Research in Support of Enhanced Automatic Crash Notification

Prof. Kennerly Digges
VDI Symposium

8/3/11

IMPACT RESEARCH, INC.

enhanced Automatic Crash Notification

We think there is a better way --- eACN

Definition of Terms

- ACN Automatic Crash Notification –
  - Transmits geometric coordinates of crash
  - May also have voice communication with crashed vehicle occupants
- eACN enhanced Automatic Crash Notification
  - Transmits geometric coordinates
  - Provides for voice communication with occupants
  - Transmits vehicle crash data
- AACN Advanced Automatic Crash Notification
  - Similar to eACN

Definition of Terms

- URGENCY – a mathematical algorithm for estimating the risk of serious injury in crashes
  - Uses primarily on data measured by vehicle crash sensors
  - May also use occupant data such as age
- NHTSA – National Highway Traffic Administration (Federal Safety Regulations)
- CDC – Center for Disease Control (Federal Agency to reduce Disease and Trauma)
- WLIRC – William Lehman Injury Research Center of U of Miami (Augenstein, Digges & Bahouth)

Presentation Overview

- History of URGENCY
- URGENCY Crash Data Elements
- URGENCY Calculations and Accuracy

eACN Benefits to Injured Occupants

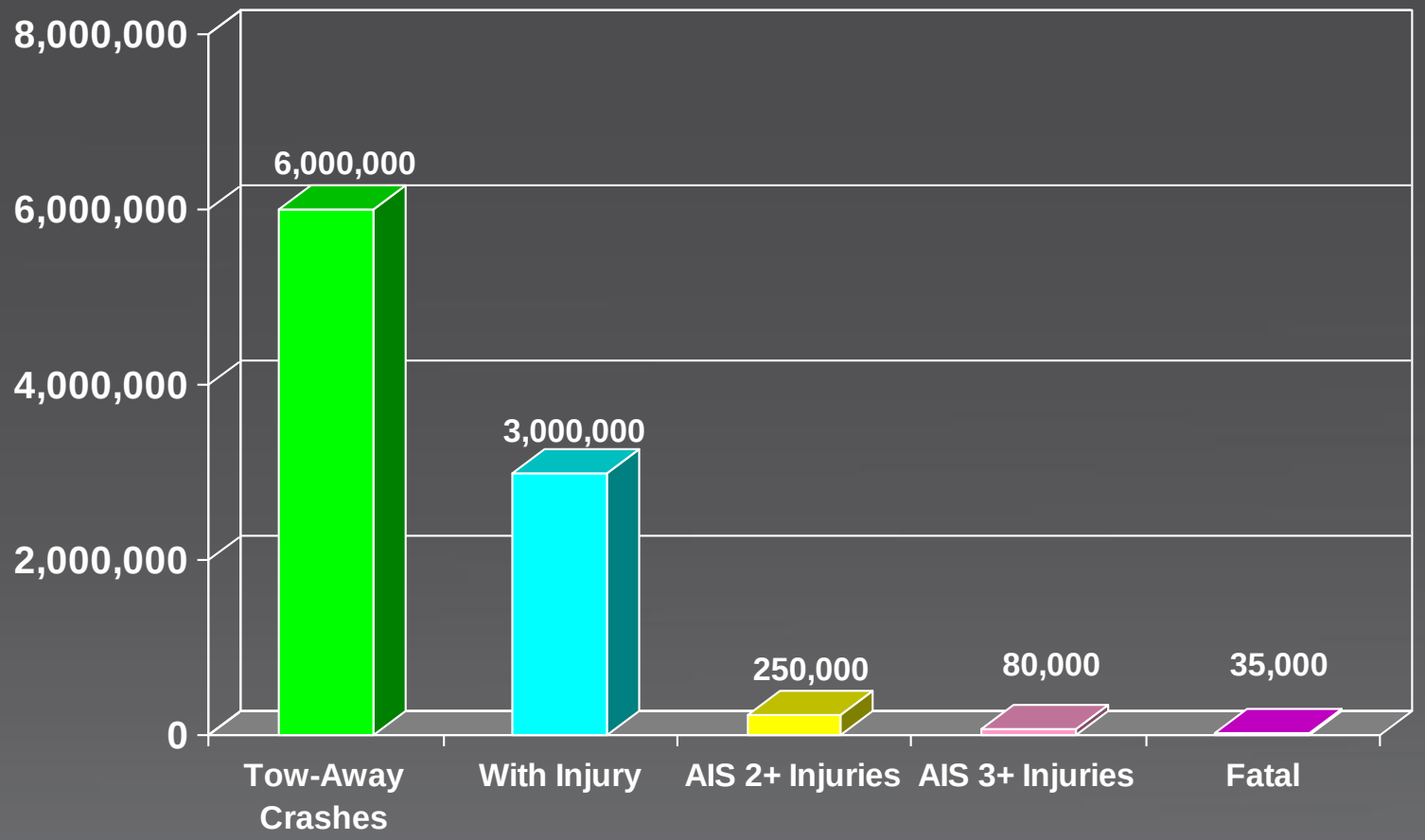
ACN BENEFITS

- Rapid and Accurate Location Would Help:
  - people with time critical injuries but are treated too late

eACN BENEFITS

- Improved Triage Would Reduce the Number of:
  - People who are mis-diagnosed and poorly triaged to the wrong care facility
  - People who are improperly treated in the right hospital due to missed injuries

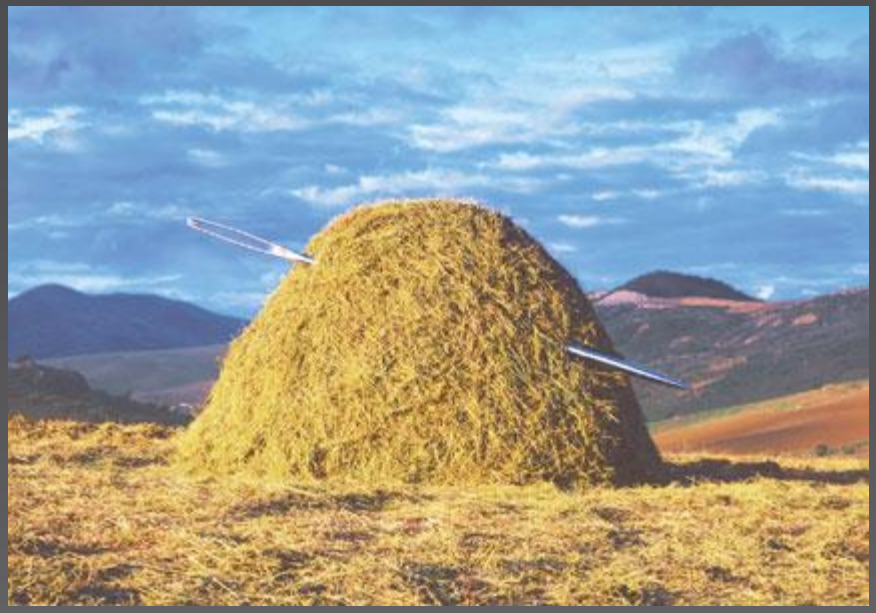
US Annual Crash Distribution



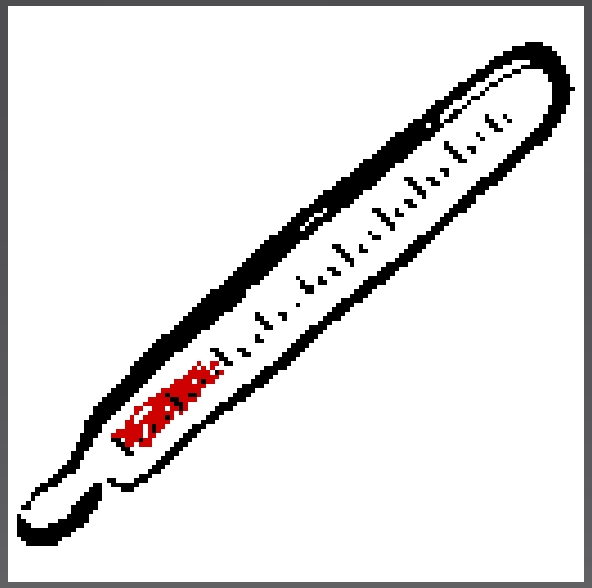
* Based on NASS/CDS 1997-2005 Annual Averages

Recognizing Crash Injured Occupants

- How do we distinguish these 80,000 MAIS 3+ from the 6,000,000 rapidly and remotely?
- What information will help rescue provide care to potentially injured occupants?



