GM GENERAL MOTORS NORTH AMERICA
Safety Center
64198

September 17, 1999
USG 3454; Part 5

Mr. L. Robert Shelton
Associate Administrator for
Safety Performance Standards
National Highway Traffic
Safety Administration
400 Seventh St., S.W.
Washington, D.C. 20590

Subject: Supplemental Information to the General Motors Corporation Comments to Docket 98-4405; -150
Notice 1, regarding Proposed Rulemaking to require Advanced Air Bags.

Dear Mr. Shelton:

On June 18, 1999, representatives of General Motors Corporation (GM) met with the agency in Washington, DC to discuss additional technical information regarding GM's December 17, 1998 comments to the subject NPRM. This supplement provides a copy of the material presented during the discussion. The complete presentation being provided includes some materials previously submitted to the agency. Attachment A includes the materials presented at the June 18 meeting.

On July 26, 1999, representatives of GM also met with the agency in Washington, DC to discuss technical information regarding air bag sensoring related to GM's comments to the subject NPRM. This supplement also provides a copy of the material presented during that discussion. Attachment B includes the materials presented at the July 26 meeting.

Portions of the information in Attachments A and B is confidential information within the meaning of Section 1905 of Title 18 of the United States Code, and is entitled to confidential treatment pursuant to Section 552(b)(4) of Title 5 of the United States Code (Exemption 4 of the Freedom of Information Act) and Section 112(e) of the National Traffic and Motor Vehicle Safety Act of 1966, as amended and implemented in Part 5 12 of Title 49 of the Code of Federal Regulations. Accordingly, GM respectfully requests that it be given confidential treatment by NHTSA for an indefinite period.

The information for which confidentiality is being requested consists of test data, design and engineering assessments, future product plans and materials revealing specific GM engineering approaches and methods. This is the type of information the agency has determined would presumptively result in competitive harm if disclosed (Part 5 12, Appendix B). The information for which confidential treatment is requested includes trade secrets and confidential commercial information. The confidential information has been marked "GM Confidential" or "GM Proprietary", and is being furnished with a copy of this letter to the Office of the Chief Counsel.

This information has great value to GM and would be of competitive value to other motor vehicle manufacturers. Knowledge of the test data, design and engineering assessments and criteria, future product plans, and information revealing specific GM engineering approaches and methods could enable a competitor to alter its vehicle strategy in a manner which is likely to have adverse affect on the sales of our vehicles, with a resulting decrease in revenue. Thus, disclosure of this information would be likely to result in substantial competitive harm to GM.

GM treats the information for which confidential treatment is requested as confidential, proprietary information available only to authorized personnel of GM and selected suppliers and customers, and is not otherwise available to the public. Documents containing information of this type are maintained under a recordkeeping system which is intended to control dissemination of these materials within GM, and to assure that the materials are not disseminated outside GM. To the best of our knowledge, none of the information for which confidentiality is being requested has been disseminated outside GM, except to GM suppliers and customers who have entered into appropriate confidentiality agreements. To the best of our knowledge, no prior determinations of the confidentiality of this specific information have been made by NHTSA, other Federal agencies, or the Federal courts.

Should NHTSA receive a request for disclosure of these materials, GM requests that it be notified of the request, and be given an opportunity to provide further information, as necessary, as to why the confidentiality of these materials should be maintained. If there are any questions regarding this request for confidential treatment, please contact Mr. Charles W. Babcock (8 10/986-1 8 19), GM Legal Staff, Warren, Michigan.

We welcome the opportunity to discuss this information or any aspects of our December 17, 1998 response with you or members of your staff. If there are any questions, please do not hesitate to contact Mr. John E. Kromrei (810/947-1735) of my staff, or Mr. Richard F. Humphrey (202/775-5071) of GM's Washington Office.

Sincerely,

C. Thomas Terry, Director
Safety Affairs & Regulations
Safety Center

attachments

cc: Office of Chief Counsel, NHTSA; 2 copies with & 1 copy without confidential information
Docket 98-4405; 2 copies without confidential information
Mr. Clarke Harper, NHTSA; 1 copy without confidential information

CERTIFICATE IN SUPPORT OF **REQUEST** FOR CONFIDENTIALITY

I, C. Thomas Terry, pursuant to the provisions of 49 CFR Part 5 12, state as follows:

(1) I am Director of Safety Affairs & Regulations, Safety Center, and I am authorized by General Motors Corporation (GM) to execute documents on its behalf;

(2) Portions of the information in Attachments A and B which have been marked "GM Confidential" or "GM Proprietary", consists of tests data, design and engineering assessments and future product plans. The material reveals specific GM engineering approaches and methods which is being submitted with the claim that it is entitled to confidential treatment pursuant to 5 USC 552(b)(4) and Section 112(e) of the National Traffic and Motor Vehicle Safety Act of 1966, as amended and implemented in 49 CFR Part 512;

(3) I, or members of my staff, have personally inquired of the responsible GM personnel who have the authority in the normal course of business to release the information for which a claim of confidentiality has been made to ascertain whether such information has ever been released outside GM;

(4) Based upon such inquiries and to the best of my knowledge, information and belief, the information for which GM has claimed confidential treatment has never been released or become available outside GM, except as needed by GM's restraint system suppliers and customers which have entered into appropriate confidentiality agreements;

(5) I make no representations beyond those contained in the certificate and in particular, I make no representations as to whether this information may become available outside GM because of unauthorized or inadvertent disclosure; and

(6) I certify under penalty of perjury that the foregoing is true and correct, to the best of my information and belief.

Executed on this day the 17th of September, 1999.

C. Thomas Terry

C. Thomas Terry, Director
Safety Affairs & Regulations
Safety Center

Attachment A

USG 3454; Part 5

53 pages
(including this cover)

Agenda NHTSA/GM Meeting
June 18, 1999

I) Introductions and Agenda Topics

II) Rationale for continuance of depowered air bags

- Out-of-position driver test results on six depowered vehicles

- Variability and compliance margin

- Depowered 30 mph rigid barrier test results

- Air bag depth issues

- Generic Sled Tests facilitating similar aggressivity for all vehicles

III) "Up to" Speed Conflicts

IV) Market Research Results

V) Unbelted Test Alternatives based on the Generic Sled

VI) Dual Level Air Bags

Six Depowered Competitive Vehicles

Background

NHTSA barrier tested six 1998 vehicles with "depowered" air bags (validated with Generic Sled Test)

- 5 of 6 vehicle tests met FMVSS 208, one did not
- 30 mph, zero degree, rigid barrier, unbelted 50^{th}
- Chrysler Minivan and Neon, Ford Taurus and Explorer, Toyota Camry, Honda Accord

Out-of-Position 5th Female - Six Depowered Competitive Vehicles

Objective of GM Tests

Determine if the vehicles were sufficiently depowered to meet IARV for out-of-position 5th female driver

- Test NPRM Position #1 and Position #2
- Compare four IARV proposals (AAMA, three per NPRM)
- Investigate test variability (need for compliance margin if proposed tests become FMVSS)
- Obtain competitive assessment information

Number of 5th Female Parameters Above 80% and 100% IARV - Out-of-Position Driver

	Parameters > 80% IARV				Parameters > 100% IARV			
	AAMA [2]	NPRM Peak Value	NPRM Nij < 1.O	NPRM Nij < 1.4	AAMA [2]	NPRM Peak Value	NPRM Nij < 1.0	NPRM Nij < 1.4
Number of ATD Parameters Considered [1]	16	20	16	16	16	20	76	16
Vehicle								
1998 Chrysler Minivan	6	6	6	4	4	4	3	2
1998 Dodge Neon	2	3	2	2	1	1	2	2
1998 Ford Explorer	2	3	3	1	0	2	0	0
1998 Ford Taurus	1	1	1	1	1	0	0	0
1998 Toyota Camry	5	5	5	4	4	4	4	2
I998 Honda Accord [3]	2	2	1	1	2	2	1	0

(1) Total number of ATD measurements considered from one test in Position #1 plus one test in Position #2

(2) One chest defl ection rate parameter was included from each test (four can be measured)

(3) Only one test was conducted for this vehicle (Position #1)

Variability - Three Repeat Tests - Out-of-Position 5th Female Driver

Test Condition					% of AAMA IARV										
					Head	Neck				Thorax					
Chart shows values > 0% IARV					HIC 15 ms	Flex. Mom.	Ext. Mom.	Tension Force	Comp. Force	Chest Defl.	Defl. Rate	Defl. Rate - Accels Upper	Mid	Lower	Accel. 3 ms
				IARV	779	95	39	2.07	2.52	53	8.2	8.2	8.2	0.2	73
Vehicle	Position	Side	Lateral	Test	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1998 Honda Civic (fixture)	#1	Dr	Cl. mod.	L42797	26	8	151	109	21	33	33	#####	#####	#####	27
1998 Honda Civic (fixture)	#1	Dr	CL mod.	L43816	12	0	195	116	0	48	37	47	33	24	30
1998 Honda Civic (fixture)	#1	Dr	CL mod.	L43817	26	4	192	124	15	52	37	44	32	29	33
1998 Honda Civic (fixture)	#2	Dr	CL mod.	L42796	6	0	92	71	1	83	93	#####	#####	#####	48
1998 Honda Civic (fixture)	#2	Dr	CL mod.	L43809	6	0	118	87	3	100	85	81	89	98	49
1998 Honda Civic (fixture)	#2	Dr	CL mod.	L43810	6	1	82	73	3	98	79	71	76	81	47

Not measured [box] Value ≥ 80% IARV

Out-of-Position 5th Female Driver

Results

1) Three vehicles exceeded at least one requirement for all four IARV proposals (>100% IARV not considering compliance margin)

2) None of the designs met IARV with the necessary compliance margins recognized by vehicle manufacturers (<80% IARV)

3) Variation of results in repeat tests demonstrate need for compliance margin

- Variation near 40%
- In repeat tests, some parameters were above as well as below proposed limits

Conclusions

1) The air bags tested were ndt sufficlently depowered to comply with proposed out-of-position tests

2) FMVSS 208 should limit the aggressivity of air bags

3) More severe inflation loads are expected if new unbelted test requirements drive higher aggressivity

GM Test Data

Return to Unbelted 30 mph Rigid Barrier Test Will Require More Aggressive Air Bags

Demonstrated by Comparing Barrier Test Results for:

- Pre-1998 Full Power Air Bag - Unbelted 50^{th} Designed to 30 mph Rigid Barrier
- Current Depowered Air Bag - Unbelted 50^{th} Designed to 30 mph Generic Sled

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GM Test Data

Compatibility of Unbelted 50th Male and 5th Female

Relative to:

- Air Bag Geometry
- Severity of Crash Test Used for Unbelted 50th Testing

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Unbelted Barrier "Up To" Requirement
Should Be Eliminated Because:

1. With addition of neck injury criteria, "all deployment" thresholds would have to be lowered resulting in substantially more deployments.

   - 50th male right front passenger neck criteria are sometimes exceed at current threshold levels
   - 5th female right front passenger neck criteria exceeded even in 10 mph tests
   - Questionable whether dummy kinematics are biofidelic in low severity crashes
   - Field data does not support need for lower thresholds

Projections of Frontal Crashes per Million Car – Years

X, MPH	Events Per Million Car – Year With Lont. Delta V > X
6	8,415
7	8,063
8	7,491
9	6,860
10	6,116
11	5,291
12	4,591
13	3,948
14	3,167
15	2,592
16	2,113
17	1,682
18	1,299
19	1,020
20	803
21	647
22	516
23	417
24	321
25	239
26	198
27	171
28	137
29	119
30	99
35	45

Data Source: Passenger Cars in 1988 – 95 NASS - CDS

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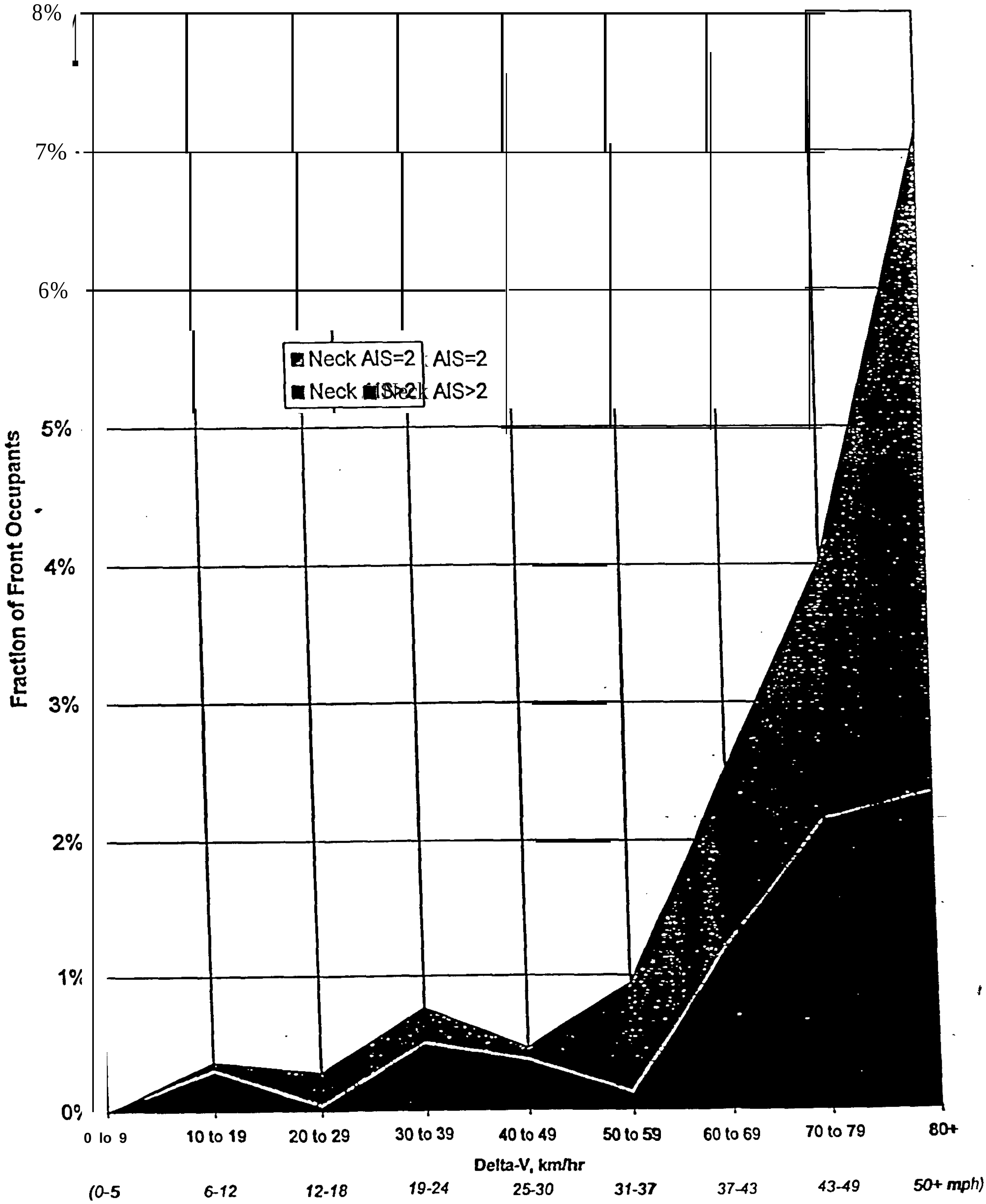
Neck and Cervical Spine Injury to Unbelted Front Seat Occupants of Non-airbag Vehicles in Frontal* Crashes



Data Source: Towaway Cars and Trucks in 1993-96 NASS-CDS

*Note: Frontal defined as non-rollover with |long. Dv| > |lat. Dv| and long. Dv<0

Unbelted Front Seat Occupants with AIS 2+ Neck Injury in Frontals with Delta-V < 50 km/hr

Drivers

Delta-V, km/h Lat.	Long.	Neck AIS	Age	Sex	AIS90				
-2	-10	2	22	M	650216.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of NFS
-2	-12	4	66	M	640214.4	Cervical Spine	Cervical Spine	Cord	Contusion, incomplete cord syndrome, with fracture
0	-15	2	47	M	650216.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of NFS
0	-10	2	60	F	650230.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body NFS
-3	-19	4	79	M	640214.4	Cervical Spine	Cervical Spine	Cord	Contusion, incomplete cord syndrome, with fracture
-10	-18	2	70	M	650230.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body NFS
-17	-20	3	58	M	650224.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of lamina
-17	-20	3	28	F	650228.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of odontoid (dens)
-7	-20	2	42	M	650232.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body, minor compression (< 20% loss of ant. ht)
8	-21	2	45	F	650216.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of NFS
-4	-24	2	40	M	650232.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body, minor compression (< 20% loss of ant. ht)
14	-24	3	49	M	650228.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of odontoid (dens)
2	-26	2	16	M	340202.2	Neck	Internal Organs	Larynx,	Contusion (hematoma)
5	-27	2	24	M	650204.2	Cervical Spine	Cervical Spine	Disc	Dislocation w/o frac., cord contusion/laceration NFS
-6	-28	2	83	F	650209.2	Cervical Spine	Cervical Spine	Disc	Dislocation w/o frac, cord contusion/lace, of facet NFS
-20	-23	5	44	M	640222.5	Cervical Spine	Cervical Spine	Cord	Contusion, complete cord syndrome, C-4 or below w/ no frac. or disloc.
-10	-28	2	24	F	650232.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body, minor compression (< 20% loss of ant. ht)
-26	-28	3	87	M	650224.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of lamina
0	-30	2	79	M	340202.2	Neck	Internal Organs	Larynx,	Contusion (hematoma)
0	-30	4	31	F	340210.4	Neck	Internal Organs	Larynx,	Laceration, puncture, massive destruction
0	-30	2	55	M	350200.2	Neck	Skeletal	Hyoid	Fracture
0	-31	2	87	F	650232.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body, minor compression (< 20% loss of ant. ht)
0	-32	2	20	M	650204.2	Cervical Spine	Cervical Spine	Disc	Dislocation w/o frac., cord contusion/laceration NFS
0	-34	2	38	M	650230.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body NFS
0	-39	3	20	F	650222.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of facet
-23	-39	3	75	F	650226.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of pedicle
0	-40	3	34	M	650206.3	Cervical Spine	Cervical Spine	Disc	Dislocation w/o frac., cord contusion/laceration of atlanto-axial (odontoid)
12	-42	4	70	M	640212.4	Cervical Spine	Cervical Spine	Cord	Contusion, incomplete cord syndrome, w/ no frac. or disloc.
-8	-43	3	28	M	640200.3	Cervical Spine	Cervical Spine	Cord	Contusion NFS
4	-44	3	17	F	650228.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of odontoid (dens)
17	-45	6	74	F	640236.6	Cervical Spine	Cervical Spine	Cord	Contusion, complete cord syndrome, C-3 or above w/ frac. and disloc.
			37			Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of transverse process
0	-46	2	69	M	650208.2	Cervical Spine	Cervical Spine	Disc	Dislocation w/o frac., cord contusion/laceration of atlanto-occipital
12	-47	2	39	M	650216.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of NFS
0	-47	2	50	M	650204.2	Cervical Spine	Cervical Spine	Disc	Dislocation w/o frac., cord contusion/laceration NFS
0	-48	2	57	M	650216.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of NFS

Data Source: Towaway Cars and Trucks in 1993-96 NASS-CDS

*Note: Frontal defined as non-rollover with (long, Dv| > |lat. Dv| and long, Dv<0.

"NFS" Not Further Specified

Unbelted Front Seat Occupants with AIS 2+ Neck Injury in Frontals with Delta-V < 50 km/hr

Delta-V, km/h Lat.	Delta-V, km/h Long.	Neck AIS	Age	Sex	AIS90				
Right Front Occupants									
9	-15	2	48	M	650220.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of transverse process
-7	-20	4	48	F	640212.4	Cervical Spine	Cervical Spine	Cord	Contusion, incomplete cord syndrome. w/ no frac. or disloc.
13	-22	3	45	F	650224.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of lamina
-12	-22	3	67	M	650206.3	Cervical Spine	Cervical Spine	Disc	Dislocation w/o frac., cord contusion/laceration of atlanto-axial (odontoid)
0	-23	3	22	M	650222.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of facet
11	-29	2	16	F	390604.2	Neck	Whole Area	Skin	Laceration, major (> 20 cm long and into subcutaneous tissue)
-5	-29	2	23	M	650230 1.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/lacerationw/ or w/o dilsloc. of verteb. body NFS
-5	-30	2	68	F	650232.2	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of verteb. body, minor compression (< 20% loss of ant. ht)
0	-33	2	16	F	650204.2	Cervical Splne	Cervical Spine	Disc	Dislocation w/o frac., cord contusion/laceration NFS
1	6 -	4 5	5	5 F	640262.5	Cervical Spine	Cervical Spine	Cord	Laceration, complete cord syndrome , C-4 or below w/ no frac. or disloc.
Center Front Occupants									
-12	-33	3	22	F	650226.3	Cervical Spine	Cervical Spine	Disc	Fracture w/o cord contusion/laceration w/ or w/o disloc. of pedicle

Data Source: Towaway Cars and Trucks in 1993-96 NASS-CDS

*Note: Frontal defined as non-&lover with (long. Dv| > (lat. Dv| and long. Dv<0.

[illegible]

Unbelted Barrier "Up To" Requirement
Should Be Eliminated Because:

1. With addition of neck injury criteria, "all deployment" thresholds would have to be lowered resulting in substantially more deployments.

