NHTSA Roof Crush Tests and Other Tests for Validating Computer Models

FHWA / NHTSA National Crash Analysis Center
The George Washington University Virginia Campus

NHTSA 216 Tests

Yr	Make	Model	Nr	Pitch	Roll	Crush in at 1.5 wgt	Initial Head Clr	Crush Head Clr
89	Nissan	Pickup	1	5	25	2.19	7.52	5.33
89	Dodge	Colt	1	5	25	1.41	5.98	4.58
89	Dodge	Colt	2	0	15	1.26	5.98	4.72
89	Nissan	Pickup	2	0	15	1.37	7.52	6.15
90	Chevy	Cavalier	1	5	25	2.14	7.99	5.85
90	Honda	Accord	1	5	25	2.41	7.48	5.07
91	Chevy	Caprice	1	5	25	3.24	9.02	5.78
91	Ford	Explorer	1	5	25	2.03	8.74	6.71
90	Chevy	1500 PU	1	5	25	2.53	10.98	8.45
89	Ford	Taurus	1	5	25	1.88	5.98	4.10
92	Ford	Taurus	1	5	25	1.96	5.00	3.04

5” Allowable

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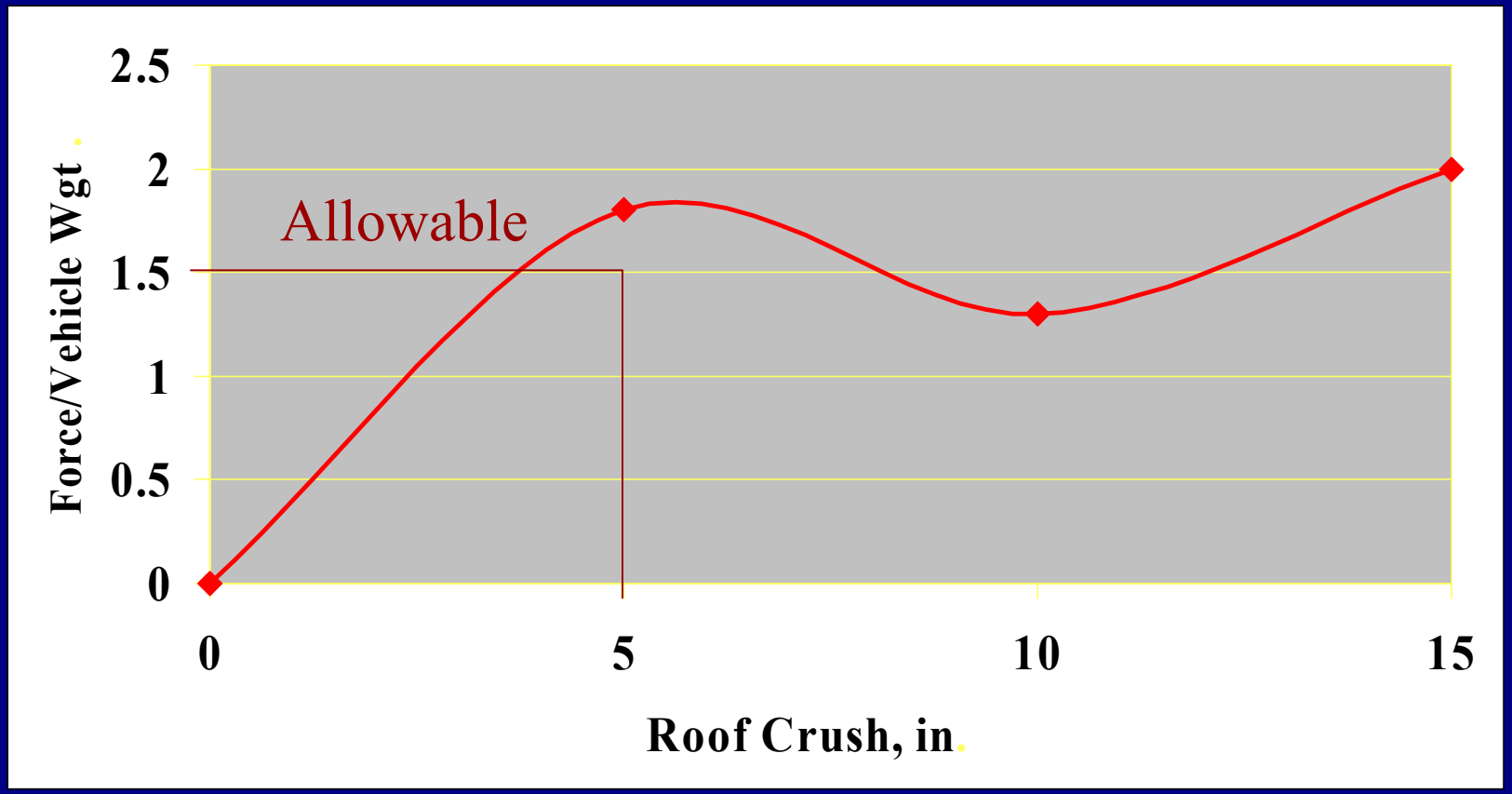
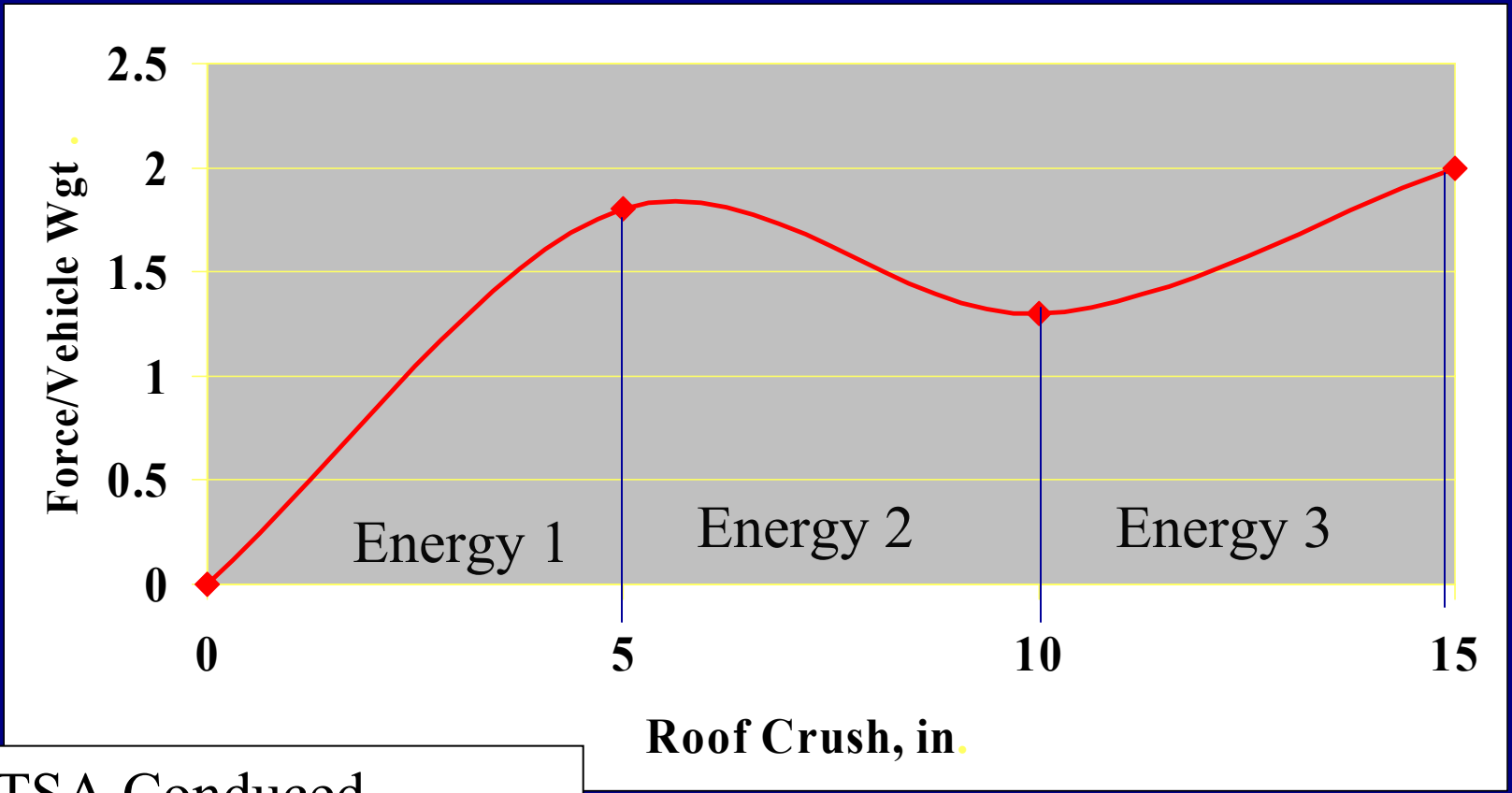
Observation