URGENCY Algorithm Offers Help



URGENCY –
A Thermometer for Trauma

- Uses crash data
- Estimates the risk of serious injury

Precursers to the URGENCY Algorithm

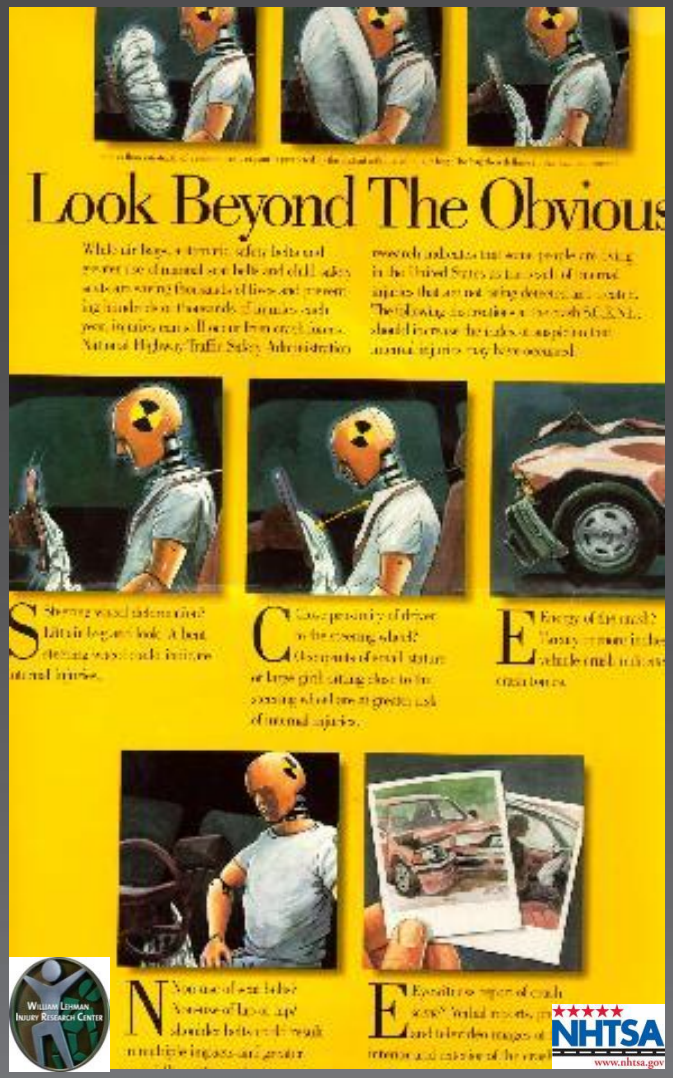
Jones and Champion; Journal of Trauma; 1989 – *Damage Greater than 20" is indicator of severe injury* - (1 Variable)

Precursers to the URGENCY Algorithm

Lombardo and Ryan; *NHTSA Research Note* 1993 "Detection of Internal Injuries in Drivers Protected by Air Bags", *Steering wheel deformation* (1 Variable)

1993 Scene SCALE

- Proposed by WLIRC
- Triggered by Unexpected Injuries at **Low Delta-V**
  - **S**evere Loading of the Chest - A Bent Steering Wheel – “Lift & Look”
  - **C**lose-in Occupants
  - **E**xcessive Energy in the Crash
  - **N**on-Use of Lap Belts (2-point belts)
  - **E**ye-witness Observations On- scene



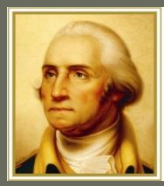
Precursers to the URGENCY Algorithm

Malliaris, Digges & DeBlois;

SAE 970393 “Relationships Between Crash Casualties and Crash Attributes” Regression Analysis of NASS/CDS-

(21 Variables) -Basis for

URGENCY



THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON DC

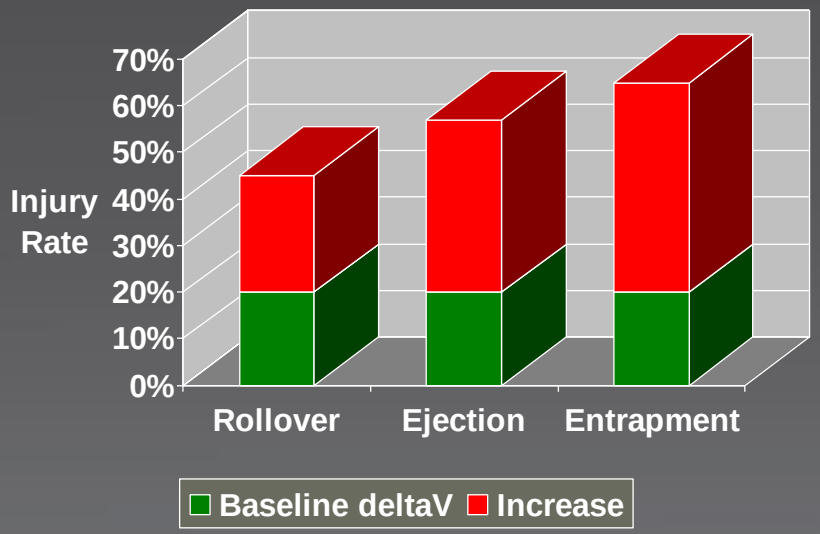
NHTSA
www.nhtsa.gov

NHTSA Post-Crash Injury Control Study- 1997

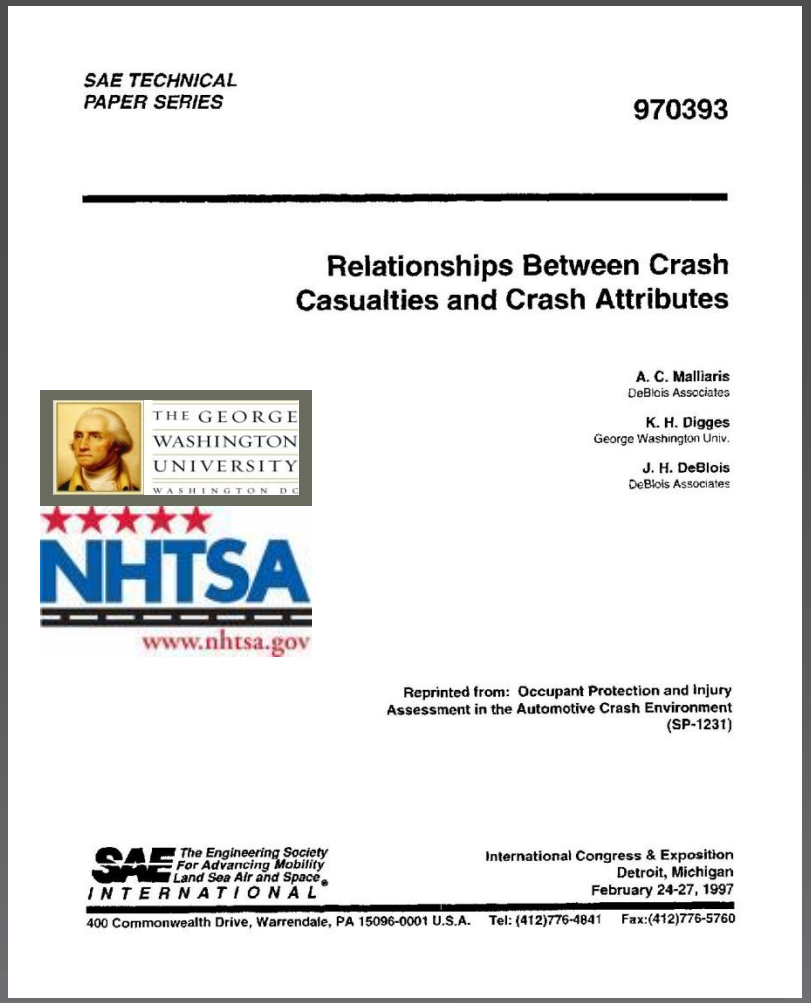
Produced the basis for the URGENCY Algorithm

21 crash variables include

Influences other than DeltaV



Baseline – 25 mph Frontal



SAE TECHNICAL PAPER SERIES

970393

Relationships Between Crash Casualties and Crash Attributes

A. C. Malliaris
DeBlois Associates

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J. H. DeBlois
DeBlois Associates

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WASHINGTON DC

NHTSA
www.nhtsa.gov

Reprinted from: Occupant Protection and Injury Assessment in the Automotive Crash Environment (SP-1231)

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International Congress & Exposition
Detroit, Michigan
February 24-27, 1997