   - 50th male right front passenger neck criteria are sometimes exceed at current threshold levels
   - 5th female right front passenger neck criteria exceeded even in 10 mph tests
   - Questionable whether dummy kinematics are biofidelic in low severity crashes
   - Field data does not support need for lower thresholds

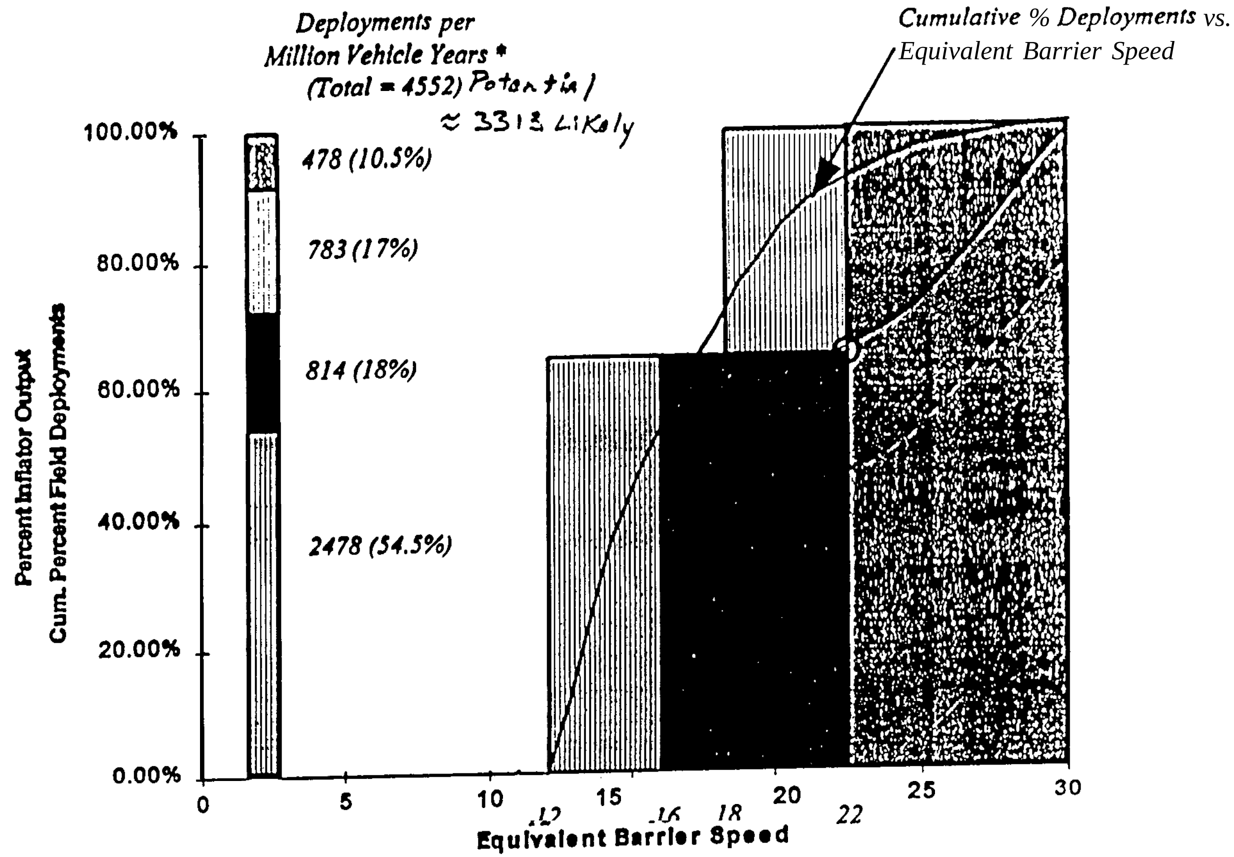
2. The conflict between the "up to" unbelted barrier and low risk deployment requirements inhibits rather than facilitates implementation of crash severity based variable level inflation technology.

   - In a 22 mph barrier, the 50th male "bottoms through" low level of a variable level air bag capable of managing the out-of-position 5th female. This indicates the limit of restraint capacity. Therefore, the "up to" requirement necessitates some higher inflation level at or below a 22 mph frontal barrier resulting in a higher inflation level "all deploy" threshold at or below 22 mph frontal barrier and a "no deploy" threshold around 16 - 18 mph frontal barrier.

   - Low level is needed to meet the proposed 5th low risk deployment requirement but cannot be assured in a 20 mph barrier

6/16/99

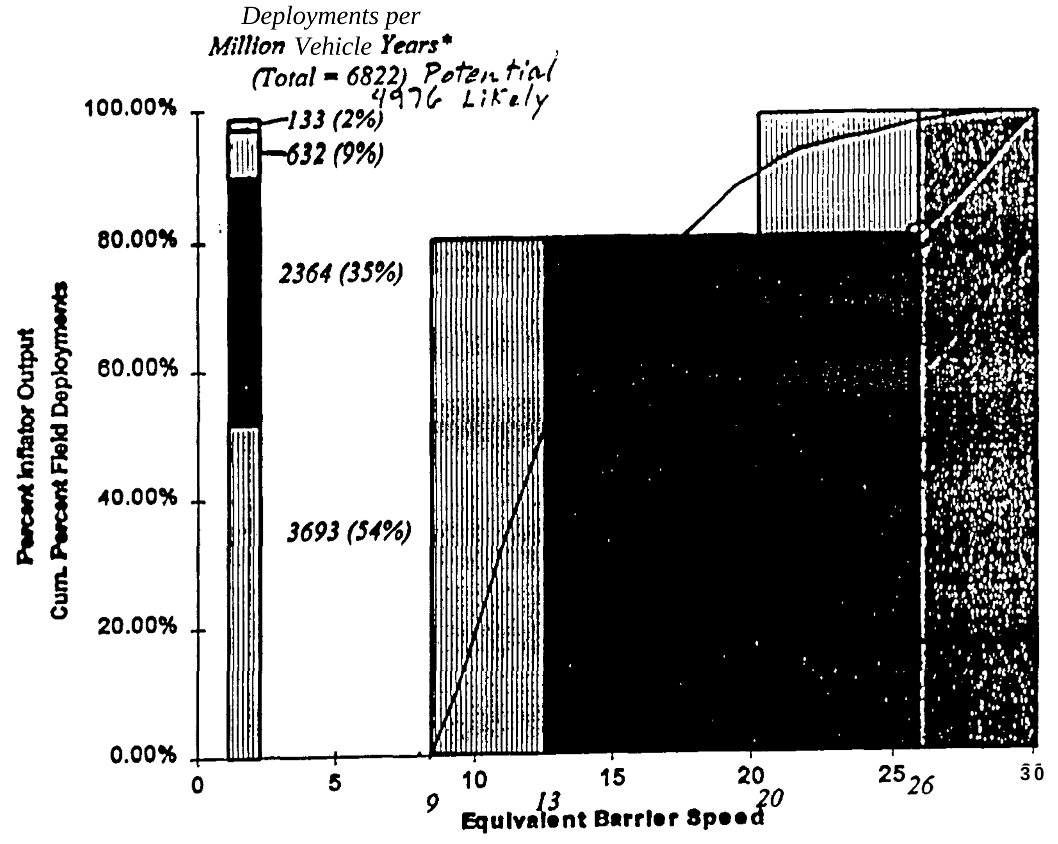
Dual Level Air Bag with Proposed Deployment Thresholds



* from 1988-95 NASS-CDS

Figure 5

Dual Level Air Bag with Reduced Low Level Deployment Threshold and Increased High Level Deployment Thresholds



* from 1988-95 NASS-CDS

Figure 7

Figure I: Position #1 Laboratory Test - Out-of-Position Small Adult Driver

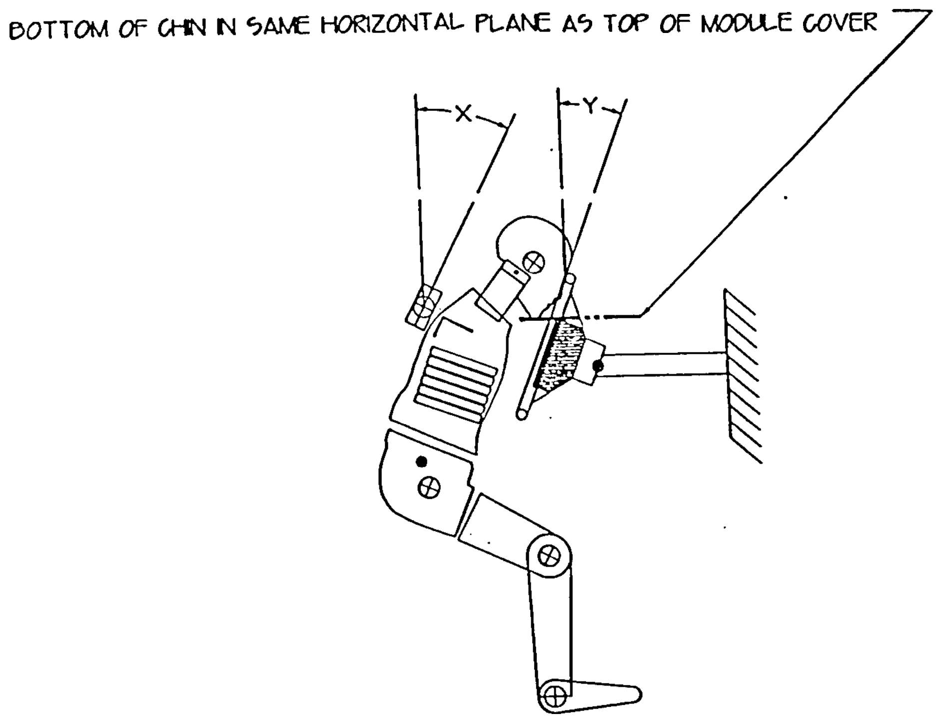
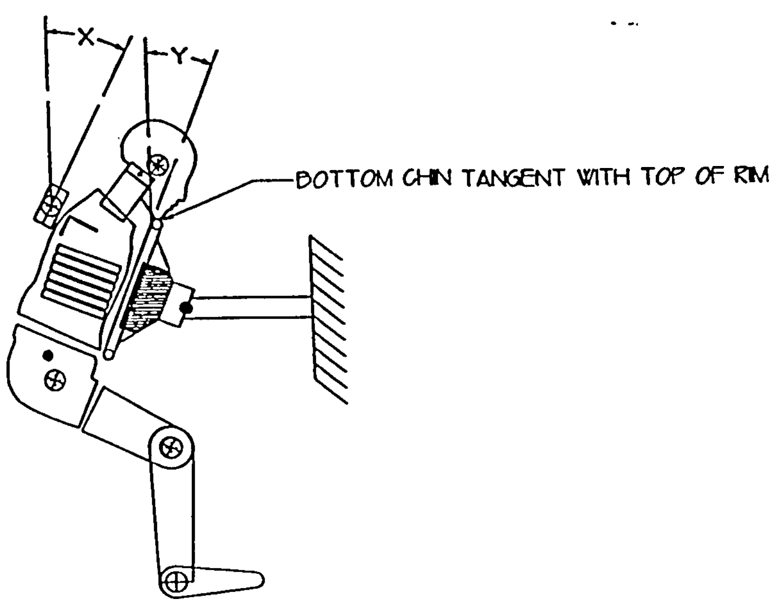


Figure 2: Position-#2 Laboratory Test - Out-of-Position Small Adult Driver



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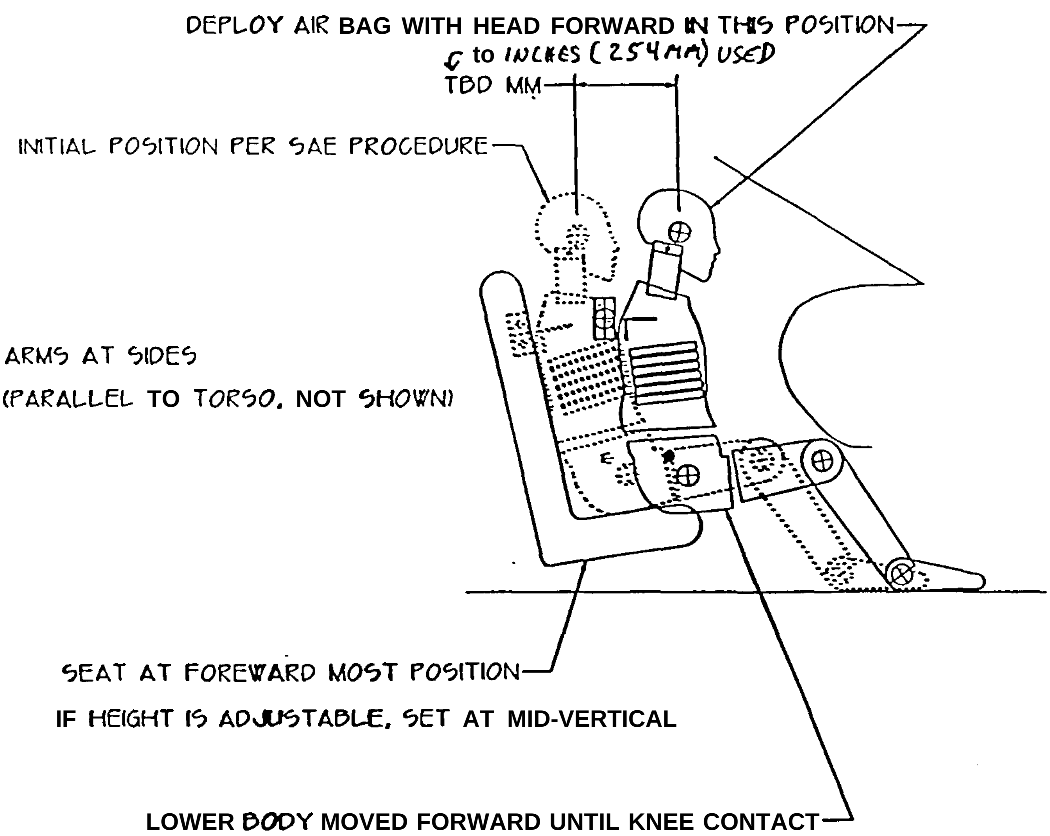
Example

Out-of-Position Small Adult Passenger



1. Conduct static air bag deployment test in a vehicle or buck with windshield, Instrument panel, seat., and any trim that may affect deploying air bag.
2. Use 5th %-tile female Hybrid III with <u>tbd</u> head / neck skin. Adjust neck bracket to 0^0.
3. Adjust seat to most forward position. If height is adjustable, set at mid-vertical.
4. Initial Position of ATD - first setup ATD per SAE procedure (for in-position testing with 5th female Hybrid III). ATD is to be centered on vehide specific lateral seating location.
5. After positioning ATD per SAE procedure, slide ATD forward on seat while maintaining angle of pelvis and upper legs until knees contact Instrument panel.
6. Bend torso forward to locate head <u>*tbd*</u> mm forward of Initial Position. Stabilize ATD torso with masking tape. Use minimum strength tape (weaken tape by a partial cut before test).
7. Deploy air bag.

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Unbelted Barrier "Up To" Requirement
Should Be Eliminated Because:

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   - 50th male right front passenger neck criteria are sometimes exceed at current threshold levels
   - 5th female right front passenger neck criteria exceeded even in 10 mph tests
   - Questionable whether dummy kinematics are biofidelic in low severity crashes
   - Field data does not support need for lower thresholds

2. The conflict between the "up to" unbelted barrier and low risk deployment requirements inhibits rather than facilitates implementation of crash severity based variable level inflation technology.

   - In a 22 mph barrier, the 50th male "bottoms through" low level of a variable level air bag capable of managing the out-of-position 5th female. This indicates the limit of restraint capacity. Therefore, the "up to" requirement necessitates some higher inflation level at or below a 22 mph frontal barrier resulting in a higher inflation level "all deploy" threshold at or below 22 mph frontal barrier and a "no deploy" threshold around 16 - 18 mph frontal barrier.

   - Low level is needed to meet the proposed 5th low risk deployment requirement but cannot be assured in a 20 mph barrier

3. If it is necessary to regulate air bag restraint capacity for unbelted occupants in moderate severity crashes, a moderate severity sled test at a discrete speed would be more appropriate.

Cbnsumer Market Research

- GM just completed an extensive and quantitative consumer market research analysis
- Over 1000 participants representing all product segments and demographic groups
- Purpose was to test consumers' level of interest and purchase consideration for 28 new technologies and features
- Gathered importance ratings producing a hierarchy of voice-of-the-customer needs
- Gathered satisfaction ratings for current features and vehicles

Consumer Market Research

Results:

- Importance Ratings for primary VOC needs (see slide)

- Dual level
  - » Received strongest purchase consideration scores among "Protection in a crash"
  - » Participants liked that this system could determine the situation (crash severity, how close the occupant is to the air bag, seat belt usage) and deploy the air bag appropriately

- Suppression
  - » 20% would prefer "Front air bags that are always suppressed for infants,children and small people"
  - » 80% would prefer "Front air bags that are always suppressed for infants, but deploy at a safe, low power for children and small people knowing that lower power air bags might have less benefit for properly restrained adults."
  - » Participants clearly prefered air bags that are safer, lower power versus more powerful air bags

- Focus Group Video

FMVSS 208 - In-Position Occupant Test Alternatives

		Air Bag	Belted					Unbelted					Practicability	
	Ref.	Aggressivity	Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female	Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female	Tests (2)	Criteri (3)
Current	1	Less	30	Barrier	± 30 deg	X		@ 30	Generic		X		4	52
	2		30	Barrier	± 30 deg	X		@ 30	Generic		X		4	80
	3		30	Barrier	± 30 deg (1)	X	X	@ 30	Generic		X		7	140
	4		30	Barrier	± 30 deg (1)	X	X	@ 30	Generic		X	X	8	160
NPRM	5	More	30	Barrier	± 30 deg	X	X	Up to 30	Barrier	± 30 deg	X	X	12	288

(1) 25 mph, 40% ODB with belted 5th female is redundant with belted 5th female angle barrier requirement

(2) Number of unique compliance test conditions. Does not include:
- 25 mph, 40% ODB with belted 5th female
- Repeat tests to assure fleet compliance
- Development tests to optimize design

(3) Based on number of test conditions; ATD sizes; driver and passenger; injury criteria (FMVSS 208 for Ref # 1, AAMA for Ref # 2,3,4, and NPRM for Ref # 5)

Reference 1 - Current FMVSS 208 - In-Position Occupant Test Alternative

Belted					Unbelted				
Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female	Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female
30	Barrier	± 30 deg	X		@ 30	Generic		X	
• Addresses frontal and angle / offset belted performance up to 30 mph barrier which includes extremely severe injury producing frontal crashes. • Scope encompasses safety of major portion of crash occupant population. Requirements focus on medium to large teenagers and adults.					• Addresses frontal unbelted performance in *a* crash simulation that represents field relevant impacts that are more severe than 97% of injury producing frontal crashes. • Scope encompasses safety of major portion of crash occupant population. Requirements focus on medium to large teenagers and adults. • Provides for comparable air bag restraint capacity / aggressivity across the spectrum of vehicle types. • Facilitates restraint system optimization early in vehicle development process.				

Reference 2 - In-Position Occupant Test Alternative

Belted					Unbelted				
Speed (mph)	Frontal Impact	Other Impact	50^{th} Male	5^{th} Female	Speed (mph)	Frontal Impact	Other Impact	50^{th} Male	5" Female
30	Barrier	± 30^{0}	X		@ 30	Generic		X	

Belted:

- Addresses frontal and angle / offset belted performance up to 30 mph barrier which includes extremely severe injury producing frontal crashes.
- Scope encompasses safety of major portion of crash occupant population. Requirements focus on medium to large teenagers and adults.
- ***Injury criteria added to improve occupant protection including reduction of air bag inflation injury risk.***

Unbelted:

- Addresses frontal unbelted performance in a crash simulation that represents field relevant impacts that are more severe than 97% of injury producing frontal crashes.
- Scope encompasses safety of major portion of crash occupant population. Requirements focus on medium to large teenagers and adults.
- Provides for comparable air bag restraint capacity / aggressivity across the spectrum of vehicle types.
- Facilitates restraint system optimization early in vehicle development process.

Reference 3 - In-Position Occupant Test Alternative

Belted					Unbelted				
Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female	Speed (mph)	Frontal Impact	Other Impact	50’” Male	5th Female
30	Barrier	$\pm 30^0$	X	X	@ 30	Generic		X	
• Addresses frontal and angle / offset belted performance up to 30 mph barrier which includes extremely severe injury producing frontal crashes. • Scope encompasses safety of major portion of crash occupant population. ***Requirements** focus **on small teenagers and small adults in addition to medium to lame teenagers and adults.*** • Injury criteria added to improve occupant protection including reduction of air bag inflation injury risk.					• Addresses frontal unbelted performance in a crash simulation that represents field relevant impacts that are more severe than 97% of injury producing frontal crashes. • Scope encompasses safety of major portion of crash occupant population. Requirements focus on medium to large teenagers and adults. • Provides for comparable air bag restraint capacity / aggressivity across the spectrum of vehicle types. • Facilitates restraint system optimization early in vehicle development process.				

Reference 4 - In-Position Occupant Test Alternative

Belted					Unbelted				
Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female	Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female
30	Barrier	± 30°	X	X	@ 30	Generic		X	X
• Addresses frontal and angle / offset belted performance up to 30 mph barrier which includes extremely severe injury producing frontal crashes. • Scope encompasses safety of major portion of crash occupant population. Requirements focus on small teenagers and small adults in addition to medium to large teenagers and adults. • Injury criteria added to improve occupant protection including reduction of air bag inflation injury risk.					• Addresses frontal unbelted performance in a crash simulation that represents field relevant impacts that are more severe than 97% of injury producing frontal crashes. • Scope encompasses safety of major portion of crash occupant population. ***Requiremenfs focus on small feenagers and small adults in addition to medium to large teenagers and adults.*** • Provides for comparable air bag restraint capacity / aggressivity across the spectrum of vehicle types. • Facilitates restraint system optimization early in vehicle development process.				

Reference 5 - NPRM - In-Position Occupant Test Alternative

Belted					Unbelted				
Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female	Speed (mph)	Frontal Impact	Other Impact	50th Male	5th Female
30	Barrier	± 30°	X	X	**Up to 30**	**Barrier**	± 30°	X	X
• Addresses frontal and angle / offset belted performance up to 30 mph barrier which includes extremely severe injury producing frontal crashes. • Scope encompasses safety of major portion of crash occupant population. Requirements focus on small teenagers and small adults in addition to medium to large teenagers and adults. • Injury criteria added to improve occupant protection including reduction of air bag inflation injury risk.					• Addresses frontal ***and angle*** /offset unbelted performance up ***to 30 mph barrier*** which includes ***extremely*** severe injury producing frontal crashes. • ***Intent of*** scope is to encompass safety of major portion of crash occupant population. Requirement: focus on small teenagers and small adults in additio to medium to large teenagers and adults. • ***Requires higher air bag restraint capacity / aggressivity for all types of vehicles.*** • ***Requires increased depth of air bag which conflicts with small teenager and small adult requirements.*** • ***Higher deployment frequency will result from the unbelted "up to" barrier requirement as deployment thresholds are lowered fo meet new injury criteria at "any speed up to."***				

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Attachment B

USG 3454; Part 5

100 pages
(including this cover)

Conflicts and Challenges Affected by Sensing

- Lower deployment thresholds needed to meet 5th and 50th neck criteria at "all deployment" threshold.

- High level inflation "no deploy" threshold needed for low risk deployment is incompatible with high level inflation "all deploy" threshold needed for "up to" unbelted requirement.

- Potential for inappropriate inflation levels in some types of crashes based on prediction early in crash event.

- Adapting air bag inflation to nominally balance restraint capacity and aggressivity is incompatible with "all" / "up to" requirement and sensing "gray zones".

Many of the NPRM conflicts and adaptive air bag technical challenges are agg-revated or exist because of crash sensing limitations.

