Hugh DeHaven:
Still Relevant for Rollovers

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Objectives of the Presentation

Interpret dynamic rollover test results by applying DeHaven’s principles

Hugh DeHaven: A Pioneer of Occupant Crash Protection

- Injured in a mid-air crash in 1917
- Studied why different injury outcomes occur in the same crash.
- 1942 - a research associate at Cornell University Medical College; established Cornell Crash Injury Research (CIR) Program.
- 1950's in-depth crash investigations
- In 1952 he published *the most important paper* on the fundamentals of crash survivability.

Hugh DeHaven
1895- 1980

DeHaven’s Principles

Hugh De Haven: *Accident Survival – Airplane and Passenger Automobile*, Society of Automotive Engineers, January 1952, a seminal paper in our field.

”. . . the first principle followed by packing engineers: this principle states that the package should not open up and spill its contents and should not collapse under reasonable or expected conditions of force and thereby expose objects inside it to damage.”

. . . .

The vehicle occupant compartment should* contain its occupants (no ejection) *and* should not collapse *under reasonable or expected conditions of force.

"The second principle considered by packaging engineers is closely related to the first: it states that packaging structures which shield the inner container must not be made of brittle or frail materials; they should resist force by yielding and absorbing energy applied to the outer container so as to cushion and distribute impact and thereby protect the inner container. Either by good fortune or good design this second packaging principle is represented in most of the protective structures ahead of, and behind, passenger compartments in automobiles as well as in small airplanes."

The materials that surround and shield the occupant compartment should be capable of resisting crash forces by yielding and absorbing energy.

“The third principle of good packaging states that articles contained in the package should be held and immobilized inside the outer structure by what packaging engineers call interior packaging. This interior packaging is an extremely important part of the over-all design, for it prevents movement and resultant damage from impact against the inside of the package itself.

. . . .

“The driver thereby avoids being thrown against dangerous structures inside the car during the crash deceleration – and simultaneously he takes full advantages of the cushioning effects provided by collapse of forward structures. . . .”

Vehicle occupants should be restrained within the occupant compartment to prevent the second collision.

(injurious impact with the interior of the occupant compartment).

Padding must be provided for parts of the occupant compartment that the occupant might strike.

“This fourth packaging principle says that the wadding, blocks, or means for holding an object inside a shipping container [i.e. safety belts] must transmit forces to the strongest parts of the contained objects. This principle certainly is not complicated; . . . . It is this principle which governs the placement of safety belts in aircraft so as to transmit crash loads to strong skeletal structures in the pelvic area of the human body.”

Occupant restraints must apply their forces to the strong parts of the occupant skeleton (the pelvis and rib cage). **DeHaven proposed the 3-point belt concept. Nils Bolen developed production 3-point belts in Volvo’s**

DeHaven Protection Applied to Rollovers

- The roof/pillars must resist intrusion.
- The occupant compartment must not permit ejection.
- Occupants must wear safety belts *that work well under the dynamics of a rollover*.
- Critical areas of the interior must be appropriately padded.

Santos/CFAS JRS Tests

- Sponsored by:

  Santos Family Foundation
- Vehicles provided by:

  State Farm
- 10 Vehicles tested
- Vehicles were tested twice (2 roof impacts) using the Jordan Rollover System (JRS) with Hybrid III dummies by Center for Injury Research
- NHTSA conducted FMVSS 216 tests on the same vehicles

Tested Vehicles

4-door Passenger Cars

- 2006/07 Pontiac G6
- 2006 Chrysler 300
- 2006 Hyundai Sonata
- 2007 Toyota Camry
- 2007 Volkswagen Jetta

Light Trucks

- 2006 Honda Ridgeline
- 2007 Jeep Cherokee
- 2007 Chevrolet Tahoe
- 2007 Honda CRV
- 2005 Volvo XC90

What We Have Learned

- Some vehicles –performed well in both FMVSS 216 and the JRS tests
  - VW Jetta
  - Volvo XC90
- Some performed ok on 216 but poorly on the JRS tests
  - Honda Ridgeline
  - Pontiac G6.