All vehicles tested easily passed 216

Roof Force vs. Crush Typical of 216 Loading



Roof Force vs. Crush Typical of 216 Loading



NHTSA Conduced
3 Drop Tests from Heights
To Absorb Energy 1, 2 & 3

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NHTSA Drop Test Research

- Dropped 2 vehicle types – with 2 different orientations each and several different drop heights (total of 8 vehicles)
- Drop height based on non-linear static crush test data (Test as in 216, but with 2 test orientations)
- Initial drop test was to achieve the max crush in the crush test (Based on energy 1+2+3)
- Comparative vehicle dropped sequentially three times – Drop heights determined by Energy 1, Energy 2, and Energy 3

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NHTSA Drop Tests
Nissan Pickup

Yr	Make	Energy Area	Nr	Pitch	Roll	Drop Hgt	Roof Crush	Crush Head Clr
89	Nissan	1	8	5	25	7.5	6.8	-0.62
89	Nissan	2	8	5	25	8.0	11.7	-5.54
89	Nissan	3	8	5	25	7.7	12.8	-6.68
89	*Nissan*	*1+2+3*	*7*	*5*	*25*	*23.5*	*11.4*	*-5.23*
89	Nissan	1	5	0	15	9.0	7.0	-0.90
89	Nissan	2	5	0	15	7.5	11.7	-5.58
89	Nissan	3	5	0	15	9.5	14.3	-8.10
89	*Nissan*	*1+2+3*	*4*	*0*	*15*	*26.0*	*13.6*	*-7.43*

Initial Roof Clearance 6.15”

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NHTSA Drop Tests
Dodge Colt

Yr	Make	Energy Area	Nr	Pitch	Roll	Drop Hgt	Roof Crush	Crush Head Clr
89	Dodge	1	4	5	25	8.5	5.3	2.68
89	Dodge	2	4	5	25	11.0	7.6	0.39
89	Dodge	3	4	5	25	13.0	9.5	-1.54
89	*Dodge*	*1+2+3*	*3*	*5*	*25*	*32.0*	*9.8*	*-1.77*
89	Dodge	1	6	0	15	10.0	3.0	5.00
89	Dodge	2	6	0	15	12.0	5.9	2.12
89	Dodge	3	6	0	15	15.5	8.2	-0.20
89	*Dodge*	*1+2+3*	*5*	*0*	*15*	*37.0*	*8.7*	*-0.71*

Initial Roof Clearance 7.99”

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Drop Test Characteristics

- Static test results could be used to predict equivalent drop height in first and subsequent roof loadings.
- In drop test, vehicle rotation absorbs energy.
- Vehicle rotation may vary with roof crush.
- In drop test, hood may impact ground.
- Drop test absorbs more energy than the static test.
- Drop test produces higher peak force.

Drop Test vs. Static Test

- Static test is more repeatable
- Static test produces generally similar damage to drop test
- Drop test is more like the real world
- Drop test permits the use of dummy

- Issue for both:

  Relationship to real world; crash severity

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Roof Crush Tests by NHTSA
Vehicles Tested to 10+ in. of Crush

Quasi-Static Tests

1983	Honda	Prelude
1983	Pontiac	6000
1983	Suburu	GL
1984	Honda	Civic
1984	Honda	Civic CRX
1984	Isuzu	I-Mark
1984	Plymouth	Vista
1984	Plymouth	Conquest
1984	Pontiac	Fiero
1984	Renault	Fuego
1984	Toyota	Corolla
1984	VW	Quantum
1985	Chevrolet	Spectrum
1985	Dodge	Colt
1985	Dodge	Lancer
1985	Renault	Encore

Quasi-Static + Dynamic

1990	Nissan	PU
1989	Dodge	Colt
1990	Chevrolet	Cavalier
1990	Honda	Accord
1991	Chevrolet	Caprice
1991	Ford	Explorer
1990	Chevrolet	C/IK Pickup
1989	Ford	Taurus
1992	Ford	Taurus
1995	Dodge	Neon