- Crash sensors cannot wait to "measure" crash severity but must predict early in the crash event.
- "Gray zones" exist between "no deploy" and "all deploy" thresholds.
- The higher the crash severity used to adapt air bag inflation, the more difficult it is to timely accurately predict,

Basics of GM Frontal Crash Sensing Systems

NACG Interior Center
July 26, 1999

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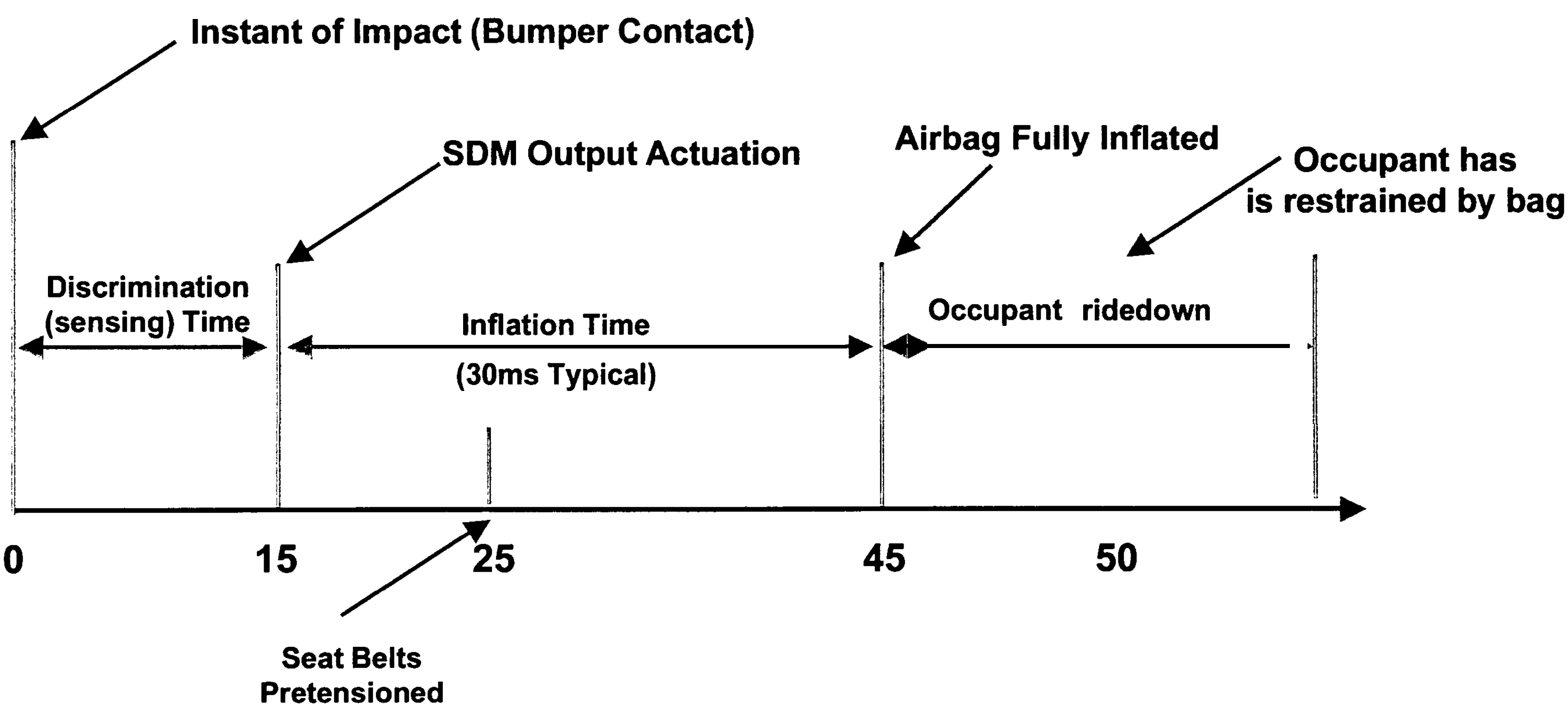
Objectives

- Gain familiarity with basic principles and philosophies in GM's crash sensing systems.

- Recognize that robust crash sensing is complex and a predictive, and not a deterministic problem.

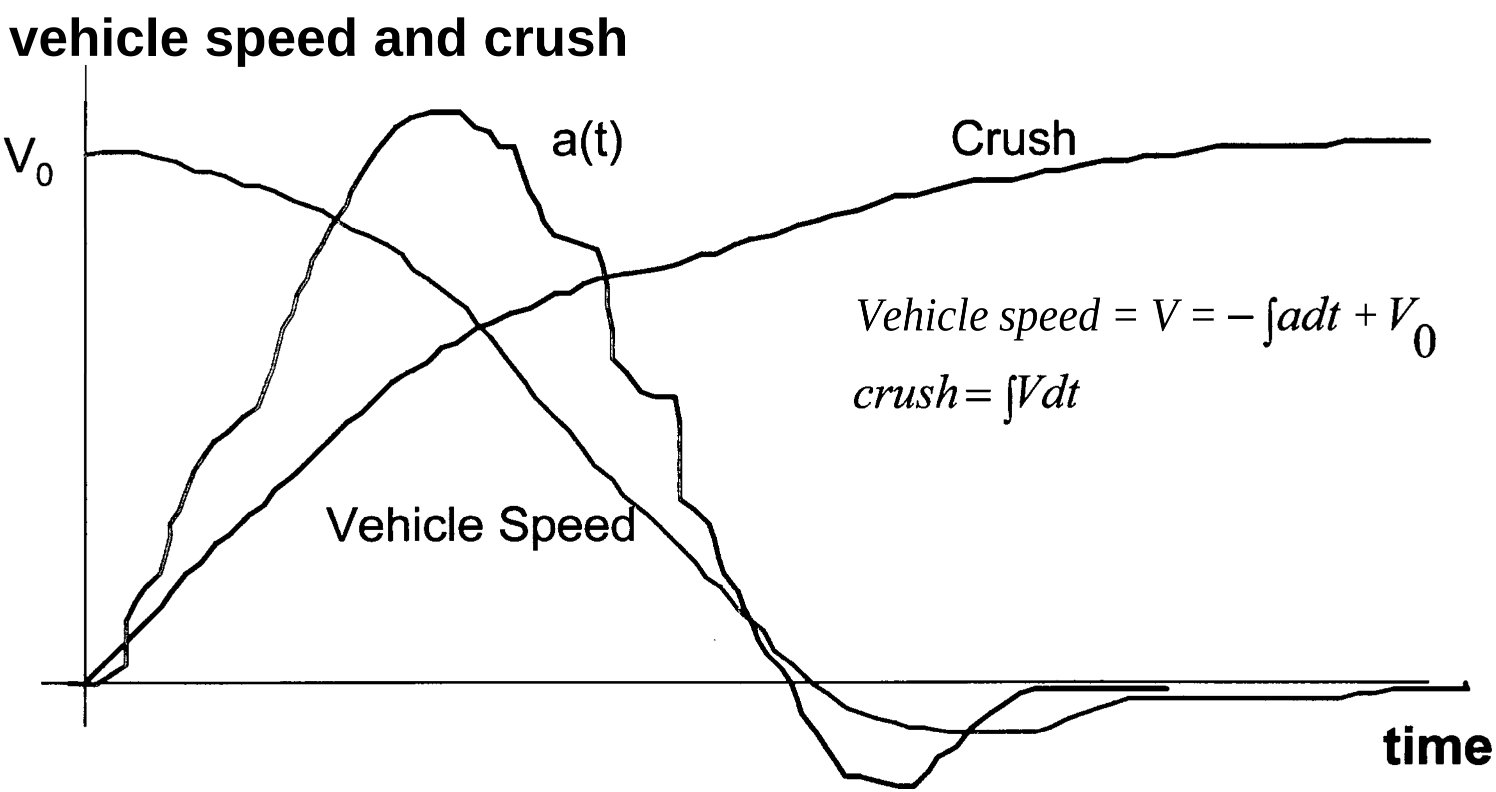
- Realize that multi-stage sensing systems are even more difficult to design, and validate for field use and may not offer significant advantages from some vehicles.

Crash analysis
Sequence of Crash Events



Times Shown are for Typical 30 MPH Frontal Barrier Crash

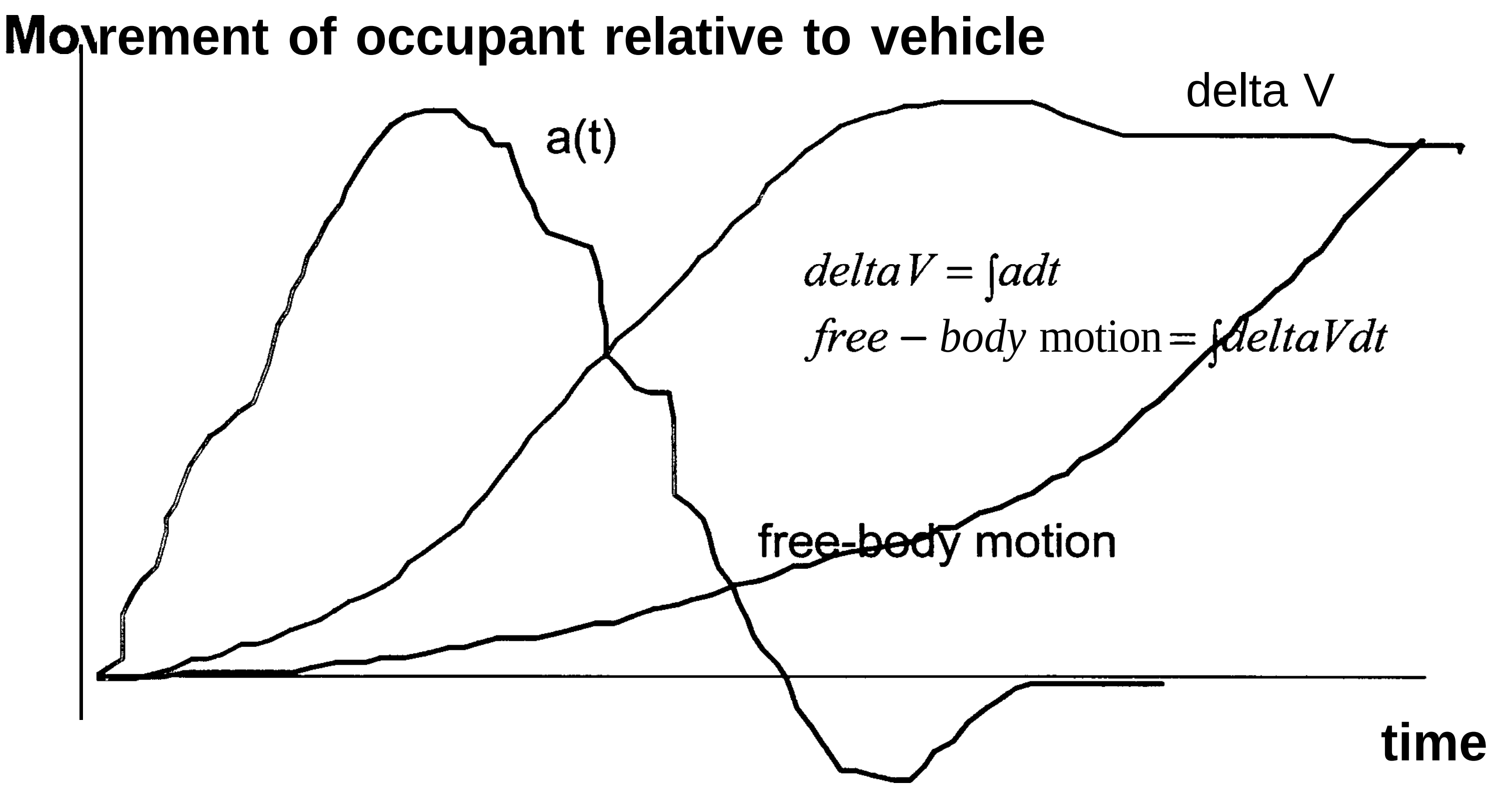
Crash analysis
Fixed coordinate system (outside the vehicle)



Vehicle speed $= V = -\int a\,dt + V_0$

$crush = \int V\,dt$

Crash analysis - delta V definition
Moving coordinate system (Inside the vehicle)



Key Challenges for Crash Sensing

A. Rapid Deployment in Barrier-like Events, ***but . . .***

Can detect offsets
Can detect poles
Can detect underbody hits
Can detect bumper underride hits
Recognize multiple impact events
while
making a timely decision to deploy or not

B. Immunity to:

Railroad Crossings
Off road and service abuse
Deer hits
Undercarriage impacts

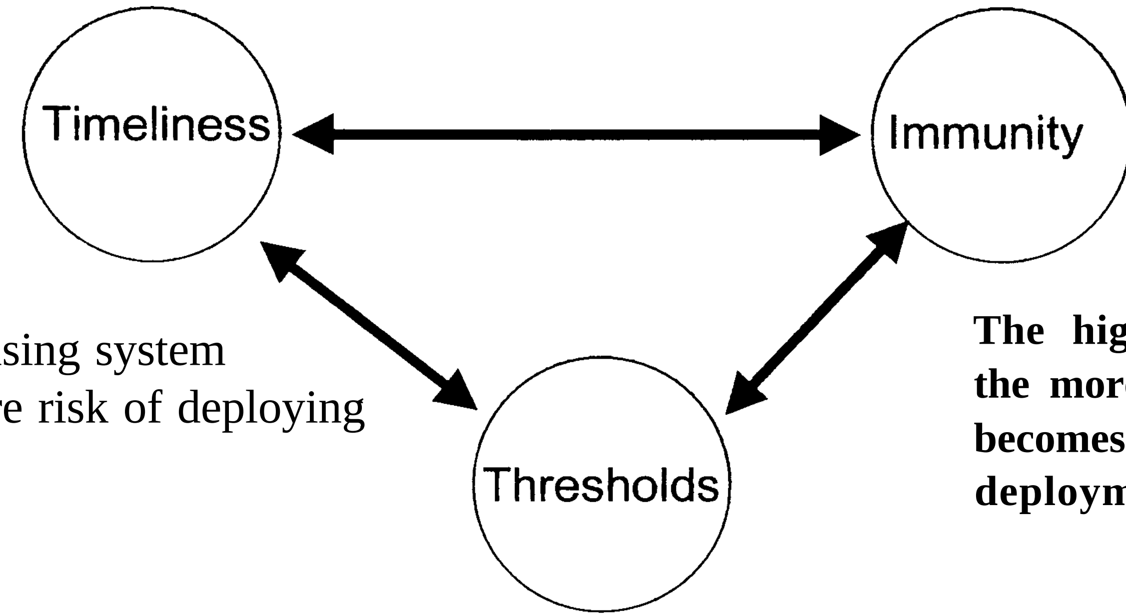
GM Sensing System Goals

1. Robust to vehicle/sensor variations
2. Can discriminate virtually all foreseeable events "in time."
3. High reliability
4. Tolerant of Concatenated events

5. Calibrateable so as to meet required thresholds and deployment timing for <u>all</u> GM vehicles.
6. Requires small number of tests to calibrate while yielding good field performance. (Full understanding of the system allows some calibration parameters to be pre-selected)
7. Understandable system - related to physics. Must be able to extrapolate to real-world events
8. Implementable using commonly available microprocessors

Critical Linkage Dependencies

Crash sensors must be predictive!



The faster the sensing system responds, the more risk of deploying when not needed.

The higher theimmunity, the more difficult it becomes to achieve timely deployments

Higher threshold(s) mean greater immunity to rough road/abuse events but the more difficult to deploy early in the event

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Possible Sensing System Measures Used to Predict Need for Deployment

- Displacement of occupant
- Vehicle crush

a AV *(passenger compartment or front of car)*

- Acceleration *(passenger compartment or front of car)*
- Jerk *(passenger compartment or front of car)*
- time

GM and competitive systems use combinations of 2 or more of these

Theory of Crash Sensing.
Crush zone (CZ) vs. non-crush zone

- Crush zone (CZ) and non-crush zone sensors behave identically prior to a crush zone sensor being impacted.
- When impacted, CZ sensors “see” a larger signal initially that will eventually (by design intent) be seen in the passenger compartment
- Sensors intended to be in the crush zone but are not in the crush zone, will provide a “late” signal.
- CZ sensors are vulnerable to rotation, affecting their accuracy and wire damage affecting their functionality. They must be on stable structures and protected.
- CZ sensors have traditionally estimated localized delta V, and were two-state devices, open or closed. New technology is providing increased capability. - *more later*

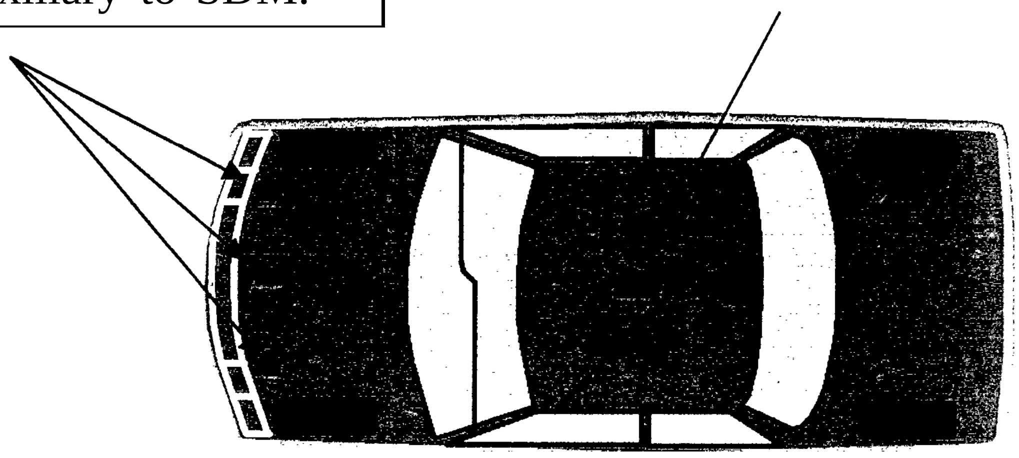
Sensor Candidate Locations

Crush zone sensors

Non-crush zone sensor

Up-front Sensors (EMS or electronic). Auxiliary to SDM.

Single point sensor

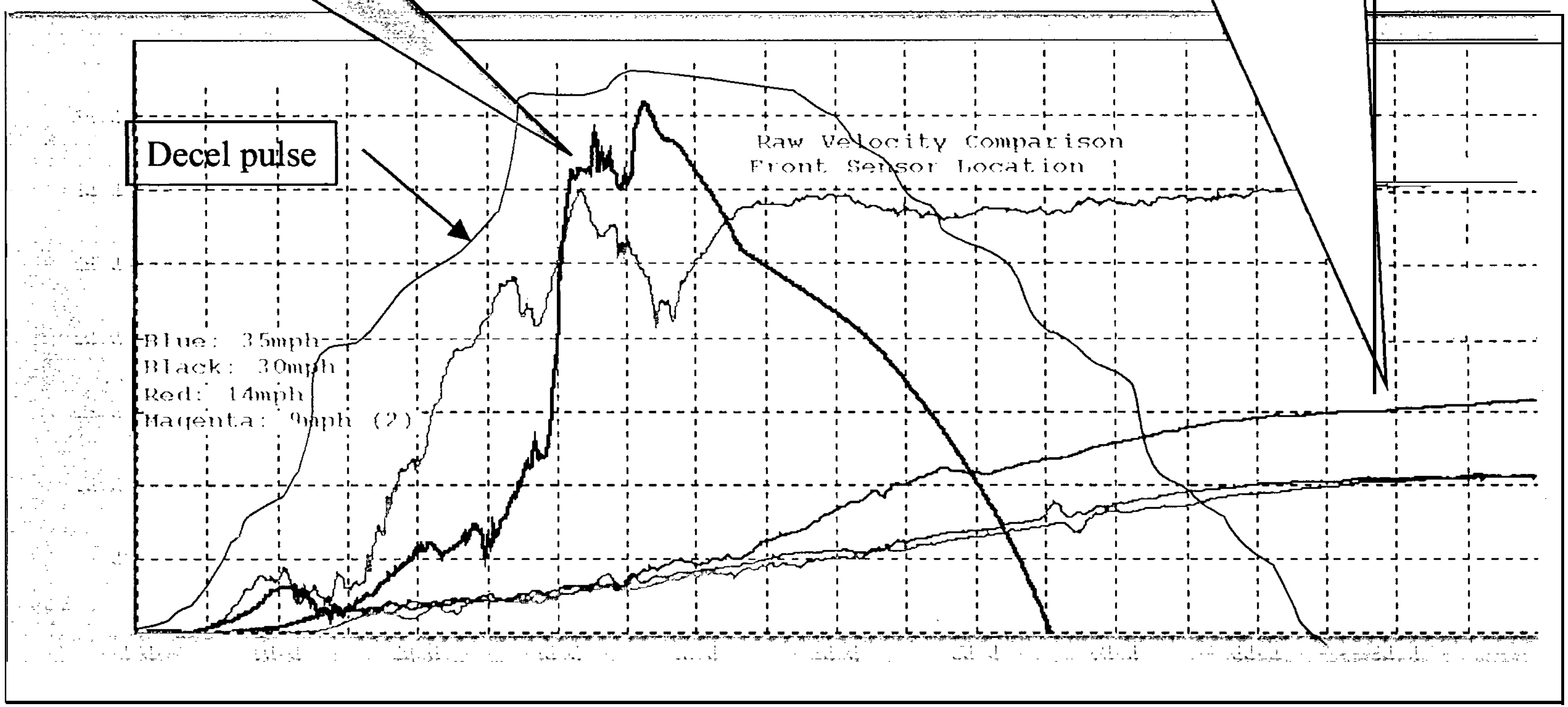


Location is critical to performance.
Front sensors must be located so they are crushed at or before the time of desired deployment

Sensor Behavior when in or out of the Crush Zone (accelerometer-derived)

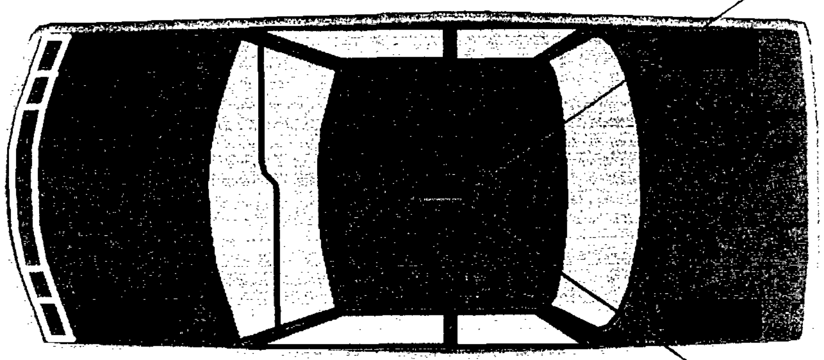
Sensor is in the crush zone for 30 and 35 mph pulses

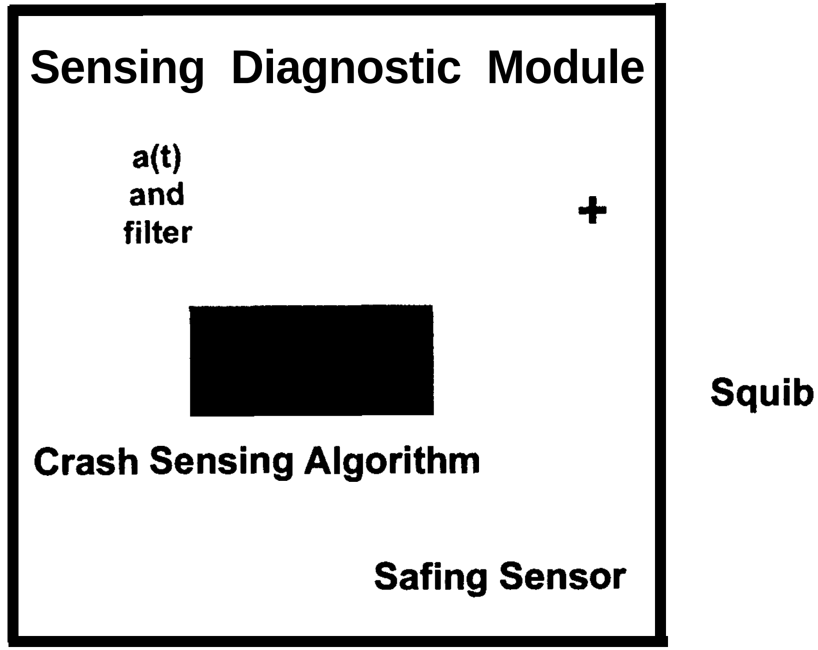
Sensor not in crush zone for 9 and 14 mph pulses and acts as if it was in the passenger compartment



SDM
Introduced in 1994

Most GM cars use Single Point Sensing.
Trucks use multi-point sensing.