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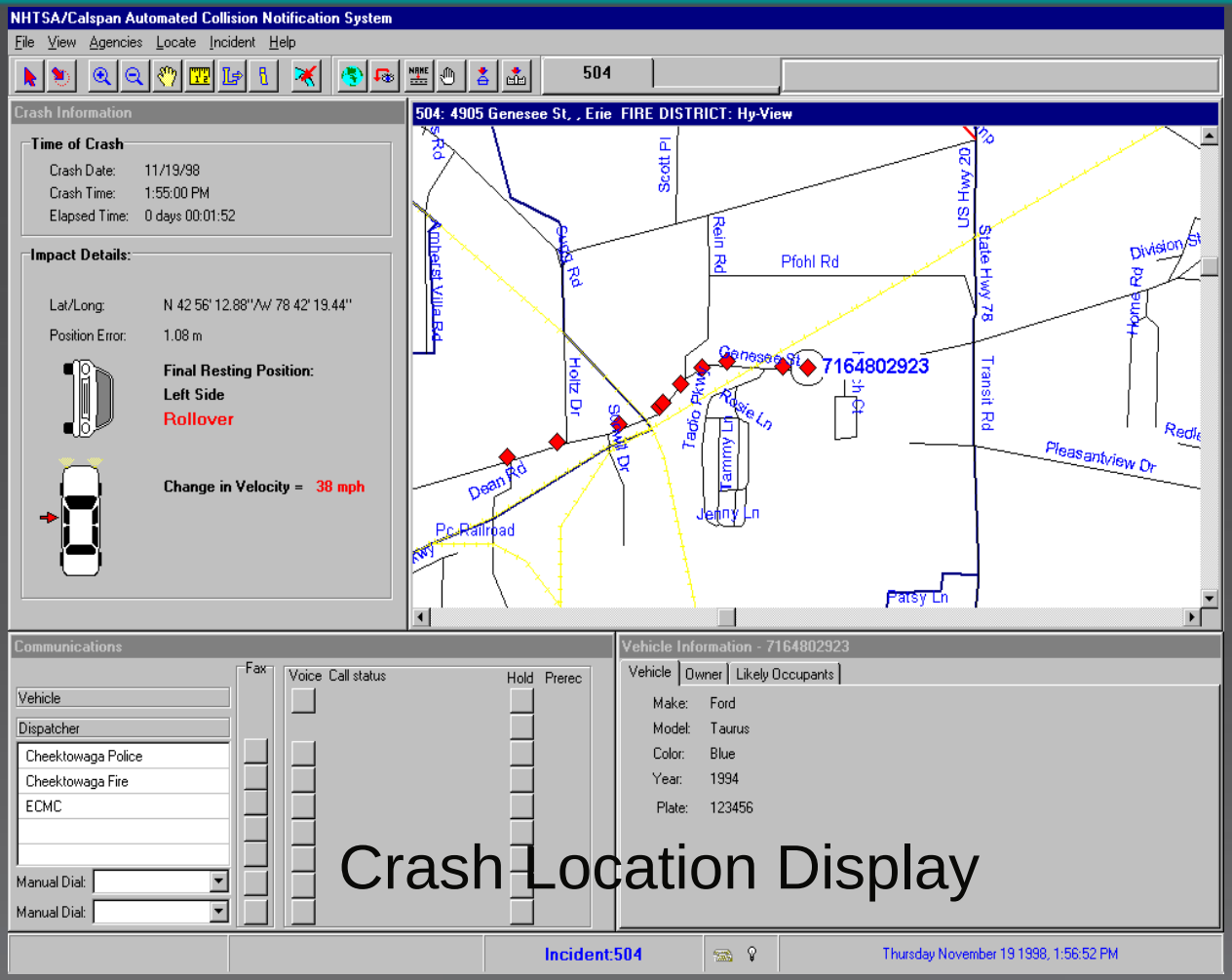
NHTSA ACN Field Operational Test

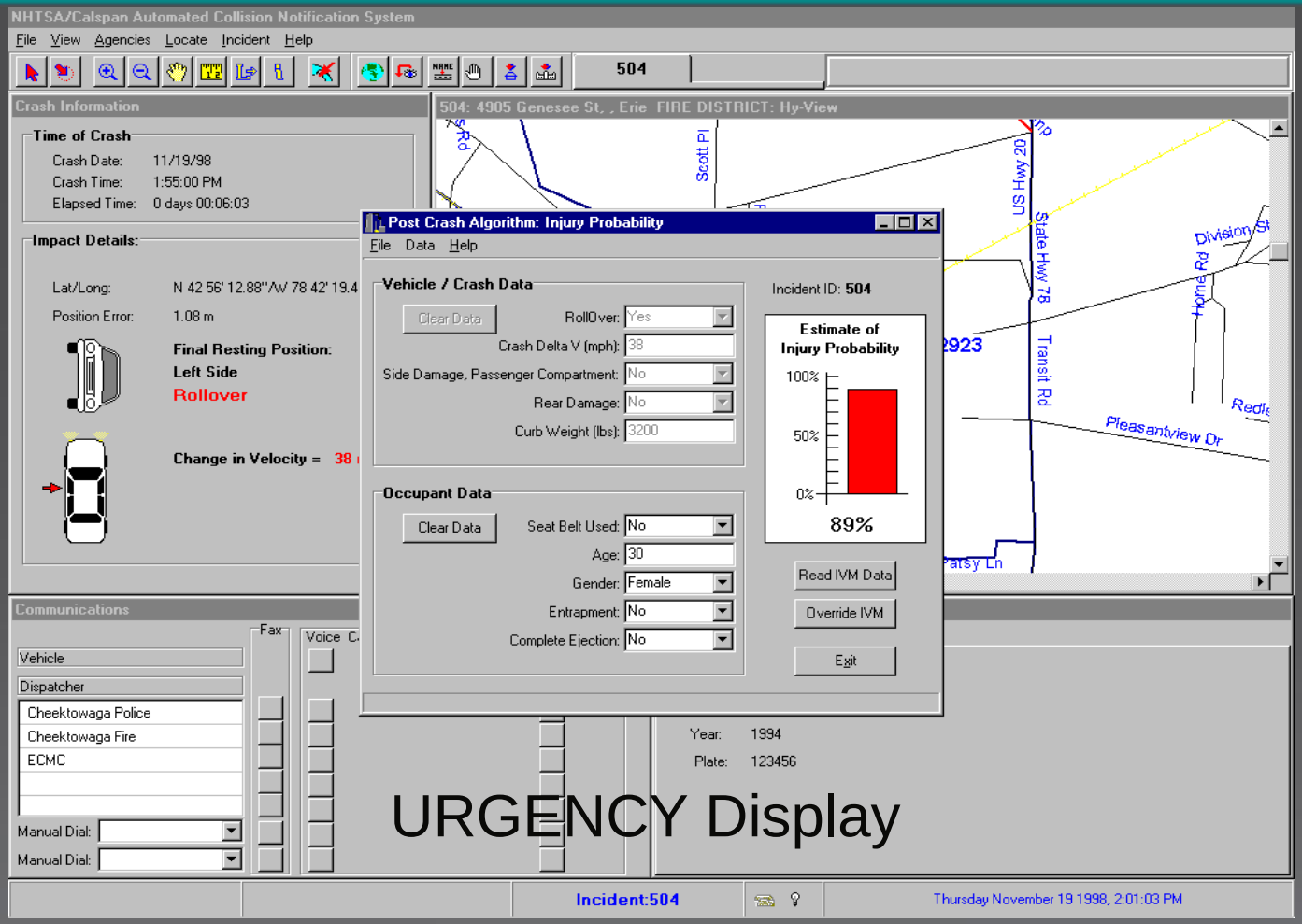


Crash Location Display

850 Vehicles in New York State with ACN – 1997-2000

NHTSA
www.nhtsa.gov

NHTSA ACN Field Operational Test



First Application of URGENCY

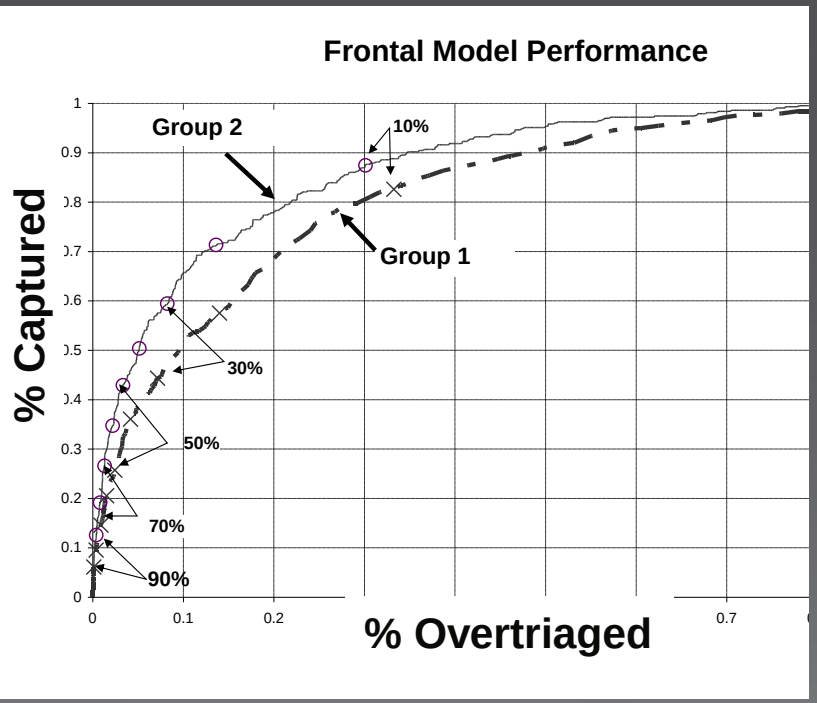
NHTSA
www.nhtsa.gov

Dissertation by Bahouth- 2002

Refined and Validated URGENCY
Determined the accuracy for

- groups of risk predictors
- threshold risk for prediction

Published AAAM 2002, ESV 2003



DEVELOPMENT AND VALIDATION OF INJURY PREDICTING ALGORITHMS FOR AUTOMOTIVE CRASH APPLICATIONS

By

George T. Bahouth

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF SCIENCE
AT
THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, D.C.
JANUARY 2003

