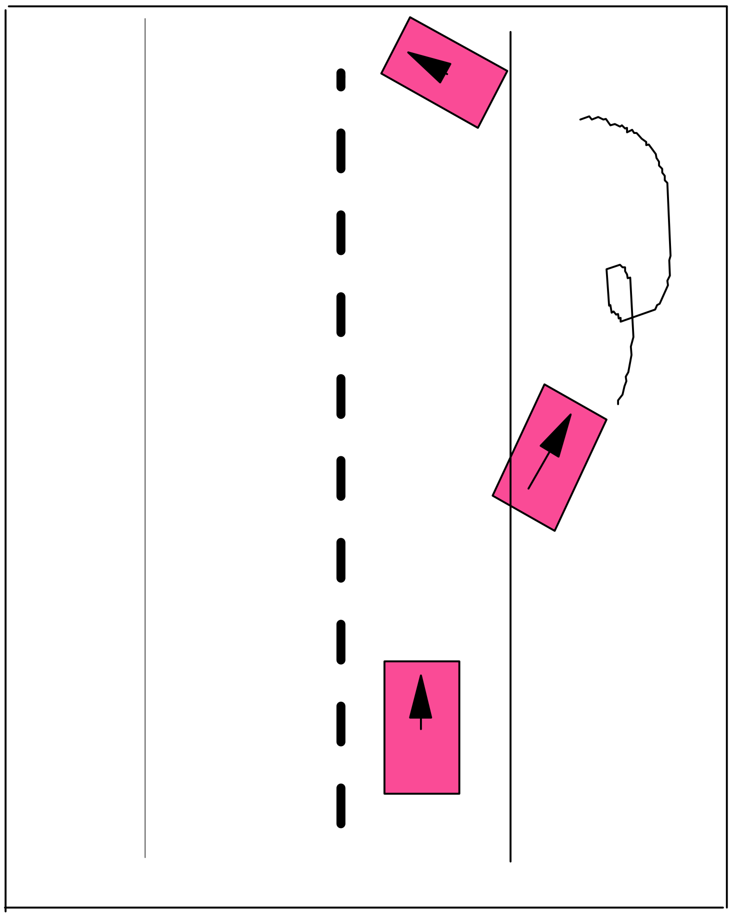
Introduction

- Rollover accidents selected for modeling:
  - NASS investigated cases
  - Single vehicle rollovers
  - Occupant ejection or severe contact with side glazing

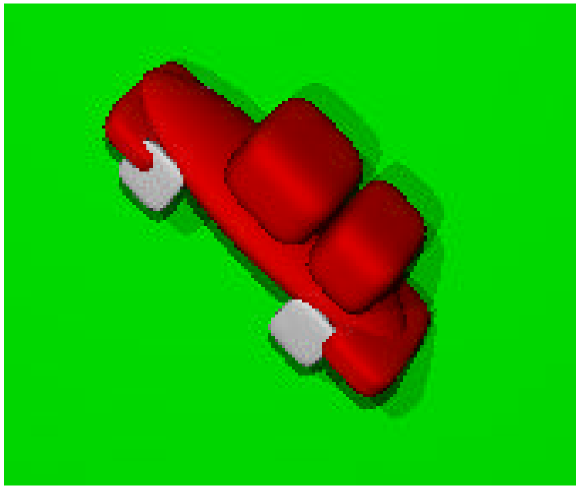
Methodology

- Estimate vehicle motion at the onset of rollover using VDANL
- Estimate complete rollover motion of vehicle using MADYMO
- Simulate occupant kinematics to match with the NASS reported interior contacts
- Set up parametric runs with different glazing materials

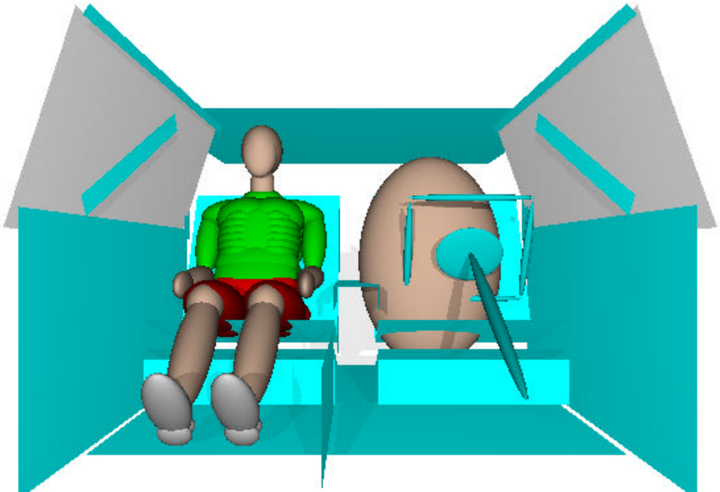
Simulation set up



Vehicle trajectory during rollover



Vehicle model



Occupant model

Matrix of Parametric Runs

	Belted	Unbelted
No glazing	x	x
Tempered Glass	x	x
Rigid plastic	x	x
Trilaminate, 7mm	x	x
Bilaminate	x	x

Rollover of Volkswagen Jetta

Unrestrained Passenger

	Open	Tempered	Rigid plastic	Trilaminate	Bilaminate
HIC	197	414	171	233	269
Neck load (N)	**3416**	**3416(wns)** 500(glaz)	**3416(wns)** 800(glaz)	**3416(wns)** 800(glz)	**3416(wns)** 1000(glz)
Retention	**No**	**No**	yes	yes	yes

Restrained Passenger

	Open	Tempered	Rigid plastic	Trilaminate	Bilaminate
HIC	66	98	191	340	249
Neck load (N)		3222(hdr) 250 (glaz)	3222(hdr) 1000(glaz)	3222(hdr) 1500(glaz)	3222(hdr) 500(glaz)
Retention	**No**	**No**	Yes	Yes	Yes

Rollover of Toyota Pickup

Restrained Driver

	Open	Tempered	Rigid plastic	Trilaminate	Bilaminate
HIC	78	200	276	369	217
Neck load (N)	369	2413	1994	2256	2927
Retention	**No**	**No**	yes	yes	yes

Unrestrained Driver

	Open	Tempered	Rigid plastic	Trilaminate	Bilaminate
HIC		303	439	727	214
Neck load (N)		**6086(hdr)** 500 (glaz)	**5915(hdr)** 1000(glaz)	**6086(hdr)** 1500(glaz)	**5924(hdr)** 500(glaz)
Retention	**No**	**No**	Yes	Yes	Yes

Conclusions

- In rollover accident simulations with alternative side glazing
  - Most HICs are less than 500
  - Neck loads due to the direct contact with glazing are less than 3000 N.
  - All glazing prevented ejection
  - Head to glazing impact velocity varied from 14 kph to 20 kph

Side Impact Simulation

MDB into Chevrolet Achieva

	Open	Tempered	Rigid plastic	Bilaminate
HIC	132	168	320	422
Neck load (N)	413	643	1352	2935
Retention	**No**	**No**	Yes	Yes
TTI	125	125	125	125

Cost, Weight and Lead Time Analysis

Alternative Glazing in Side Windows

NHTSA

People Saving People

Study Sources

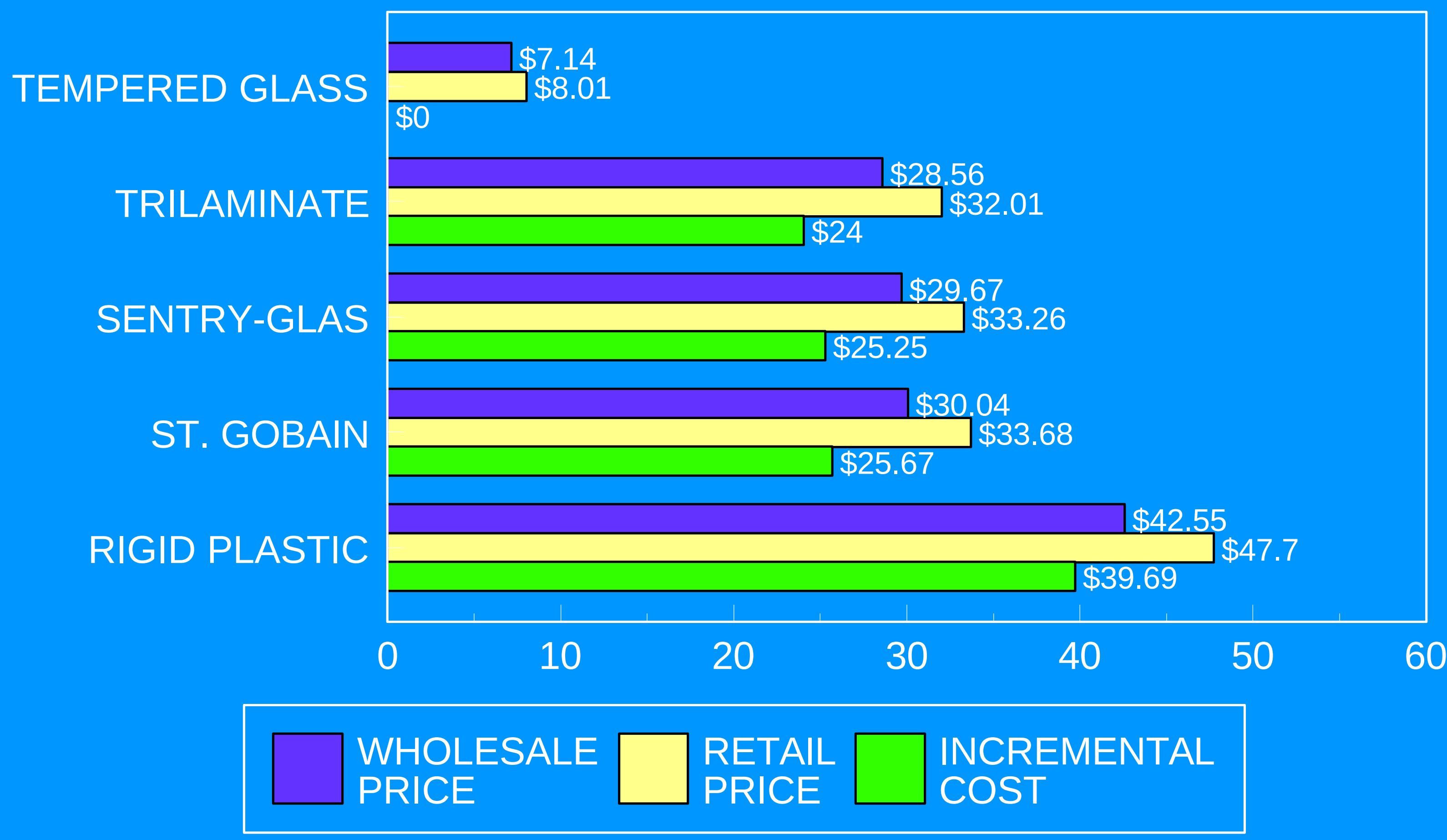
- Management Engineering Associates Conducted
  - Literature Searches Regarding Advances in Encapsulation and Abrasion Resistant Coatings
  - Teleconferences with authorities in flat glass, automotive glazing fabrication, polymer molding, plastic coating, encapsulation and automobile assembly industries
  - Plant visits to AP Technoglass, Excel Industries, Guardian Industries and United Glass
- Corporate Financial Analysis

