Side Impact Vehicle Testing: Development of A Lateral Test Procedure for Child Restraints

Taryn Rockwell, ACE Systems Technologies, Inc.

Background

- TREAD Act – Nov. 2000
- Mandated that NHTSA determine whether to:
  - Apply scaled injury criteria performance levels developed for FMVSS No. 208, to CRS covered in FMVSS No. 213
  - Include CRS in NCAP crash tests
- In response, NHTSA:
  - Issued NPRM to address proposed changes to 213 (Docket No. 2002-11707-3) – proposed 208 scaled injury performance levels
  - Issued ANPRM for child protection in side & rear impact
  - Conducted frontal & side NCAP vehicle tests with CRABI 12MO & Hybrid III 3YO in CRS

Ongoing Research to Address Issues Raised in the ANPRM

- Evaluating real world side impact data
  - CHOP, NASS, FARS, SCI
- Evaluating different lateral test procedures for evaluating CRSs
  - ISO, Japan NCAP, Australia, Euro NCAP
- Sled testing
  - Countermeasures
  - Dummies
    - Q3 vs. Hybrid III
  - IARVs
- Vehicle testing
  - NCAP and R&D

Objectives of This Research

- Address some of the issues raised in the ANPRM including:
  - Determining child injury mechanisms in side impact vehicle tests
  - Compare performance in vehicle tests to that of suggested 90^{o} sled tests

Vehicle Selection

- 8 vehicles selected:
  - 5 from list of vehicles to be selected for 2002 SINCAP
  - 3 vehicles piggy-backed to R&D tests with ES-2 dummy
- The following considered when selecting vehicles:
  - Difficulty of correctly positioning rear SID dummy – exempt from side NCAP testing
  - Popular models
  - Covered various vehicle classes (2-dr. pass. cars, 4-dr. pass. cars, SUVs, vans, pickups)
  - Vehicle availability

*** Did NOT attempt to get cross-sample from vehicle manufacturers**

Vehicle Configuration

- For any one particular vehicle, the following were identical for both outboard rear seating positions:
  - Model of CRS
  - CRS orientation
  - CRS belt configuration
  - Child dummy

Model of CRS

- Safety 1st Forerunner
  - 5-point harness
  - Convertible
    - 5-35 lbs. rear-facing
    - 22-40 lbs. forward-facing
  - Equipped with lower anchorages & tether (LATCH)
- Evenflo On-My-Way
  - 5-point harness
  - Rear-facing only (Infant seat)
    - 5-20 lbs.
  - Equipped only with tether – not used

CRS Belt Configuration & Orientation

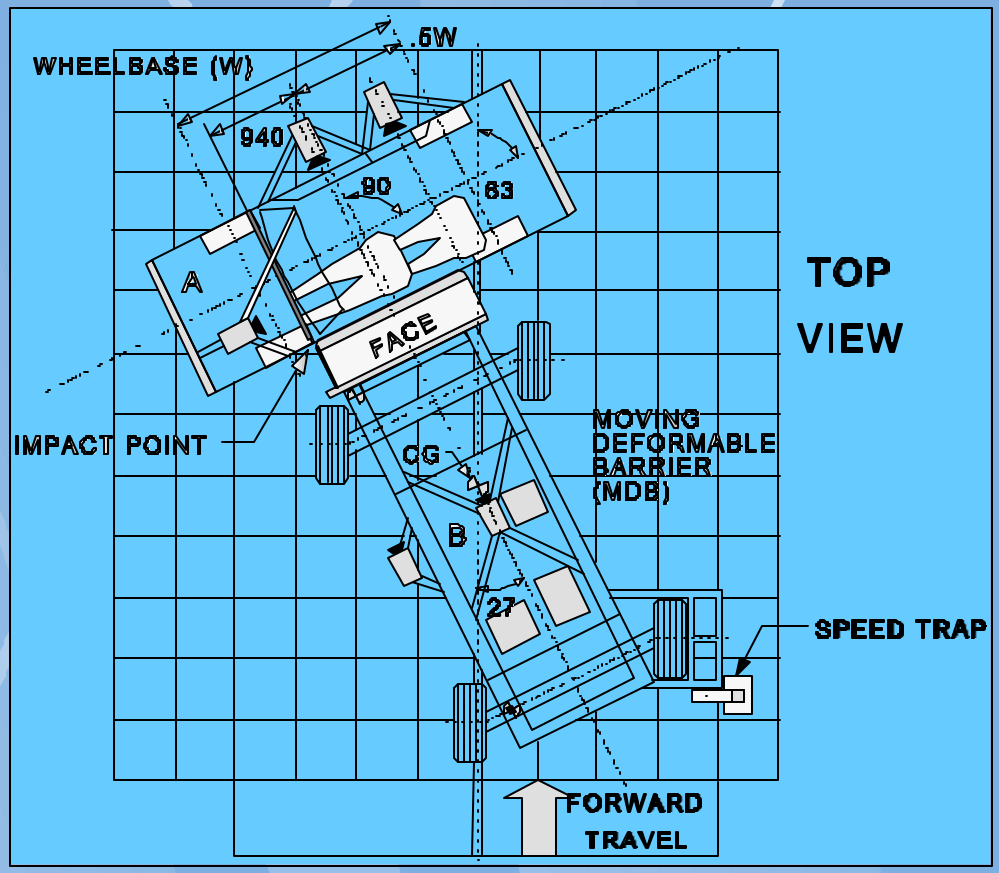
- Safety 1st Forerunner
  - VSB, no tether, RF
  - VSB, tether, FF
  - LATCH, FF
  - Lower anchorages, no tether, RF
- Evenflo On-My-Way
  - VSB, no tether, RF

Child Dummy Selection & Instrumentation

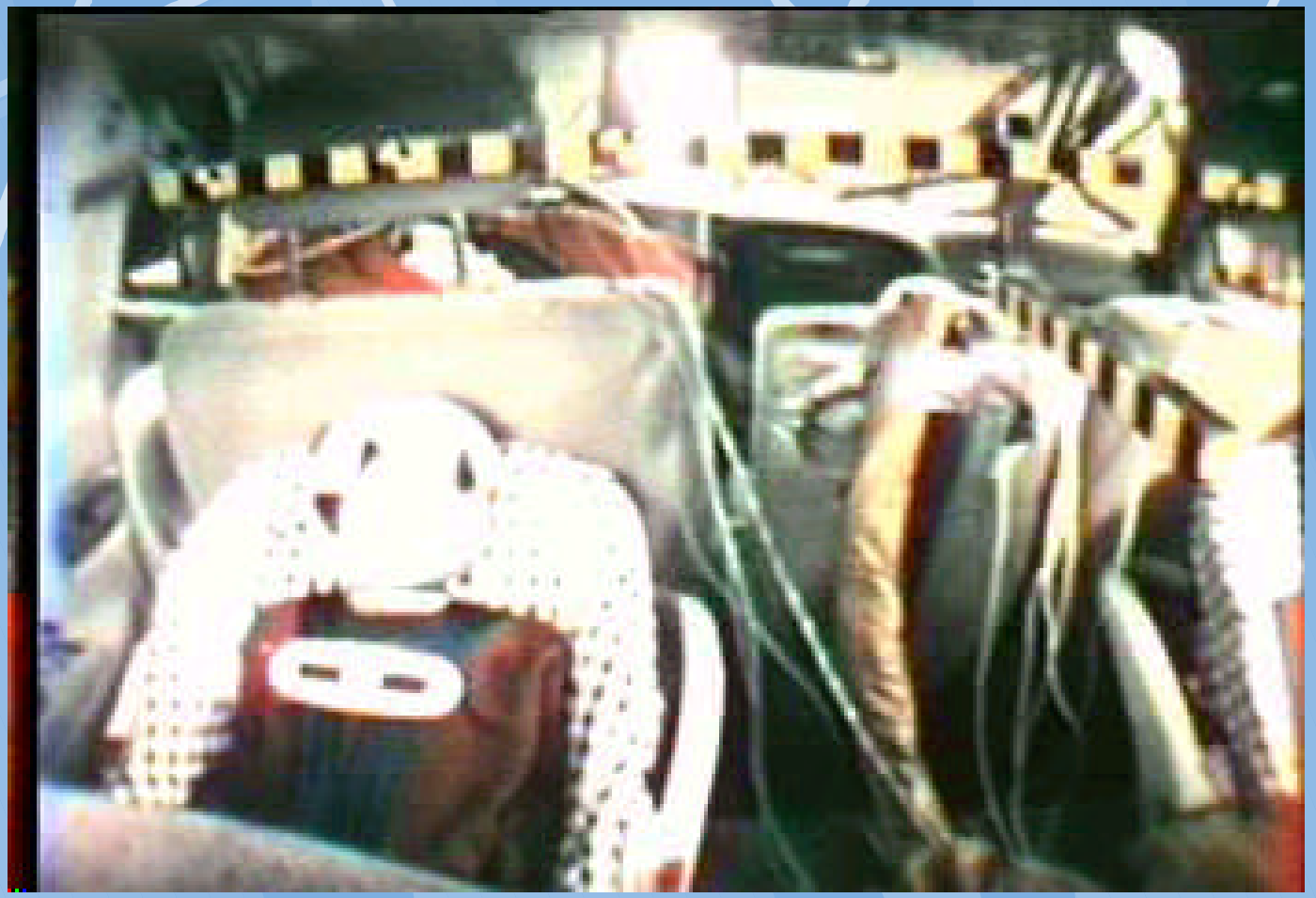
- Hybrid III 3YO dummy
- 12MO CRABI dummy
- Equipped with:
  - Upper & lower neck load cells
  - Tri-axial head, chest, and pelvis accelerometers
  - Chest lateral spring potentiometer for 3YO only