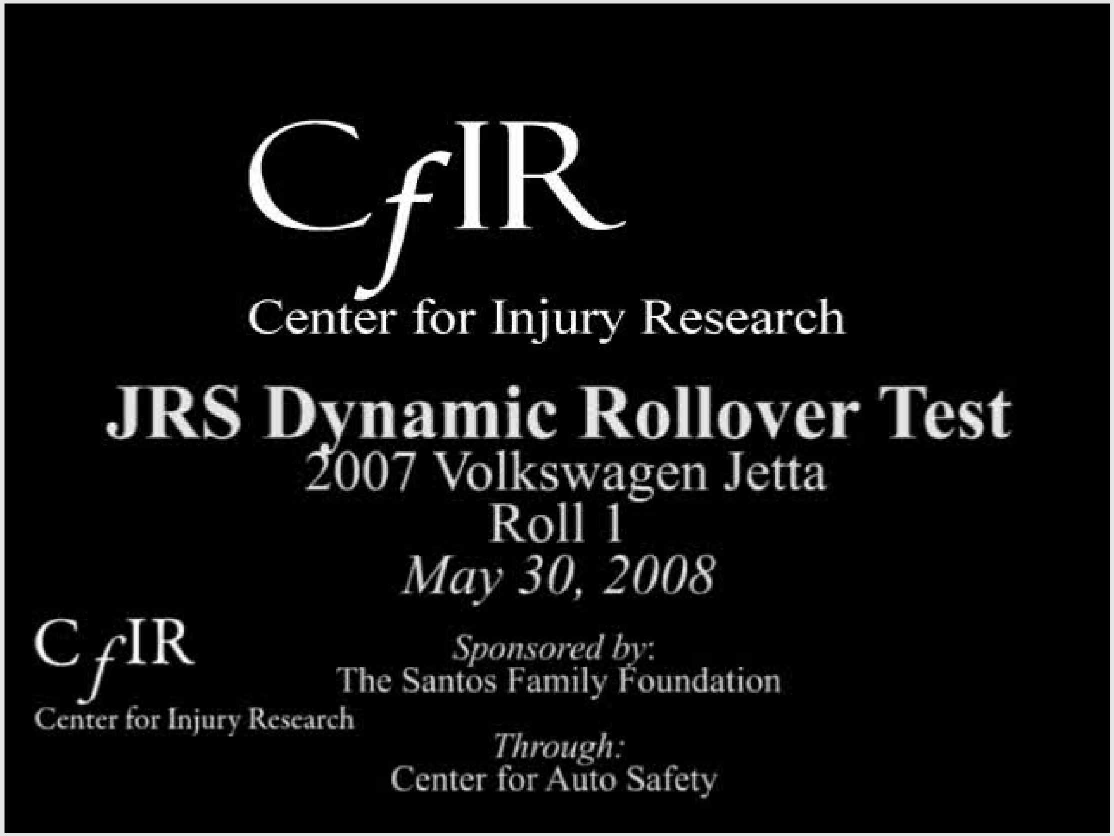
What We Have Learned

- The far-side of the roof always suffered the most damage.
  - The far-side must halt the fall of the vehicle and then lift it or crush.
  - The near-side roof strength can reduce far-side loads.
- Side windows did not break if the roof crush was limited.
  - Even tempered side glazing can be protected by limiting roof crush. (Ejection prevention)

What We Have Learned

- ***Vehicles with strong roofs stop the vehicle's fall with the near-side impact.***
  - ***The far-side doesn't have to stop the fall and lift the vehicle again.***

What We Have Learned



JRS test of VWJetta and Pontiac G6

What We Have Learned

- In the JRS test, there is often damage to the front fenders indicating a pitch of at least 10º.
  - The far-side load direction is 10º or greater.
- Vehicle tests of maneuver induced rollover indicate a tendency of the vehicle to pitch forward during the rollover.
- The roof should withstand loading at a pitch 10º or greater

What We Have Learned

- Video of Rollover Test

What We Have Learned

- When a vehicle rolls it often initially yaws.
- ***Thus, the forces on the roof are not only concentrated on the forward part of the roof, they pitch the vehicle forward putting most of the force over the A pillar.***
- This shows why the 5º pitch angle of FMVSS 216 is too shallow.

What We Have Learned

- Some vehicles have strong B pillars, apparently to improve their side impact protection.
  - The Subaru Forester, which C*f*IR used for JRS repeatability testing, is a good example.
- Many vehicles also have strong A pillars and roof rails to improve offset frontal performance.
- These improvements also enhance rollover protection performance.