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Analysis of NHTSA Roof Crush Tests

- Tests with and without glass bonded in the windshield
- Tests of different vehicle classes
- Tests demonstrating different load deflection characteristics
- Tests comparing 216 test and drop test

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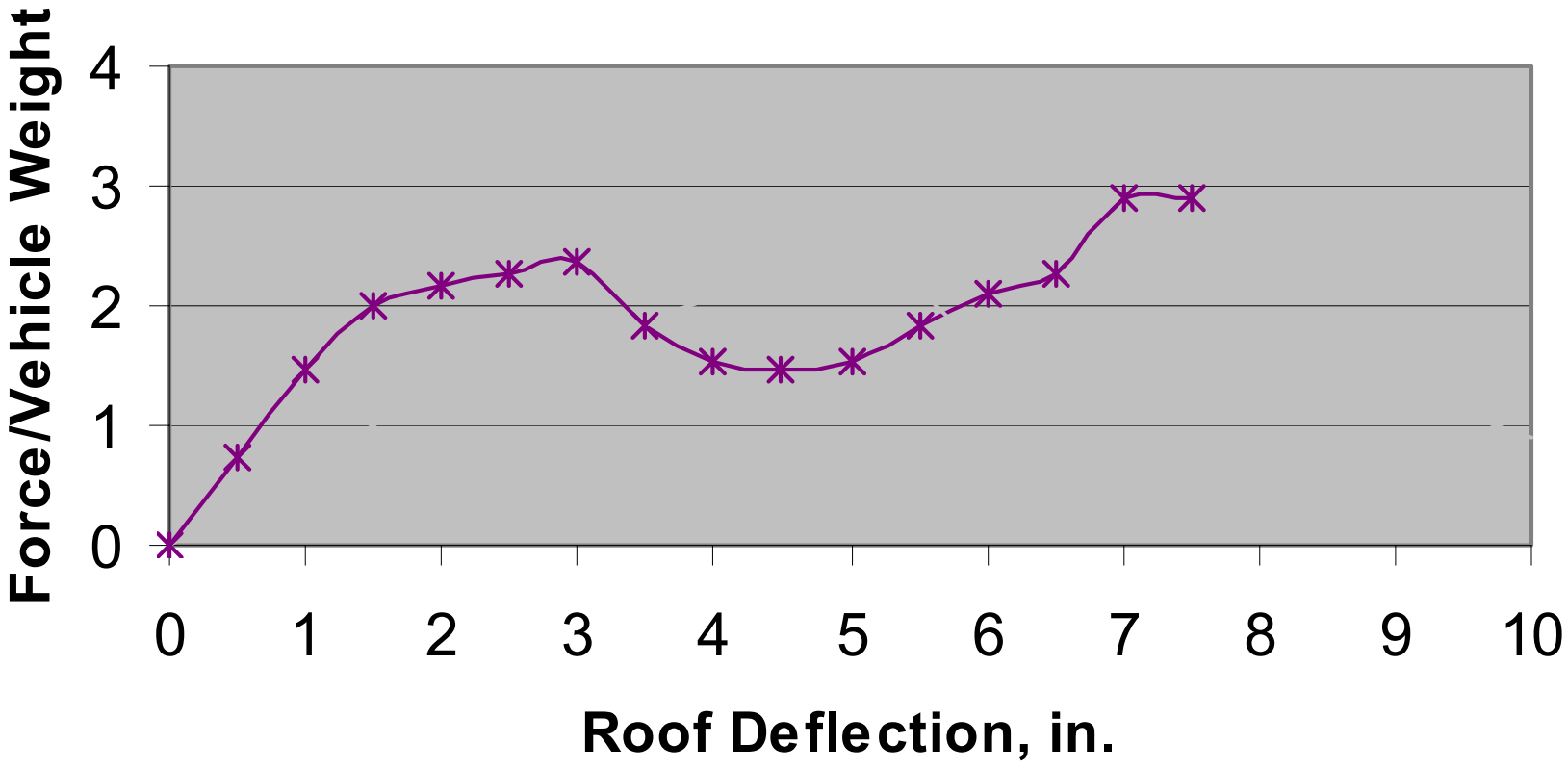
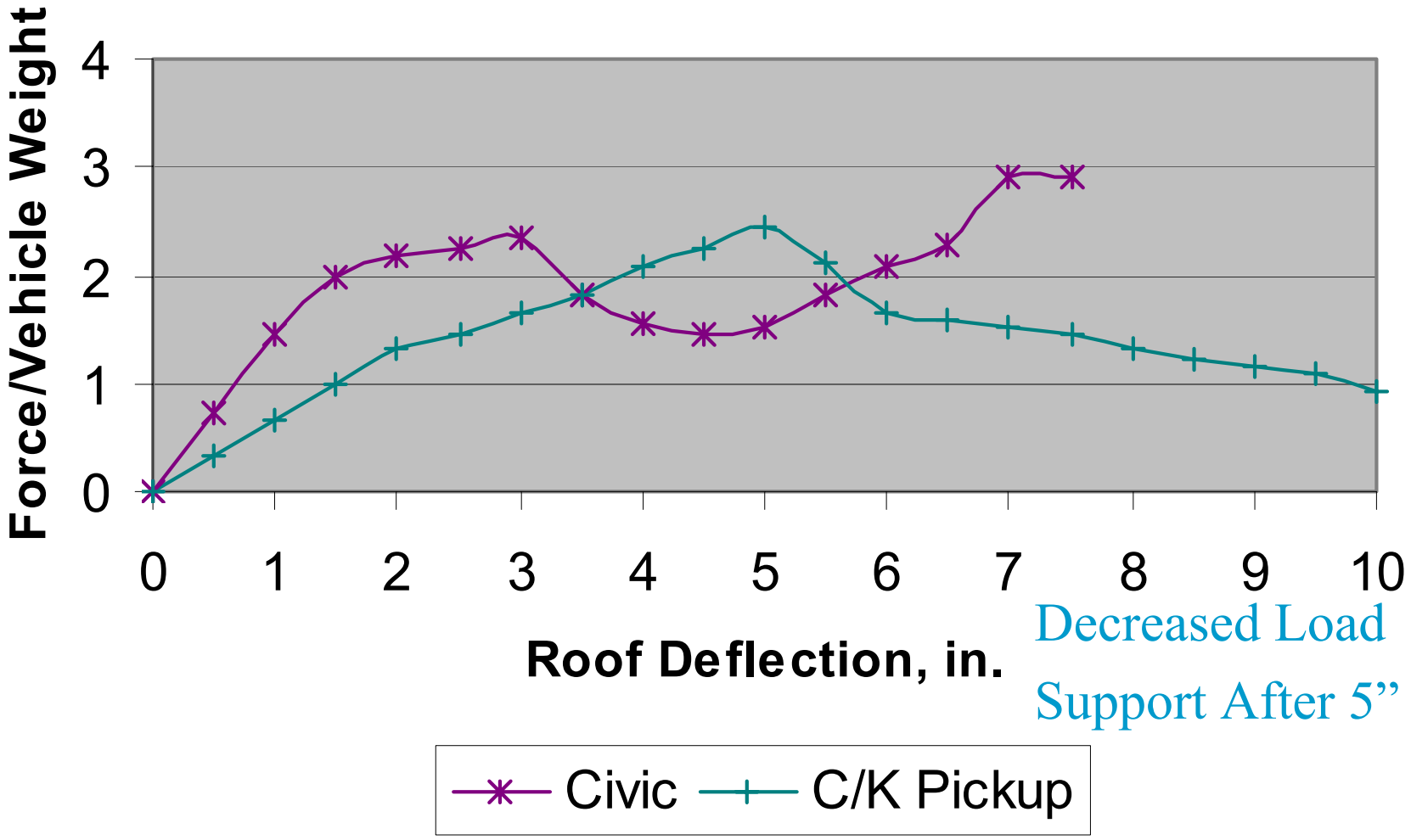
NHTSA Roof Tests – Honda Civic