Side NCAP Test Procedure

- MDB
  - 27° crabbed angle
  - 62.0 km/h (38.5 mph)
- Target vehicle
  - Positioned at 63° to the line of forward motion
  - Stationary
  - Impacted on driver's side
- Simulates car moving at 55 km/h hitting another car moving at 27 km/h



Video of Crash Test – Vehicle B (Pickup)



Post-Test CRS Examination

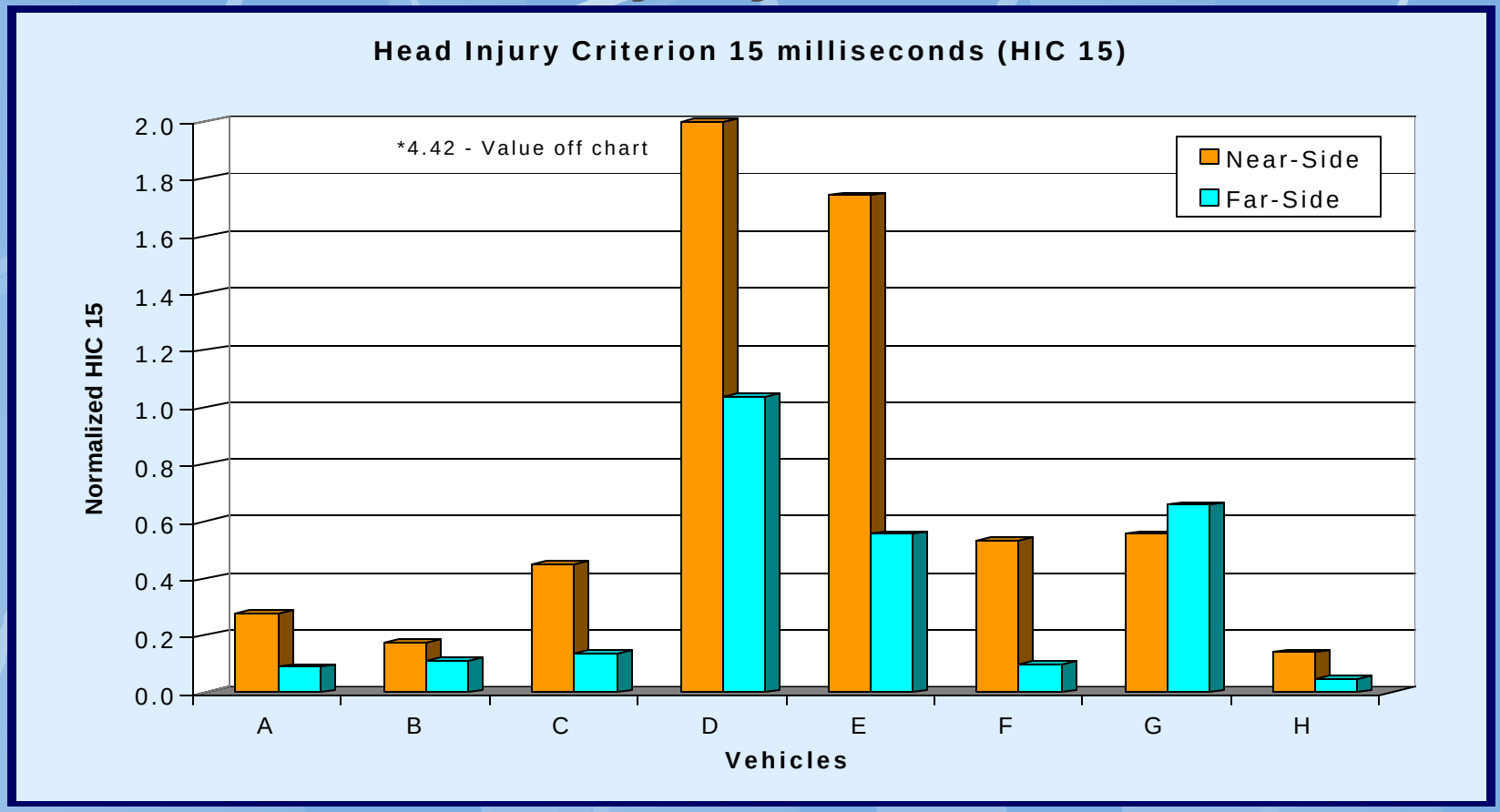
- Post-test examinations showed:
  - No CRS damaged
  - No plastic (permanent) deformation of lower anchorages in vehicle or connection hooks on CRS
  - All vehicle seat belts intact and without damage

Injury Criteria

INJURY CRITERION		12MO CRABI	3YO Hybrid III
HIC 15		390	570
3 ms Chest Clip		50	55
Chest Deflection		34	34
Nij Intercepts:	Tension	1460	2340
	Compression	1460	2120
	Flexion	43	68
	Extension	17	30

- Suggested in ANPRM issued to address side impact protection for child occupants – Docket No. 02-12151
- Examination of IARVs for side impact dummies only used as a baseline comparison

Head Injury Criterion

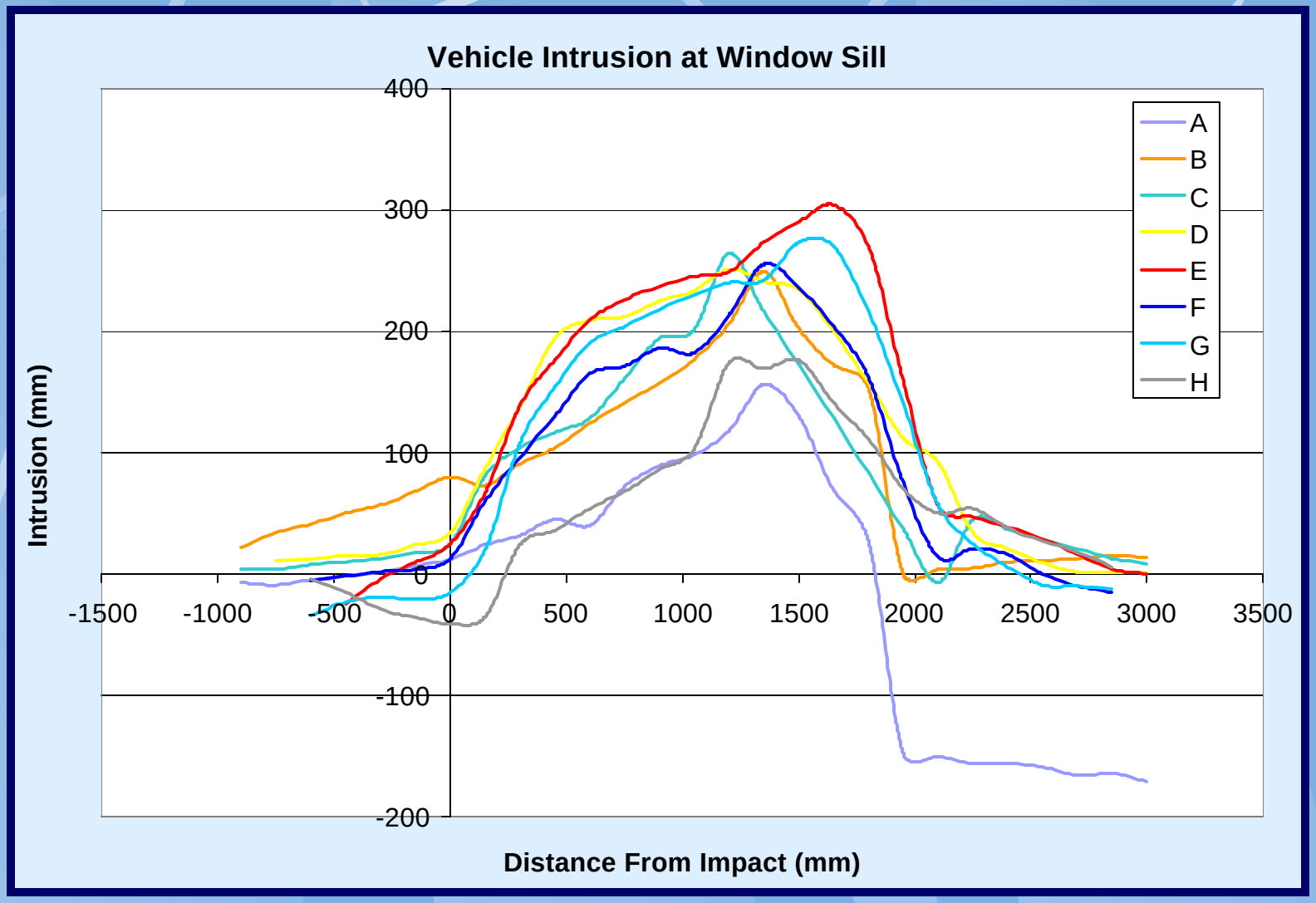


Pickup	Pickup	Van	4-dr car	4-dr car	4-dr car	2-dr car	SUV
NL	NL	L	L	L	L	L	NL
RF	RF	RF	RF	FF	FF	FF	FF
12MO	12MO	12MO	12MO	12MO	3YO	3YO	3YO