BMW eACN Support Research- 2002 - on

- National Survey of First Responders
  - What rescue data is most useful?
- Further URGENCY development
  - What vehicle crash data is most useful?
  - What are the benefits for each data element?
  - What should be the threshold for the ACN call?
  - What should be the criteria for “Severe Crash”?
- Research to improve the eACN performance
- Research to remove impediments to the use of the eACN technology by 1st responders

BMW eACN Support Research- 2002 - on

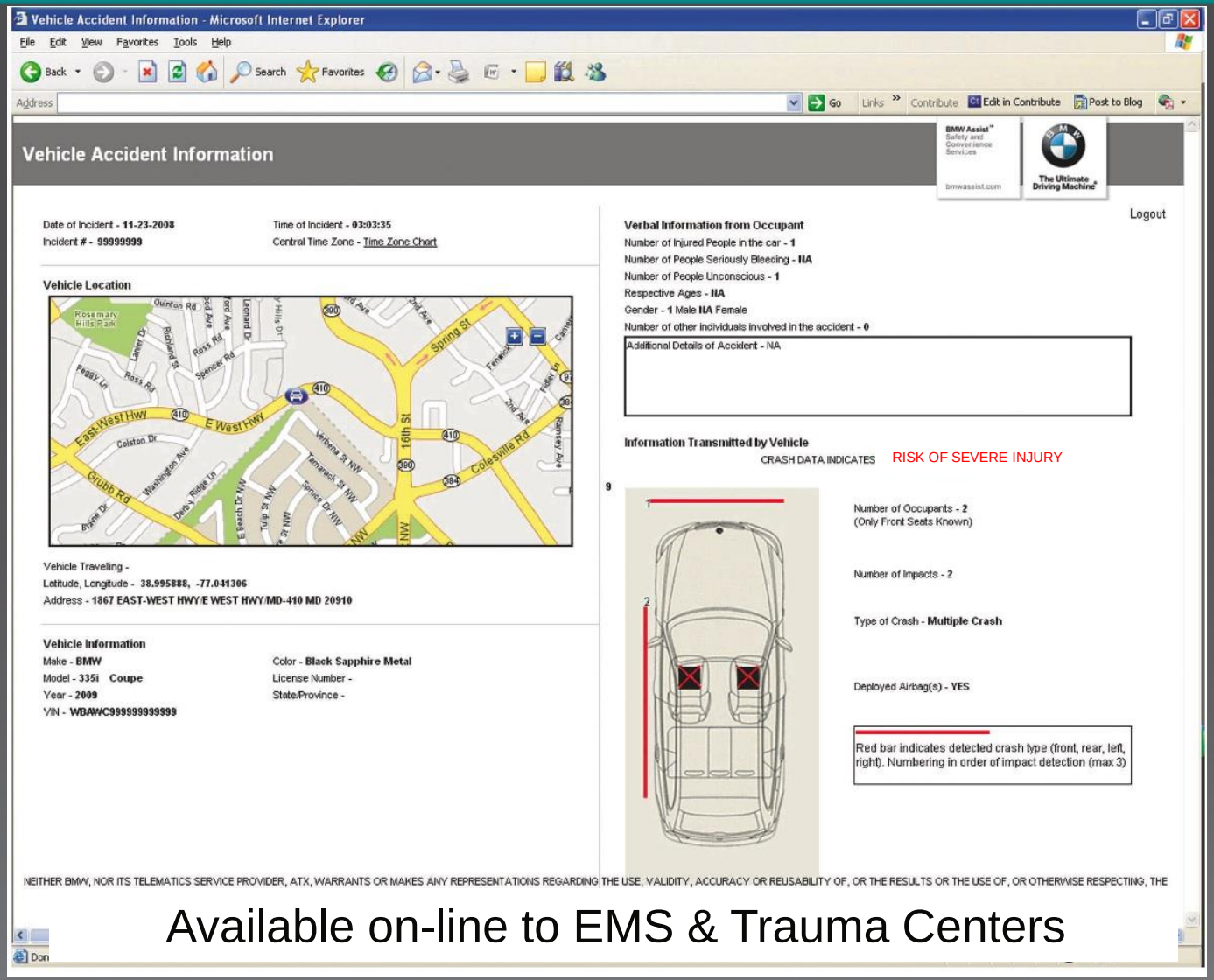
BMW Supported Publications

- Augenstein, J, Perdeck, E., Stratton, J., Digges, K., and Bahouth, G., "Characteristics of Crashes that Increase the Risk of Injury", 47th *Annual Proceedings of the Association for the Advancement of Automotive Medicine,* p. 561-576, September, 2003.
- Augenstein, J, Bahouth, G, and Perdeck, E, Digges, K., "Injury Identification: Priorities For Data Transmitted", Paper 05-0355, 19th ESV Conference, June 2005.
- Augenstein, J, Perdeck, E., Digges, K., Bahouth, G., Baur, P., and Borcher, N., "A More Effective Post-Crash Safety Feature to Improve the Medical Outcome of Injured Occupants", SAE 2006-01-0675, April 2006.
- Augenstein, J., Digges, K. Perdeck, E., Stratton, J., and Bahouth G., "Application of ACN Data to Improve Vehicle Safety and Occupant Care" Paper, 07-0512, *20th ESV Conference*, June 2007.
- Rauscher, S., Messner, G., Baur, P., Augenstein, J., Digges, K., Perdeck, E., Bahouth, G., Pieske, O., "Enhanced Automatic Collision Notification System – Improved Rescue Care Due To Injury Prediction – First Field Experience", Paper Number: 09-0049, *Proceedings of the 21st ESV Conference,* June 2009.

Early eACN Vehicles

- GM OnStar - 2004 Chevrolet Malibu “Safe and Sound” Package – Capability to send crash data
- BMW 2008 All Models – “Assist Package” Capability to send crash data.
  - Database of eACN calls maintained by WLIRC (University of Miami)
  - Incorporated the URGENCY risk prediction