Study Parameters

- Window and Door Configurations are for a 1995 Ford Taurus
- Cost, Weight and Lead Time Analysis of :
  - Tempered Glass
  - Trilaminate
  - Two Bilaminates
    - DuPont "Sentry-Glas"
    - St. Gobain's film
  - Rigid Plastic
  - Encapsulation
  - Abrasion Resistant Coating

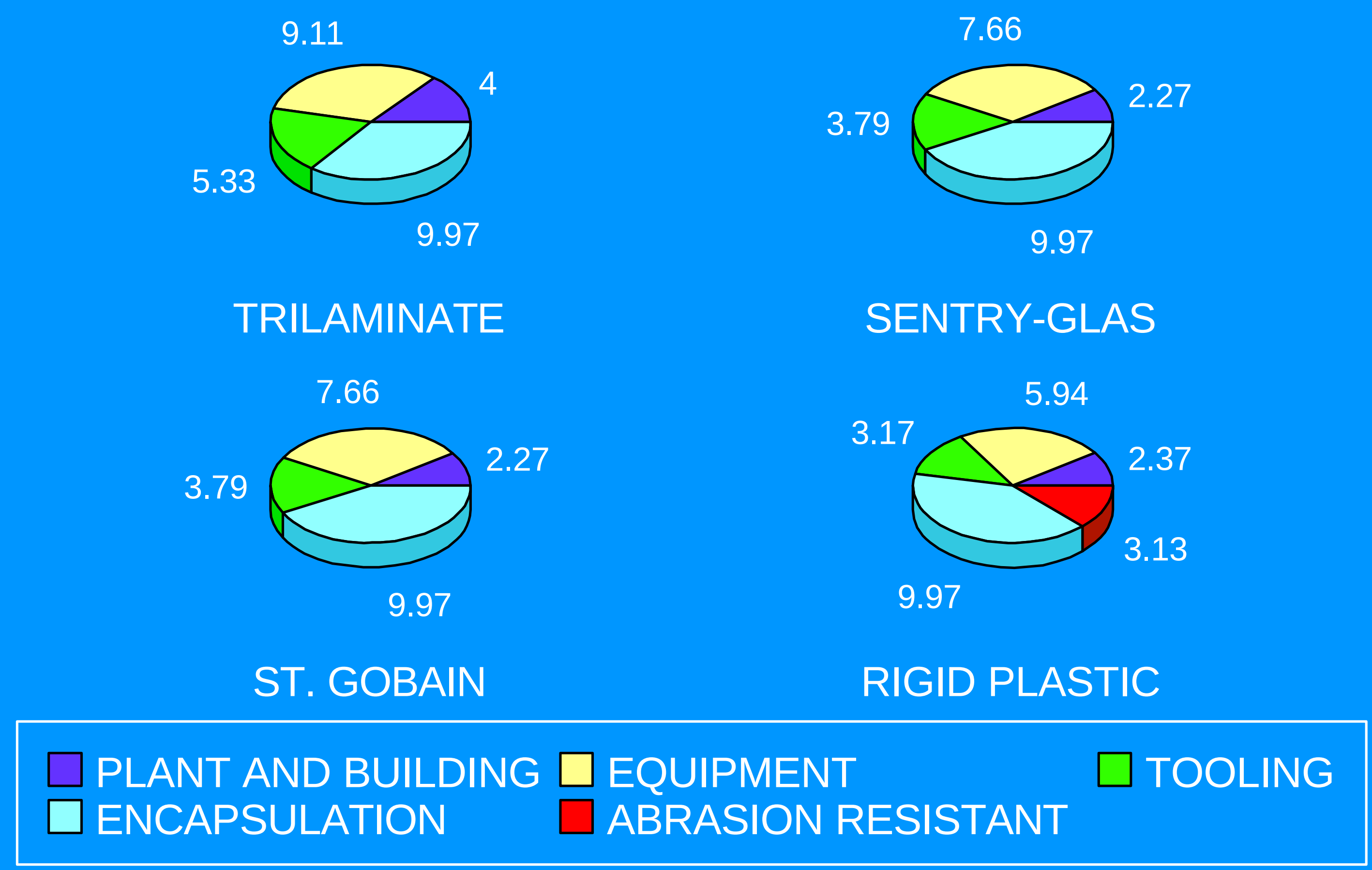
COST OF VEHICLES EQUIPPED WITH ALTERNATIVE GLAZING

COST OF WINDOWS EQUIPPED WITH ALTERNATIVE GLAZING



CAPITAL INVESTMENT PER INDUSTRY

CAPITAL INVESTMENT PER INDUSTRY PER PART



WEIGHT ESTIMATES

Materials	Weight
Tempered Glass	8.82 lbs.
Trilaminate	8.82 lbs.
Bilaminate - DuPont "Sentry-Glas"	8.21 lbs.
Bilaminate - St. Gobain Vitrage	8.20 lbs.
Rigid Plastic	4.32 lbs.

LEAD TIME

- **We estimate that the automobile industry should be able to incorporate the use of alternative glazing in side windows within 36 months**

SUMMARY

- **51** of the **78 STUDY** cases were potentially addressable
- Findings indicate that it is possible for alternative glazings to remain intact given the structural damage seen in real-world crashes

NEXT STEP

Maximum Magnitude of Intrusion	Projected **Rate** of Retention for the Advanced Glazing
No Relevant Intrusion:	
Rollover	0.667
Non-Rollover	0.750
Cases with Relevant Intrusive Damage:	
3 - 8 cm	1.000
8 -15 cm	0.750
15 -30 cm	0.500
30+ cm	0.000