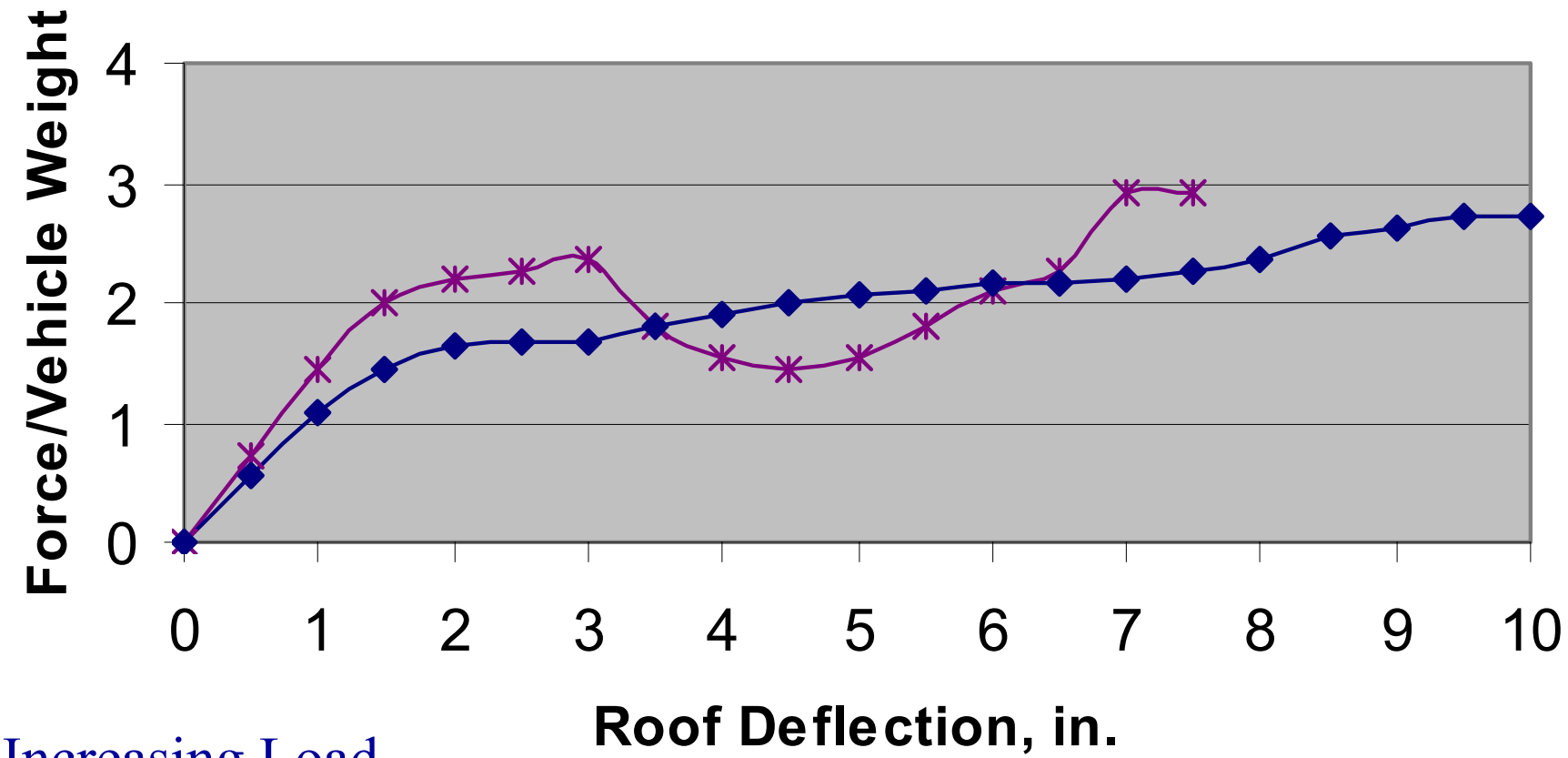


Decreased Load Support After 3”