BMW eACN Report

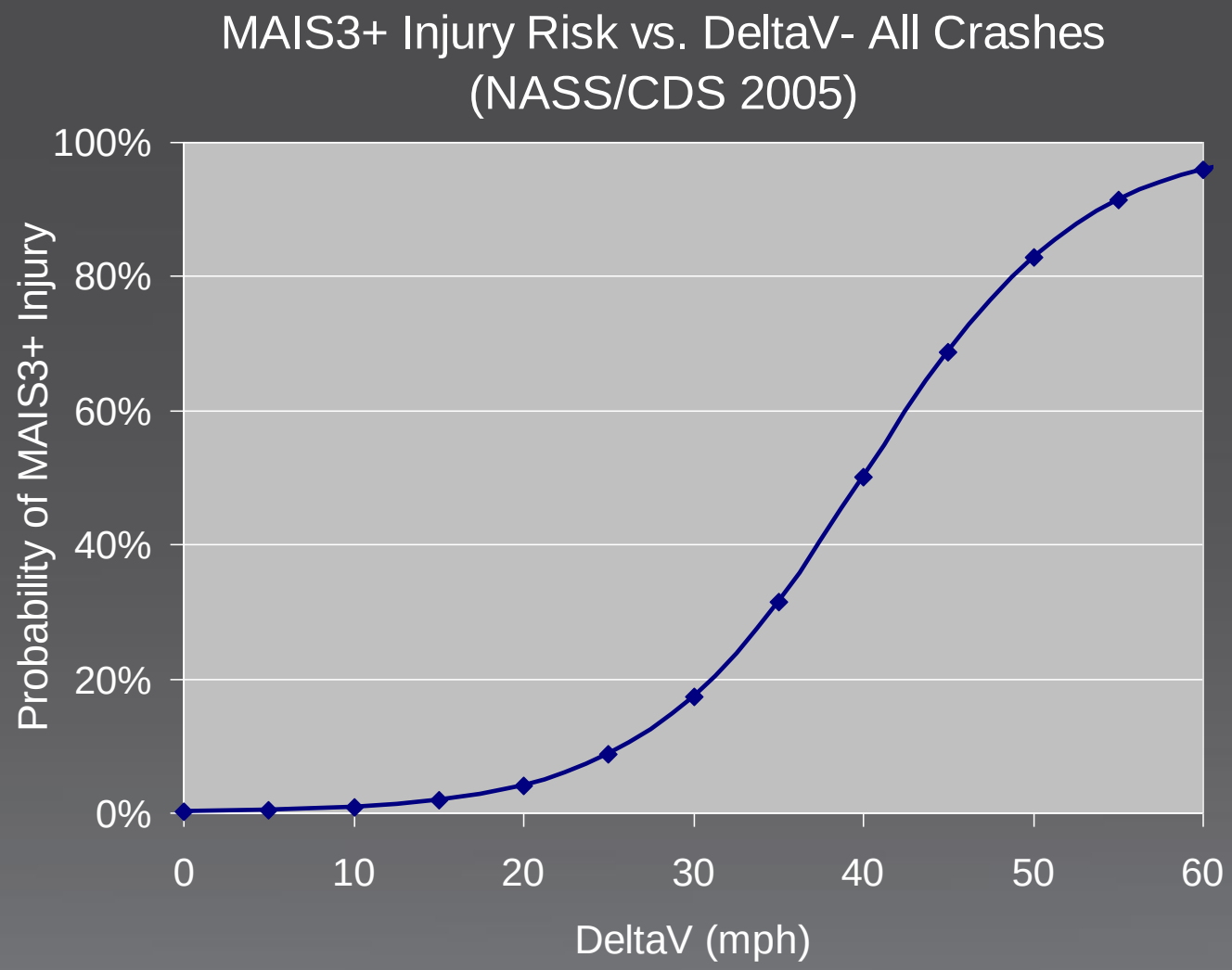


Available on-line to EMS & Trauma Centers

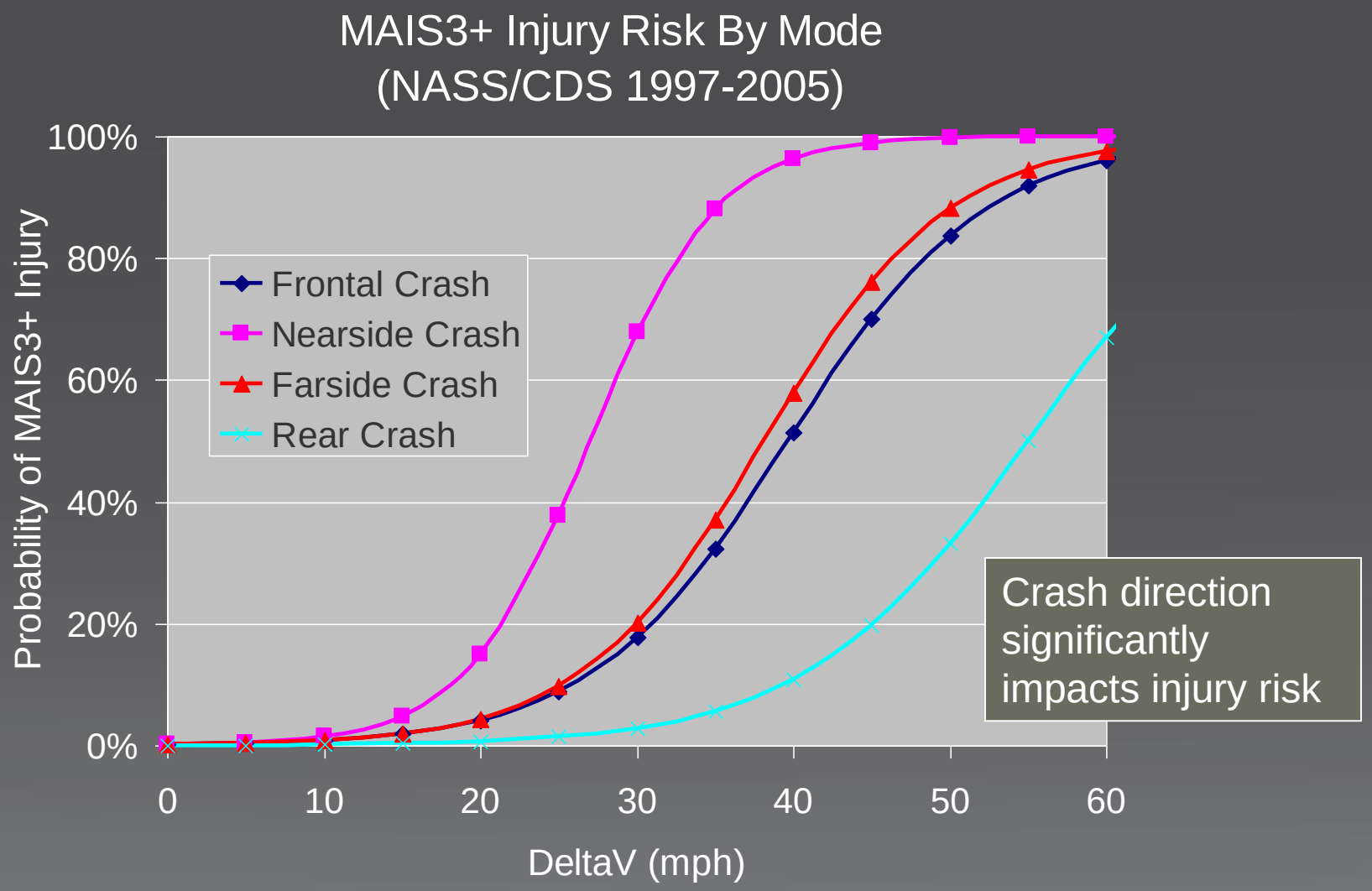
Presentation Overview

- History of URGENCY
- URGENCY Crash Data Elements
- URGENCY Calculations and Accuracy

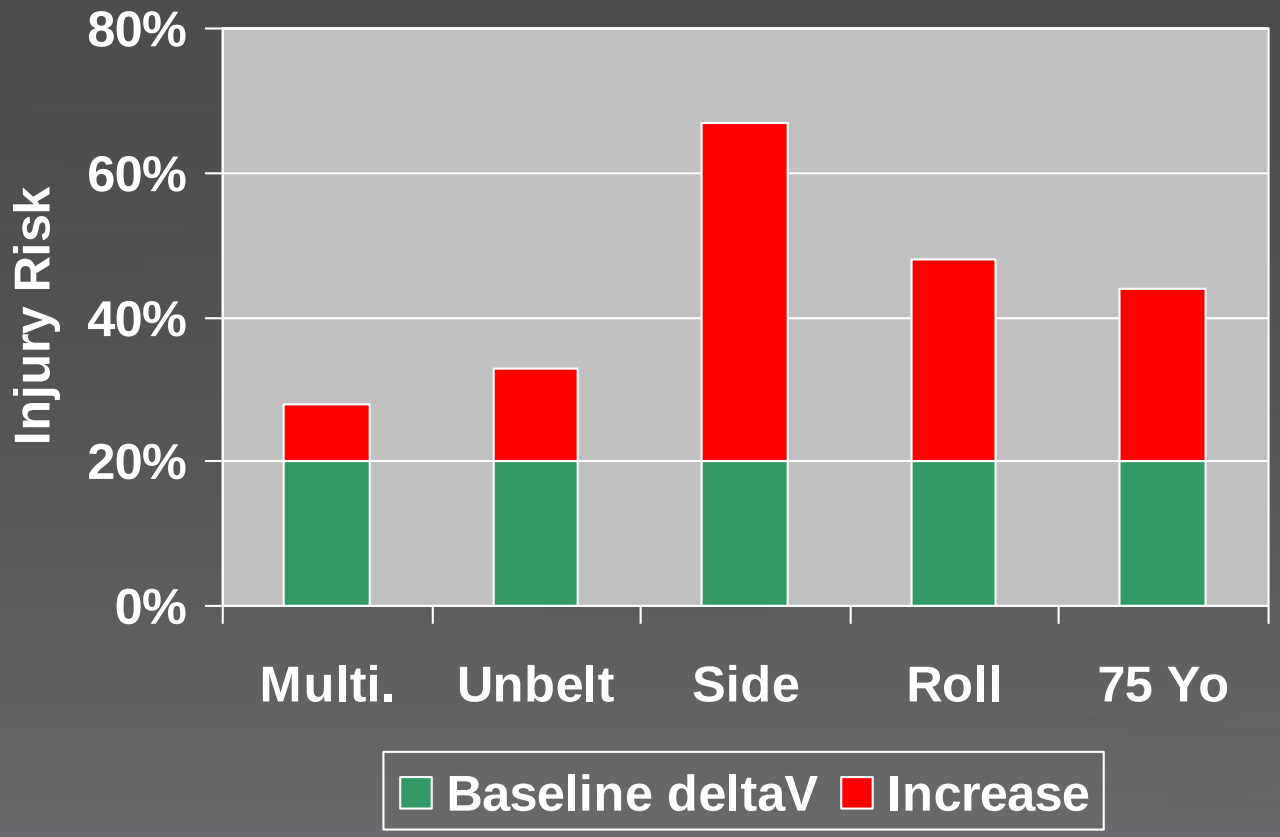
Probability of Injury Versus Crash DeltaV