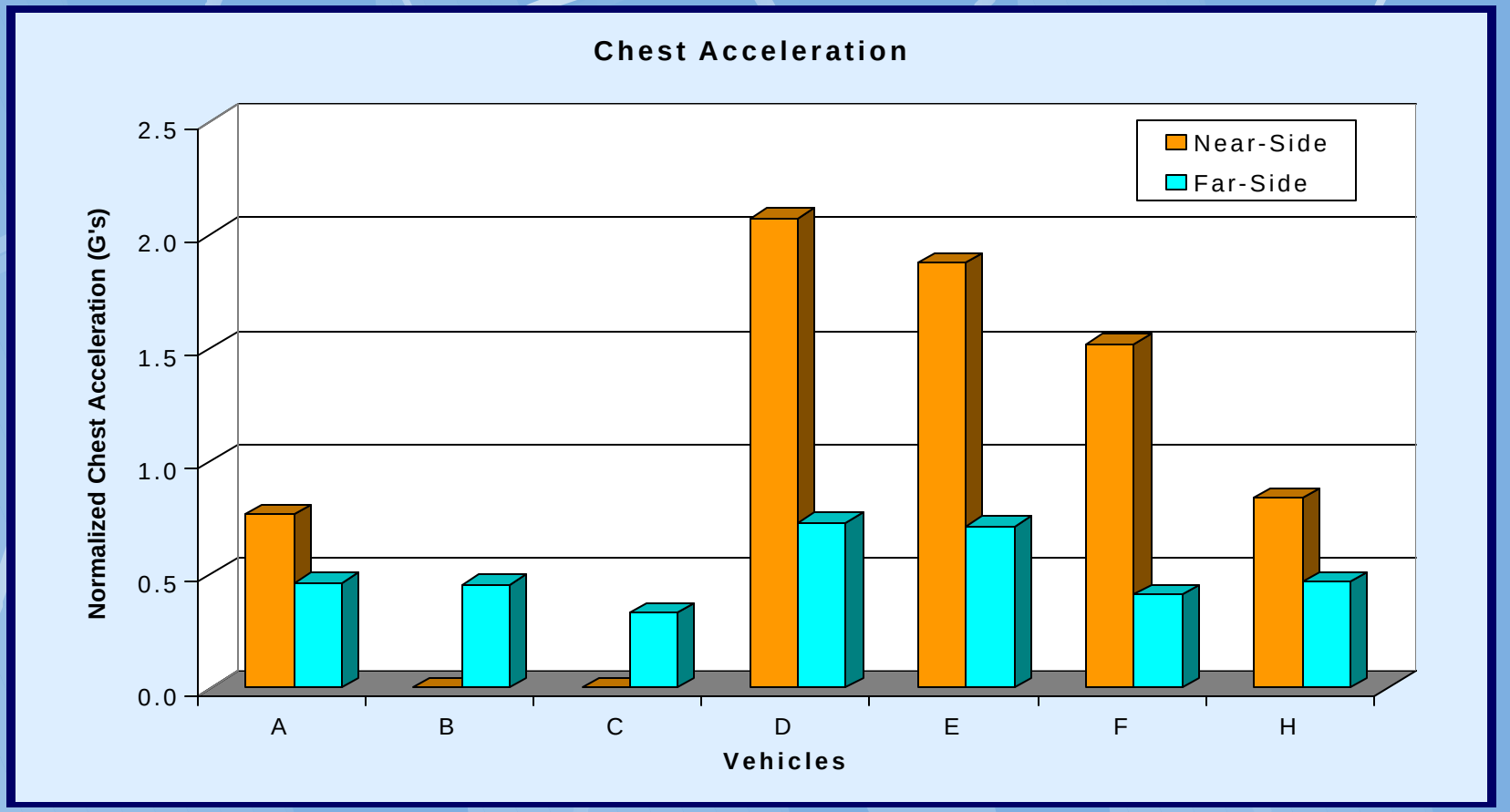
Head Injury Criterion – Vehicle E (4-dr. car)

Intrusion – Vehicle E (4-dr. car)