Other key features
1. accelerometer range: ± 50 gs
2. Sample @ 3-4 khz
3. Filter: HW @ 400 Hz., many software filters: 70 Hz., 100 Hz., etc.
4. Diagnostic circuitry
5. Safing sensor performance

Simplified Circuit

SDM

- Rely on sophisticated algorithms to process vehicle acceleration data using methods specific to a supplier
- Algorithms are calibrated to the vehicle using lab test data. GM goal: one algorithm, with calibrateable parameters that can be tuned for all GM applications.
- Calibration is highly dependent on the chassis suspension system, rail stiffness, and front structure, especially the bumper.
- Must be robust to component tolerances as well as vehicle variability (mass, trim levels, engine types, bumper differences).
- We'll look at more details later.

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GM Single Point Sensing System

Classification of Frontal Impact Crash Types

- Pole or tree
- Frontal barrier
- Bumper underride or override
- Angular
- Offset (deformable and non-deformable)
- Car-to-car
- Crash attenuators (barrels, guard rails)
- Undercarriage strike/snag
- Rough road (pot holes, block roads, gravel, curb strikes)
- Misuse (hammer blows, hood slams, door slams)
- Concatenation of rough road and crash

Algorithms

Empirically-based

[redacted]

[redacted]

No Single Algorithm

There are an endless variety of algorithms. At least one for each supplier.

GM routinely conducts performance benchmarking on supplier algorithms to understand lab/field performance

Balanced Performance

Deploys in events where needed

Doesn't deploy in rough road/abuse events, low level crashes

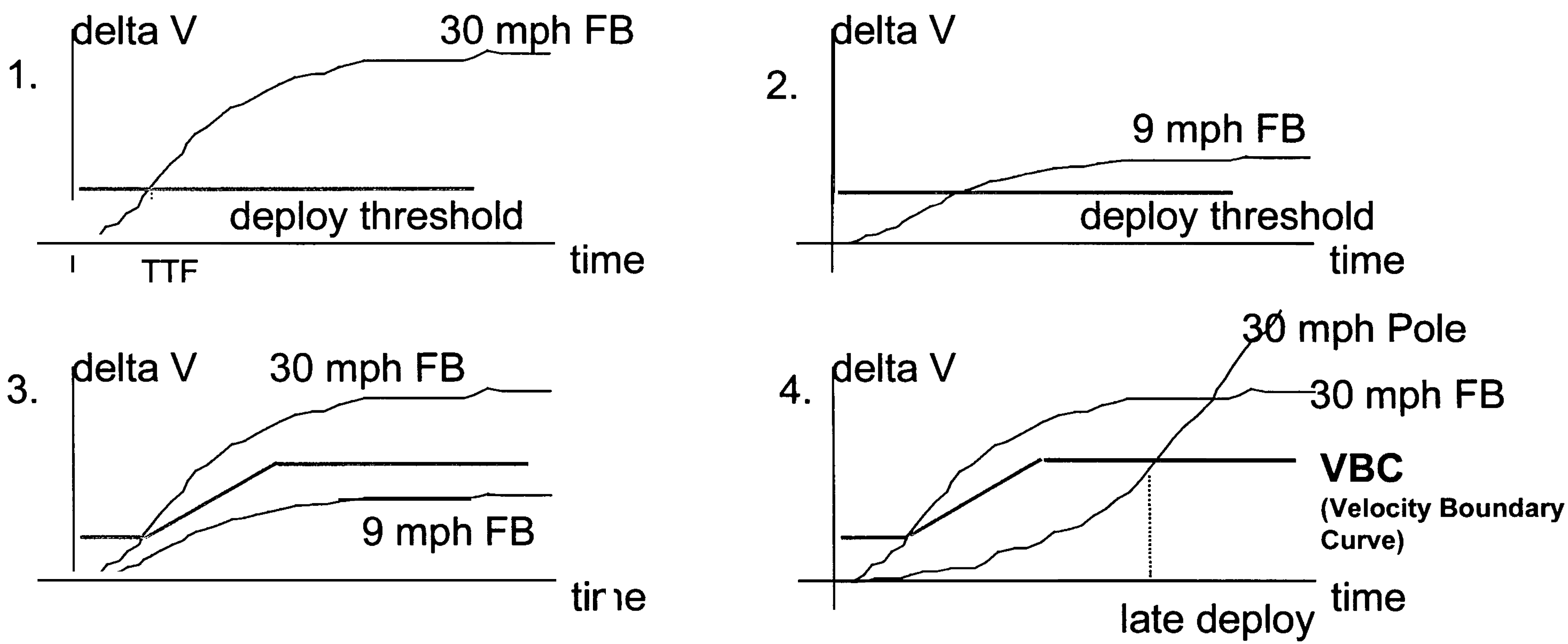
Ideal Algorithm

Occupant injury roughly correlated with delta V

So, sensing algorithms should be based primarily on delta V.

But ....

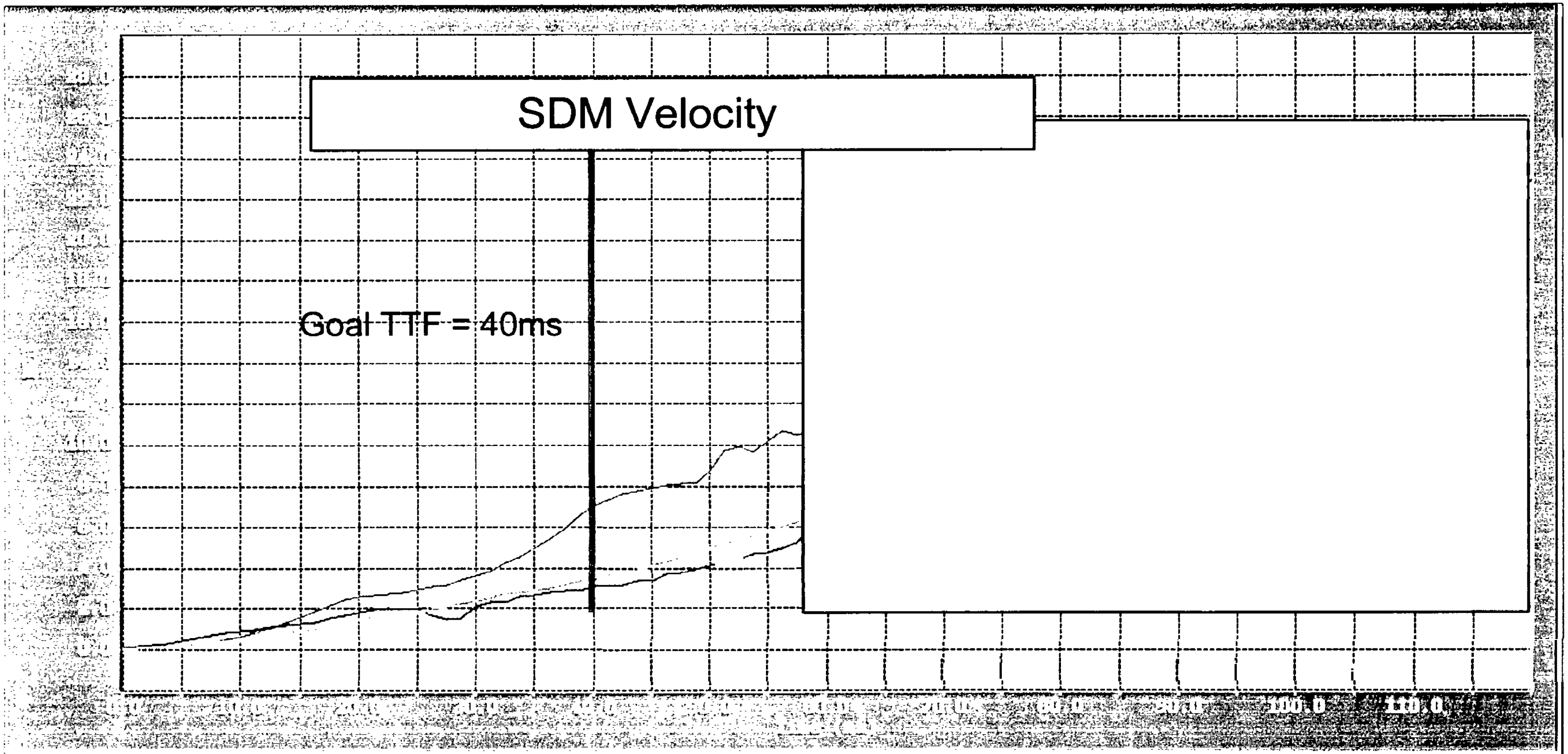
SDM Delta V-only Doesn't Meet Requirements



Another way to look at this is the relationship between the "no-deploy" threshold and a 30 mph pole impact.

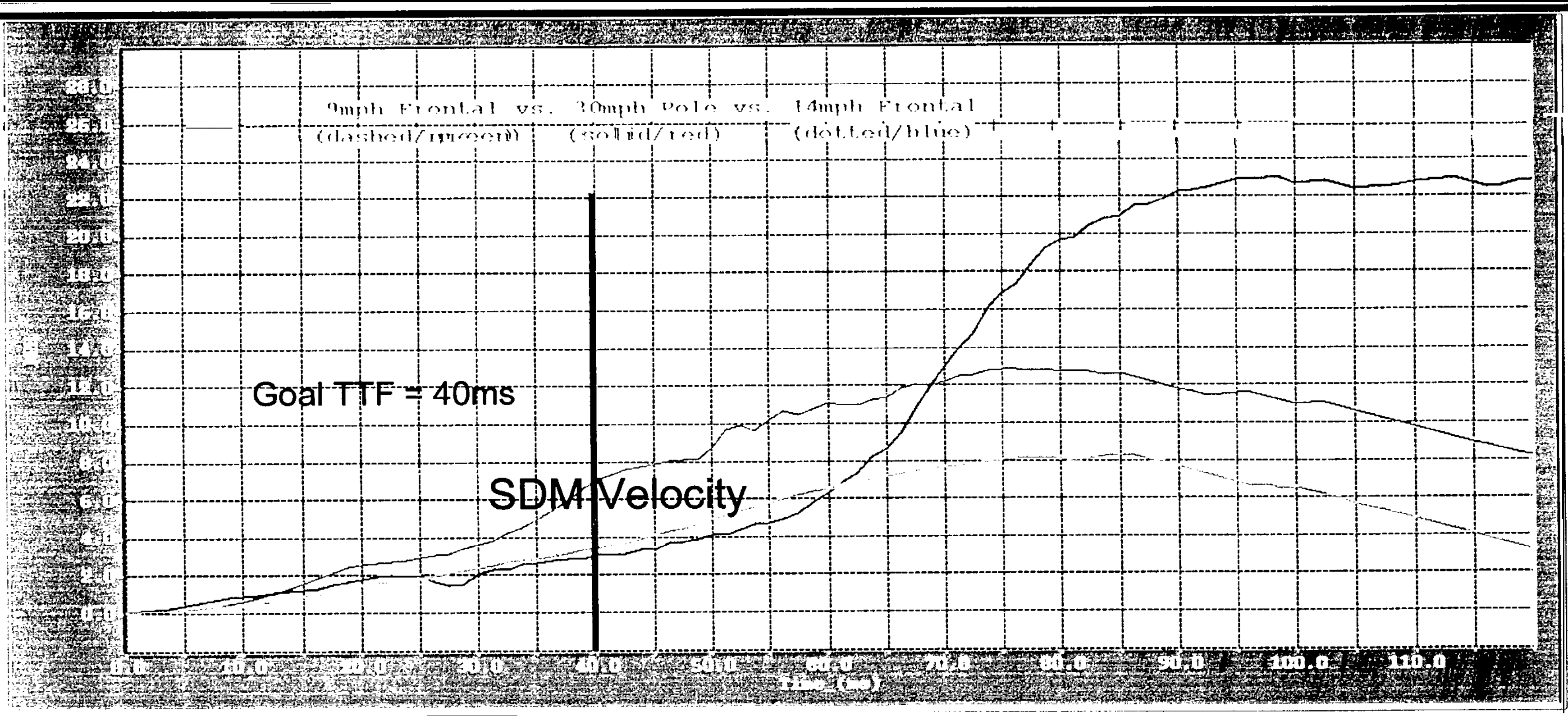
Sensing Challenge (pole impact)

Need separation of signals (including variability) to discriminate "on time"

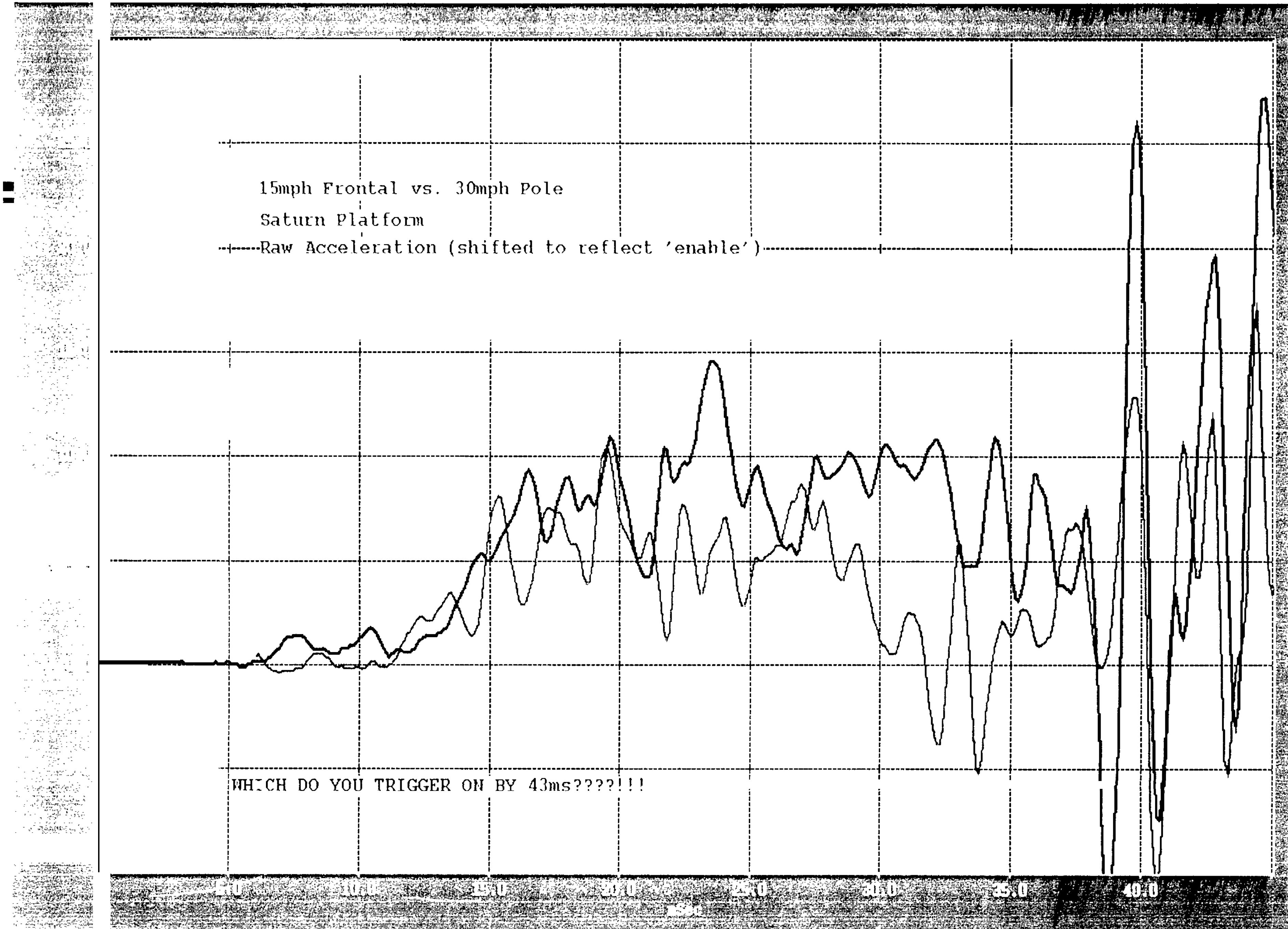


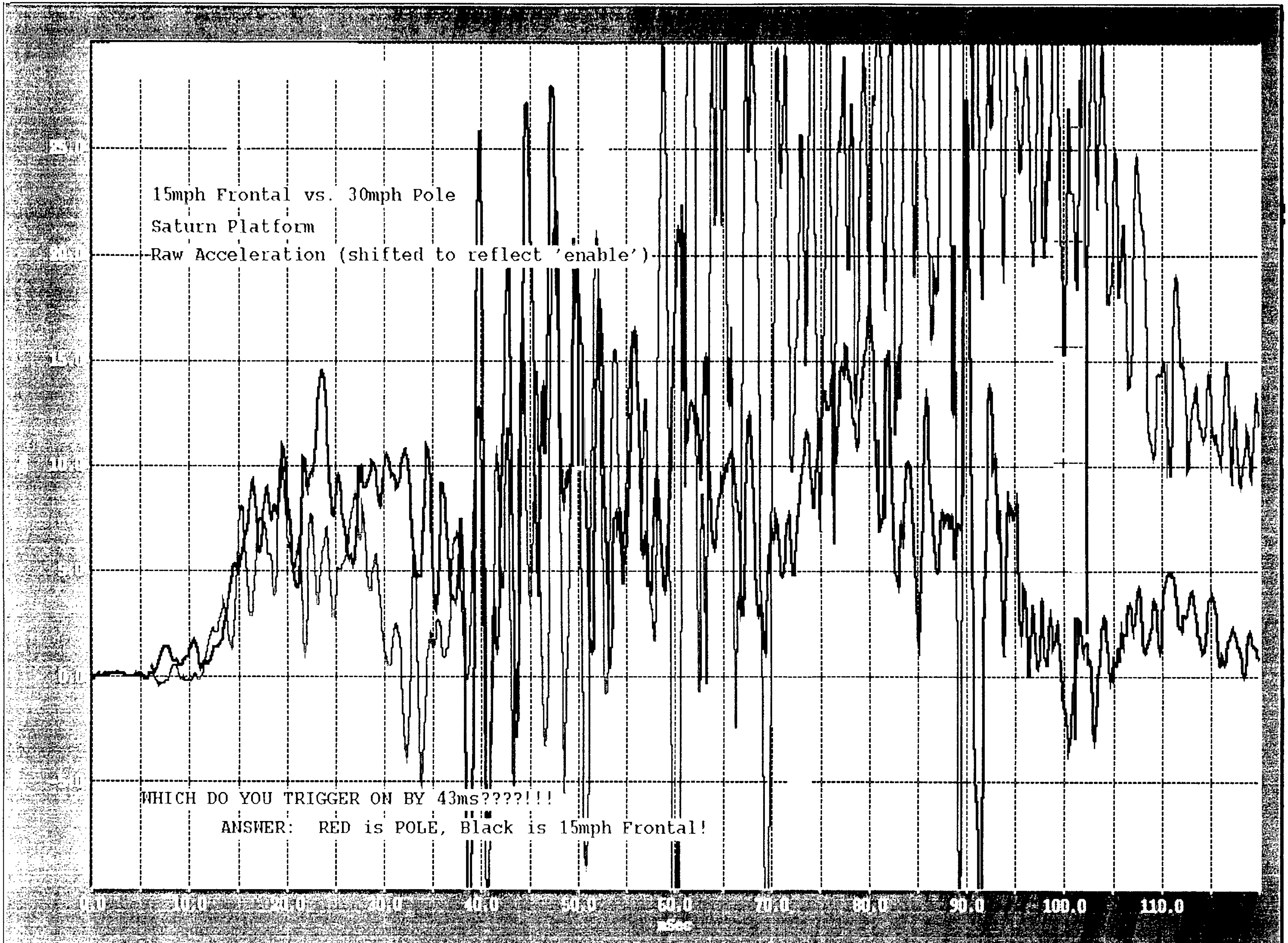
Sensing Challenge (pole impact)

Need separation of signals (including variability) to discriminate "on time"

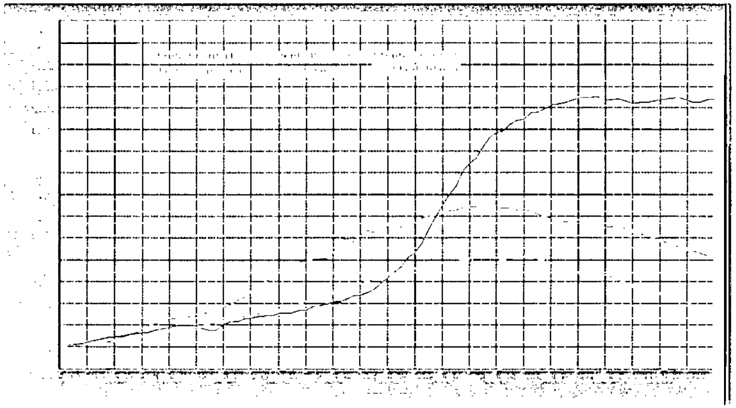
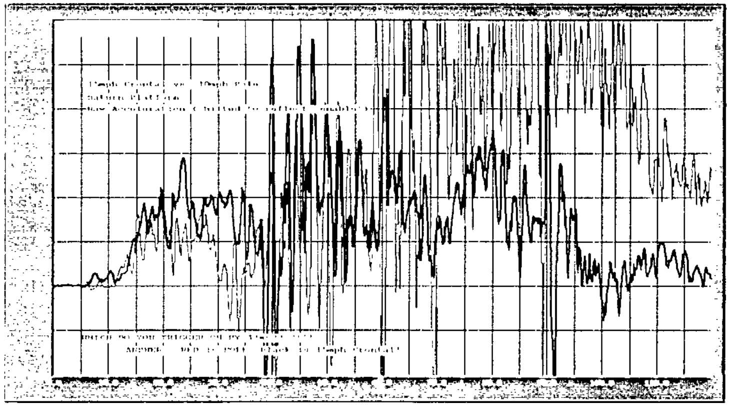


- 9mph Frontal vs. 30mph Pole vs. 14mph Frontal
- What about using acceleration?