NEXT STEP

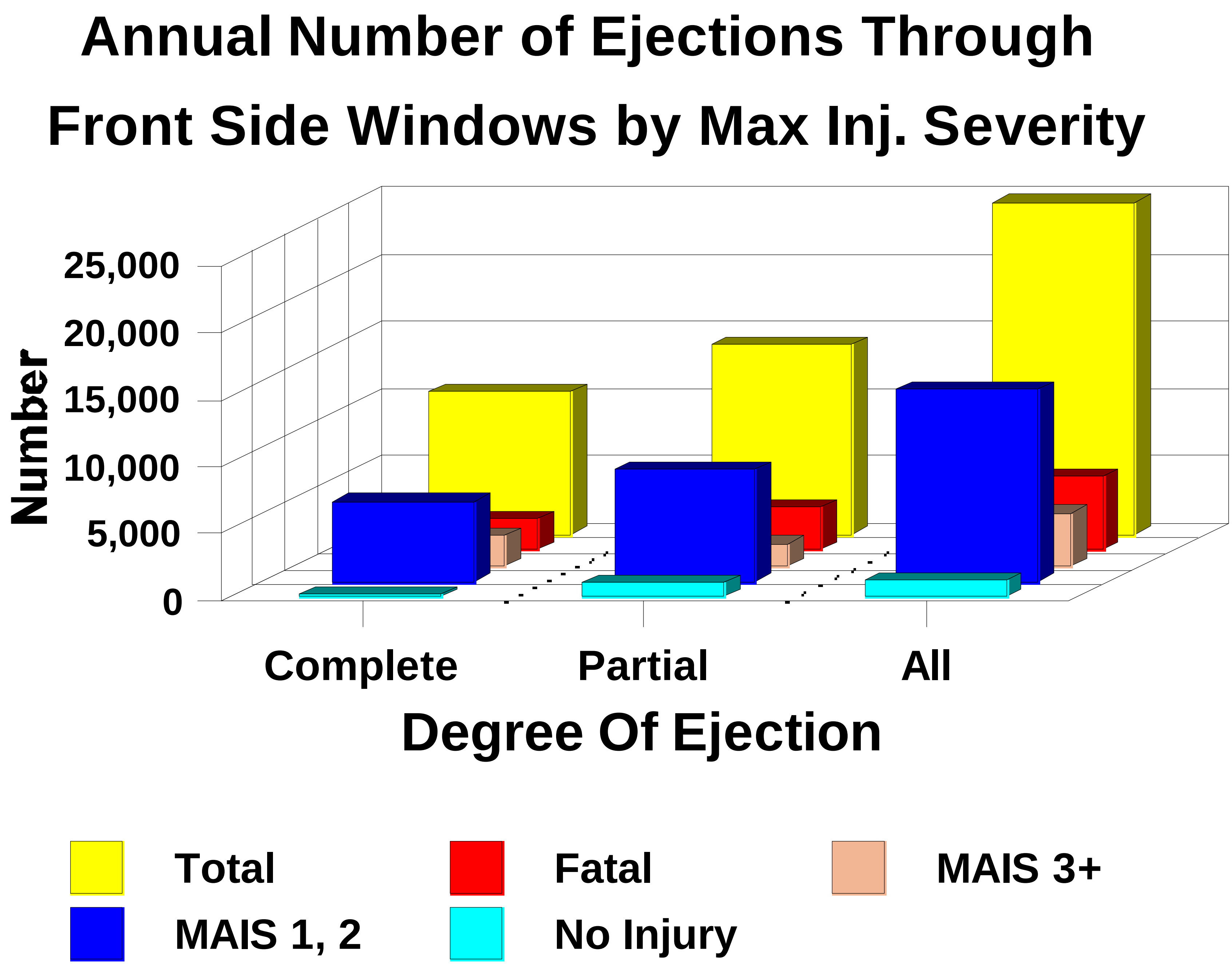
- Hardcopy cases were used as a template to extend retention capabilities to the remaining automated cases.
- An analysis was performed evaluating related intrusion codes (roof, roof side rail, window frame, A&B pillars).
- Each STUDY case was tallied according to its respective category AND max. intrusion code.

BENEFITS ESTIMATION PROCEDURE

- HARDCOPY ANALYSIS OF SPECIFIC CRASHES TO ANSWER QUESTION: WOULD ADVANCED GLAZING HAVE REMAINED IN PLACE?
- CASE-BY-CASE REVIEW OF DETAILED VEHICLE DAMAGE DATA IN AUTOMATED NASS FILES.
- ESTIMATE NUMBER OF EJECTIONS IN CRASHES IN WHICH ADVANCED GLAZING WOULD HAVE REMAINED IN PLACE.

BENEFITS ESTIMATION PROCEDURE (CON'T)

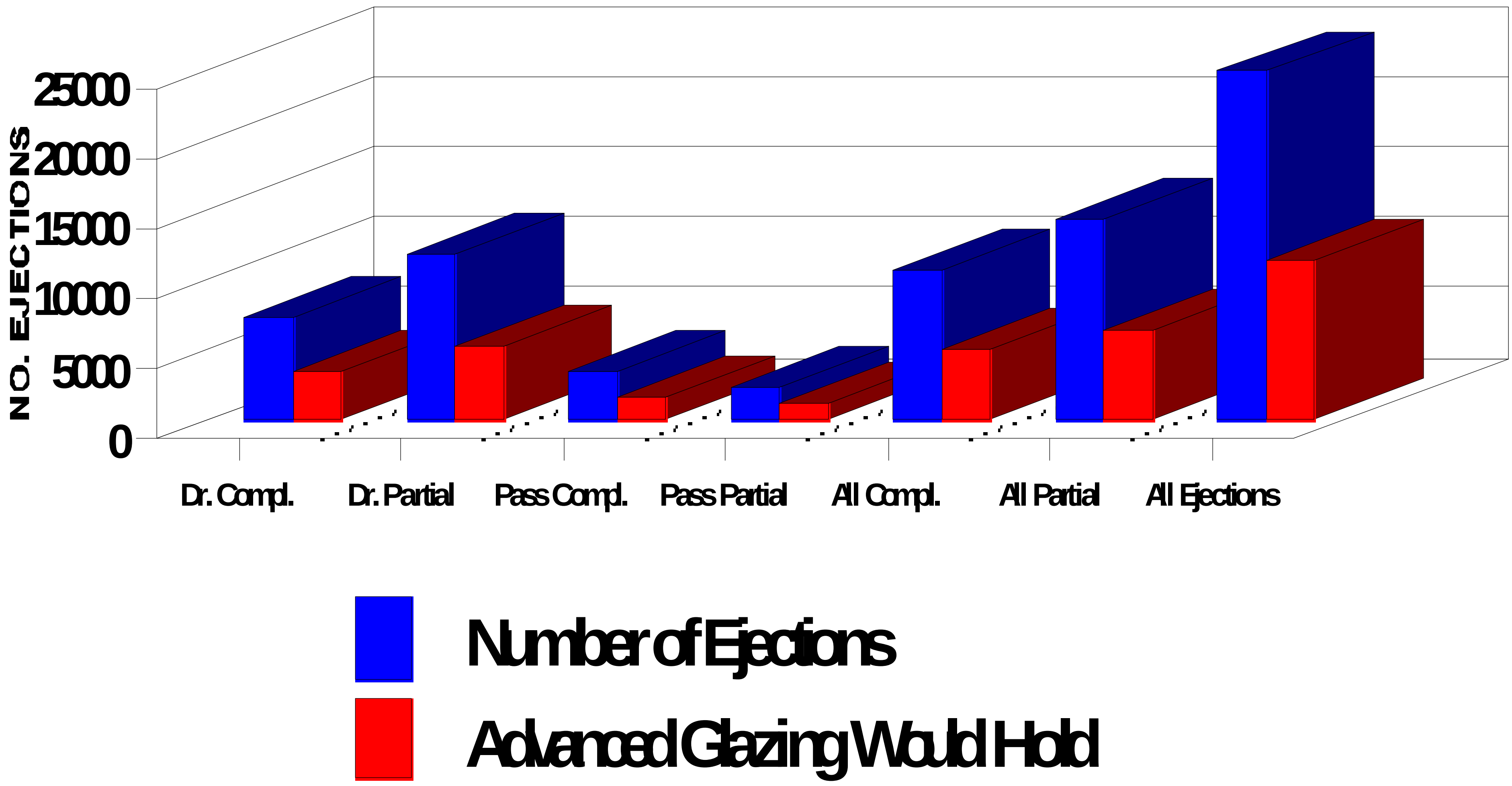
- ESTIMATE NUMBER OF FATALITIES AND NONFATAL SERIOUS INJURIES THAT WOULD BE PREVENTED BY PREVENTING EJECTION
- REDISTRIBUTE PREVENTED FATALITIES AND SERIOUS INJURIES TO LESS SEVERE INJURY LEVELS.
- ESTIMATE SAFETY BENEFITS BY SUBTRACTING THE PROJECTED (MITIGATED) INJURY DISTRIBUTION FROM THE PRESENT INJURY DISTRIBUTION


Annual Number of Ejections Through
Front Side Windows by Max Inj. Severity
Number
25,000
20,000
15,000
10,000
5,000
0
Complete
Partial
All
Degree Of Ejection
Total
Fatal
MAIS 3+
MAIS 1, 2
No Injury