Risk of Injury Versus Impact Direction



Benefit of Factors Added to DeltaV

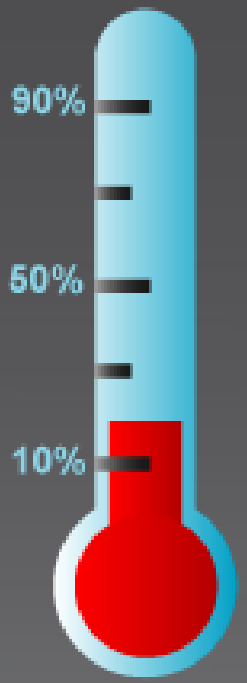


Baseline Risk – Frontal 27 mph deltaV (Belted)

Example of Injury Risk Calculation

Crash	
Delta V, Mph	27
Safety Belt	Yes
Multiple Impact	No
Rollover	No
Frontal Crash	Yes

Injury Risk Prediction



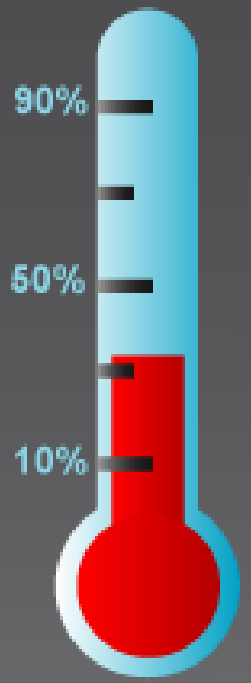
Risk - 20%

Belted Occupant

Added Variables

Crash	
Delta V, Mph	27
Safety Belt	No
Multiple Impact	No
Rollover	No
Frontal Crash	Yes

Injury Risk Prediction



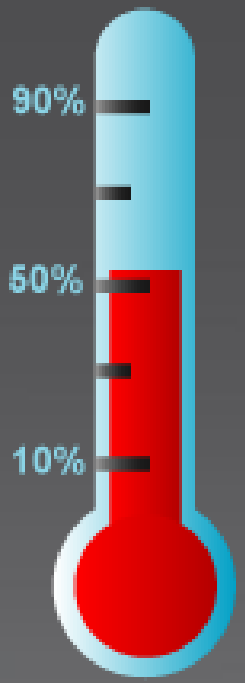
Risk - 38%

Unbelted

Added Variables

Crash	
Delta V, Mph	27
Safety Belt	No
Multiple Impact	Yes
Rollover	No
Frontal Crash	Yes

Injury Risk Prediction



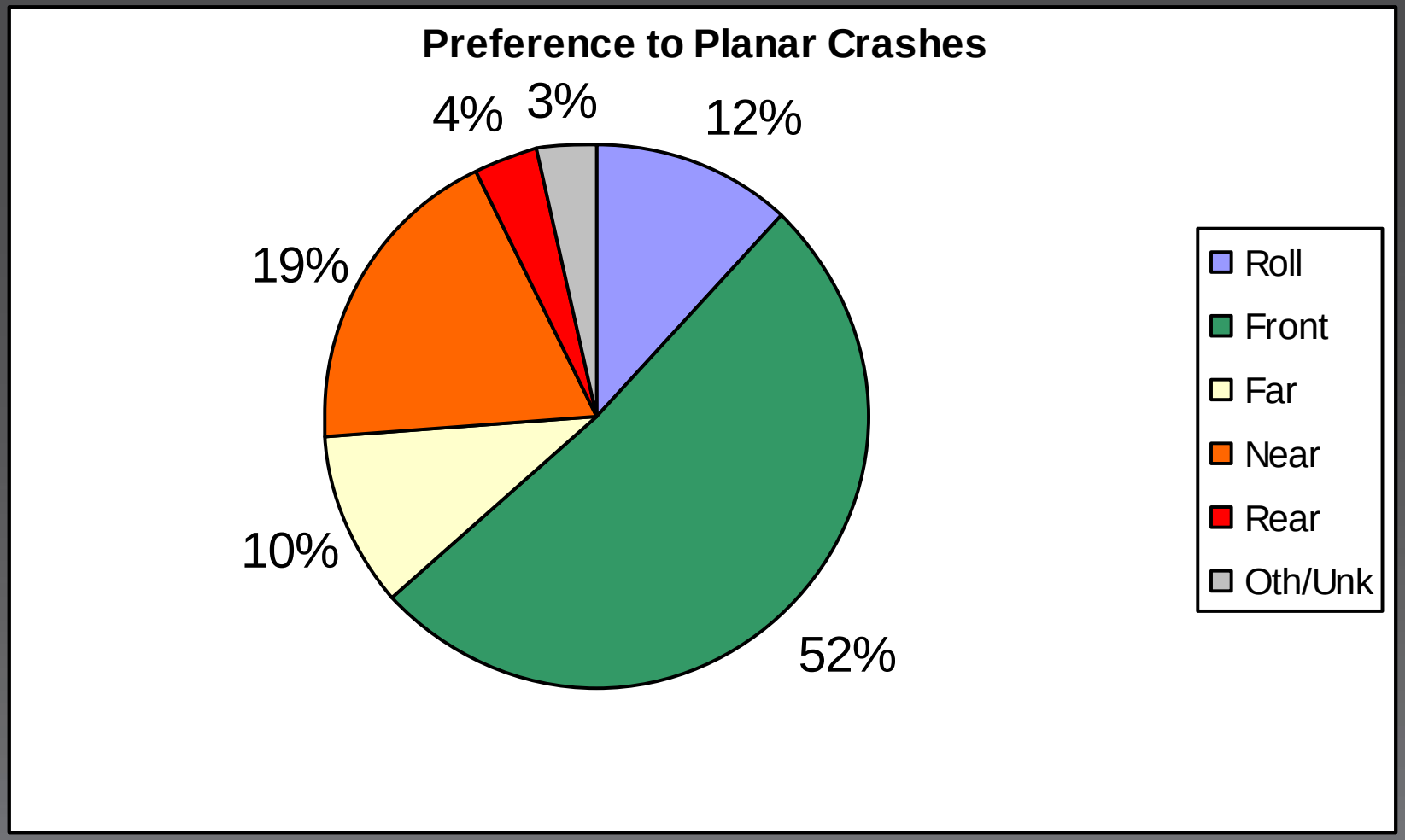
Risk - 56%

Unbelted +
Multiple Impact

Most Important Variables for URGENCY

- Crash Speed – DeltaV
- Crash Direction
- Belt Use
- Multi-impact
- Rollover
- Age of Occupant