NHTSA Roof Tests – C/K Pickup

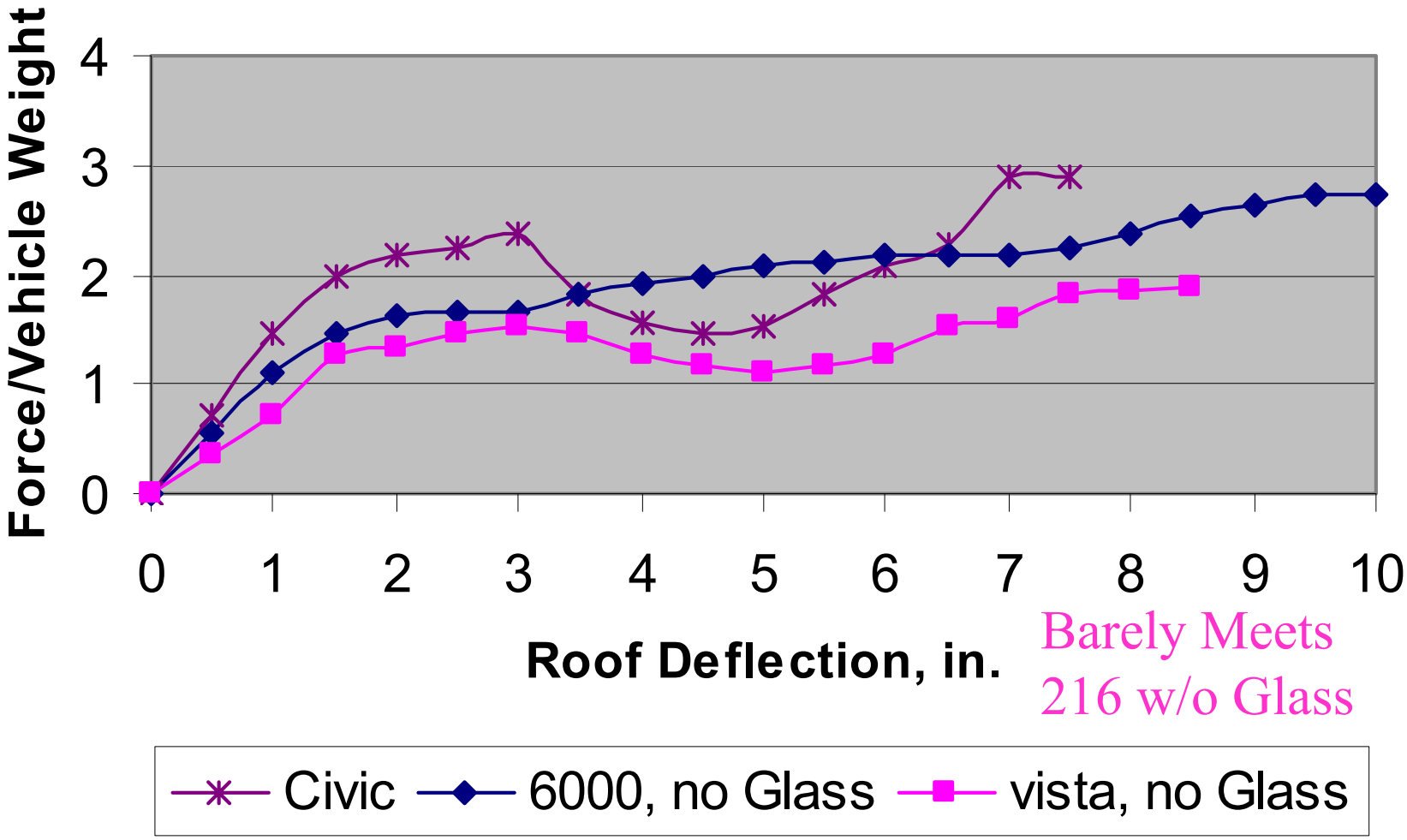


NHTSA Tests – Pontiac No Glass

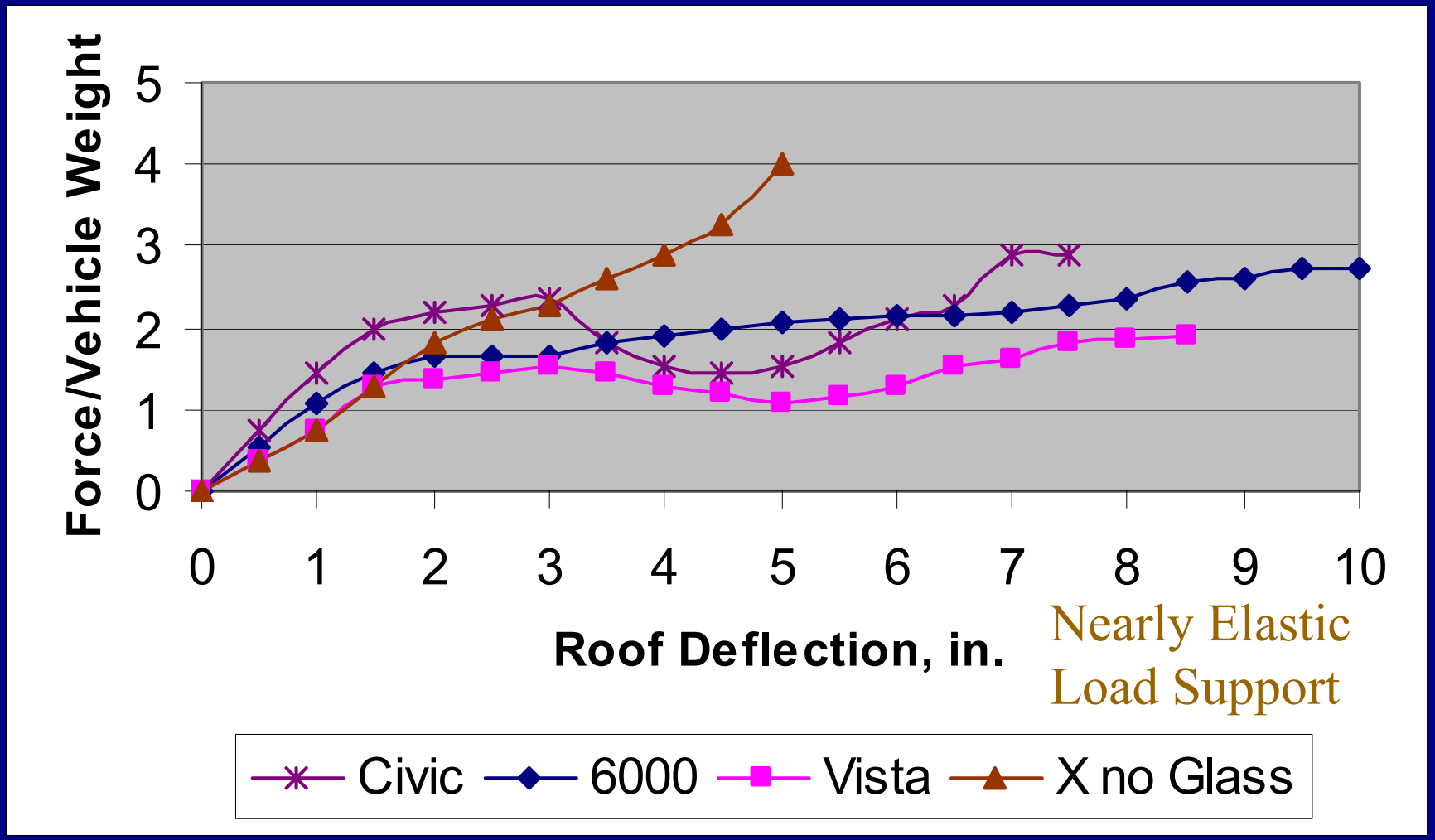


Increasing Load Support After 2”