Intrusion at Window Sill

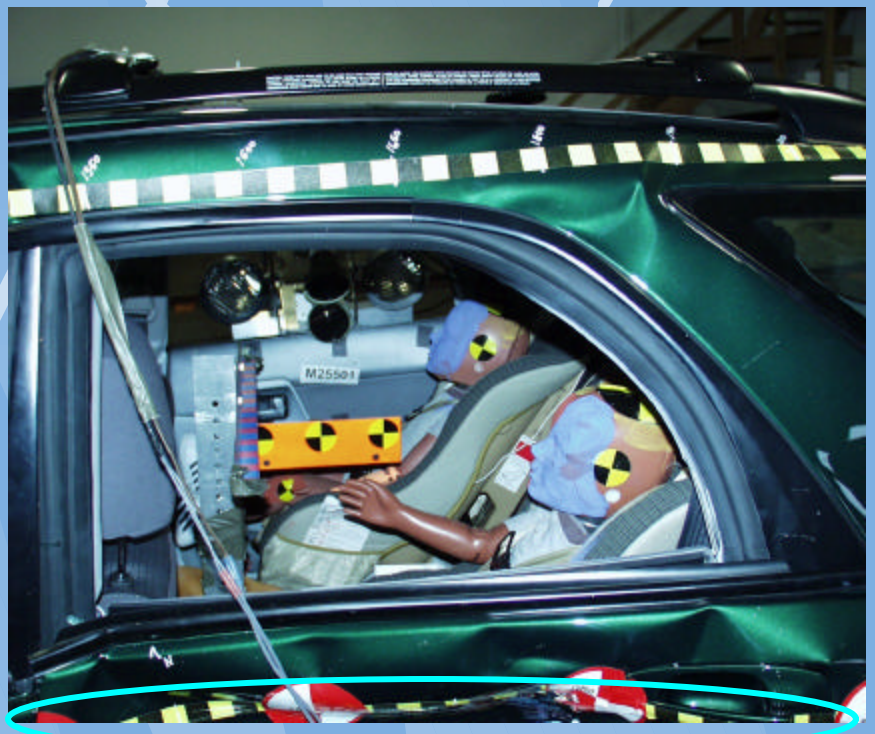


Thoracic Criteria – Chest Acceleration



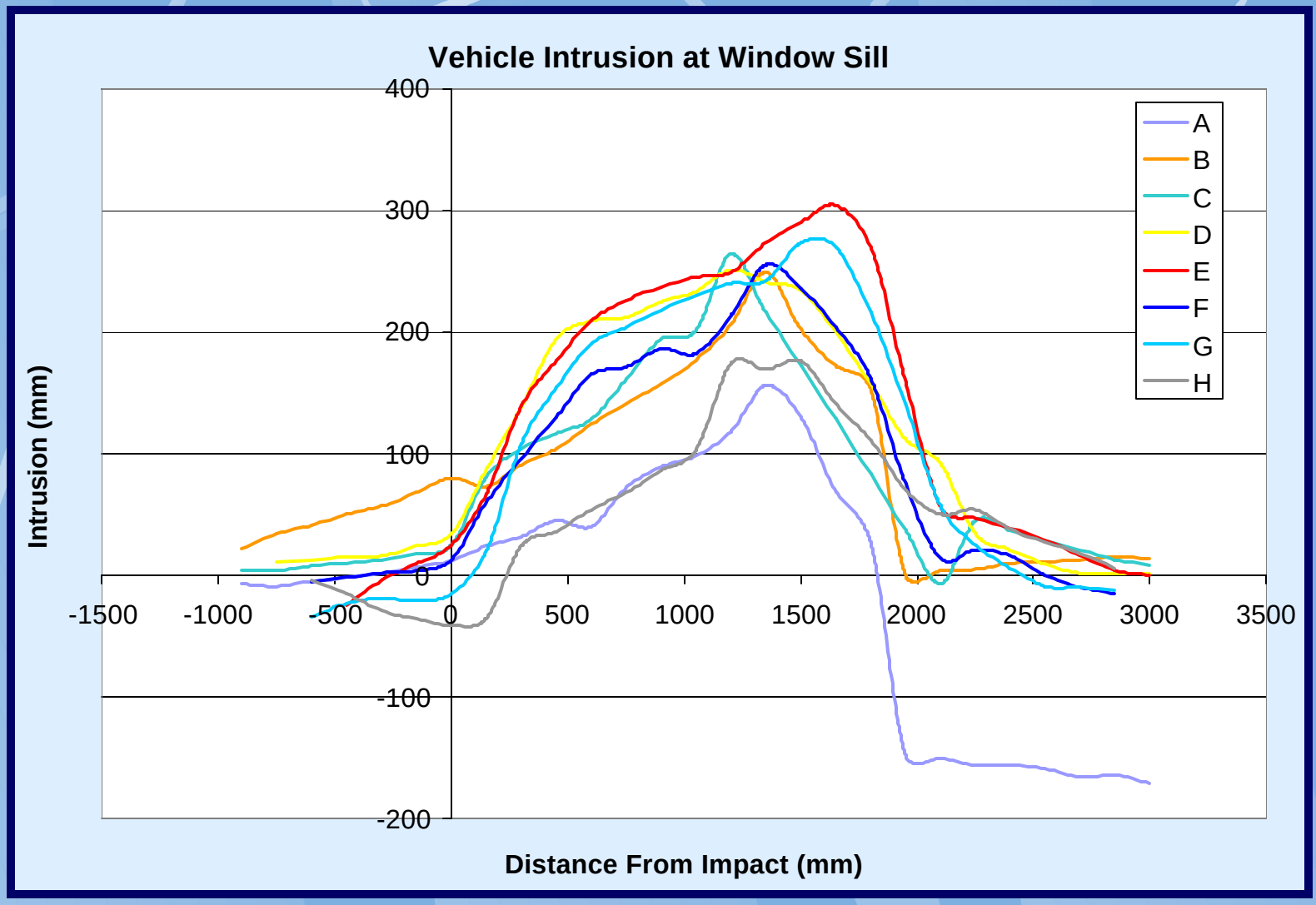
Pickup	Pickup	Van	4-dr car	4-dr car	4-dr car	SUV
NL	NL	L	L	L	L	NL
RF	RF	RF	RF	FF	FF	FF
12MO	12MO	12MO	12MO	12MO	3YO	3YO

Intrusion – Vehicle F (4-dr. car)

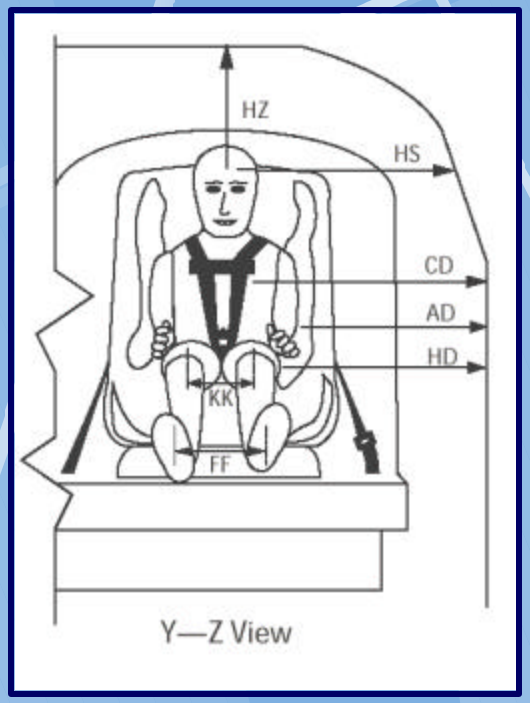


Dummy's chest at
approx. window sill level

Intrusion at Window Sill



Dummy Positioning



Vehicle	HS	CD	AD	HD	Total	Ranking
A	4	6	5	5	20	4
B	6	7	7	7	27	7
C	8	8	8	8	32	8
D	3	3	3	3	12	3
E	1	2	2	2	7	2
F	2	1	1	1	5	1
G	5	4	6	6	21	6
H	7	5	4	4	20	4

Child Dummy Closer to Door		
	F	4-dr. car
	E	4-dr. car
	D	4-dr. car
	H	SUV
	A	Pickup
	G	2-dr. car
	B	Pickup
	C	Van

Rankings 1-8

1 = closest to door

8 = farthest away from door

Thoracic Criteria – Chest Deflection

- 3YO dummy only
  - 3 vehicles – F, G, & H
- Dummy readings normalized to 34 mm
- All recorded injuries well below IARV
  - Negligible for far-side dummy
- Highest recorded value: 0.58 – near-side dummy in vehicle F

Neck Criteria - Nij

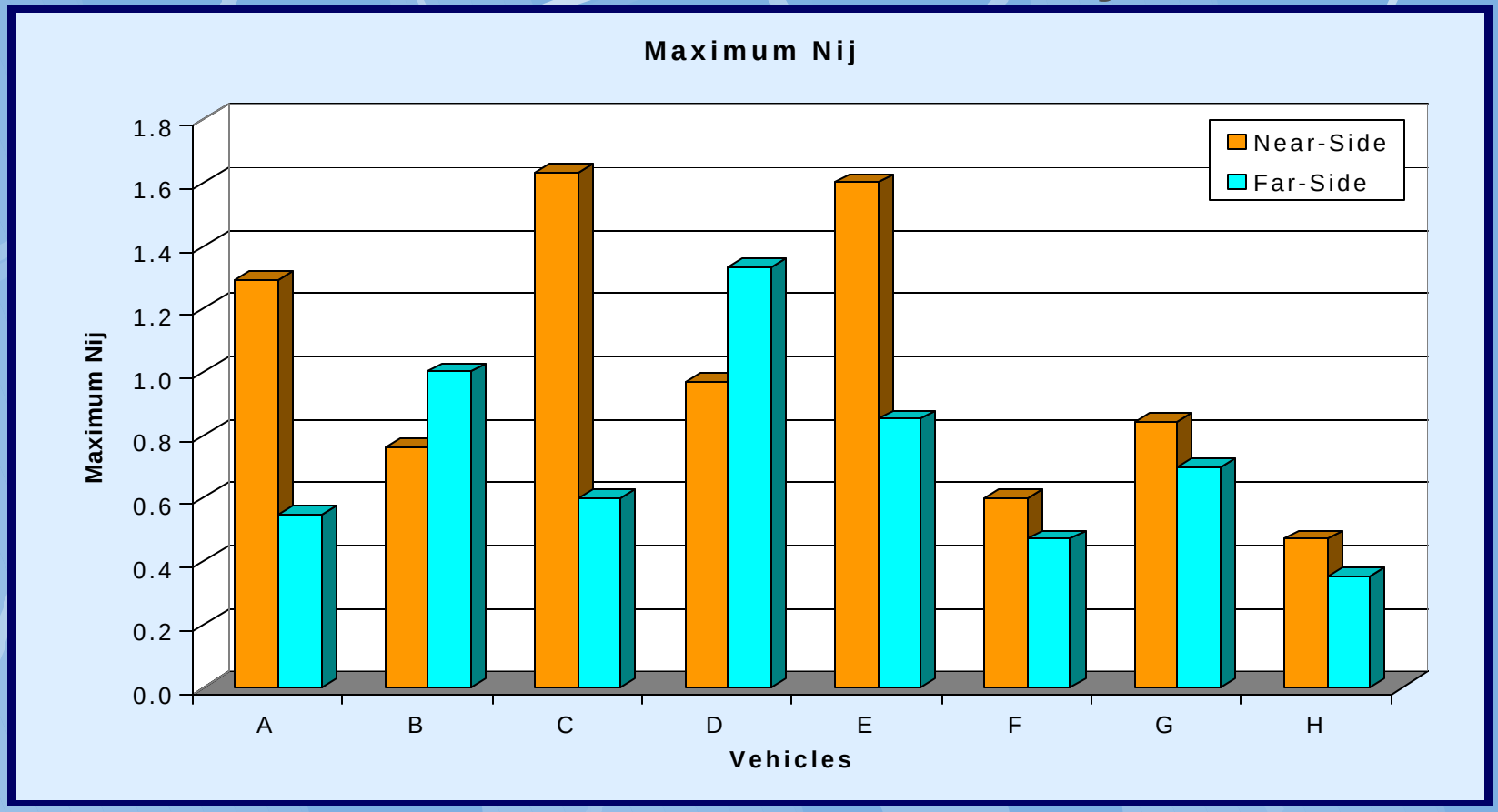
$$Nij = \max[F_{axial}/F_{critical} + M_{oc}/M_{critical}]$$

- Faxial = Fz
- Fcritical = Max. force in z-direction (tens./comp.)
- Moc = My + (correction factor)Fx
- Mcritical = Max. moment about y-axis (flex./ext.)