What We Have Learned

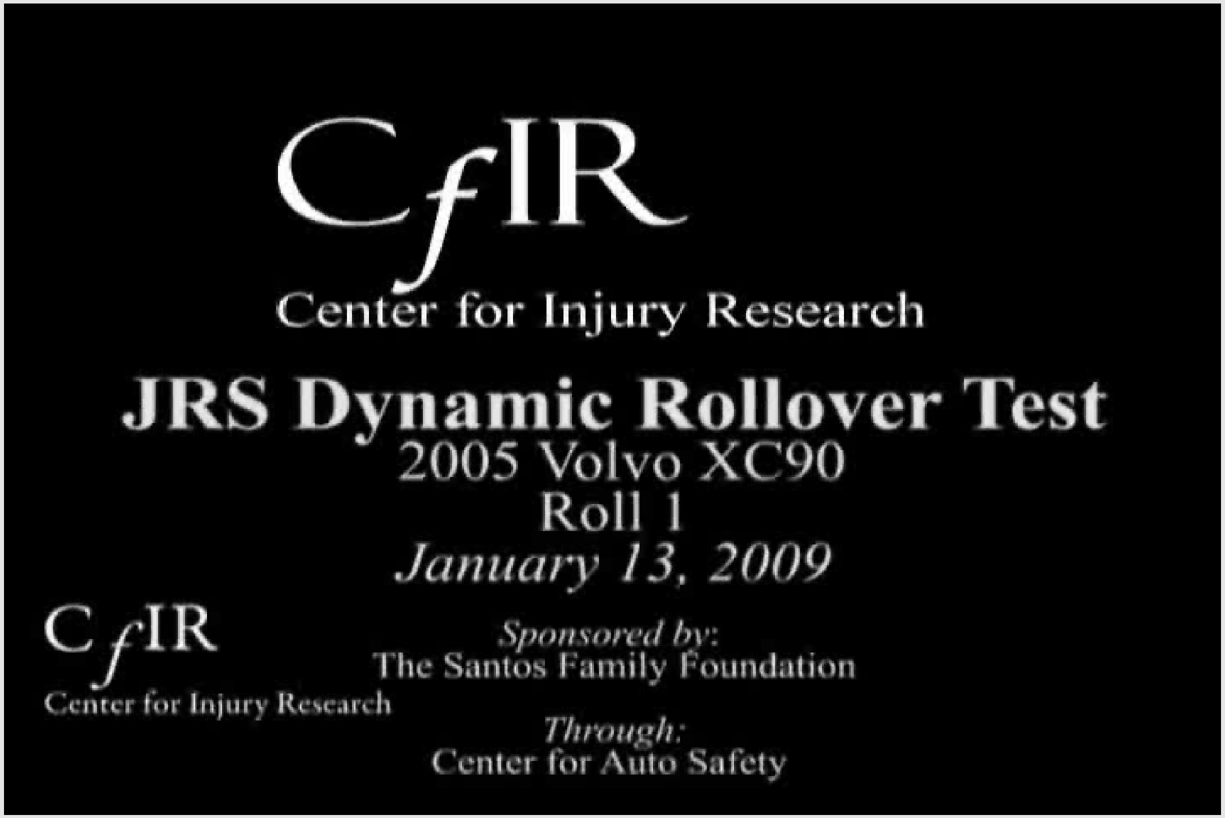
- However, a weakness of many vehicles – even some with otherwise strong roof structures – was that the windshield headers buckle.

2007 Toyota Camry after second roll on the JRS

What We Have Learned

- ***Vehicles with strong roofs can perform well in a second rollover***

What We Have Learned



Volvo 1st and 2nd roll tests

What the JRS Tests Show

- The impact of geometric shape (the squareness of the Honda Ridgeline was part of the reason for its poor performance)
- The importance of a roof with elastic response (like the Volvo XC90 and VW Jetta) in comparison with plastic response (Pontiac G6).
- The dynamic effect of the leading side roof impact on what happens to the second side.
- A dynamic test is critical to evaluate rollover safety performance.

What Next?

- The JRS has substantially advanced rollover research and testing.
- A second generation JRS is under development that will reduce costs and simplify testing.
- Other organizations, including the University of New South Wales, are procuring the JRS.
- We are developing an alternative approach that tests in a stationary, inertial frame of reference.
- We plan an expanded rollover research program at the GW National Crash Analysis Center

Some Further Thoughts

- Because the forces of rollovers are inherently low, the use of dummies to measure the potential for injury is less important in rollovers than in frontal and side crashes.
- Rather, DeHaven shows what we knew in 1970: that the primary rollover issues are:
  - occupant ejection primarily because of lack of restraint use and breakage of side windows
  - rapid and extensive roof intrusion because of plastic structural buckling and collapse
- We must go back to first principles.