US Fatalities by Crash Direction



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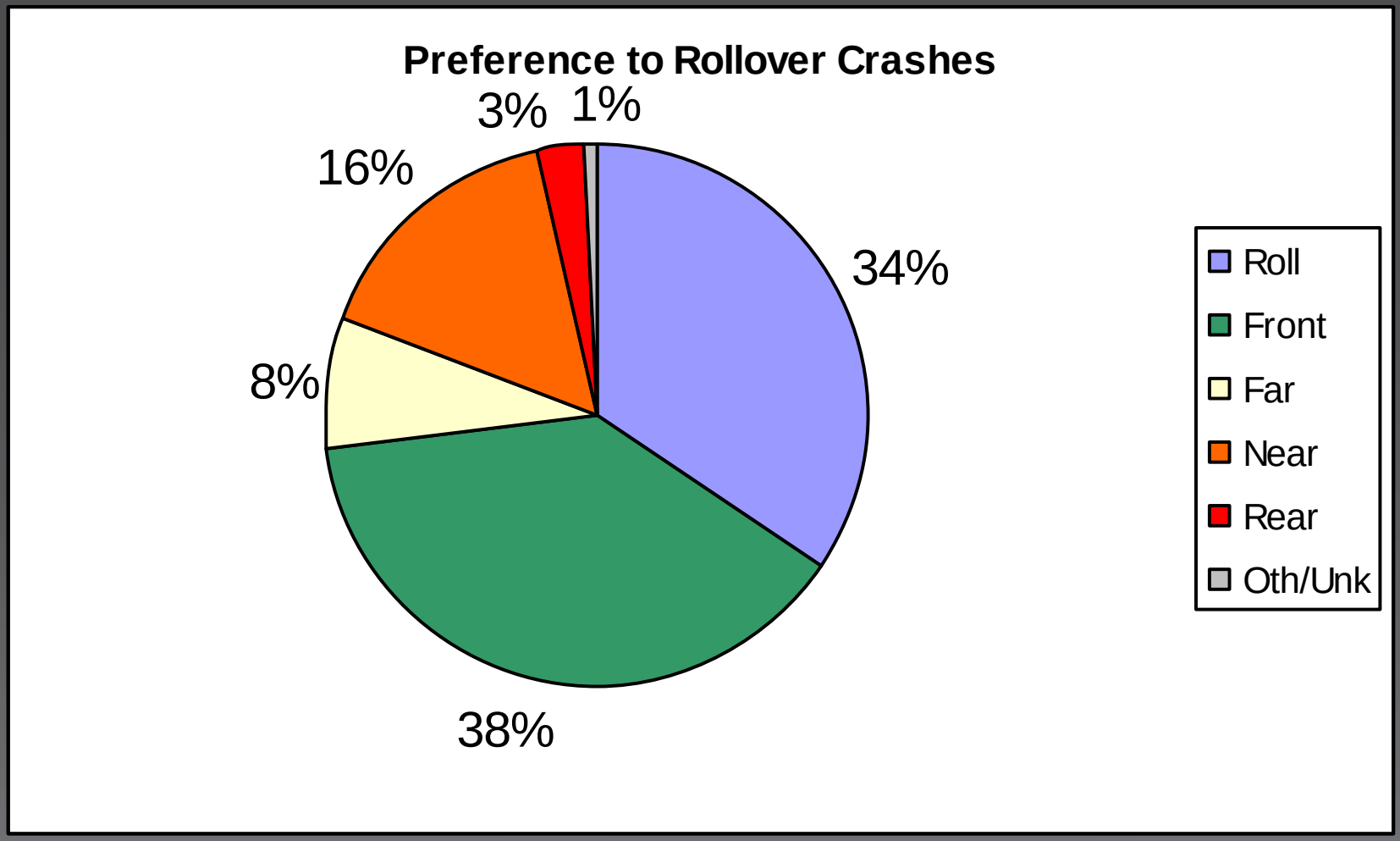

Priorities for Accuracy of URGENCY

- Predictive accuracy most beneficial in frontal, near-side and rollover crashes
- Predictions for multiple impacts with rollover desirable
- Rear impact is direction with fewest fatalities

Presentation Overview

- History of URGENCY
- Priority for Crash Data Elements
- URGENCY Calculations and Accuracy

- **URGENCY interprets key crash information to estimate injury risk**
- **Multinomial regression models are used to estimate risk based on multiple crash factors at the same time**

URGENCY Injury Predictor Algorithm

- Probability of Injury (P) Using Logistic Regression Analysis with Weighting Factors

$$P = 1/[1+\exp(-w)]$$

  - w = Ao + A1*Pred 1 + A2*Pred 2 + ...
  - Ao = Intercept
  - An= Coefficient
  - Pred n= Value of Predictor

Principle of Maximum Likelihood

URGENCY Injury Predictor Algorithm

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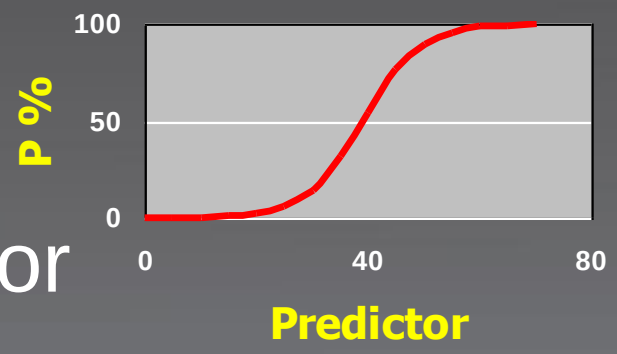

Principle of Maximum Likelihood

Calculation of Injury Risk

- 2 Regression Predictors-Frontal Crash

Variable	Type	Value
A_0 Intercept	Constant	-5.232
A_1 (DeltaV)	Continuous	0.1482
A_2 (Belt Use)	Binary	-1.143

- Principle of Maximum Likelihood
-
- (1) $P = 1/[1+\exp(-w)]$
- (2) $w = Ao + A_1 *Pred\ 1 + A_2 *Pred\ 2$
- For frontal crash
- (3) $w = -5.2319 + (0.1482)*DeltaV + (-1.143)*Belt$
- A_0 = Intercept
- A_n= Coefficient
- Pred n = Value of Predictor

Calculation of Injury Risk

- 2 Regression Predictors-Frontal Crash

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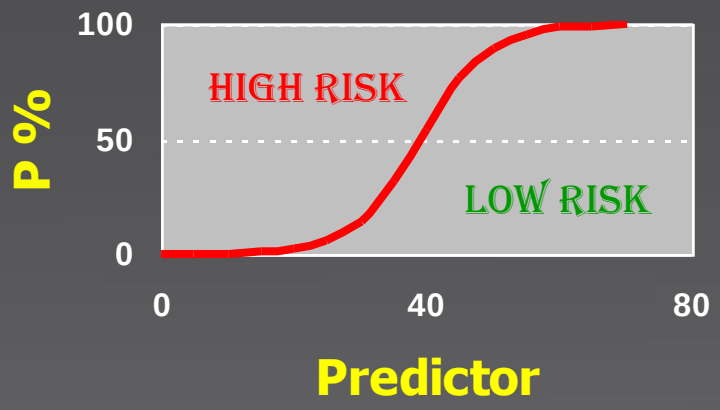

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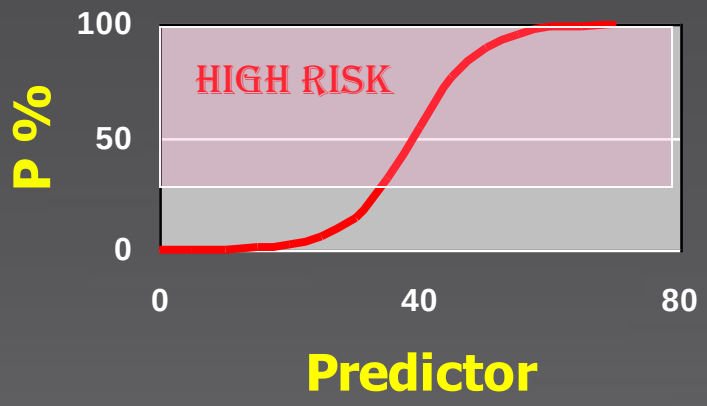
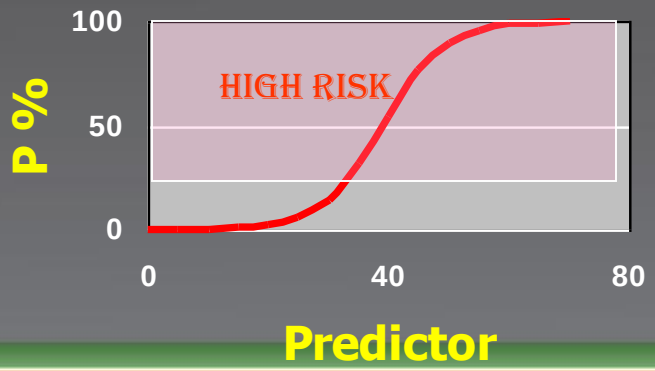