	IN-POSITION LIMITS - Nij INTERCEPTS			
Dummy	Tension (N)	Compression (N)	Flexion (N-m)	Extension (N-m)
12MO	1460	-1460	43	-17
3YO	2340	-2120	68	-30

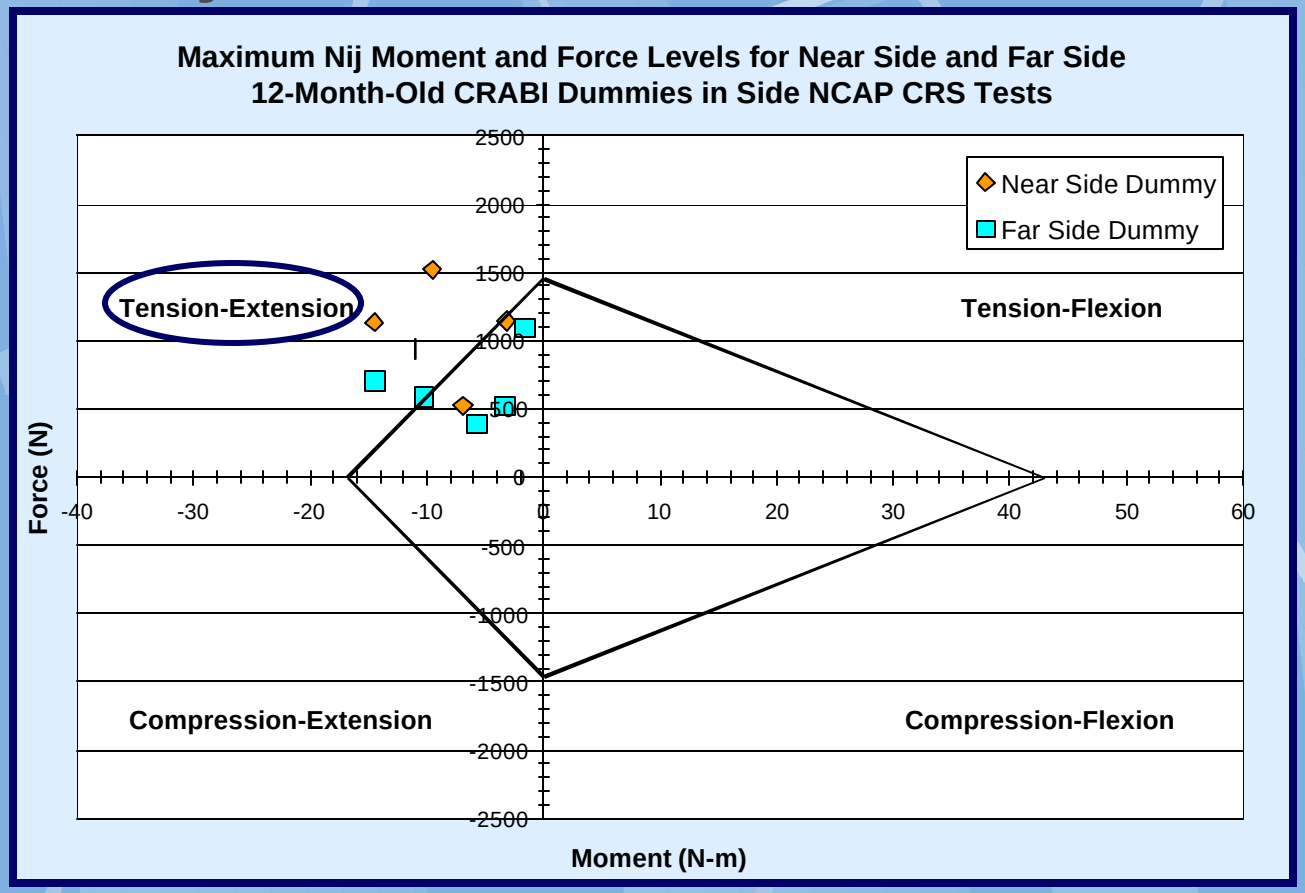
* “Development of Improved Injury Criteria for the Assessment of Child Restraint Systems.” – Docket No. 2002-11707-18

Neck Criteria - Nij



Pickup	Pickup	Van	4-dr car	4-dr car	4-dr car	2-dr car	SUV
NL	NL	L	L	L	L	L	NL
RF	RF	RF	RF	FF	FF	FF	FF
12MO	12MO	12MO	12MO	12MO	3YO	3YO	3YO

Nij – Failure Modes for 12MO CRABI



A	B	C	D	E
Pickup	Pickup	Van	4-dr car	4-dr car
NL	NL	L	L	L
RF	RF	RF	RF	FF
12MO	12MO	12MO	12MO	12MO

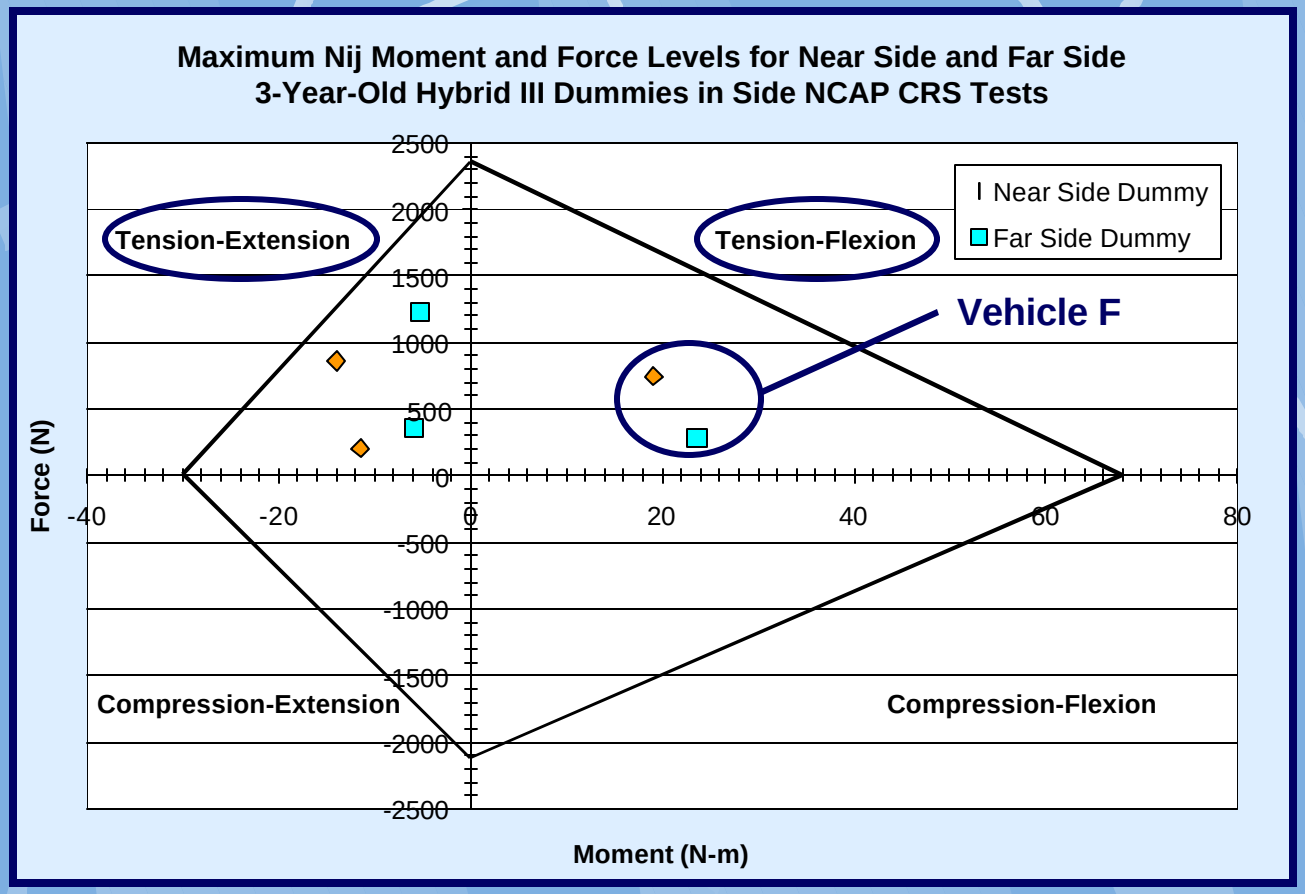
- Diamond formed by Nij intercepts
- My & Fz injury values at time of max. Nij found
- Exceed 1 of 4 modes of neck motion if recorded moment/force combination falls outside diamond

Nij – Failure Modes for 12MO CRABI

Tension/ Extension in vehicle C (van)

- *Neck tension* – head up relative to neck *or* chest down relative to neck
- *Neck extension* – chin up, away from sternum, forcing head back