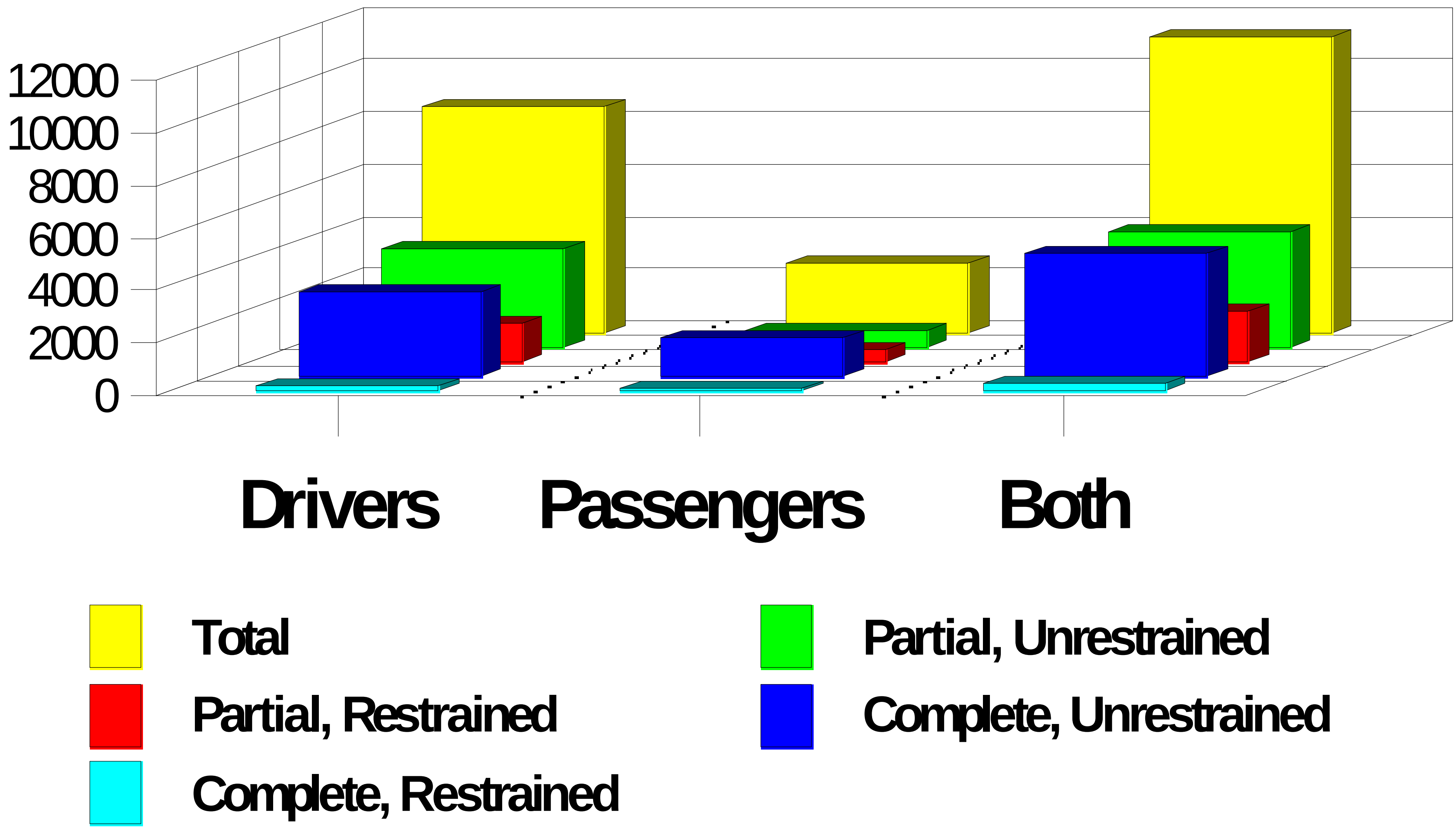
CRITERIA FOR ESTIMATING ADV. GLAZING RETENTION IN CRASHES

MAGNITUDE OF INTRUSION	PROJECTED RATE OF RETENTION FOR ADVANCED GLAZING
NO RELEVANT INTRUSION	
ROLLOVER	0.667
NON-ROLLOVER	0.750
CASES WITH RELEVANT INTRUSION	
3 - 8 cm	1.000
8 - 15 cm	0.750
15 - 30 CM	0.500
30+ CM	0.000

PRESENT SITUATION - TOTAL EJECTIONS AND NUM. FOR WHICH ADVANCED GLAZING WOULD HOLD



Present Ejections in Which Advanced Glazing Would Hold



ABBREVIATED INJURY SCALE*

AIS 0 = NO INJURY
AIS 1 = MINOR
AIS 2 = MODERATE
AIS 3 = SERIOUS
AIS 4 = SEVERE
AIS 5 = CRITICAL
AIS 6 = UNSURVIVABLE

* ASSOCIATION FOR THE ADVANCEMENT OF AUTOMOTIVE MEDICINE (1990)

STATES' INJURY RATING SCALE "KABCO"

A = INCAPACITATING

B = NON-INCAPACITATING

C = POSSIBLE INJURY

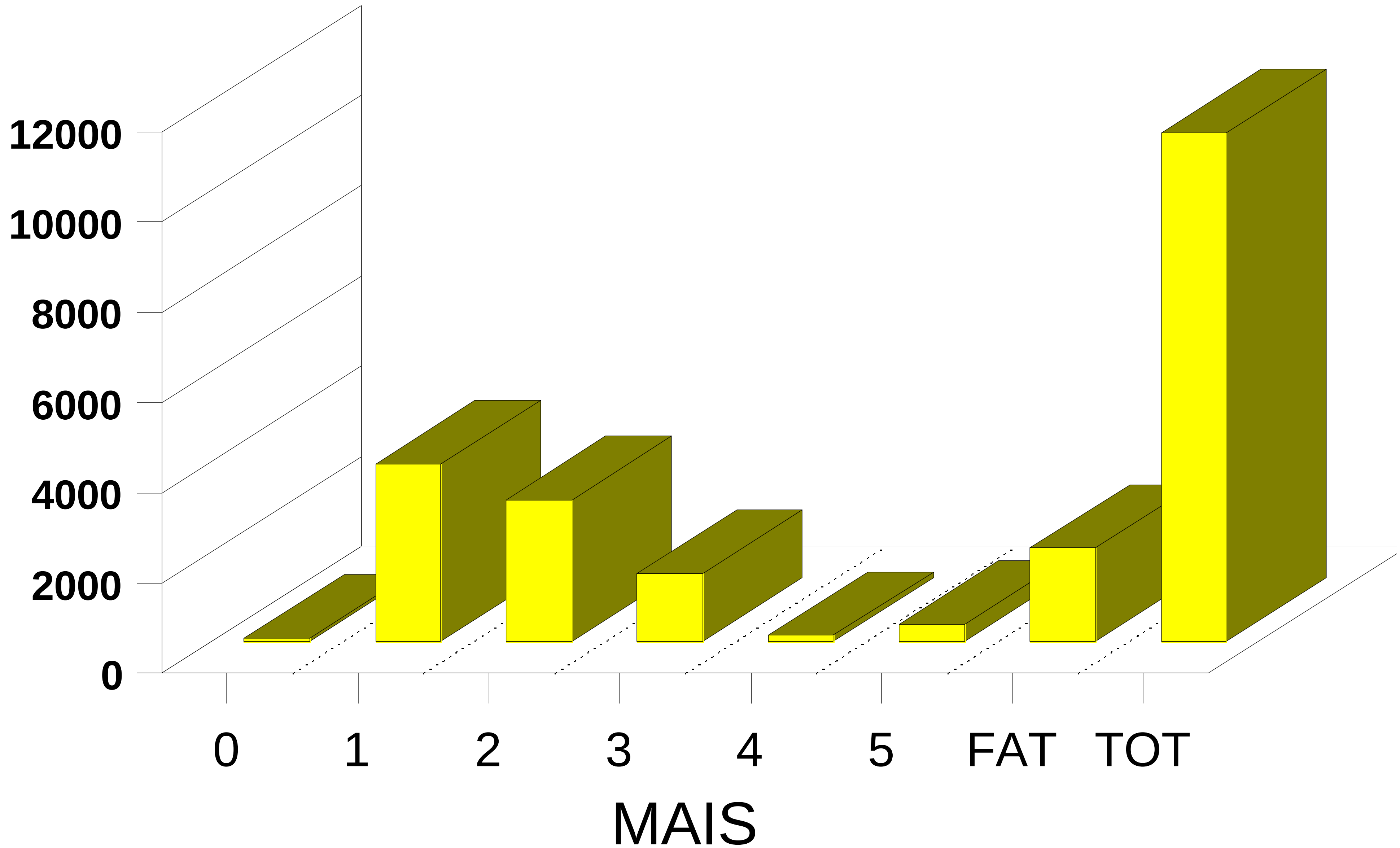
K = KILLED

O = NO INJURY

ISU= INJURED, BUT SEVERITY UNKNOWN

UNK = UNKNOWN IF INJURED

INJURY SEVERITY OF EJECTED OCCUPANT PRESENT CRASHES- ADV GLAZ WOULD HOLD



ESTIMATION OF BENEFITS

APPLICATION OF MATCH-PAIR RESULTS:

EXAMPLE:

PARTIALLY EJECTED, UNRESTRAINED DRIVERS

INJURY SEVERITY	ANN. NUMBER
0	56
1	1755
2	818
3	276
4	45
5	179
FATAL	602

FATAL. PREV. 602 x 0.712 = 429

ESTIMATION OF BENEFITS

REDISTRIBUTION OF PREVENTED FATALITIES TO LESSER INJURY SEVERITY LEVELS

PARTIALLY EJECTED, UNRESTRAINED DRIVERS
429 FATALITIES PREVENTED

MAIS	REDIST. FATALITIES
0	83
1	253
2	60
3	26
4	4
5	3
FATAL	429

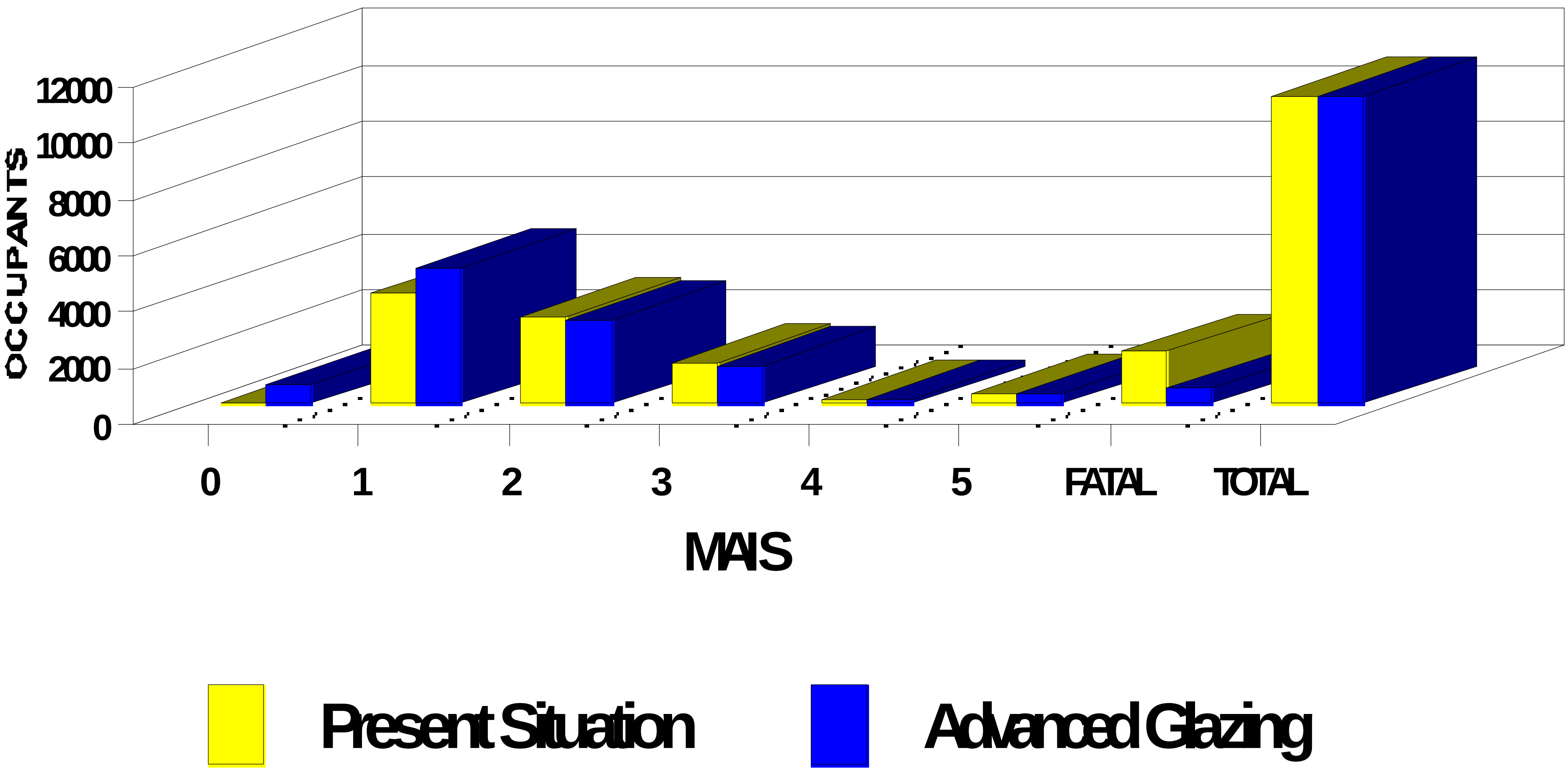
SUMMARY

BENFITS OF ADVANCED GLAZ. IN FRONT SIDE WINDOWS

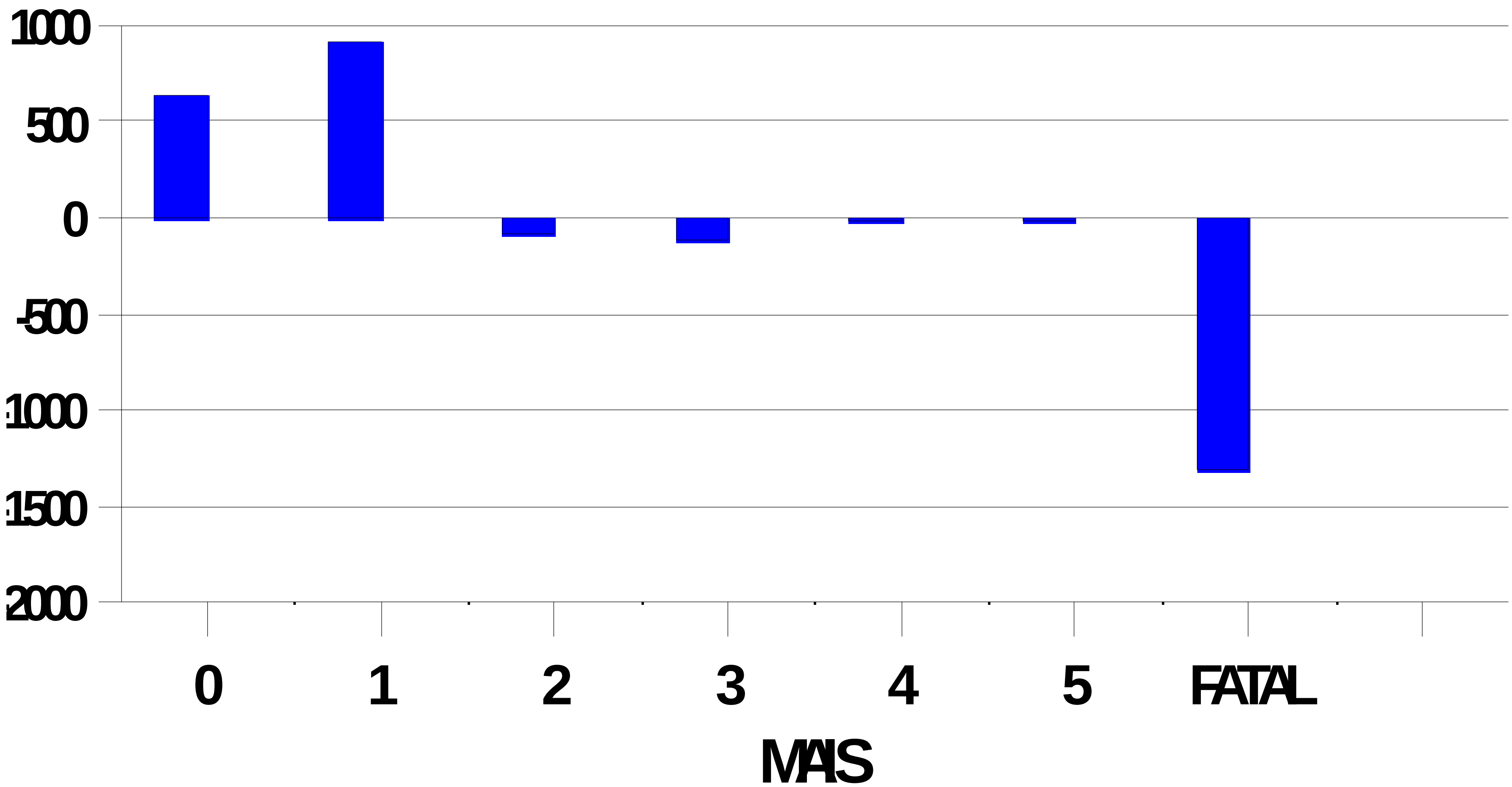
MAIS	PRESENT	ADVANCED GLAZING	DIFF. = NET SAF. BEN.
0	76	720	-644
1	3928	4845	-917
2	3111	3028	83
3	1506	1387	119
4	137	114	23
5	389	366	23
FATAL	1864	551	1313
TOTAL	11011	11011	0