15mph Frontal vs. 30mph Pole
Saturn Platform
Raw Acceleration (shifted to reflect 'enable')
WHICH DO YOU TRIGGER ON BY 43ms????!!!
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
mSec


15mph Frontal vs. 30mph Pole
Saturn Platform
Raw Acceleration (shifted to reflect 'enable')
WHICH DO YOU TRIGGER ON BY 43ms????!!!
ANSWER: RED is POLE, Black is 15mph Frontal!
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
mSec

Sensing Challenge

Because crash sensors cannot wait to “measure” the crash severity for the whole event they must be predictive using a small portion of the crash event.

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Delta V and Acceleration as Crash Criteria

Observations?

While delta V is a reasonable estimator of crash severity from an occupant's viewpoint, it is a lagging indicator as a crash sensing criterion for most crashes.

However, it is a good criterion for high speed barrier-type, car-to-car events, and is one of the measures used.

Using acceleration alone or in combination with delta V is not sufficient.

So, different, measures are needed to augment these criteria

What Characteristics must the Measure Possess?

Stable, robust, and be predictive

Based on physical phenomena to maximize reliability, understanding, and validation.

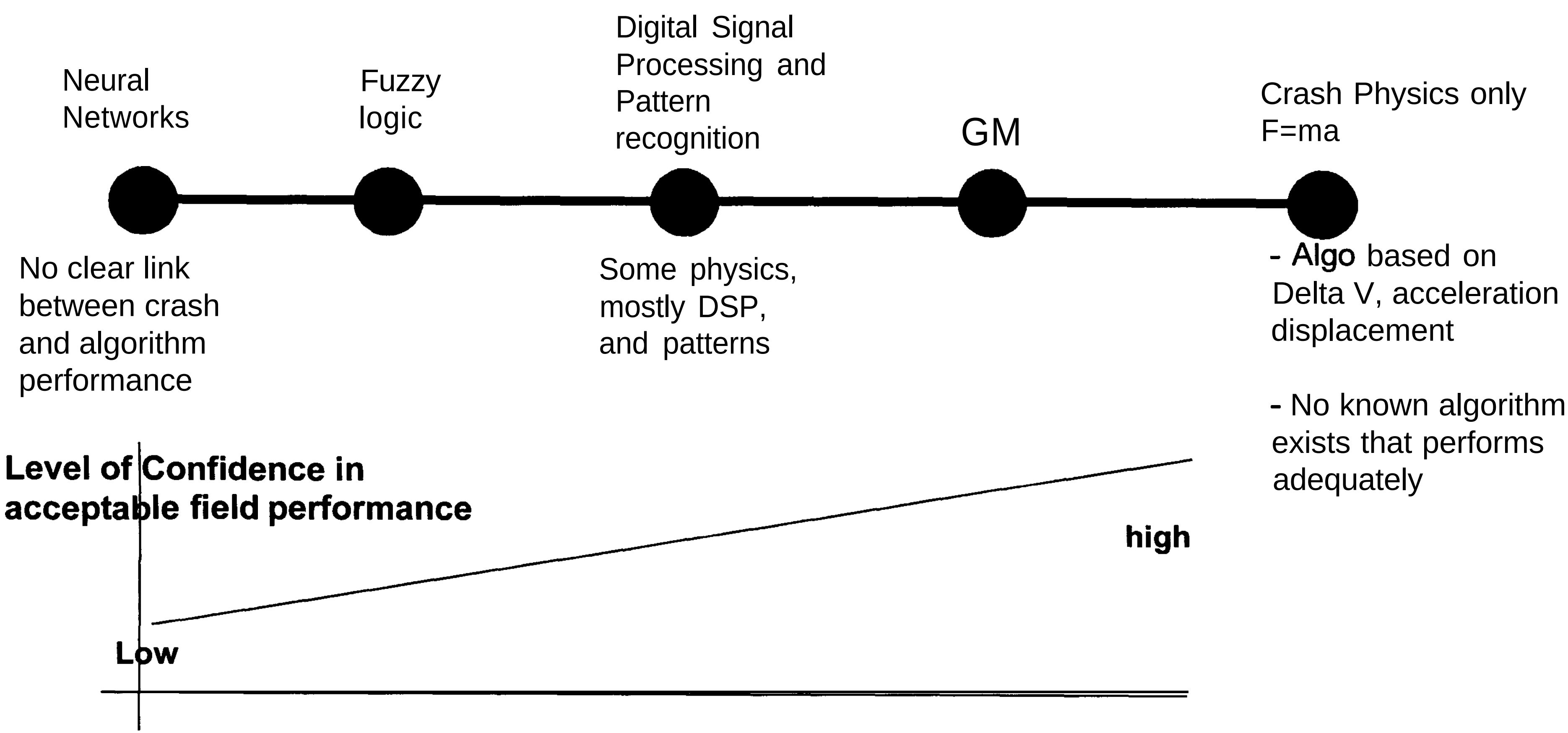
Measures must be well-behaved: the greater the crash severity, the larger the measure.

Must be derivable from passenger compartment or up-front sensors preferably using acceleration.

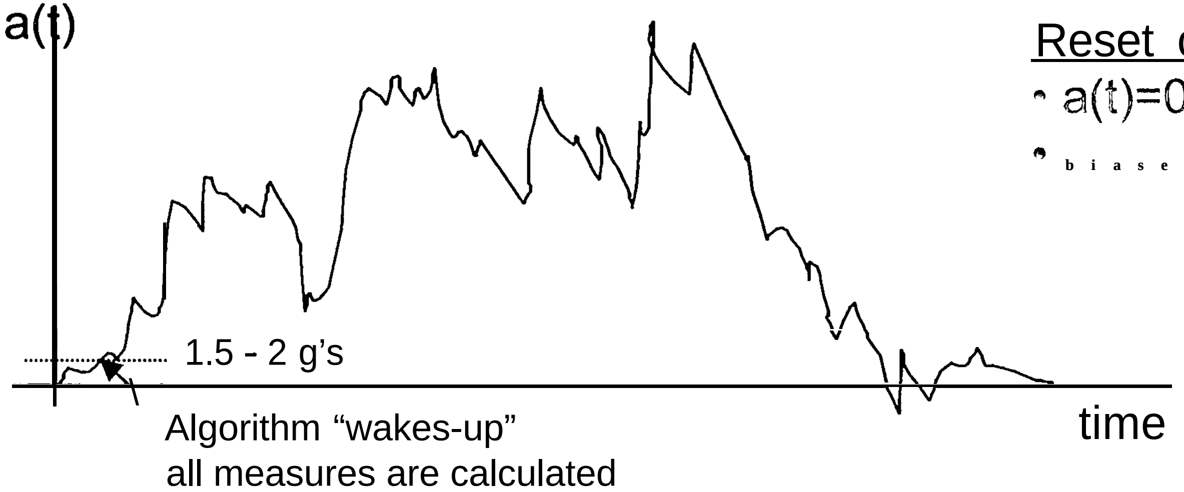
Example Measures

- Jerk (dA/dt) - also called "slope."
- Cumulative jerk (oscillation) over a time window
- Energy in a time window (partial energy) or cumulative energy (total energy)
- Power - delta V*a(t): over various time periods
- Difference in slopes at different times in event
- Energy in frequency bands

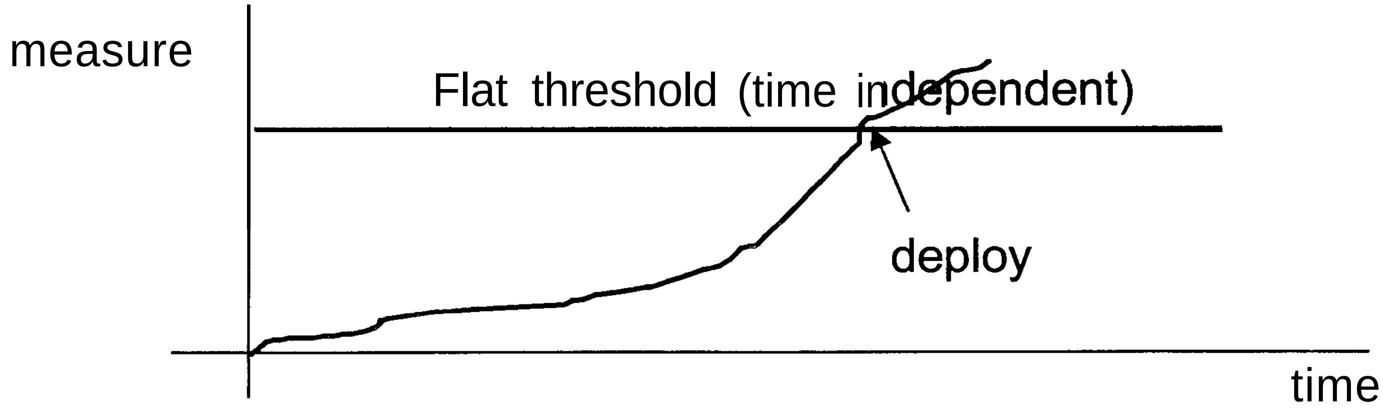
The Spectrum of Single Point Algorithms



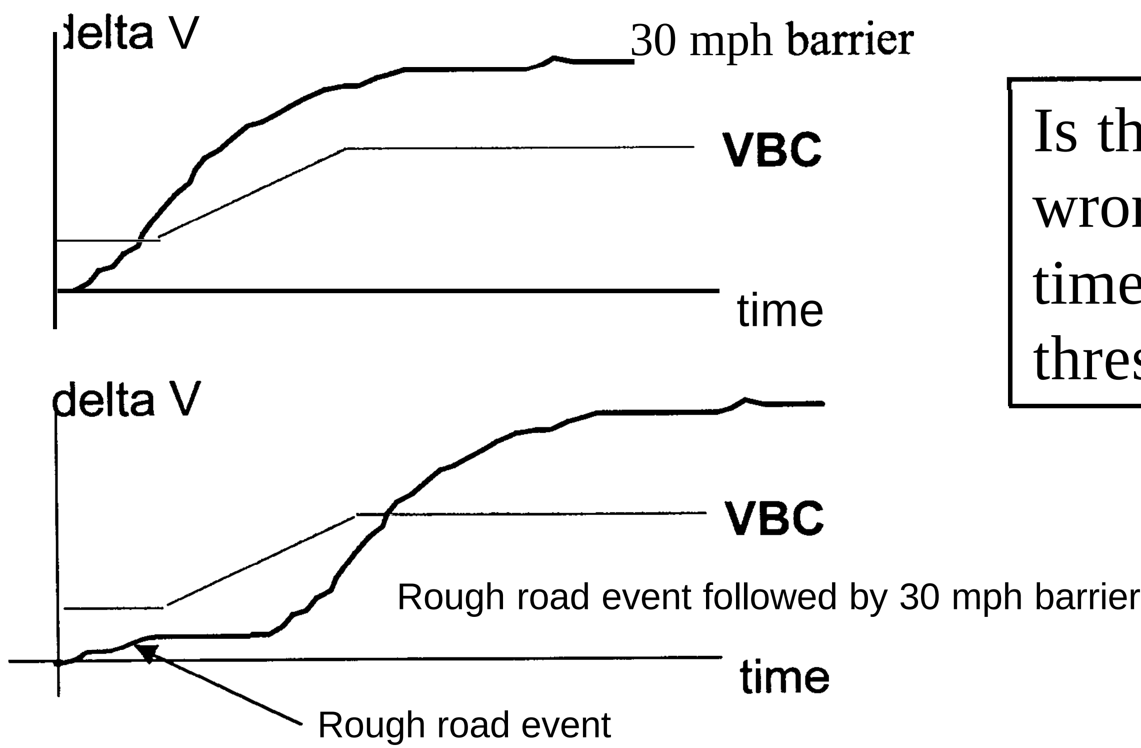
Comparison Thresholds



Reset criteria
- a(t)=0 for fixed time
- biased delta V=0



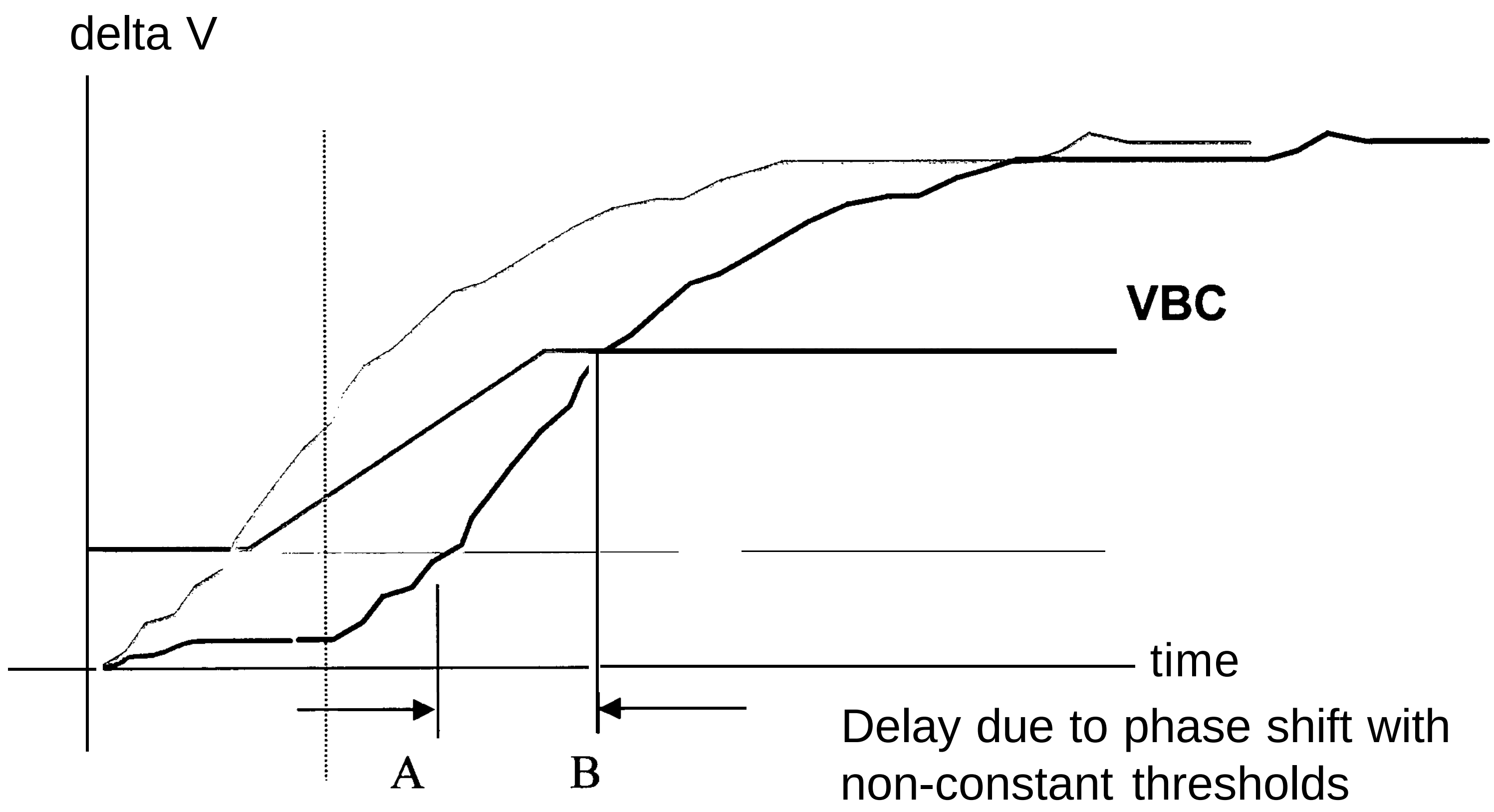
Concatenated Events with Non-Constant Thresholds



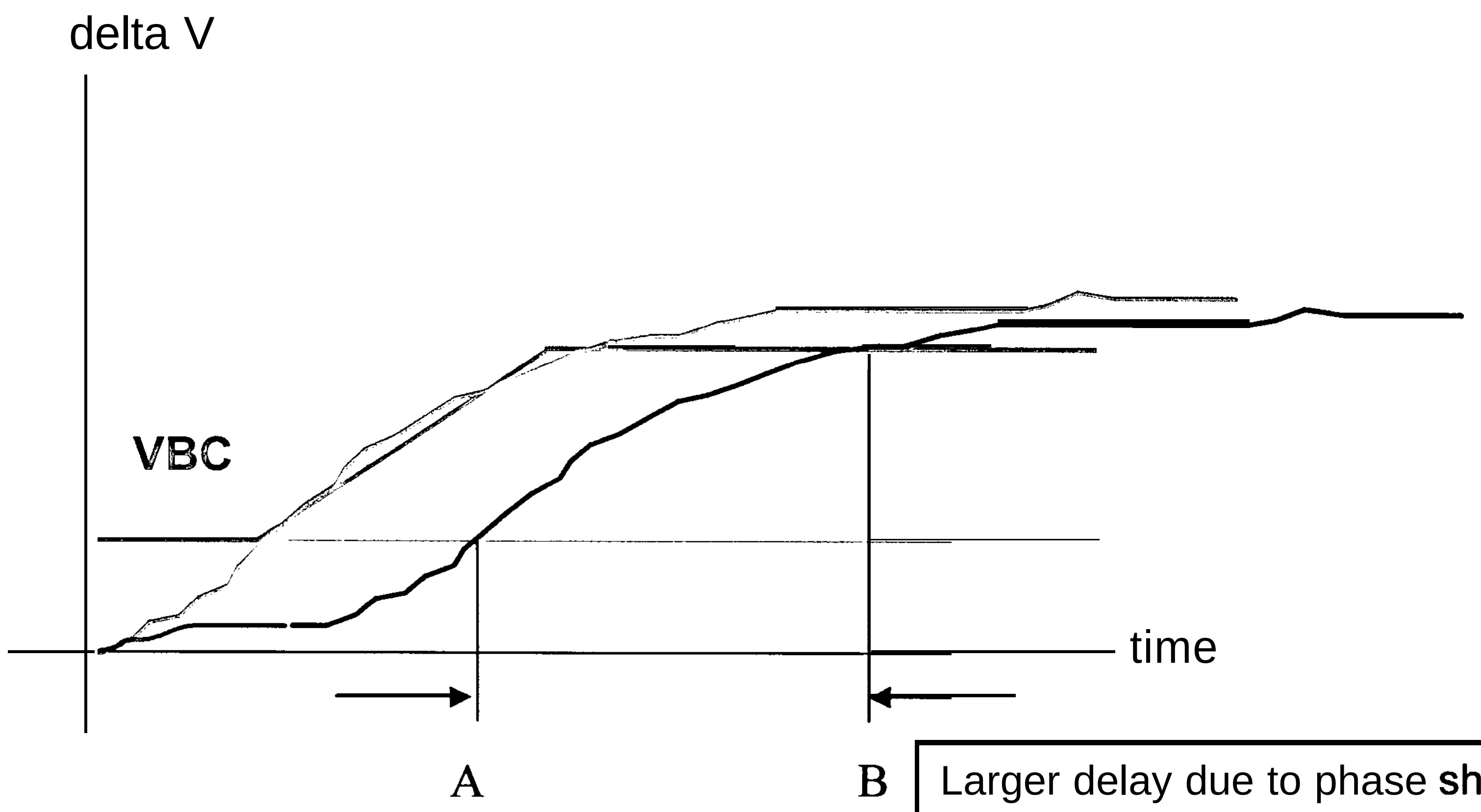
Is there anything wrong with time-dependent thresholds?

The rough road event causes a phase shift of the barrier event.

Concatenated Events
severity >> threshold



Concatenated Events
severity ~ threshold



Larger delay due to phase shift and non-constant thresholds

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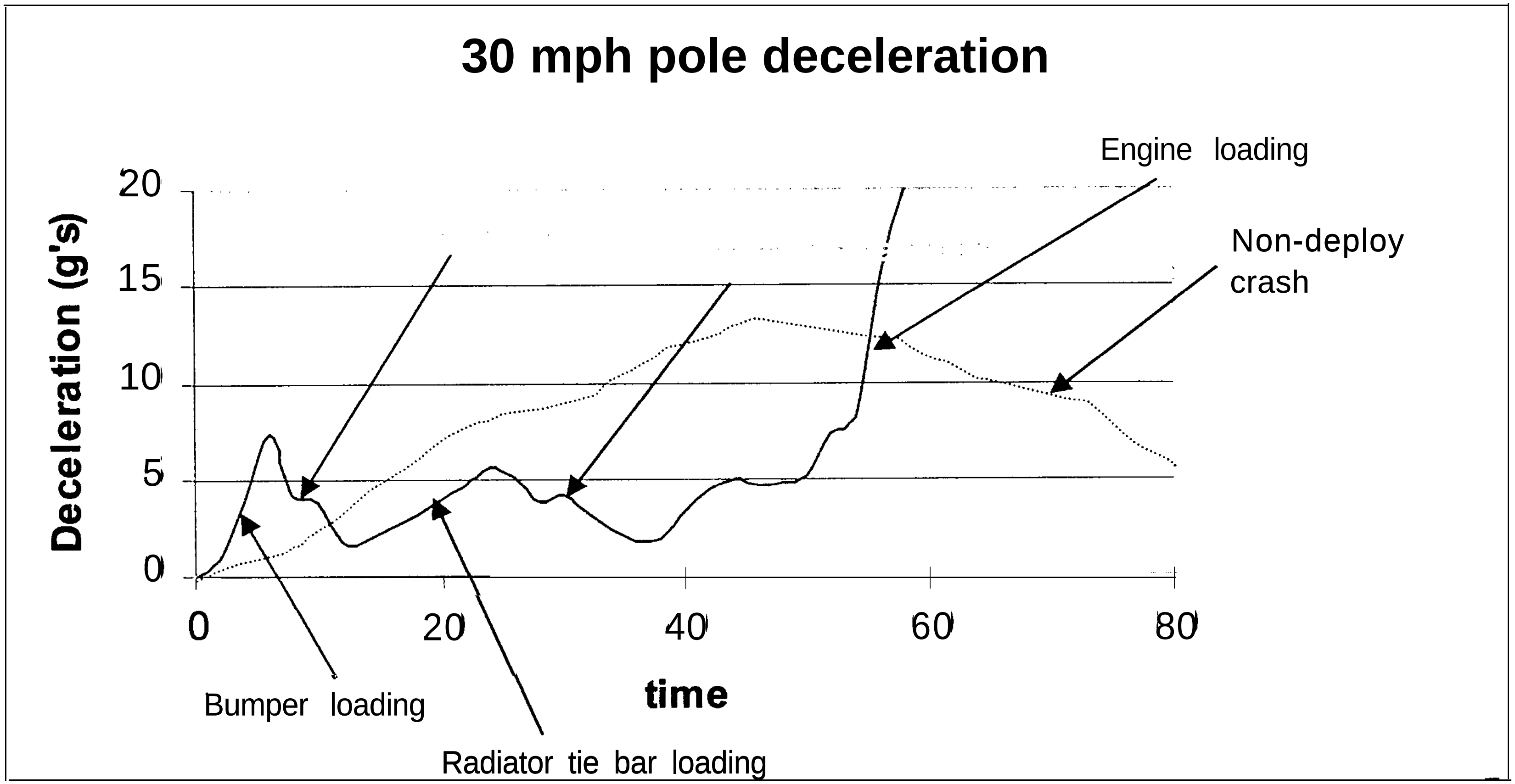
Example of one measure
Pole impacts - major structural intrusion



How to use this?