Nij – Neck Motion for 3YO Hybrid III



F	G	H
4-dr car	2-dr car	SUV
L	L	NL
FF	FF	FF
3YO	3YO	3YO

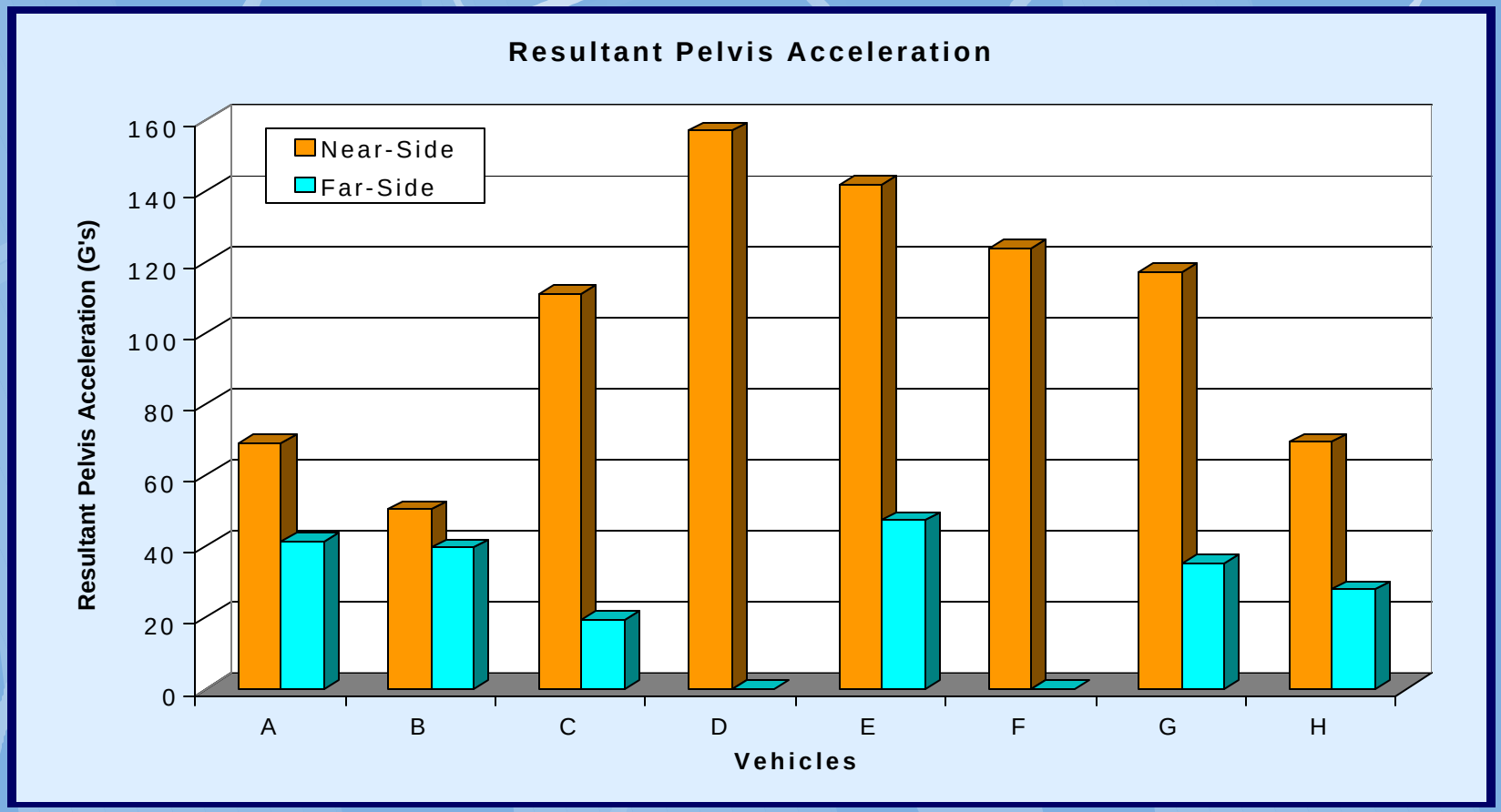
Nij – Neck Motion for 3YO Hybrid III

Tension/Extension in vehicle G (2-dr. car)

Tension/ Flexion in vehicle F (4-dr. car)

- *Neck tension* – head up relative to neck *or* chest down relative to neck
- *Neck flexion* – chin down toward sternum & head curls forward

Resultant Pelvis Acceleration



Pickup	Pickup	Van	4-dr car	4-dr car	4-dr car	2-dr car	SUV
NL	NL	L	L	L	L	L	NL
RF	RF	RF	RF	FF	FF	FF	FF
12MO	12MO	12MO	12MO	12MO	3YO	3YO	3YO

Summary of Injury

	Vehicle Type	Dummy Type	Dummy Position	HIC 15	Chest G's	Nij
A	Pickup	12MO	Near-Side	0.28	0.77	1.29
			Far-Side	0.09	0.47	0.55
B	Pickup	12MO	Near-Side	0.18	N/A	0.76
			Far-Side	0.11	0.46	1.00
C	Van	12MO	Near-Side	0.45	N/A	1.63
			Far-Side	0.14	0.33	0.60
D	4-dr. car	12MO	Near-Side	4.42	2.07	0.97
			Far-Side	1.04	0.73	1.33
E	4-dr. car	12MO	Near-Side	1.74	1.88	1.60
			Far-Side	0.56	0.71	0.85
F	4-dr. car	3YO	Near-Side	0.53	1.52	0.60
			Far-Side	0.10	0.41	0.47
G	2-dr. car	3YO	Near-Side	0.55	N/A	0.84
			Far-Side	0.66	N/A	0.70
H	SUV	3YO	Near-Side	0.14	0.84	0.47
			Far-Side	0.05	0.47	0.35

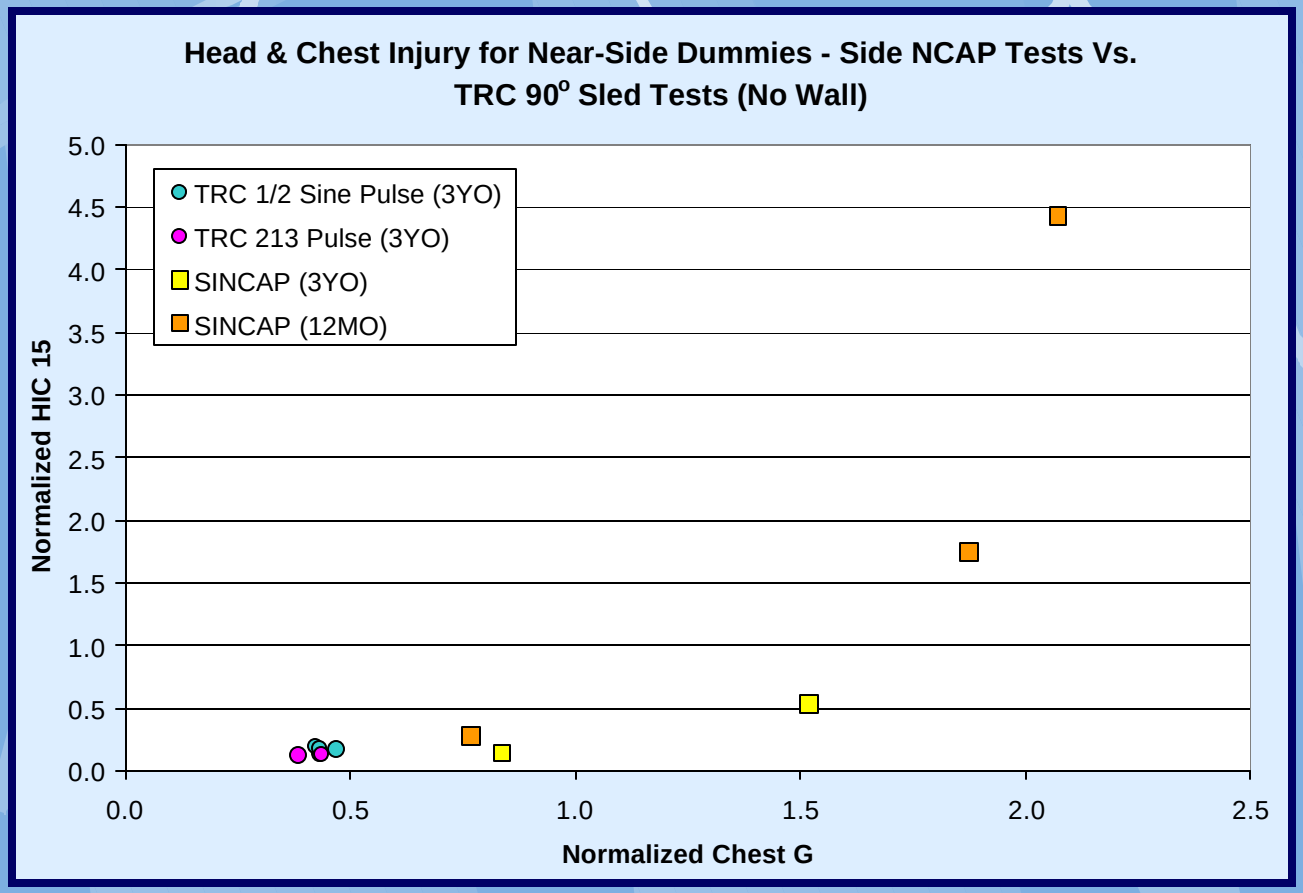
- Several vehicles exceeded numerous injury criteria