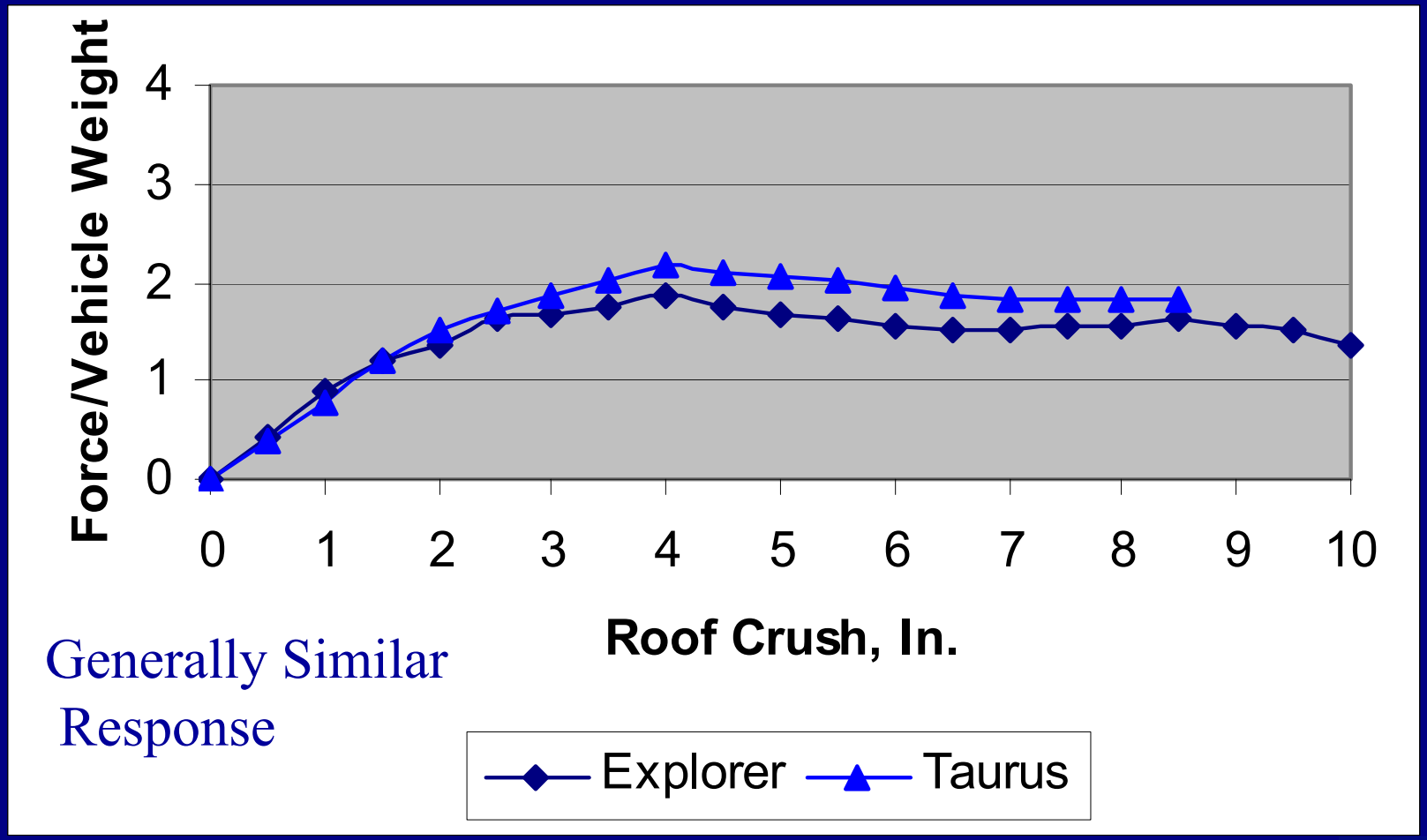
NHTSA Roof Tests - Plymouth



NHTSA Roof Tests – Range

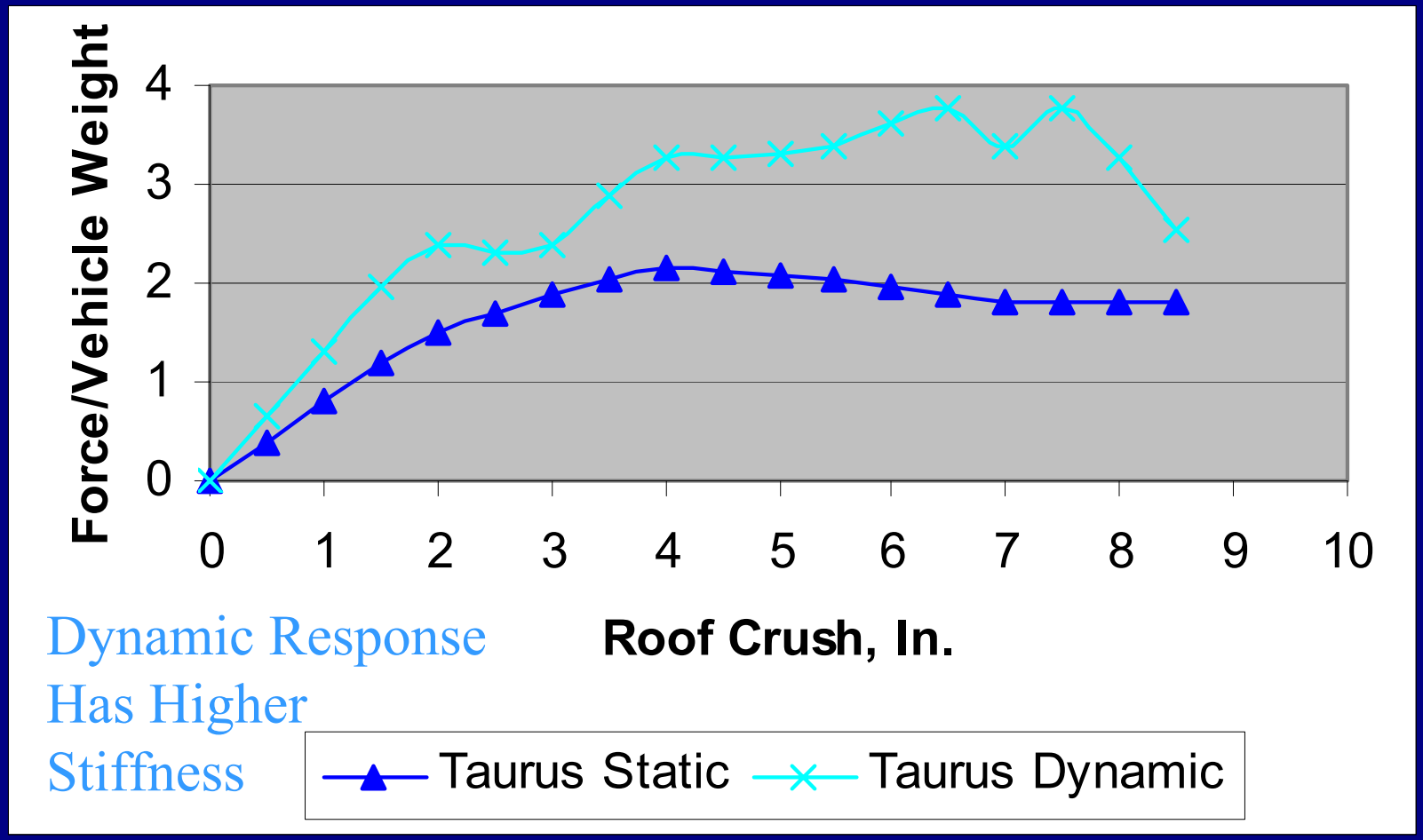


NHTSA Tests – Explorer and Taurus



Generally Similar Response

NHTSA Tests – Static vs. Dynamic



Dynamic Response Has Higher Stiffness

Dynamic Rollover Tests

- NHTSA 208 Rollovers ~ 30
- NHTSA Roll Cart Rollovers ~ 15
- Rollovers from Litigation ~ 20
- Rollover from ASRI – C/K Pickup
- Crush Test from NHTSA – C/K Pickup
- Drop Test from Litigation – C/K Pickup
- GW FEM Model for NHTSA – C/K Pickup

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Other Vehicle FEM Models Developed by GWU

- Taurus
- Caravan
- Neon
- GM C/K Pickup

- Initial Roof Crush Model – GM C/K Pickup

Additional Testing Required

- Quasi-static testing under loading conditions different from 216.
- Drop testing at different orientations from the 216 configuration.
- Roof testing and evaluation of production vehicles believed to have superior roof strength.
- Roof testing and evaluation of modified vehicles with improved roof strength.

Ongoing Research

- Rollover Roof Crush Sponsored by the Santos Family Foundation

NHTSA Rollover Crash Severity Project

- In Dec 2001 NHTSA placed high priority on developing a severity index for rollover.
- Considered a prerequisite for a roof crush standard.
- Assigned personnel to project.
- Initiated a cooperative project with GW.
- GW Roof Crush Research Project slightly broadened to accommodate opportunity to assist NHTSA.

Rollover Severity Research Project

Ms. Eigen

- Analysis of rollover accident data supplemented by modeling to assess distributions by:
  - Number of quarter turns
  - Extent of roof crush
  - Roll rate
  - Vertical velocity
  - Most harmful event
  - MAIS 3+ injuries by body region

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Harmful Factors that Contribute to Roof Crush

Mr. Lier and Mr. Godrick

- Conduct vehicle tests and film analysis to calibrate and validate computer models.
  - Instrumented vehicle test conducted Oct 2001
  - Additional data available from other tests (drop tests)
- Develop FEM computer models to study factors that contribute to roof crush.
- Exercise computer models; determine critical values for vehicle orientation, vertical velocity, roll rate