- This is a pattern but one related directly to the physics of the event
- Oscillation is caused by high forces lasting a short time (impulses) compared to relatively constant lower forces for barrier impacts.
- Oscillation is measured by the following:
  - » Osc. = SUM [ABS(dA/dt)] over a sliding window (IO-I 5 msec)
  - » E.g. $f(t) = \sin(\omega t)$, then $df/dt = \omega \cos(\omega t)$
  - » The higher the frequency of oscillation, the larger the measure
- The amount of oscillation is proportional to the impact speed

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Trucks vs Cars

Truck structures

Truck **structures** are stiffer in low speed **crashes and** softer in higher speed crashes, just the opposite of passenger cars.

Body on frame

Isolation between body and frame results in crash signals arriving later than they otherwise would in a car. Forces sensors to be located outside of the passenger compartment to achieve timely signal propagation.

Trucks

Off-Road Environments

Design@ to **handle** off-road environments which **require greater** immunity from the sensing system **than** is needed in cars.

Mass Extremes

Wider mass variations than cars,, e.g., engine families, GVW vs curb weight, 2-wheel drive vs. 4-wheel drive, pickups & SUV's.

==> wider variations in crash pulse.

Forecasting Performance for other than Full scale Lab tests

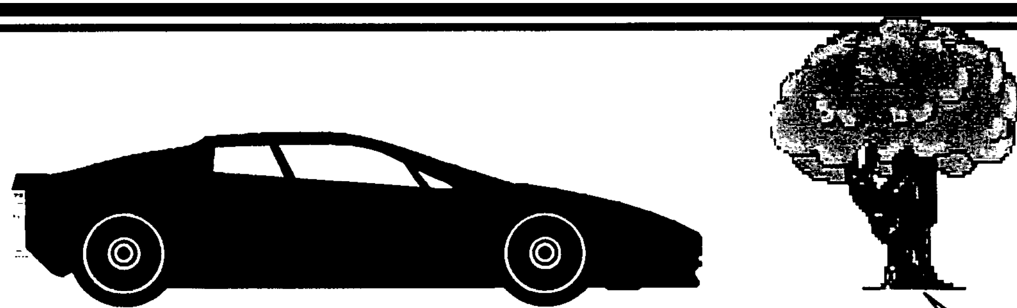
GM has done considerable studies to use existing tests to predict performance in other events.

Two specific areas include Finite Element Modeling (FEA), and Scaling for existing test data.

First, we'll look at FEA models and then scaling techniques

Understanding Field Performance

In a Perfect World, we'd have accurate math models



Chassis model

Large scale non-linear FEA front structure model (engine, rails, etc)

Floorpan model

Model of object being struck (tree, guardrail, vehicle, ditch)

Crash Sensing System (accelerometer, μC)

→ ***Predicted performance of field results by computer***

Despite perceptions, no such sophisticated capability exists at this time!

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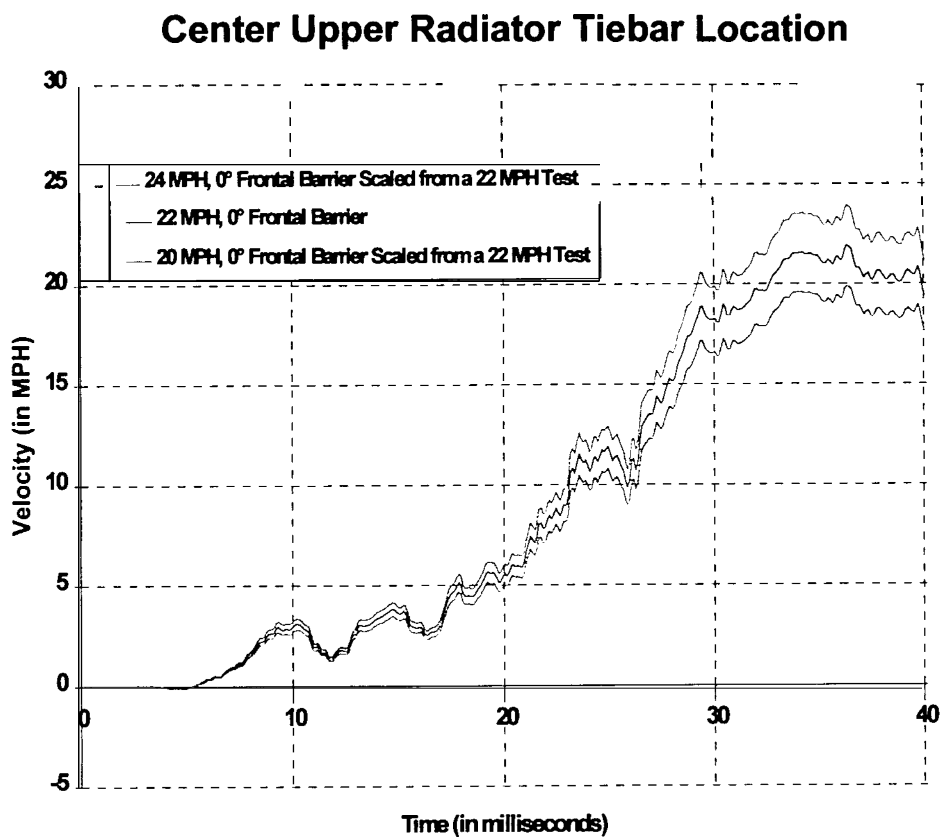
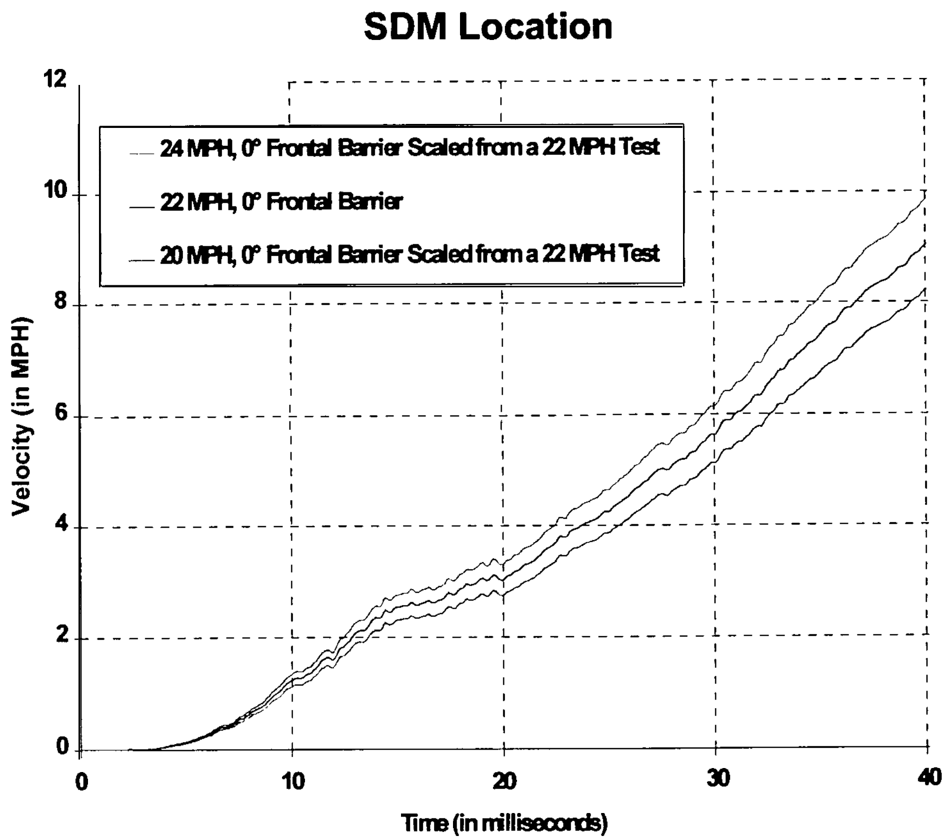
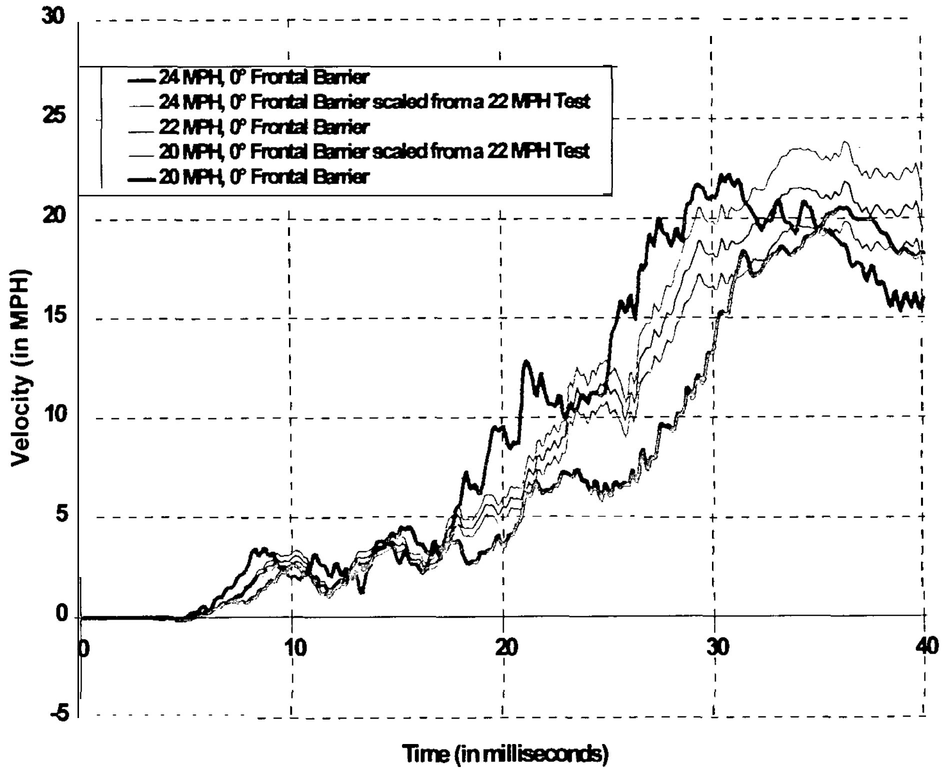
Generic Unibody vehicle
Scaled data



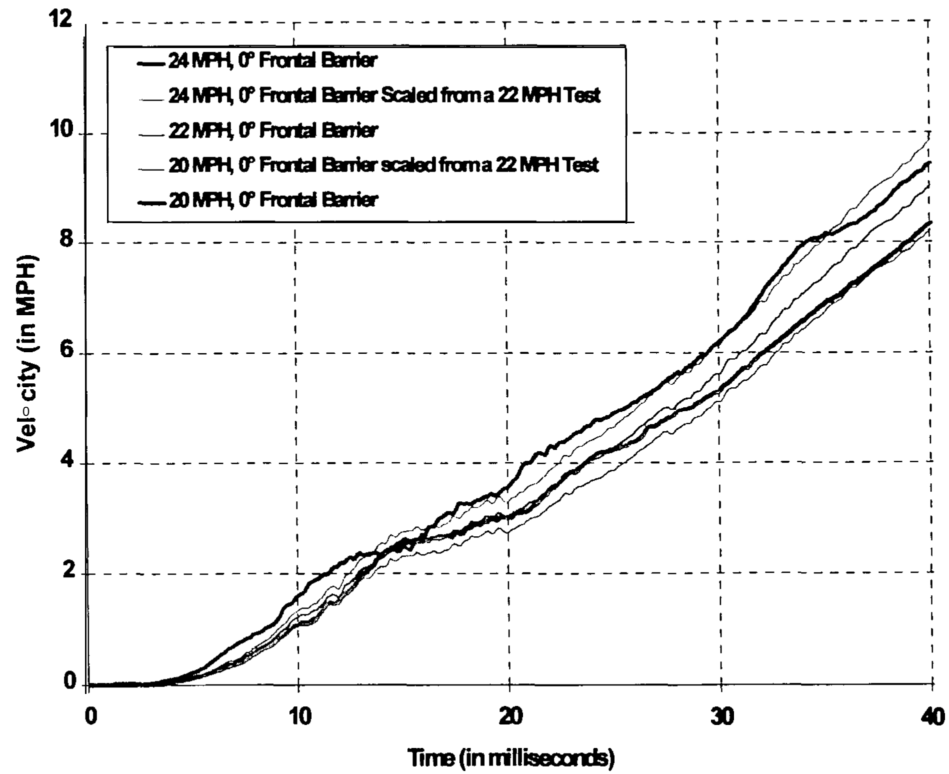


Generic Unibody vehicle
Scaled data vs. actual tests

Center Upper Radiator Tiebar Location

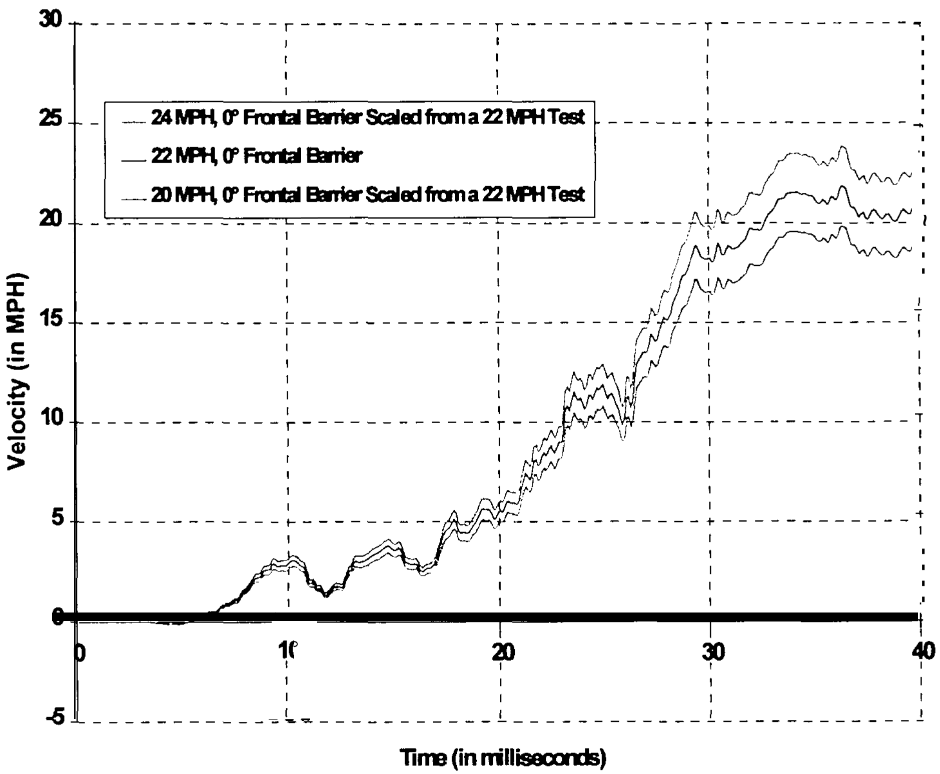


SDM Location

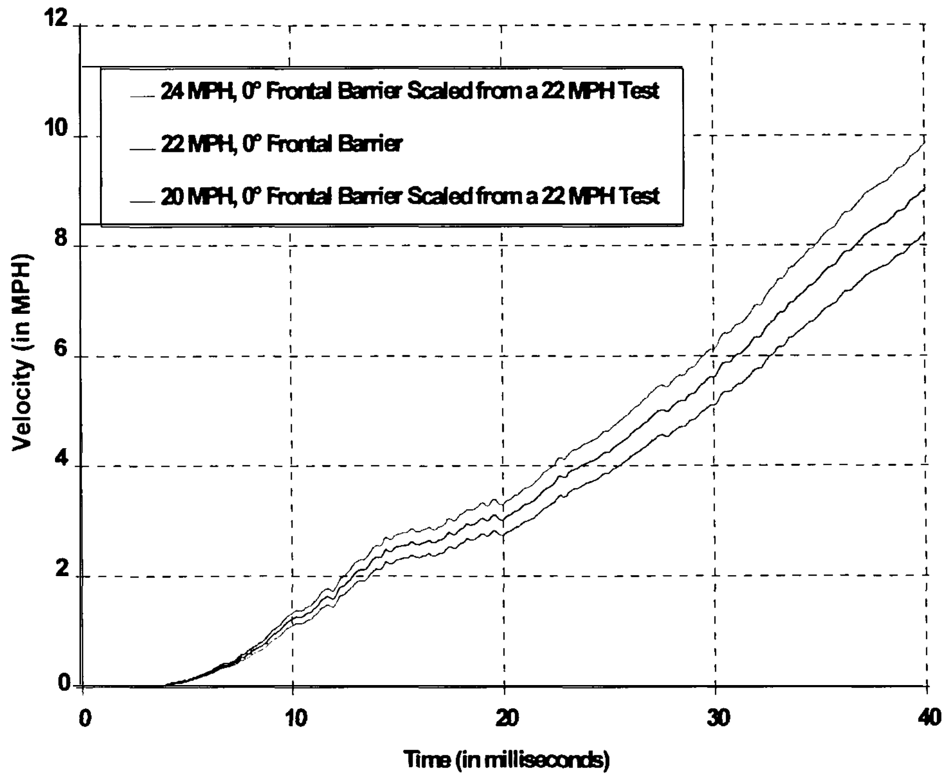


Generic Body-on-frame vehicle
Scaled data

Center Upper Radiator Tie bar Location



SDM Location



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Predicting Performance

- Observations

  » *Predicting performance in crashes other than lab tests, and especially field crashes, requires engineering judgement, hence, fully understanding the algorithm's operation.*

  » *Increasing algorithm complexity to meet Advanced airbag systems increases program risk and the ability to manage it.*

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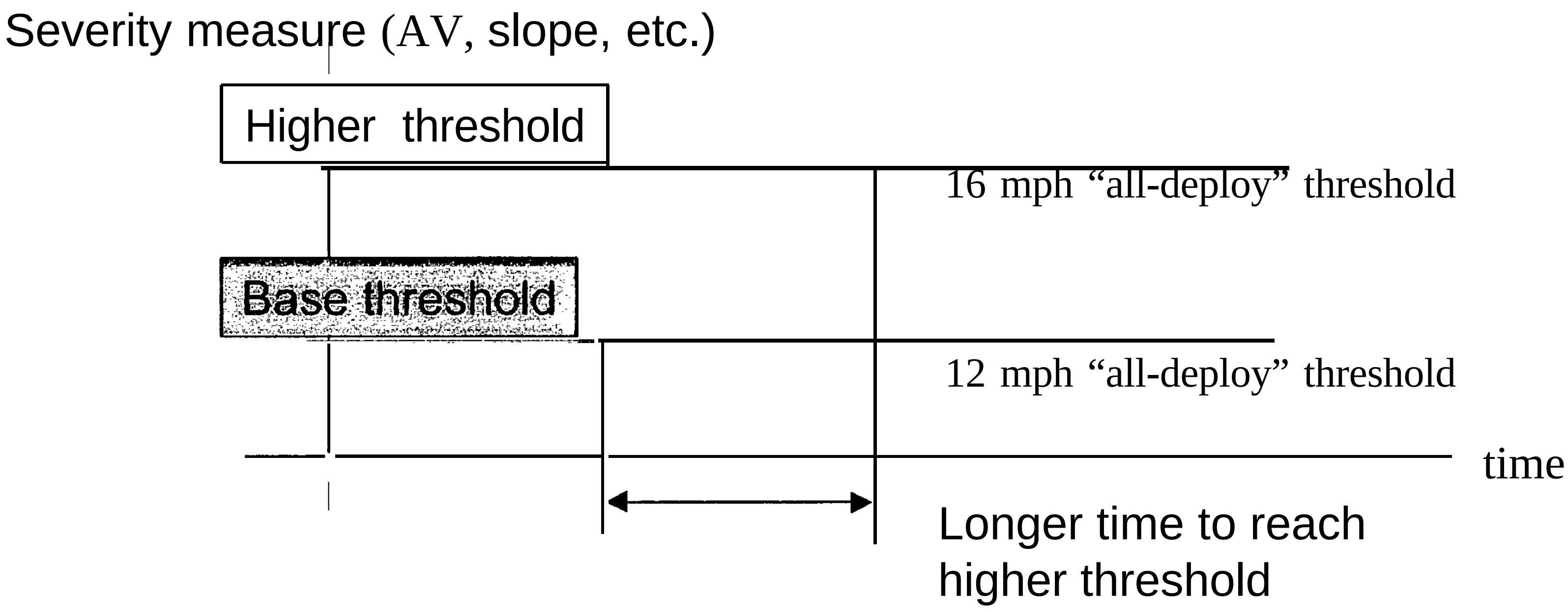
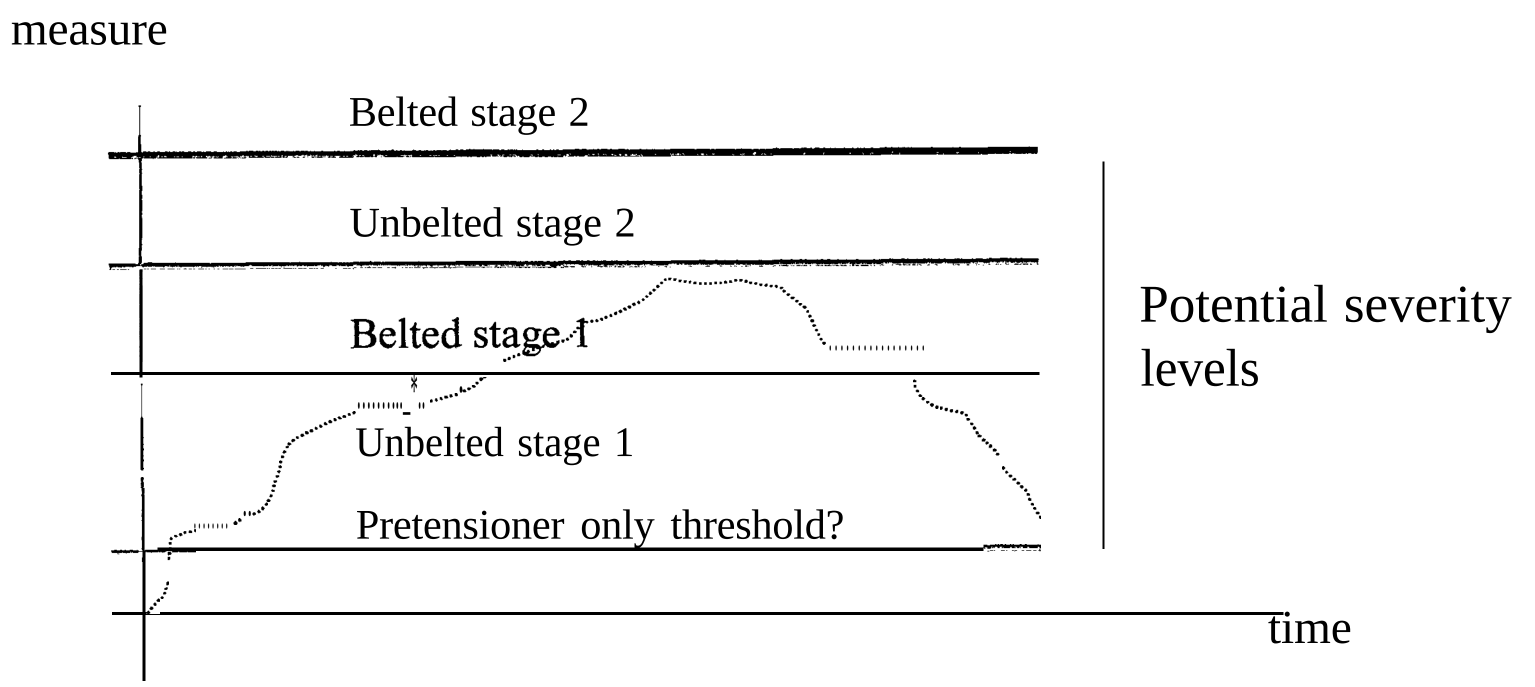
One Measure of the General Sensing Problem



The higher the crash severity used to adapt air bag inflation, the more difficult it is to accurately predict "in time."