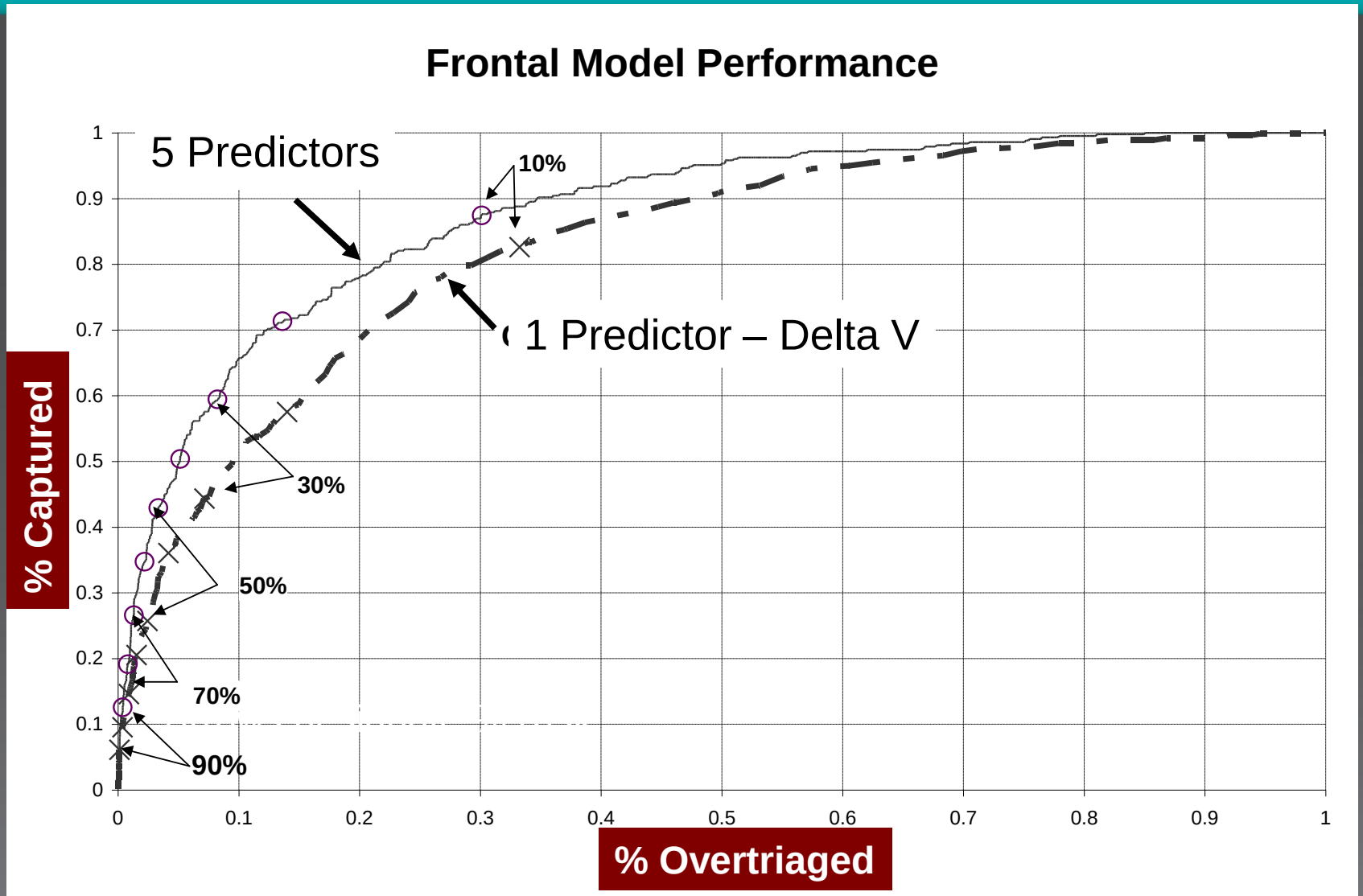
Injury Prediction requires a threshold

Injury Risk Threshold Issues

- High Threshold – Too many missed injuries
- Low Threshold - Too many uninjured
- Proper balance is an issue
- CDC suggests 1 in 5 accuracy for trauma centers
- Rescue units may permit less accuracy
- Voice communications can improve accuracy
- On-scene judgment can improve accuracy



Predictive Response for Added Variables



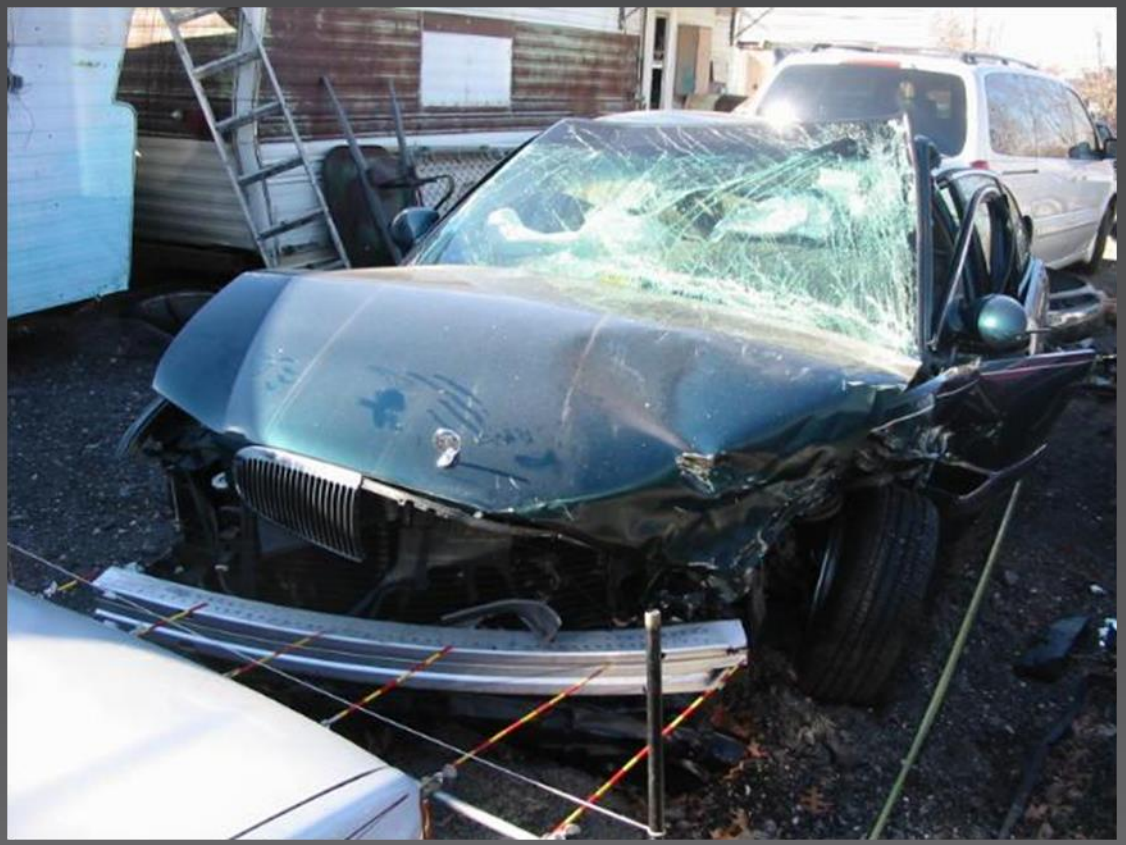
Summary of Capture Rates

Frontal Crash Direction – 20% Risk Threshold

Planar Crash Variables	MAIS 3+ Captured	MAIS 3+ Overtriaged
delta-V + Crash Direction	61.0%	20.3%
delta-V + Crash Direction + Belt Use	62.3%	20.6%
delta-V+Crash Dir.+ Belt Use+Multi-Impact	67.5%	20.7%

Above Table from Paper SAE 2006-01-0675
More Recent Research uses Risk Thresholds lower than 20%

Examples of Crashes – Missed Injury



Narrow Offset Frontal – Fatal aortic injury
DeltaV reported does not address intrusion
NASS Case 2009 9 32 2

Examples of Crashes – Missed Injury

Pole Impact – AIS 5 Chest Injury
No Air Bag deployment when needed
NASS Case 2005 50 18 1

Examples of Crashes – Missed Injury

Low Severity Offset Crash – AIS 5 Chest Injury
Driver with severe coronary atherosclerosis
NASS Case 2004 73 42 1

Examples of Crashes – Missed No Injury

Frontal Crash + Rollover – 21 YO belted male – AIS 1 Injury
Extensive damage suggests serious injury
NASS Case 2002 74 42 1

Examples of Crashes – Missed No Injury

Tree Impact – 39 YO unbelted male – AIS 1 injury
Extensive damage suggests serious injury
NASS Case 2006 73 181 1

Continuing Research

- Compare URGENCY Score from BMW crashes with actual Triage Decisions
- Compare URGENCY Score from BMW crashes with actual injuries

Summary

- URGENCY uses crash data (and occupant data when available) to estimate injury risk in a crash
- The risk estimate is immediately available to assist rescue and triage decisions
- Predictors in addition to DeltaV are needed to improve the prediction accuracy
- A 14 year research base exists for URGENCY development
- The risk threshold for “High Risk” prediction is a critical number – Agreement on acceptable levels of over-triage required

Opportunities for improving medical care and impediments to deployment of eACN to be discussed by Dr. Augenstein

- http://psap.atxg.com/aacn/welcome.do