Comparison of Sled Tests to Vehicle Tests

Suggested Lateral Sled Tests to Be Added to 213

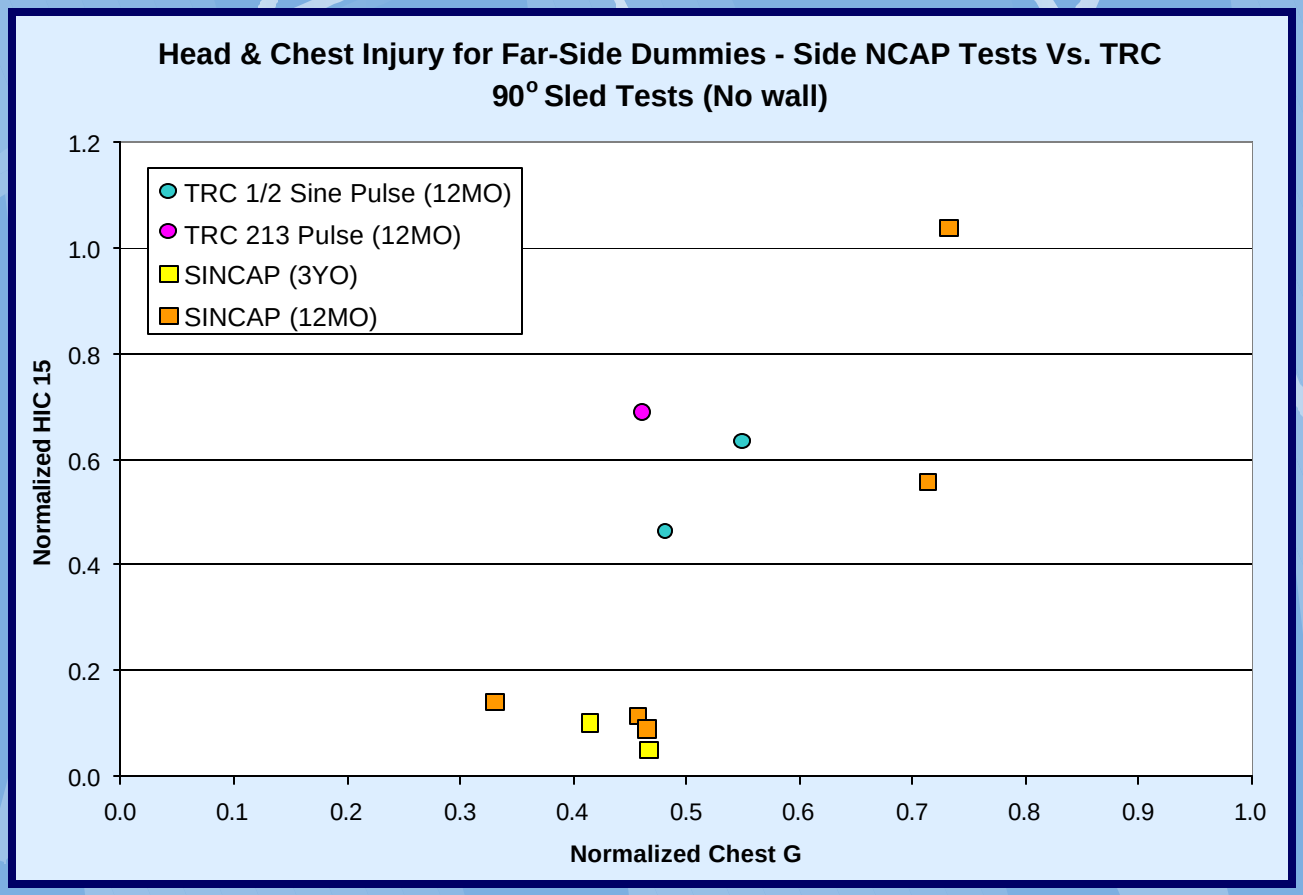
- ANPRM suggested 2 Options:
  - 90º, no rigid wall
    - 20 mph
    - ½ sine pulse or upgraded 213 pulse
    - Tethered CRS
    - Impose 20” head excursion limit
  - 90º, rigid-wall
    - 15 mph
    - Grand Am pulse – derived from pulse of Pontiac Grand Am when tested both under 214 (15 mph w/ 21g peak accel.) & side NCAP (21 mph w/ 26 g peak accel.)
    - No head excursion limit necessary

Comparison of 90º (No wall) TRC Sled Tests to SINCAP Vehicle Tests



- Near-side dummy readings for HIC 15 & chest G in sled tests (no wall) much lower than in vehicle tests

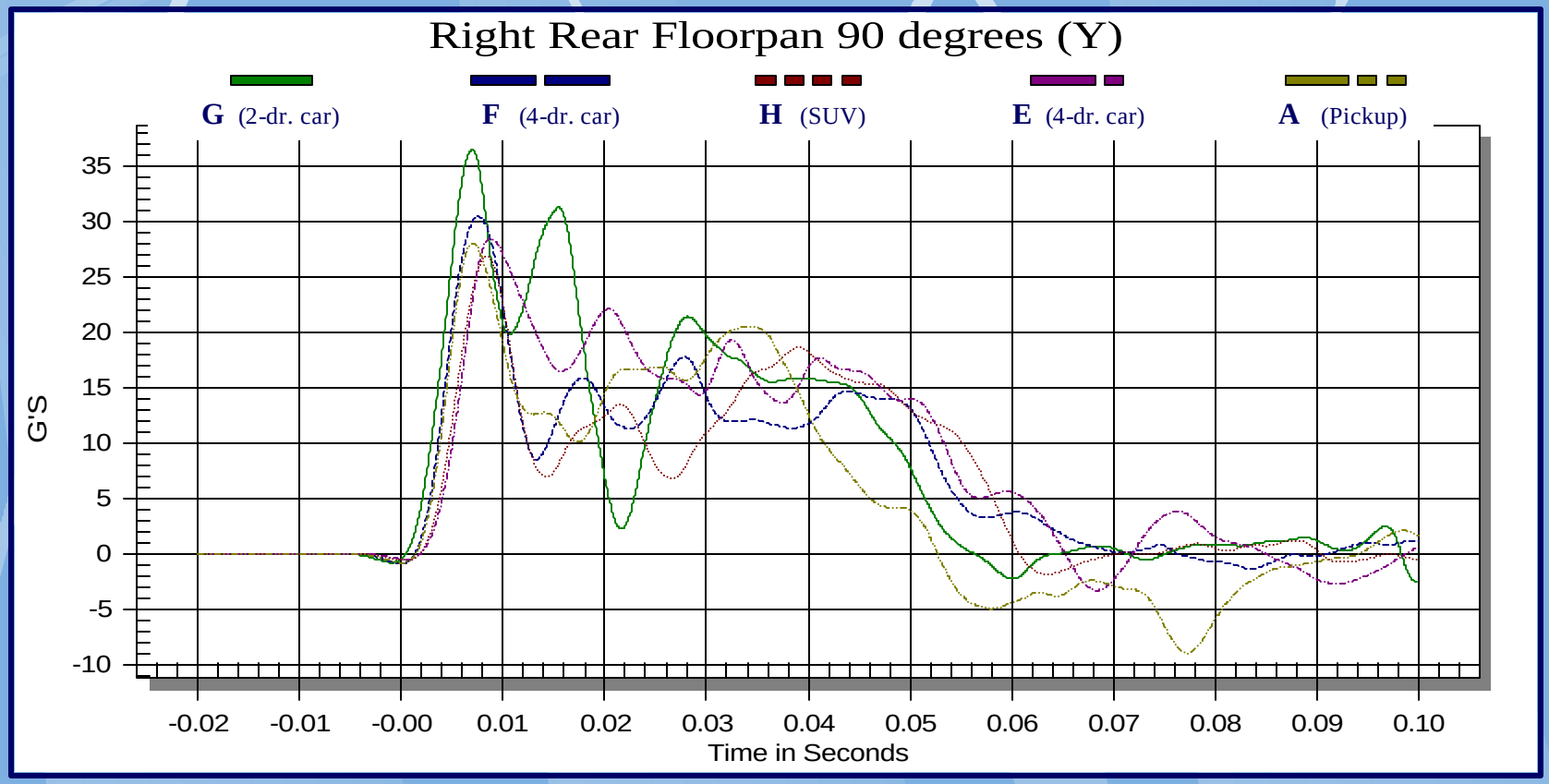
Comparison of 90º (No wall) TRC Sled Tests to SINCAP Vehicle Tests



- Inconclusive whether HIC 15 & chest G readings for far-side dummy in vehicle tests greater than in sled tests (no wall)