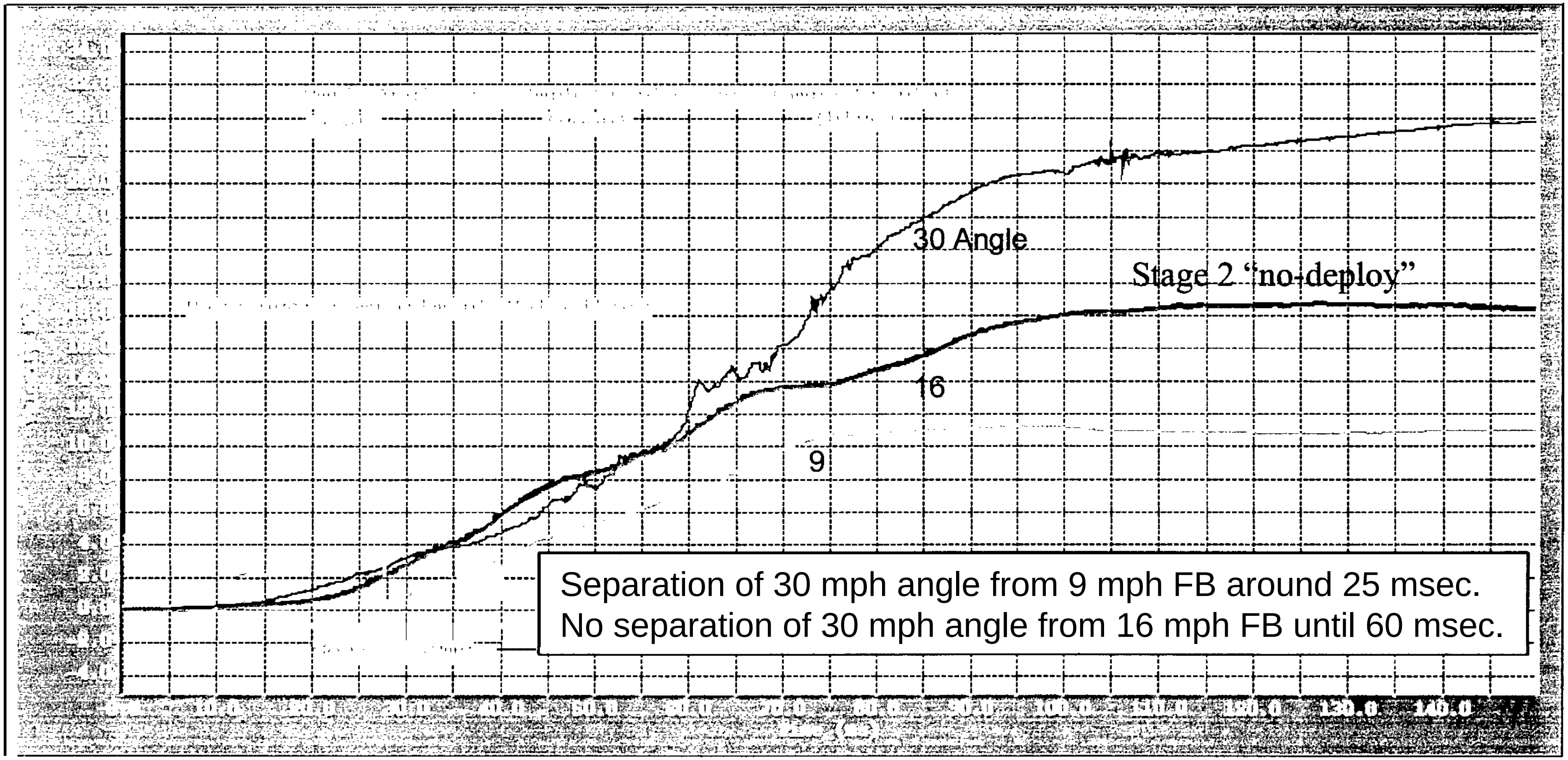
Primer on Electronic Front Sensors



As in the **SDM,** all thresholds may not be flat (i.e., could be time-dependent!

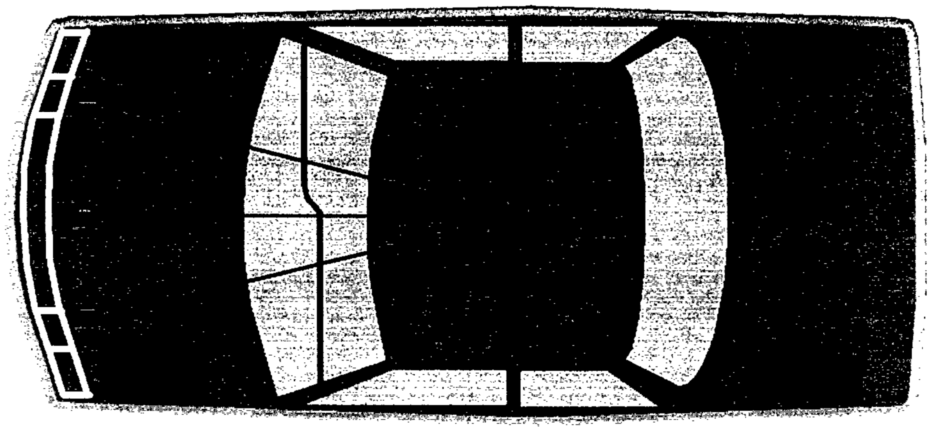
Another Measure is the Separation of
Deploy vs. non-Deploy Events for single point sensing

Signal propagation delay to SDM inhibits timely severity measurement



Potential "helper" solution

Some vehicle structures are compatible with higher thresholds for some crash types, but not all.
To compensate for the delay, will likely need earlier indication of crash severity, i.e., forward sensor(s), or departure from physics-based measures and/or increased reliance on pattern recognition, fuzzy logic.

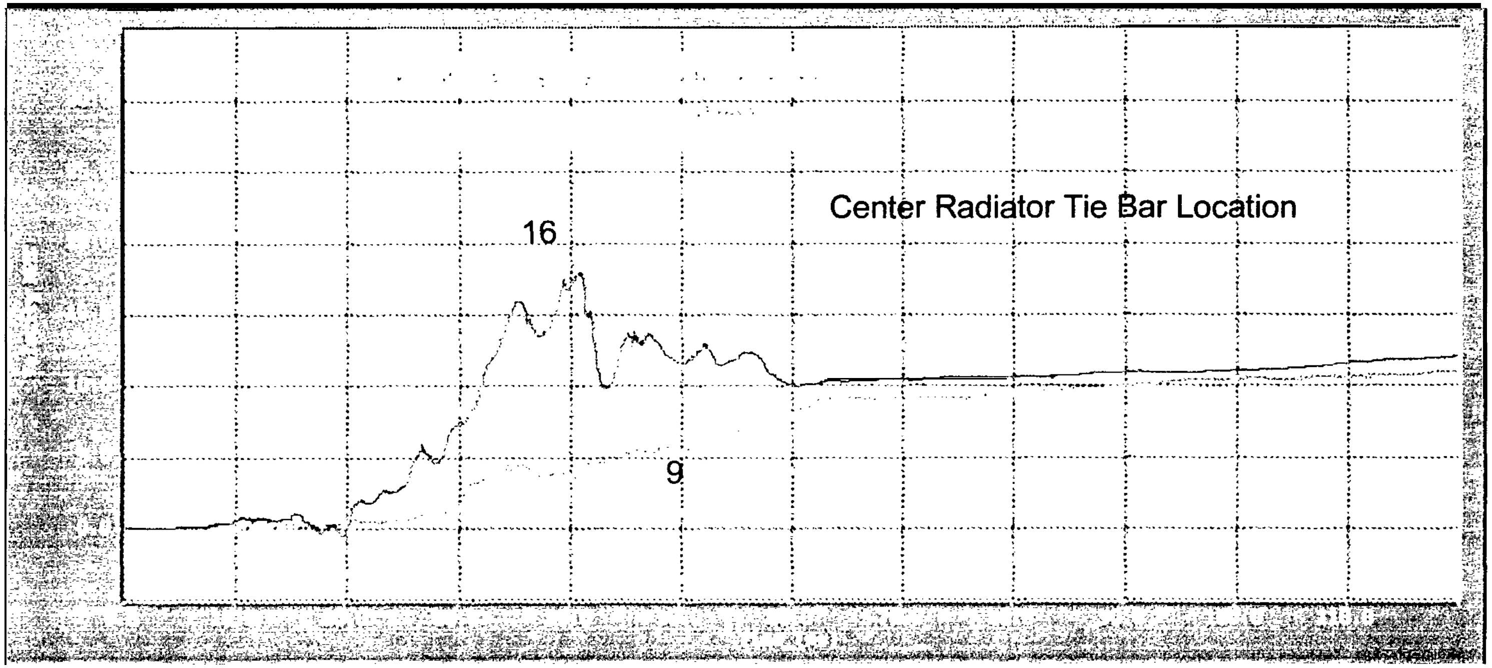


Use baseline single point algorithm which is understood but augment with front sensors to get earlier indication of severity.

Severity Sensing Challenges
Do Front Sensors help?

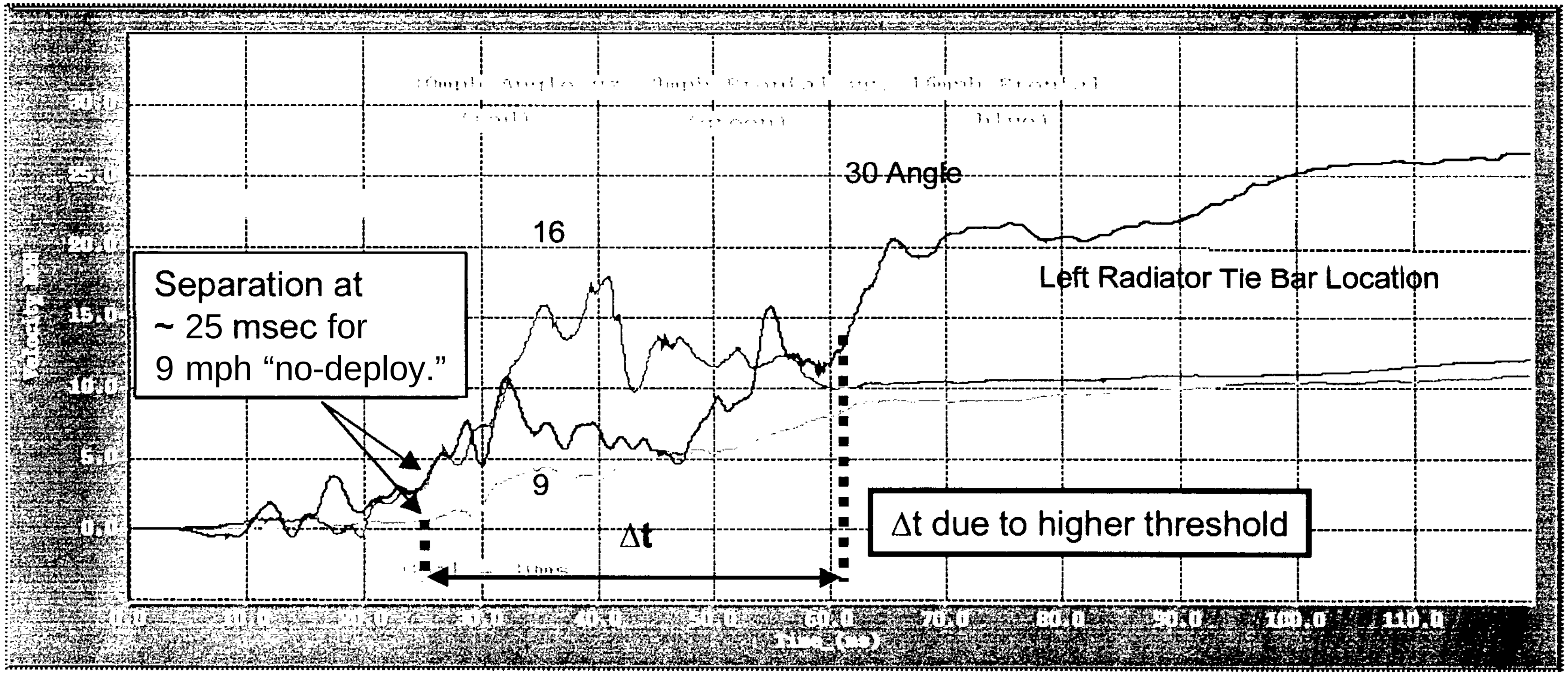
Let's look at an example

9 mph no deploy threshold for single stage compared to 16 mph all-deploy



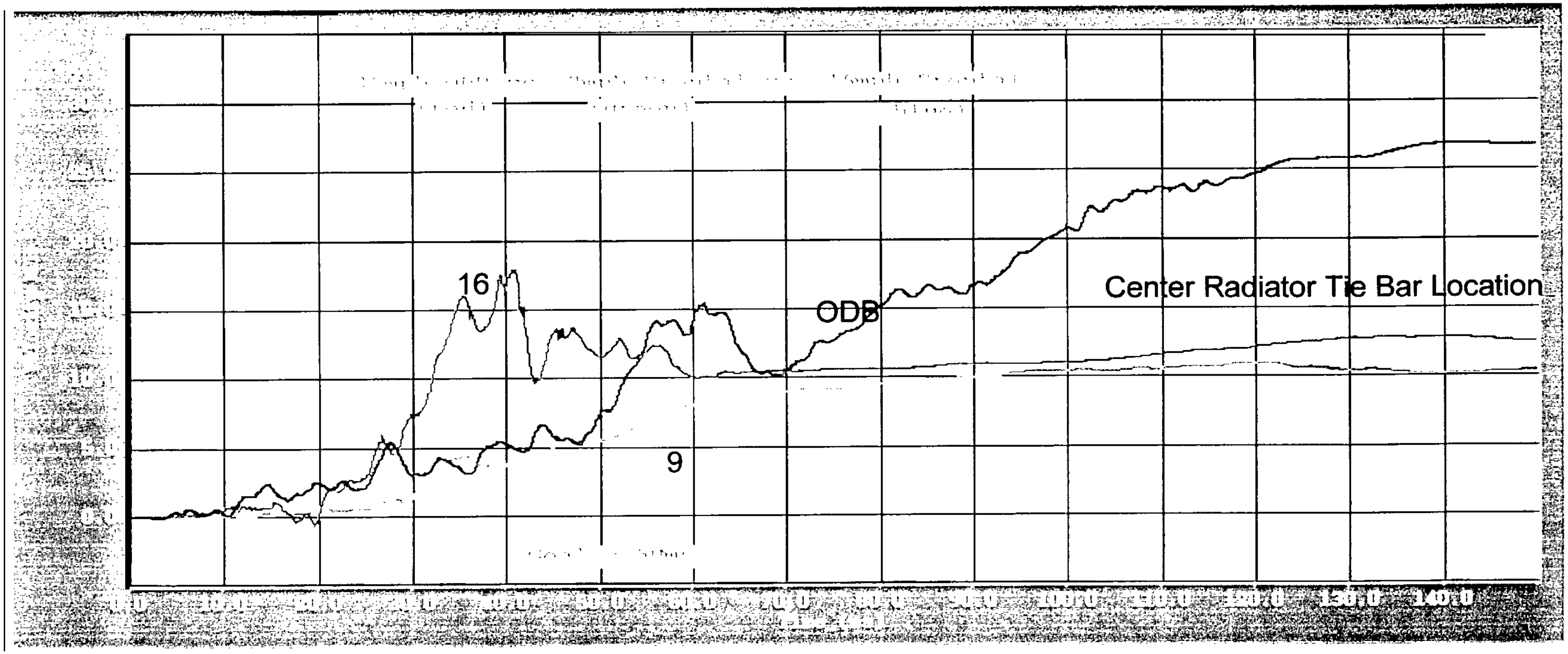
Severity Sensing Challenges - Angles

1. Now for a 2nd stage system, let's raise the "no deploy" threshold to 16 mph.
2. Now it takes considerably longer to detect this event even with a front sensor.
3. So sensor location is *critcal.*



Severity Sensing Challenges - Front Sensors w/ODBs

- » Front sensor response for ODB lags the 16 mph frontal barrier
- » In worst scenario, 'high' severity level not achieved (may have to inhibit due to late deploy)
- » Severity Indication is sensor location dependent-must be in crush zone



Severity Sensing Challenges - ODBs

Offset Deformable Barrier Challenge (note location sensitivity).

Not in crush zone until later in event

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Observations

- The ODB provides an initial ramp-up of deceleration but then it's uniformity results in a flat, low amplitude pulse. This is unlike offset car-to-car events.
- To detect ODBs earlier in some vehicles requires moving the sensor towards the front of the vehicle to be in the crush zone.
- But there is a limit to how far forward the sensor can be placed. It must be on a stable structure.
- The alternative is to use other measures from the front sensor that can be used to indicate crash severity.