SUMMARY - EFFECT OF ADVANCED GLAZING

IN FRONT SIDE WINDOWS



SUMMARY - NET SAFETY EFFECT OF ADVANCED GLAZING

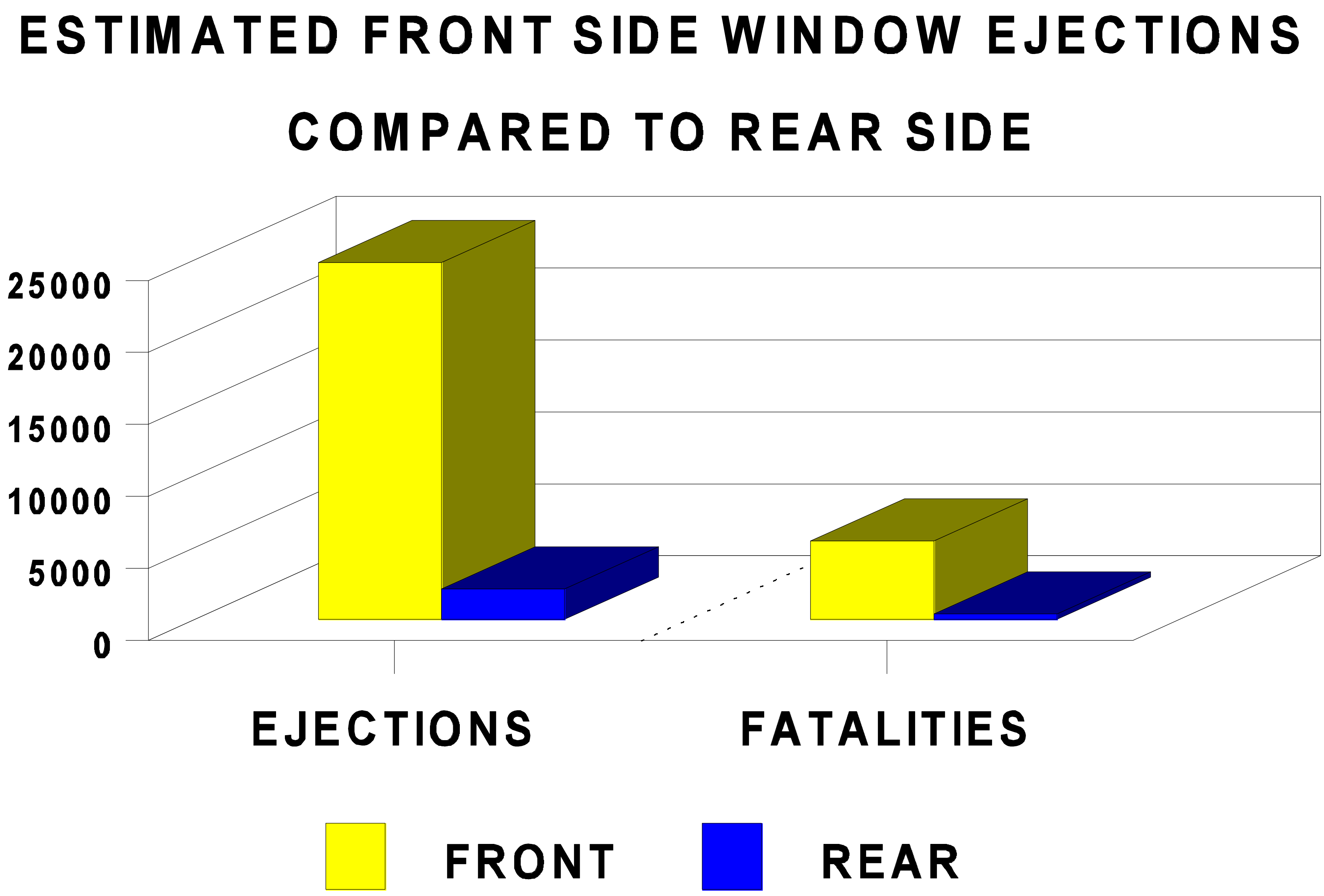


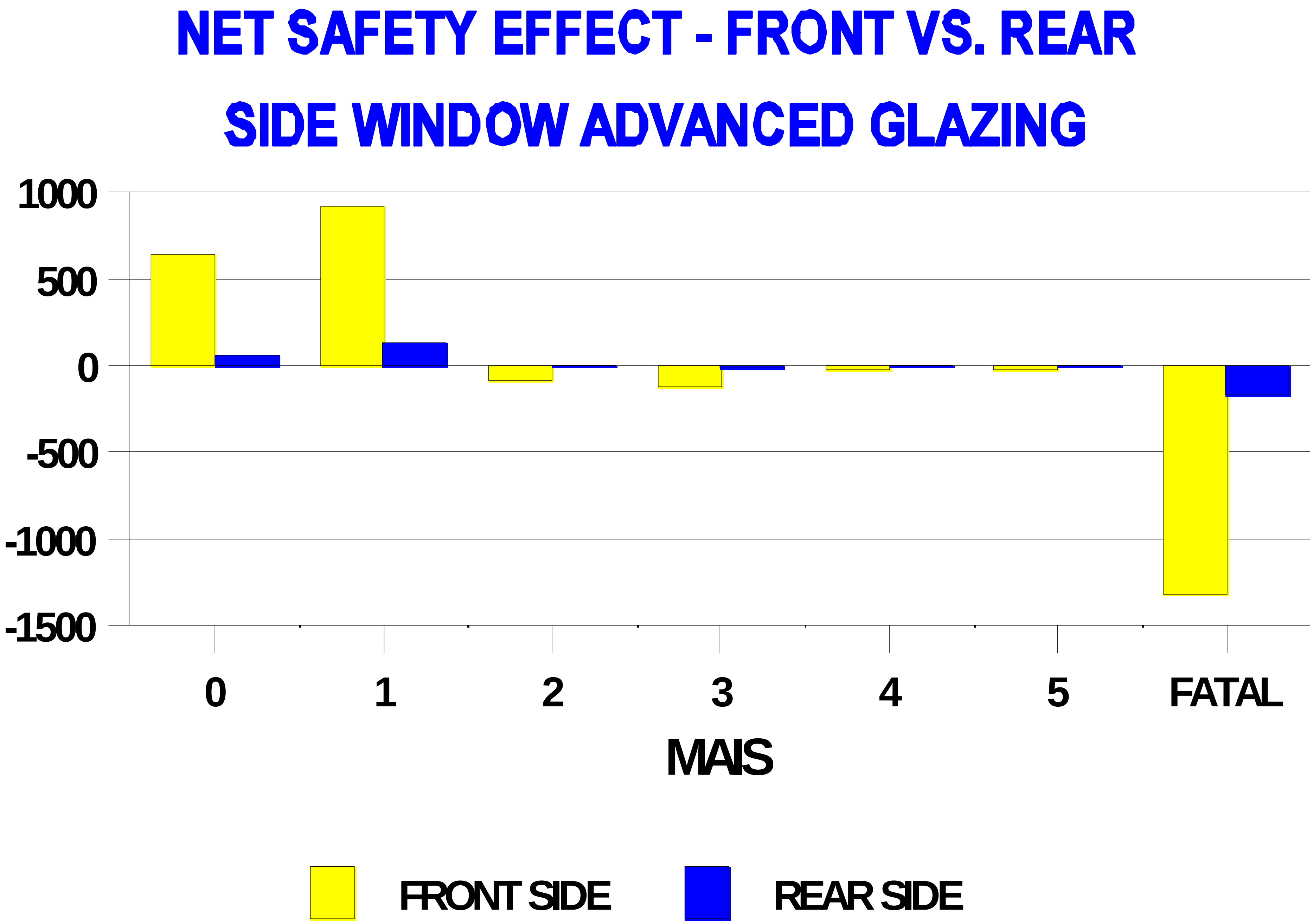
EST. COST PER "EQUIVALENT" FATALITY PREVENTED FOR ALTERNATIVE ADVANCED GLAZINGS INSTALLED IN FRONT SIDE WINDOWS

TYPE OF ADVANCED "EQUIV" GLAZING	EST. INCREM. CONS. COST	ANNUAL CONS. COST	DISC. "EQUIV." FAT. PREV.	EST. COST PER FATALITY PREVENTED
TRILAYER GLASS	$48.00	$768 MILLION	979	$784 THOUSAND
DUPONT "SENTRY GLAS"	$50.50	$808 MILLION	979	$825 THOUSAND
ST. GOBAIN BILAYER	$51.34	$821 MILLION	979	$839 THOUSAND
RIGID PLASTIC	$79.38	$1,270 MILLION	979	$1,297 THOUSAND

ESTIMATED COST PER "EQUIVALENT" FATALITY PREVENTED FOR SOME RECENT RULEMAKINGS

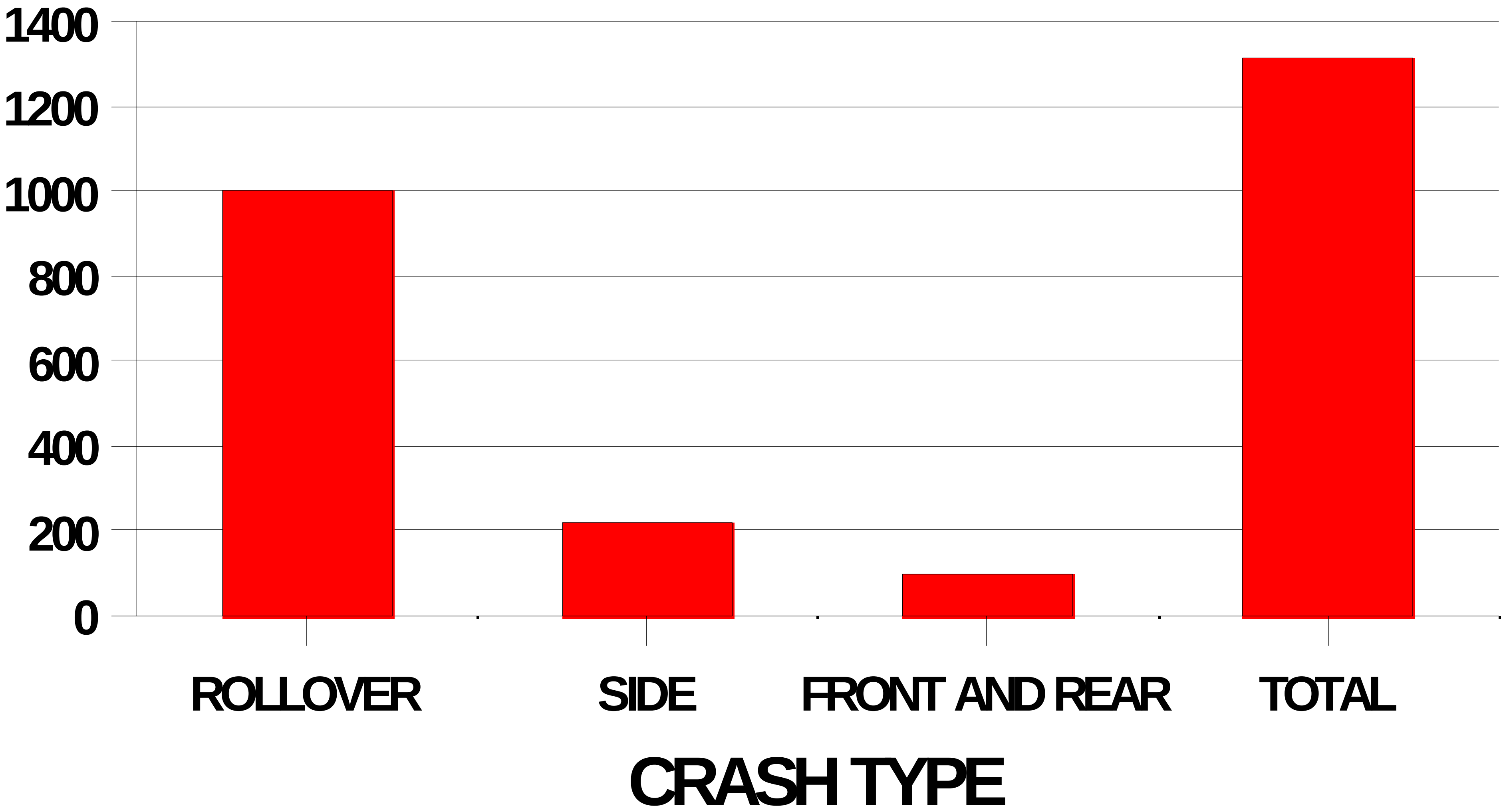
RULEMAKING	EST. COST PER "EQUIV" FATALITY PREV.
PASSENGER CARS, SIDE IMPACT PROTECTION; FMVSS NO. 214	$ 470,000 FRONT SEAT (1989$) $2,940,000 REAR SEAT $ 730,000 FRONT AND REAR SEATS
LIGHT TRUCKS; SIDE DOOR BEAM; FMVSS NO. 214	$1,500,000 - $2,500,000 (1989$)
UPPER INTERIOR HEAD PROTECTION; FMVSS NO. 201	$ 402,000 - $ 459,000 FRONT SECT. (1993$) $3,121,000 - $3,568,000 REAR SECTION $ 687,000 - $784,000 FRT. AND REAR SECT.
LT TRUCKS, AIR BAGS; FMVSS NO. 208	$560,000 - $660,000 (1989$)