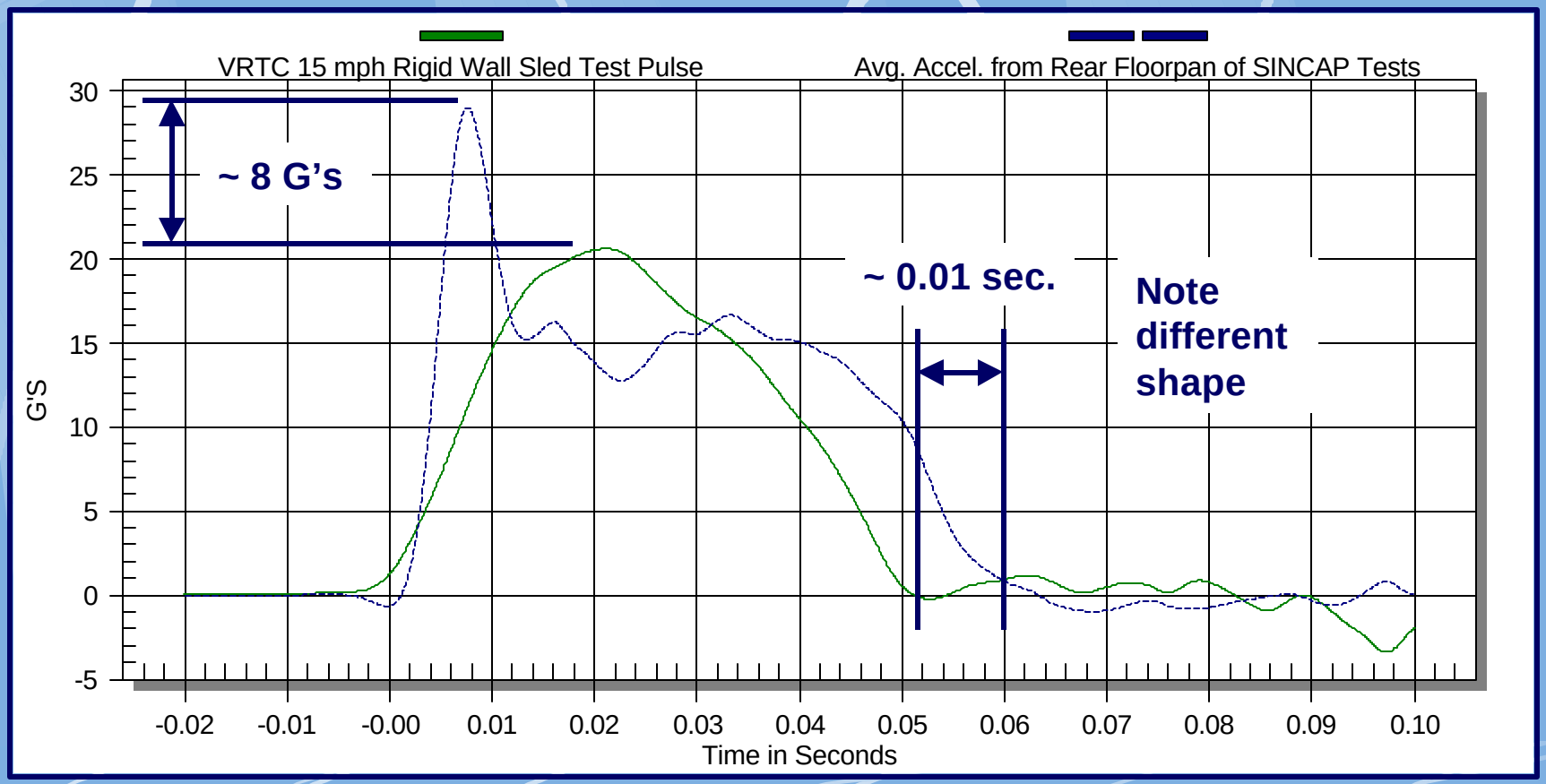
Comparison of TRC 90º Rigid Wall Sled Tests to SINCAP Vehicle Tests

- 90º Y-acceleration on rear floorpan for five vehicles

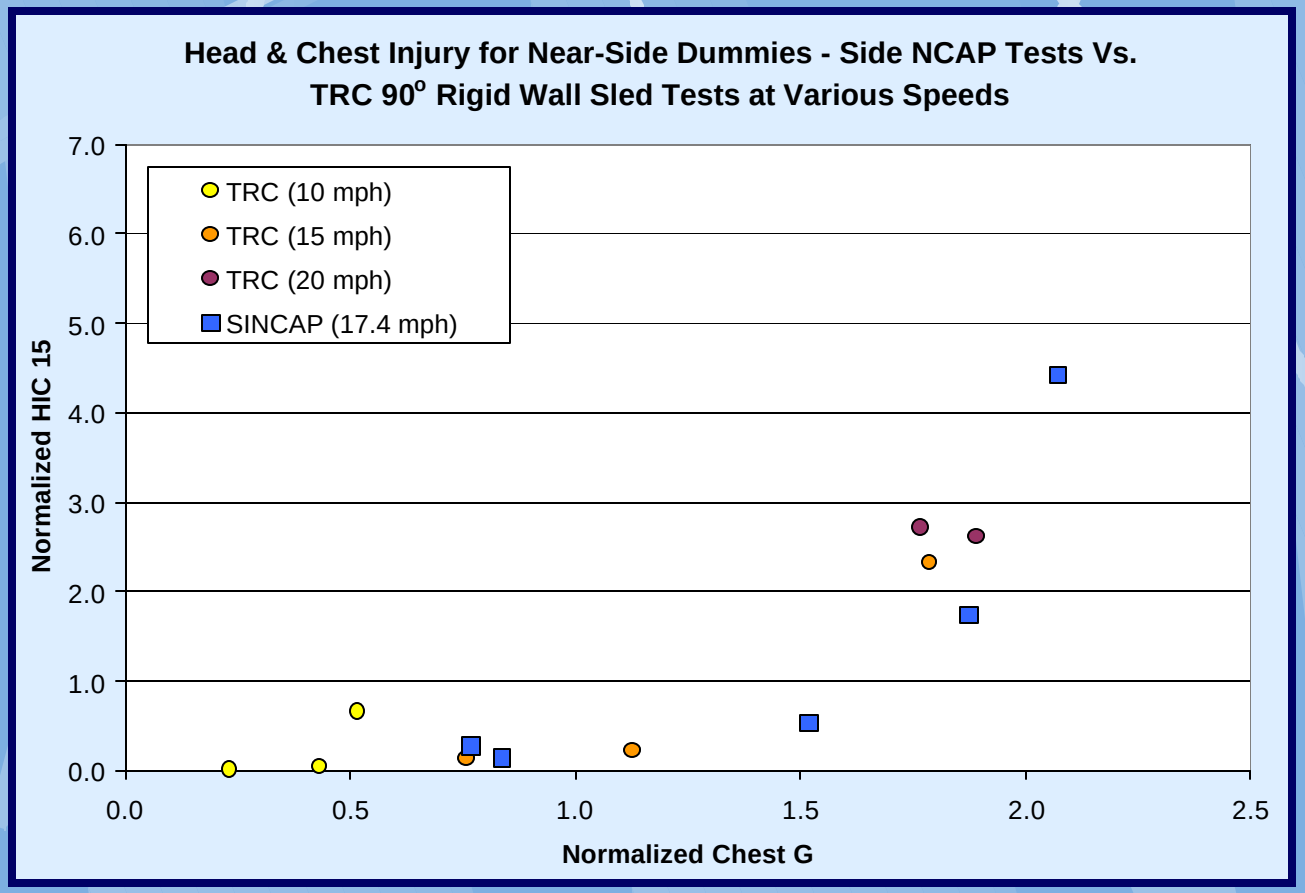


Comparison of TRC 90º Rigid Wall Sled Tests to SINCAP Vehicle Tests

- Average acceleration curve in y-direction for 5 vehicles (v = 17.38 mph) vs. pulse for 15 mph rigid wall sled test



Comparison of TRC 90º Rigid Wall Sled Tests to SINCAP Vehicle Tests



- In general, near-side dummy readings for HIC 15 & chest G in 15 mph rigid wall sled tests are similar to readings in SINCAP vehicle tests

Preliminary Observations

- Based on limited test series:
  - CRSs withstand severity of side impact crash conditions
  - Near-side dummy readings generally greater than far-side dummy readings
    - Contributors: Intrusion & lower anchorage locations – changes relative position of dummy

Preliminary Observations

- Sled tests vs. vehicle tests:
  - Sled test (no wall)
    - Near-side dummy - readings for HIC 15 & chest G much lower than in vehicle tests
    - Far-side dummy – inconclusive
  - Sled test (rigid wall)
    - Near-side dummy – readings for HIC 15 & chest G for test at 15 mph similar to dummy readings for vehicle tests

Next Steps

- Evaluation of countermeasures
- Evaluation of biofidelity of dummies for side impact
- Additional vehicle testing
- Possible development of lateral impact test procedure for CRS