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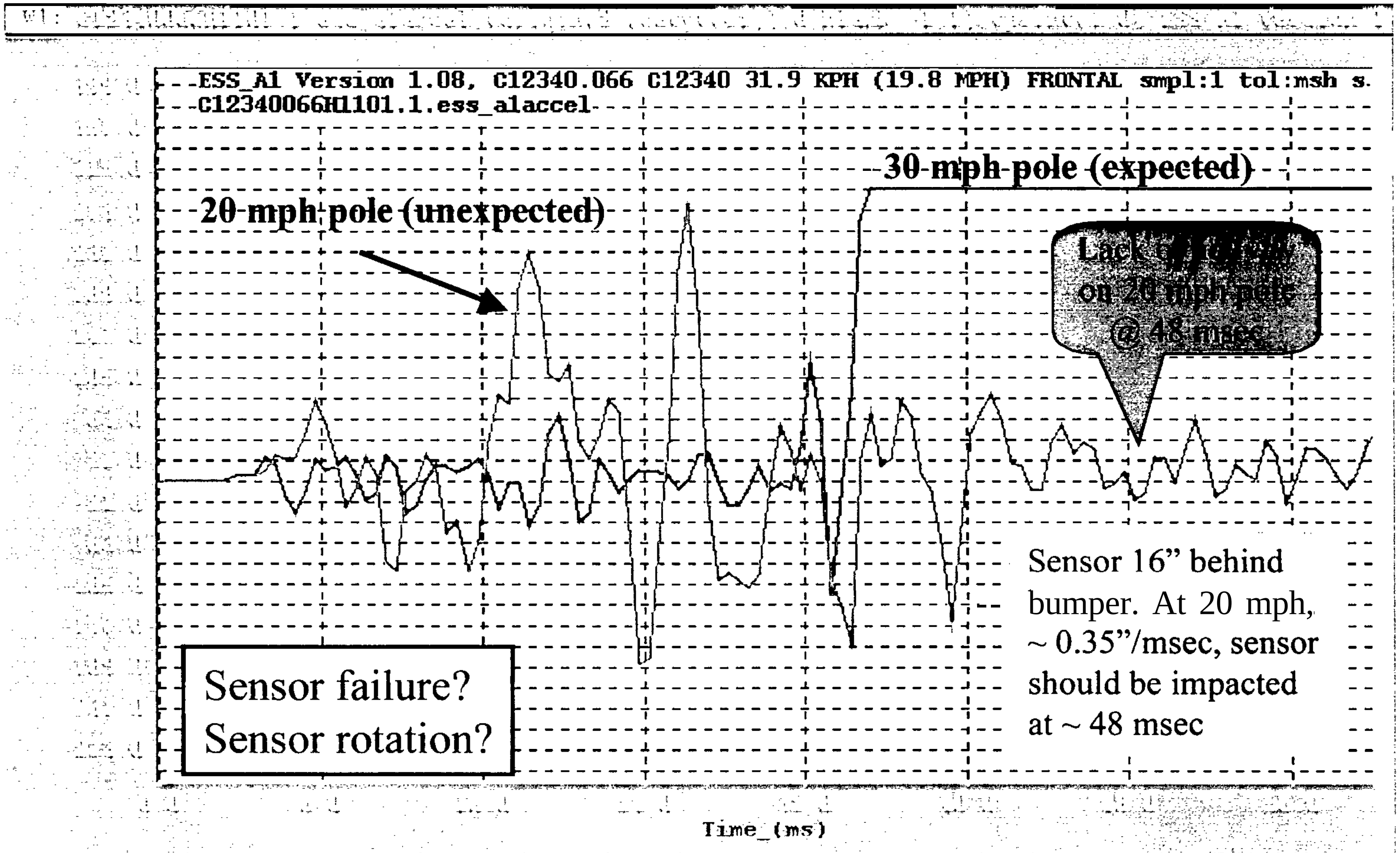
EFS acceleration vs. time
30 mph and 20 mph pole impact
(Practical Development Problems)



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Crash Sensing Development
Uni-body Structure

- 1st stage timing based on T125-30 msec
- Delay between 1 st and 2nd stage based on inflator characteristics
- IDD is Incorrect Deployment Decision Made

		Supplier A		Supplier B		Supplier C		Supplier D		Supplier E		Supplier F	
		Mid	/- 15	Mid	/- 15	Mid	+/- 15%	Mid	/- 15	Mid	/- 15	Mid	+/- 15%
Largest Deviation From Stage 1 Deployment Goals	0 Deg. Barrier	0 ms	*0 ms*	2 ms	*3 ms*	0 ms	*0 ms*	0 ms	*4 ms*	0 ms	*0 ms*	5 ms	*9 ms*
	Angle Barrier	0 ms	*0 ms*	0 ms	*2 ms*	0 ms	*4 ms*	0 ms	*0 ms*	0 ms	*0 ms*	6 ms	*7 ms*
	Pole Impact	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*3 ms*	3 ms	*4 ms*	4 ms	*7 ms*
	ODB Impact	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*1 ms*
	Other Impact	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*0 ms*	o m s	*0 ms*	0 ms	*0 ms*	o m s	*3 ms*
Largest Deviation or Stage 2 Delay After Stage 1 Deployment	0 Deg. Barrier	5 ms	*5 ms*	1 ms	*1 ms*	20 ms	*IDD*	0 ms	*0 ms*	0 ms	*1 ms*	4 ms	*10 ms*
	Angle Barrier	5 ms	*5 ms*	4 ms	*4 ms*	16 ms	*IDD*	0 ms	*0 ms*	0 ms	*6 ms*	4 ms	*9 ms*
	Pole Impact	5 ms	*6 ms*	1 ms	*1 ms*	IDD	*IDD*	0 ms	*2 ms*	5 ms	*7 ms*	0 ms	*0 ms*
	ODB Impact	5 ms	*5 ms*	3 ms	*4 ms*	26 ms	*28 ms*	0 ms	*0 ms*	1 ms	*5 ms*	0 ms	*6 ms*
	Other Impact	5 ms	*5 ms*	1 ms	*1 ms*	5 ms	*10 ms*	0 ms	*0 ms*	1 ms	*1 ms*	2 ms	*5 ms*

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Neural Networks | Fuzzy logic | Pattern recognition | Mostly crash physics

Crash Sensing Development
Body-on-frame

- 1 st stage timing based on T125-30 msec
- Delay between 1 st and 2nd stage based on inflator characteristics
- IDD is Incorrect Deployment Decision Made

	Supplier B		Supplier C		Supplier E	
	Mid	+/- 15%	Mid	+/- 15%	Mid	+/- 15%
0 Deg. Barrier	10 ms	*10 ms*	3 ms	3 *ms*	20 ms	*27 ms*
Angle Barrier	0 ms	*0 ms*	0 ms	*0 ms*	0 ms	*0 ms*
Pole Impact	**oms**	**oms**	oms	*7 ms*	0 ms	*1 ms*
ODB Impact	6 ms	*7 ms*	oms	*8 ms*	0 ms	*6 ms*
0 Deg. Barrier	1 ms	*1 ms*	IDD	IDD	Oms	**2ms**
Angle Barrier	3ms	4 *ms*	4ms	*17 ms*	IDD	IDD
Pole Impact	3 ms	*2 ms*	5 ms	*6 ms*	IDD	IDD
ODB Impact	2 ms	*1 ms*	ms	39 *ms*	0 ms	*0 ms*

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Neural Networks — Fuzzy logic — Pattern recognition — Mostly crash physics

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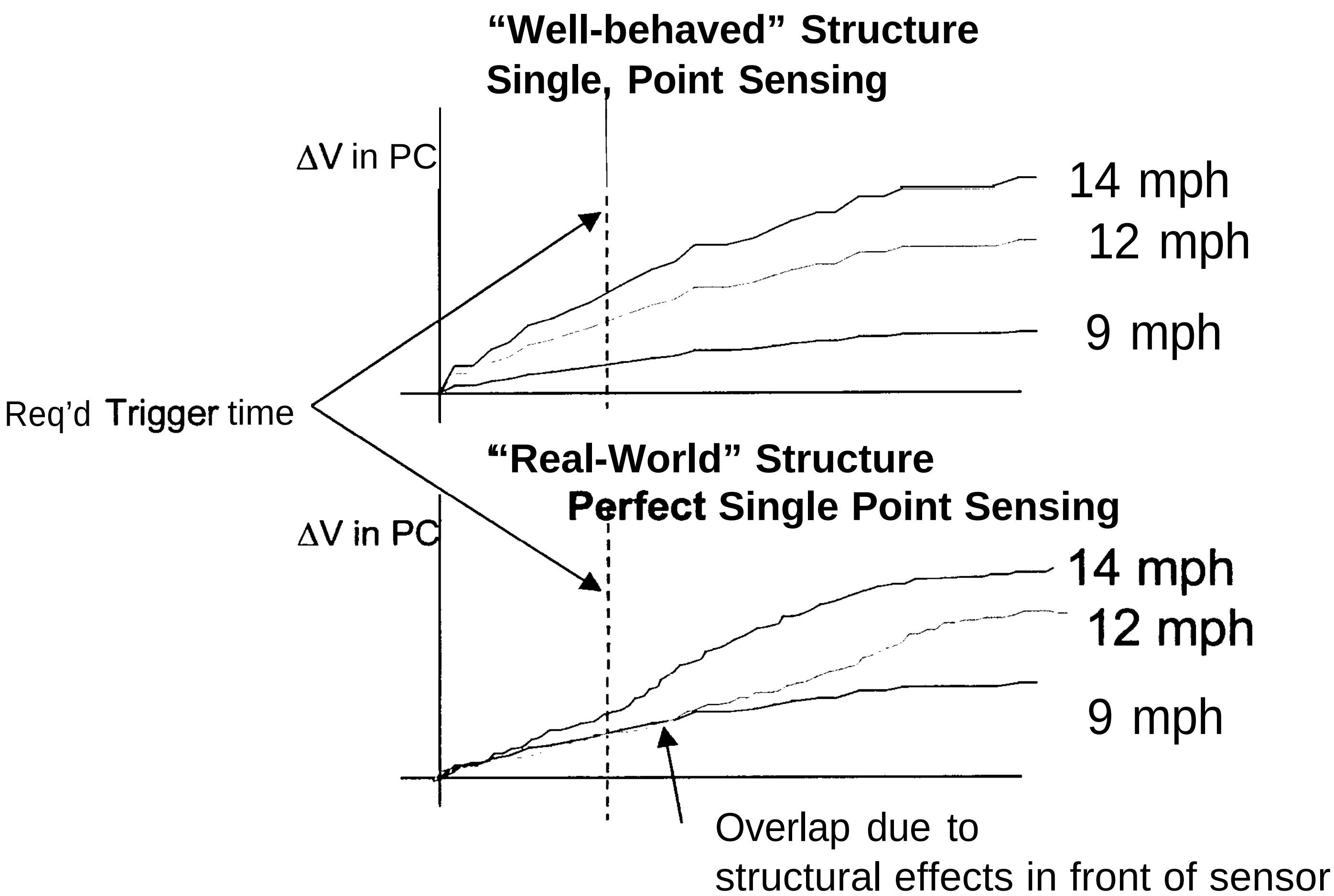
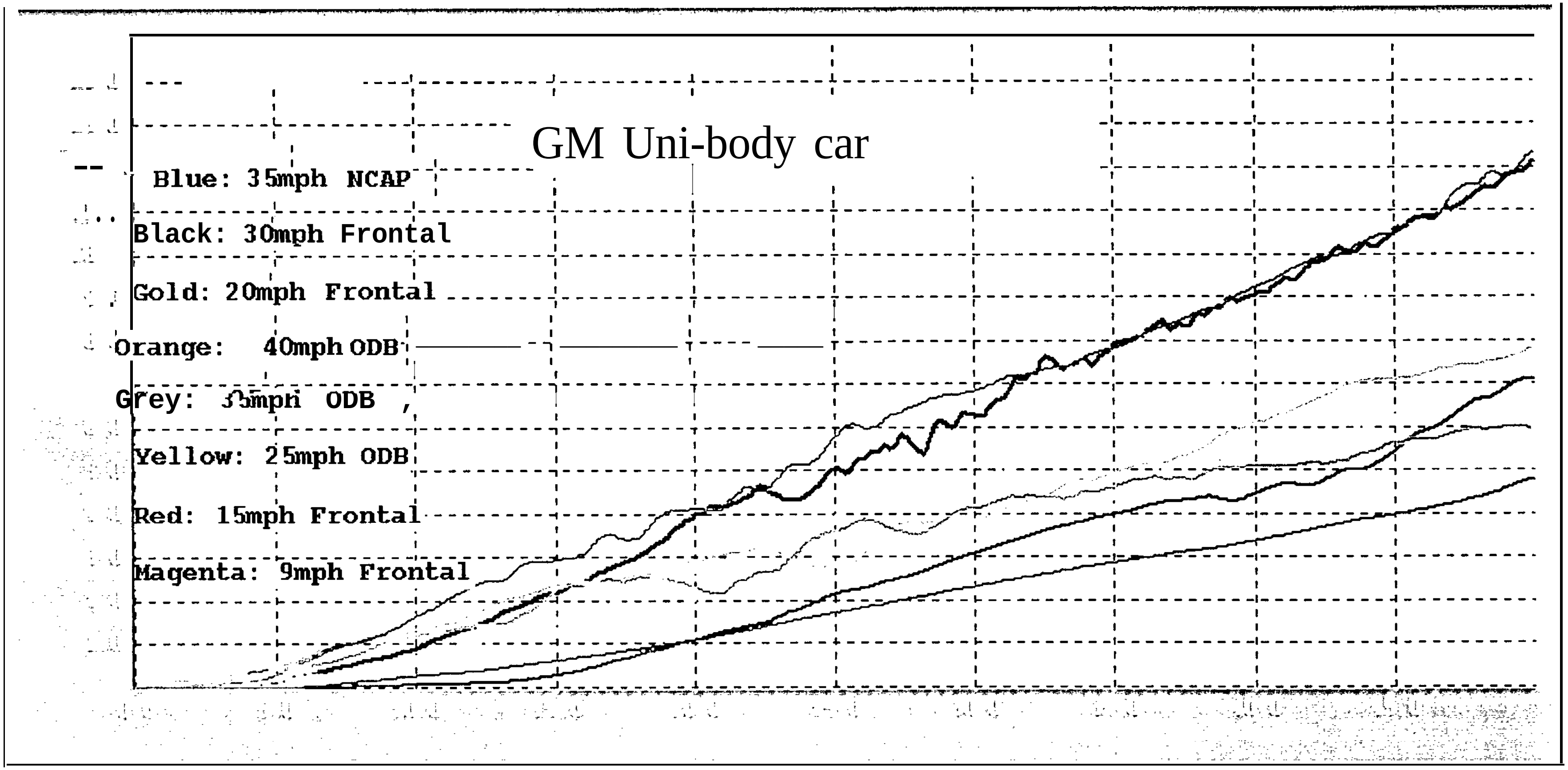
Gray Zones (concept)



Gray Zones (actual data)

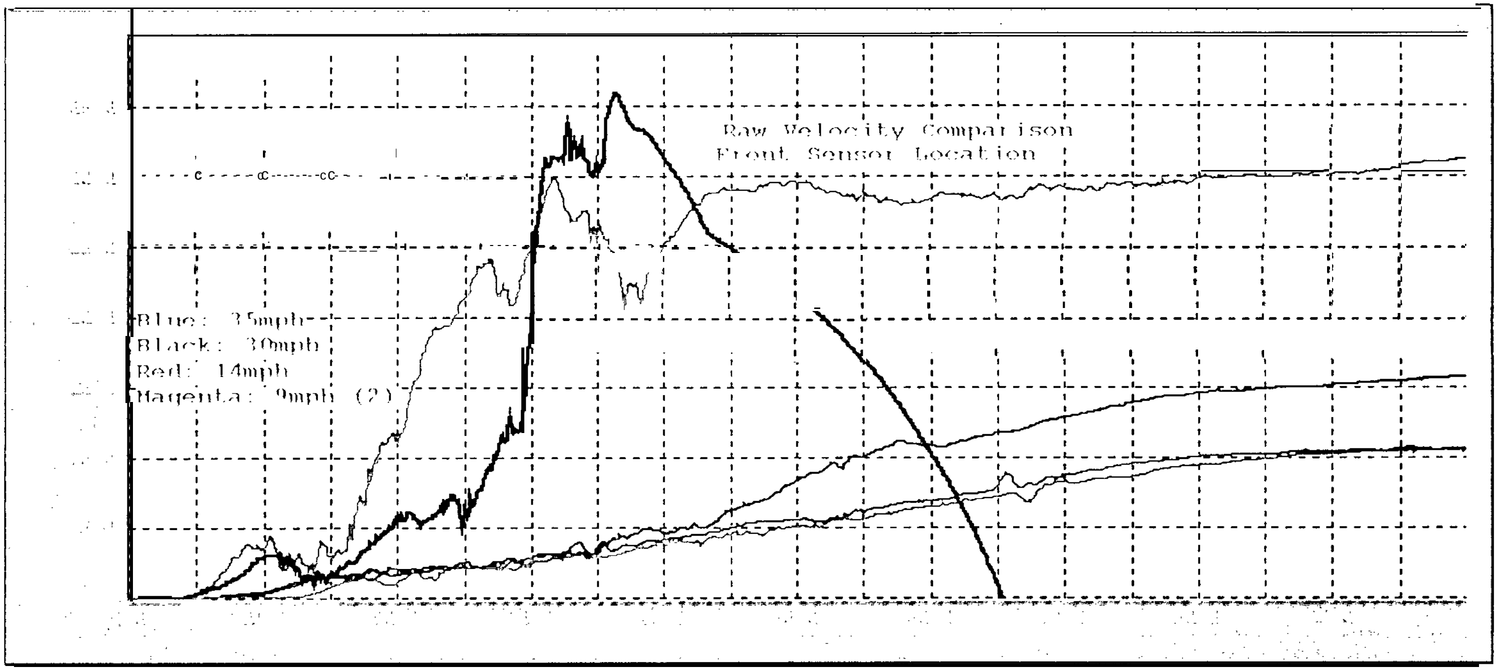


Gray Zones

A sensor's response is determined by the structure in front of it - It's what's *up-front that counts*

A properly located front sensor should reduce the gray zone because there is less structure in front of it.

GM is attempting to quantify the reduction of the gray zone.



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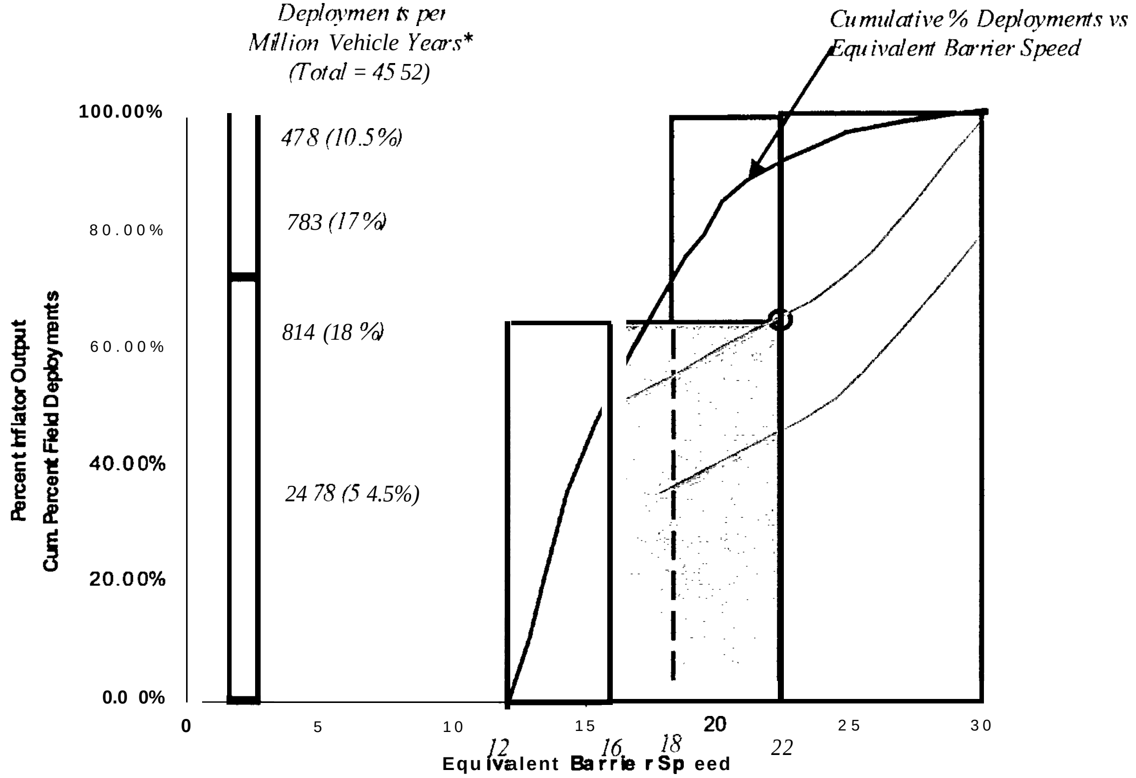
What's the Consequence of Gray zones?

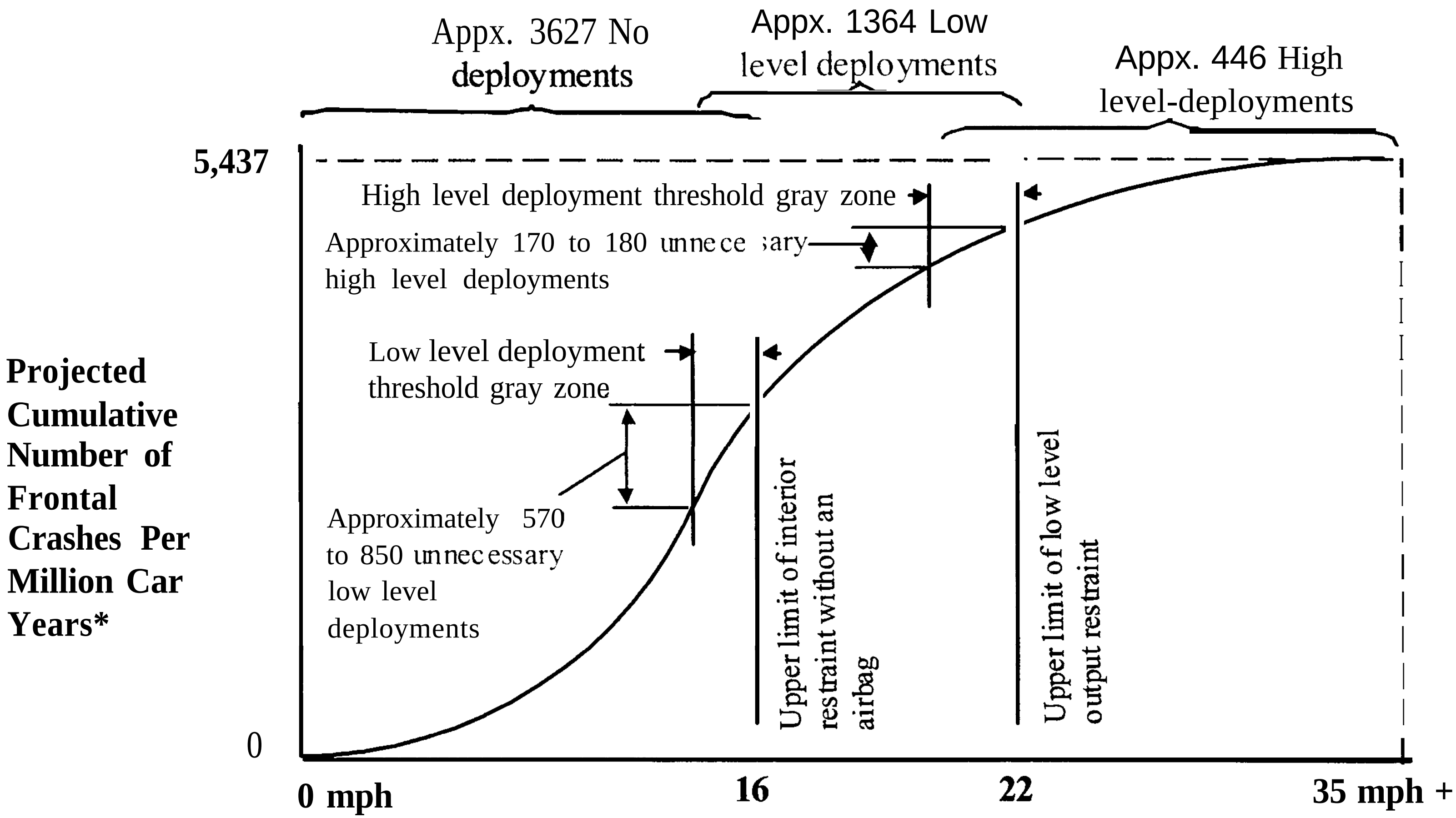
Depending on the true thresholds and the actual gray zones in <u>**all**</u> **field crashes** not just frontal barriers, there will be cases (and perhaps many) where a belted occupant will get a 1st stage deployment when not needed or a 2nd stage deployment when not needed.

Dual Level Air Bag with Proposed Deployment Thresholds



* jiim 1988-95 NASSCDS

Estimated Non-Optimal Responses Per Million Car Years Due To Gray Zones



* Cars in distributed front distributed/angle or pole/tree towawaycrashes with |longitudinal delta V| > |lateral delta V| based on 1988 - 1996 NASS-CDS. Front offset and other impacts disregarded.

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Crash Sensing
Summary

- Calibrating crash sensors to specific vehicles for dual stage systems requires many additional new full scale tests. Analytical techniques to significantly reduce testing is not yet available.

- Dual stage sensing may provide little distinction of deployments for some vehicle types. Variable stage (multi-threshold) sensing may not provide sufficient benefits with today's technology due to sensor & vehicle variability (gray zones).