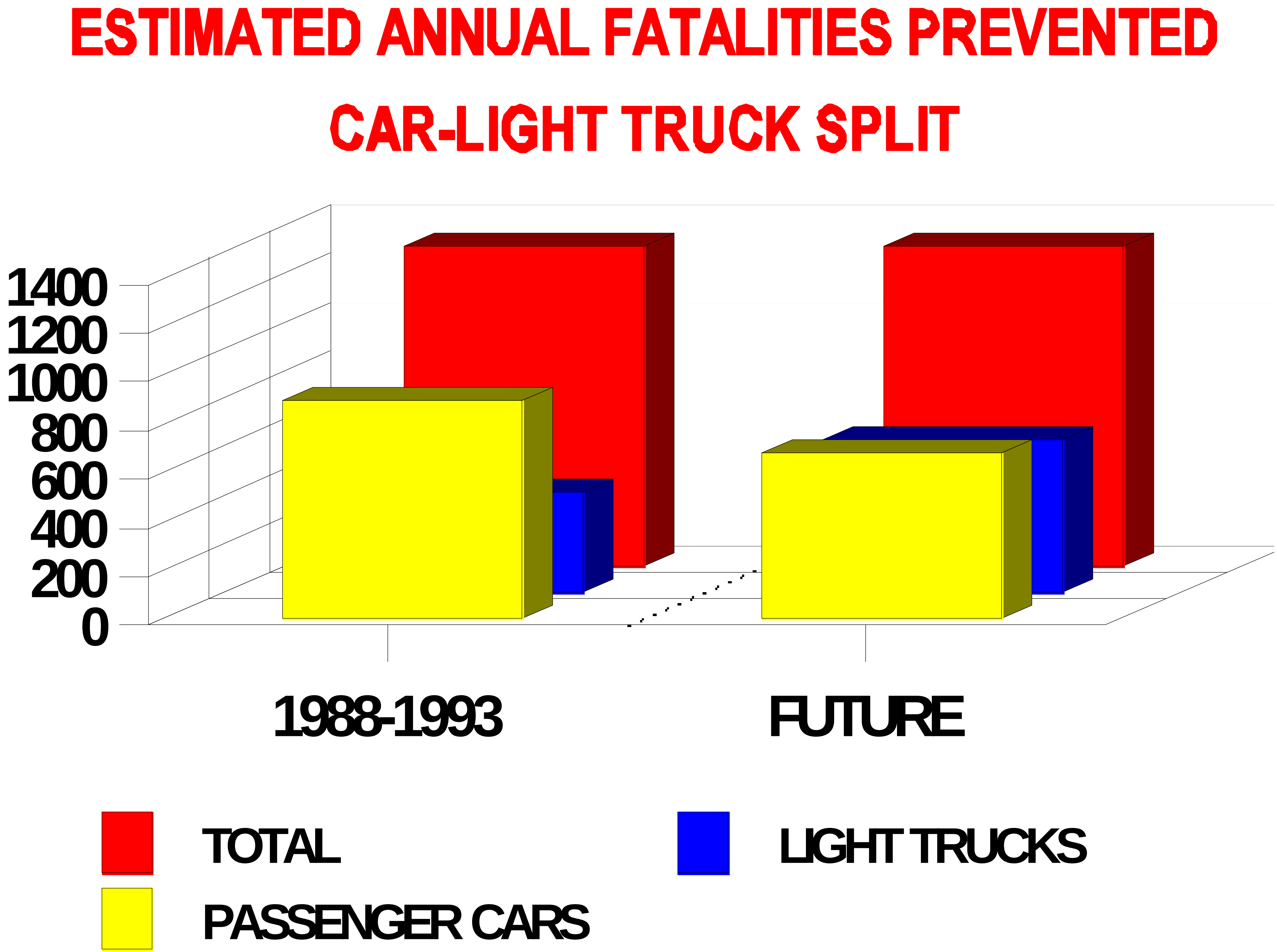

ESTIMATED FRONT SIDE WINDOW EJECTIONS
COMPARED TO REAR SIDE
25000
20000
15000
10000
5000
0
EJECTIONS
FATALITIES
FRONT
REAR



NET SAFETY EFFECT - FRONT VS. REAR
SIDE WINDOW ADVANCED GLAZING
1000
500
0
-500
-1000
-1500
0
1
2
3
4
5
FATAL
MAIS
FRONT SIDE
REAR SIDE

ROUGH ESTIMATE - ANNUAL FATALITIES PREVENTED BY CRASH TYPE




ESTIMATED ANNUAL FATALITIES PREVENTED
CAR-LIGHT TRUCK SPLIT
1400
1200
1000
800
600
400
200
0
1988-1993
FUTURE
TOTAL
LIGHT TRUCKS
PASSENGER CARS

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STATISTICAL ESTIMATION OF THE BENEFITS OF ADVANCED GLAZING

- Ejection is associated with the most severe consequences in traffic accidents.
- Advanced glazing prevents ejection, thereby reducing injuries.

PROBLEM: Using the available traffic accident data, determine fractional reduction in fatalities and serious injuries if advanced glazing is installed in the fleet of light vehicles.

BASIC APPROACH: Matched pair analysis

From database containing records of traffic accidents, select the cases involving pairs of driver and front seat passenger, one of whom was ejected and the other was not ejected.

Determine the fraction of fatalities among ejected occupants and among the non-ejected occupants.

ASSUMPTION: Injuries suffered by the non-ejected occupant are of the same severity as the injuries that would have been suffered by the ejected occupant if the vehicle had the advanced glazing.

RATIONALE: Non-ejected occupant avoids ejection because interior parts of vehicle (pillars, dashboard, door, etc.) prevented ejection.

We assume that in a crash contact with the break-resistant advanced glazing is not more harmful than contact with other parts of vehicle interior.

CRASH SEVERITY: The matched pair analysis approach takes into account crash severity, since both ejected and non-ejected occupants are in the same crash.

RESTRAINT USE: Only data on crashes in which the occupants were reported as using no restraints entered into the analysis.

Ejection is primarily associated with non-restrained motor vehicle occupants.

Data on occupants reported as restrained is unreliable due to overreporting of the belt use.

SEATING POSITION: Benefits of ejection prevention are analyzed separately for drivers and passengers.

The risk of injury and fatality are different for drivers and passengers.

BASIC CALCULATION:

Consider all pairs, say N_1, involving ejected driver and ejected passenger and all pairs, say N_2, involving non-ejected driver and ejected passenger.

Calculate the frequency of fatalities among drivers in the first group (say, d_1 out of N_1), and in the second group (say, d_2 out of N_2).

Relative risk of death for ejected compared with non-ejected driver is:

$$R = \frac{d_1/N_1}{d_2/N_2}$$

Ratio of the probability of death for ejected driver to the probability of death for the non-ejected driver.

Data on passengers serve in exposure normalizing role.

- **If the roles of drivers and passengers are reversed, we can obtain an analogous estimate of the relative risk of death for passengers (using information on drivers to normalize for risk exposure).**

- **If instead of fatalities, the frequencies of serious (incapacitating)injuries are considered, the same method allows to calculate the relative risk of serious injury for ejected compared with non-ejecteddrivers (or passengers).**

That is, let a_1 and a_2 be the counts of A-injuries on KABC0 scale.
In this calculation, only the data on non-fatal accidents are used.

Relative risk of serious injury for ejected compared with non-ejected driver is:

$$R = \frac{a_1/N_1}{a_2/N_2}$$

Ratio of the probability of serious injury for ejected driver to the probability of serious injury for the non-ejected driver.

Evans (1986) suggested the above type of calculation, calling it double-pair comparison method.

EVANS CALCULATION:

Consider $r_1 = \frac{d_1}{p_1}$ - driver to passenger fatality ratio when driver is ejected and passenger is ejected, and $r_2 = \frac{d_2}{p_2}$ - driver to passenger fatality ratio when driver is not ejected and passenger is ejected.

Then we can estimate:

$$R = \frac{r_1}{r_2} = \frac{d_1/p_1}{d_2/p_2}$$

Ratio of the probability of death for ejected driver to the probability of death for the non-ejected driver.

The estimate of the relative risk of fatality R can be used to obtain fractional reduction in fatalities due to ejection prevention

$$f = 1 - \frac{1}{R}$$

(fraction of ejected fatalities that would be prevented by eliminating ejection).