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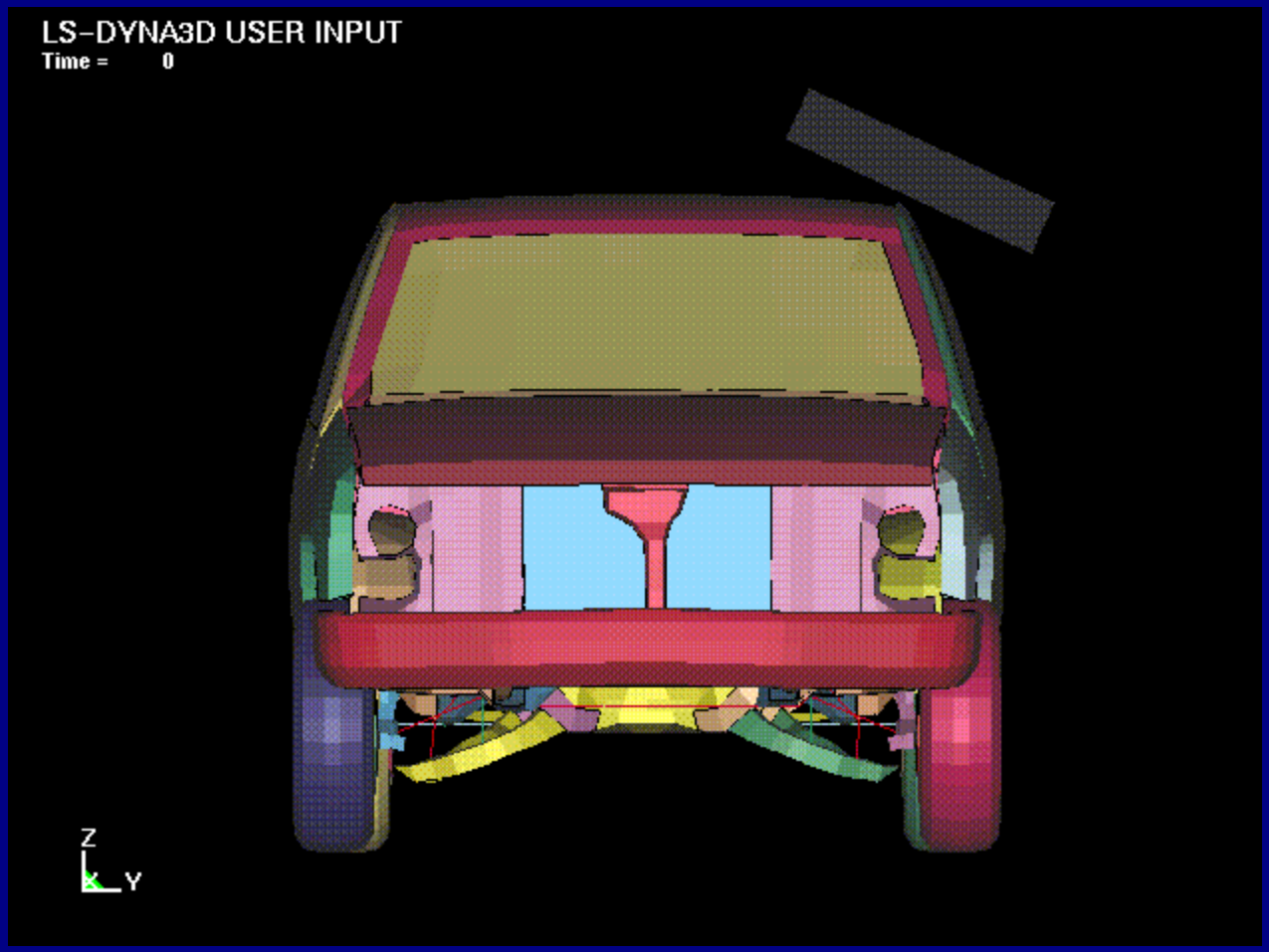
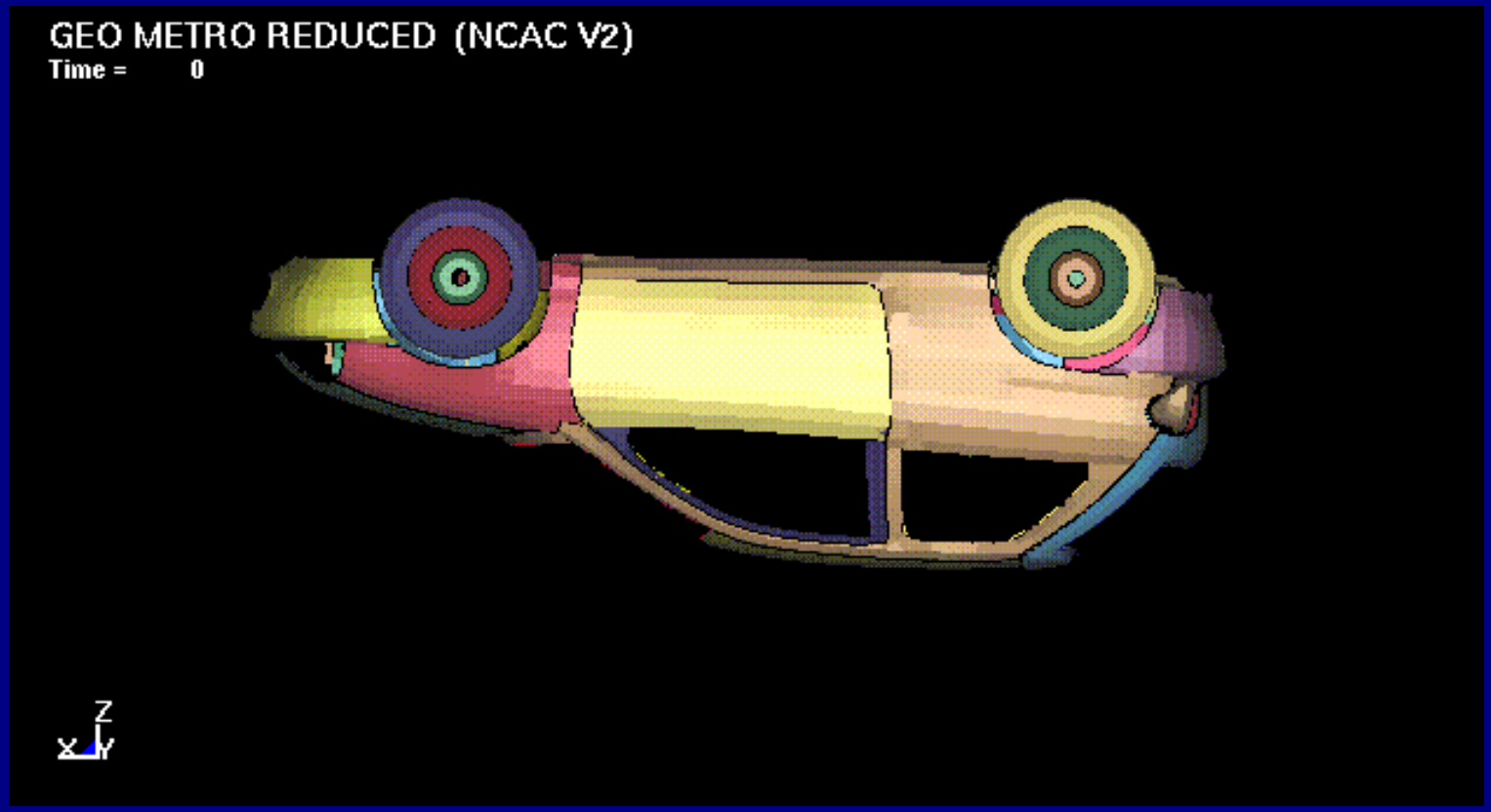
FEM Model Static Test - Pickup



FEM Drop Test



Harmful Factors During Roof Impact

Ms. Eigen & Mr. Burel

Vehicle/occupant modeling to:

- Determine the contribution of roof intrusion to occupant injury.
- Determine population of injuries that could be mitigated by increased roof strength.
- Determine the recommended vertical and horizontal velocity and vehicle orientation for roof crush testing.

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Coordination

- Work is being coordinated with NHTSA
- Briefing to Ford Motor Company staff-
  - Data for model validation requested
- Briefings to Public Citizen and Center for Auto Safety
- Advise from Carl Nash and Don Friedman
  - Subcontract with Don Friedman for Improved Roof Design