DeHaven Protection Applied to Rollovers

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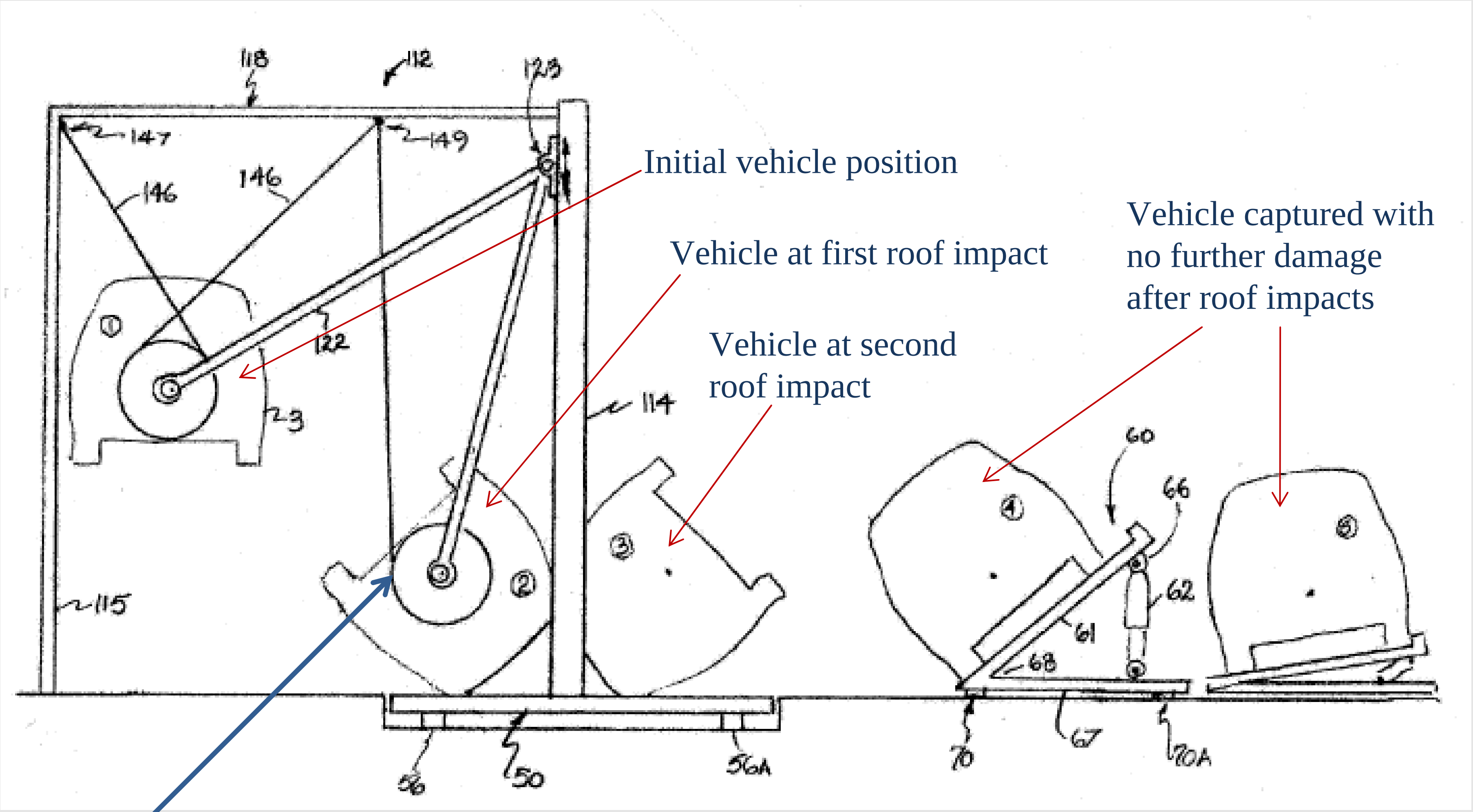
JRS Initial Conditions at Drop

- Pitch 5 degrees
- Yaw 10 degrees
- Rotation speed 190 degrees/sec
- Free fall 10 cm
- Roadbed Speed 15 mph
- Roll angle at impact 145 degrees

- Second Test – Pitch 10 degrees

Another Concept for a Dynamic Rollover Test



The cables and pulleys at the ends of the vehicle impart the appropriate roll angle and roll rate as the vehicle drops. The vehicle's potential energy is fully transformed to the lateral and rotational kinetic energy for the roof impacts.