If R is the relative risk of incapacitating injury, then f is the fractional reduction in incapacitating injuries.

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DATA: The analysis utilized the State Data files of the National Center for Statistics and Analysis at NHTSA.

State data files - records of all police accidents reports filed in the submitting states (currently, 17 states participate in State Data Program).

Problems with state data: different reporting criteria and different data elements coded in different states.

States chosen for the present analysis: California, Florida, Georgia, Indiana, Louisiana, Maryland, Missouri, Ohio, Pennsylvania, Utah, Virginia, Washington.

KABC0 scale:

K - fatality

A - incapacitating injury

B - non-incapacitating evident injury

C - possible injury

0 - no injury

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RESULTS:
Distribution of injuries for drivers compared with passengers.
Complete ejections.

Driver: completely ejected Passenger: not ejected (1,535 pairs)					
	K	A	B	C	0
Driver	15.37%	36.22%	27.30%	10.68%	10.42%
Passenger	5.34%	21.56%	36.94%	17.39%	18.76%

Driver: not ejected Passenger: completely ejected (2,167 pairs)					
	K	A	B	C	0
Driver	4.06%	20.12%	30.18%	16.29%	29.35%
Passenger	11.95%	37.24%	31.93%	13.98%	4.89%

Partial ejections.

Driver: partially ejected Passenger: not ejected (464 pairs)					
	K	A	B	C	0
Driver	25.22%	31.47%	28.01%	11.64%	3.66%
Passenger	8.19%	23.28%	34.48%	20.47%	13.58%

Driver: not ejected Passenger: partially ejected (583 pairs)					
	K	A	B	C	0
Driver	6.17%	24.36%	33.28%	15.09%	21.10%
Passenger	17.32%	37.05%	32.76%	8.75%	4.12%

All ejections (partial or complete).

Driver: ejected Passenger: not ejected (1999 pairs)					
	K	A	B	C	0
Driver	17.66%	35.12%	27.46%	10.91%	8.85%
Passenger	6.00%	21.96%	36.37%	18.11%	17.56%

Driver: completely ejected Passenger: not ejected (2750 pairs)					
	K	A	B	C	0
Driver	4.51%	21.02%	30.84%	16.04%	27.60%
Passenger	13.09%	37.20%	32.11%	12.87%	4.73%

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Relative risk of fatality and reduction in fatalities.

Complete Ejections		
	Relative Risk of Fatality	Fractional Reduction in Fatalities
Driver	3.46 (0.94)	71.06% (7.85%)
Passenger	3.10 (0.84)	67.76% (8.71%)

Partial Ejections		
	Relative Risk of Fatality	Fractional Reduction in Fatalities
Driver	3.59 (0.85)	72.15% (6.57%)
Passenger	3.15 (0.74)	68.27% (7.49%)

All Ejections		
	Relative Risk of Fatality	**Fractional Reduction in Fatalities**
Driver	**3.55 (0.83)**	**71.85% (6.56%)**
Passenger	**3.15 (0.73)**	**68.23% (7.40%)**

Relative risk of incapacitating injury and fractional reduction.

Complete Ejections		
	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	2.05 (0.52)	51.20% (12.40%)
Passenger	1.80 (0.46)	44.29% (14.23%)

Partial Ejections		
	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	2.47 (0.57)	59.54% (9.27%)
Passenger	2.00 (0.46)	50.05% (11.45%)

All Ejections		
	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	2.38 (0.54)	58.11% (9.55%)
Passenger	1.95 (0.44)	48.64% (11.72%)

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Complete Ejections - Light Truck				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	4.13 (1.48)	75.80% (8.65%)	3.14 (1.02)	68.17% (10.36%)
Passenger	3.94 (1.46)	74.60% (9.42%)	1.89 (0.62)	47.04% (17.27%)

Partial Ejections - Light Truck				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	6.42 (1.83)	84.43% (4.44%)	2.75 (0.66)	63.58% (8.82%)
Passenger	5.36 (1.53)	81.35% (5.32%)	2.23 (0.54)	55.06% (10.95%)

All Ejections - Light Truck				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	5.62 (1.49)	82.19% (4.73%)	2.76 (0.66)	63.76% (8.65%)
Passenger	4.66 (1.24)	78.55% (5.70%)	2.22 (0.53)	54.87% (10.82%)

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Complete Ejections - Passenger Cars

	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	3.25 (0.94)	69.19% (8.92%)	1.95 (0.52)	48.71% (13.62%)
Passenger	3.06 (0.87)	67.29% (9.35%)	1.81 (0.48)	44.69% (14.68%)

Partial Ejections - Passenger Cars

	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	2.84 (0.68)	64.74% (8.44%)	2.85 (0.69)	64.97% (8.42%)
Passenger	2.54 (0.61)	60.56% (9.44%)	2.54 (0.61)	60.70% (9.45%)

All Ejections - Passenger Cars					
	Relative Risk of Fatality	Fractional Reduction in Fatalities		Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	2.94 (0.69)	66.06% (8.00%)		2.37 (0.55)	57.83% (9.70%)
Passenger	2.66 (0.63)	62.46% (8.85%)		1.88 (0.43)	46.79% (12.26%)

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Complete Ejections - Front Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	3.96 (1.46)	74.72% (9.30%)	2.00 (0.63)	49.88% (15.84%)
Passenger	3.29 (1.18)	69.64% (10.85%)	1.74 (0.56)	42.49% (18.40%)

Partial Ejections - Front Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	3.41 (0.94)	70.64% (8.06%)	2.40 (0.59)	58.27% (10.32%)
Passenger	3.08 (0.84)	67.54% (8.89%)	1.78 (0.44)	43.87% (13.92%)

All Ejections - Front Impact					
	Relative Risk of Fatality	Fractional Reduction in Fatalities		Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	3.55 (0.93)	71.85% (7.33%)		2.34 (0.56)	57.18% (10.33%)
Passenger	3.17 (0.82)	68.46% (8.21%)		1.73 (0.42)	42.08% (14.01%)

All Ejections - Rear Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	3.31 (1.69)	69.75% (15.42%)	1.94 (0.69)	48.39% (18.25%)
Passenger	3.08 (1.57)	67.52% (16.61%)	1.56 (0.55)	35.69% (22.78%)

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Complete Ejections - Left Side Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	1.60 (0.82)	37.46% (32.24%)	2.16 (1.02)	53.78% (21.73%)
Passenger	3.15 (1.64)	68.22% (16.52%)	1.61 (0.83)	37.74% (32.09%)

Partial Ejections - Left Side Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	2.34 (0.88)	57.35% (16.07%)	2.11 (0.81)	52.55% (18.12%)
Passenger	3.58 (1.32)	72.03% (10.29%)	3.60 (1.35)	72.24% (10.37%)

All Ejections - Left Side Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	2.10 (0.70)	52.48% (15.91%)	1.80 (0.51)	44.59% (15.54%)
Passenger	3.46 (1.15)	71.06% (9.60%)	2.23 (0.64)	55.18% (12.88%)

Complete Ejections - Right Side Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	4.84 (2.23)	79.33% (9.54%)	1.97 (0.88)	49.16% (22.78%)
Passenger	1.81 (0.91)	44.70% (27.81%)	1.27 (0.56)	21.30% (34.38%)

Partial Ejections - Right Side Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	3.21 (1.05)	68.85% (10.23%)	3.37 (0.99)	70.32% (8.72%)
Passenger	1.67 (0.55)	40.26% (19.64%)	1.83 (0.53)	45.21% (15.96%)

All Ejections - Right Side Impact				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	3.54 (1.07)	71.73% (8.55%)	3.06 (0.85)	67.37% (9.07%)
Passenger	1.80 (0.54)	44.29% (16.90%)	1.69 (0.47)	40.90% (16.41%)

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Complete Ejections - Rollover				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	7.75 (4.13)	87.09% (6.87%)	2.03 (0.78)	50.75% (18.87%)
Passenger	9.70 (5.38)	89.70% (5.72%)	2.17 (0.86)	53.96% (18.27%)

Partial Ejections - Rollover				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	6.94 (2.28)	85.60% (4.73%)	3.21 (0.81)	68.87% (7.90%)
Passenger	10.09 (3.36)	90.09% (3.30%)	2.79 (0.71)	64.22% (9.13%)

All Ejections - Rollover				
	Relative Risk of Fatality	Fractional Reduction in Fatalities	Relative Risk of Incapacitating Injury	Fractional Reduction in Incapacitating Injuries
Driver	7.16 (2.24)	86.03% (4.37%)	3.08 (0.77)	67.52% (8.10%)
Passenger	9.94 (3.14)	89.94% (3.17%)	2.63 (0.67)	62.60% (9.38%)

For Further Information

- Phone

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  Clarke Harper (202) 366-4916
- NHTSA Docket 95-41GR
- Email
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  charper@nhtsa.dot.gov
- Via www
  http://www.nhtsa.dot.gov/nrd/nrd10/nrd11/glazing.html

Future Work

- Further Development of Component test
  - Repeatability
  - Sled Testing
- Injury Potential for Belted Occupants
- Additional Side and Planar accident analysis
- Current Door/Window designs

Research Schedule

- Revisit Rulemaking and Research Options at the end of 1996
- Potential for another Public Meeting
  - Depends upon feedback and comments

How to Submit Comments

- Comments should be submitted in writing to

  Docket Section
  National Highway Traffic Safety Administration
  Room 5109
  400 7th Street,SW
  Washington, DC 20590.

  Please refer to docket number 95-41GR when submitting written comments.