Observations from the Angus Tornado, 2014 June 17

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Objectives of Presentation

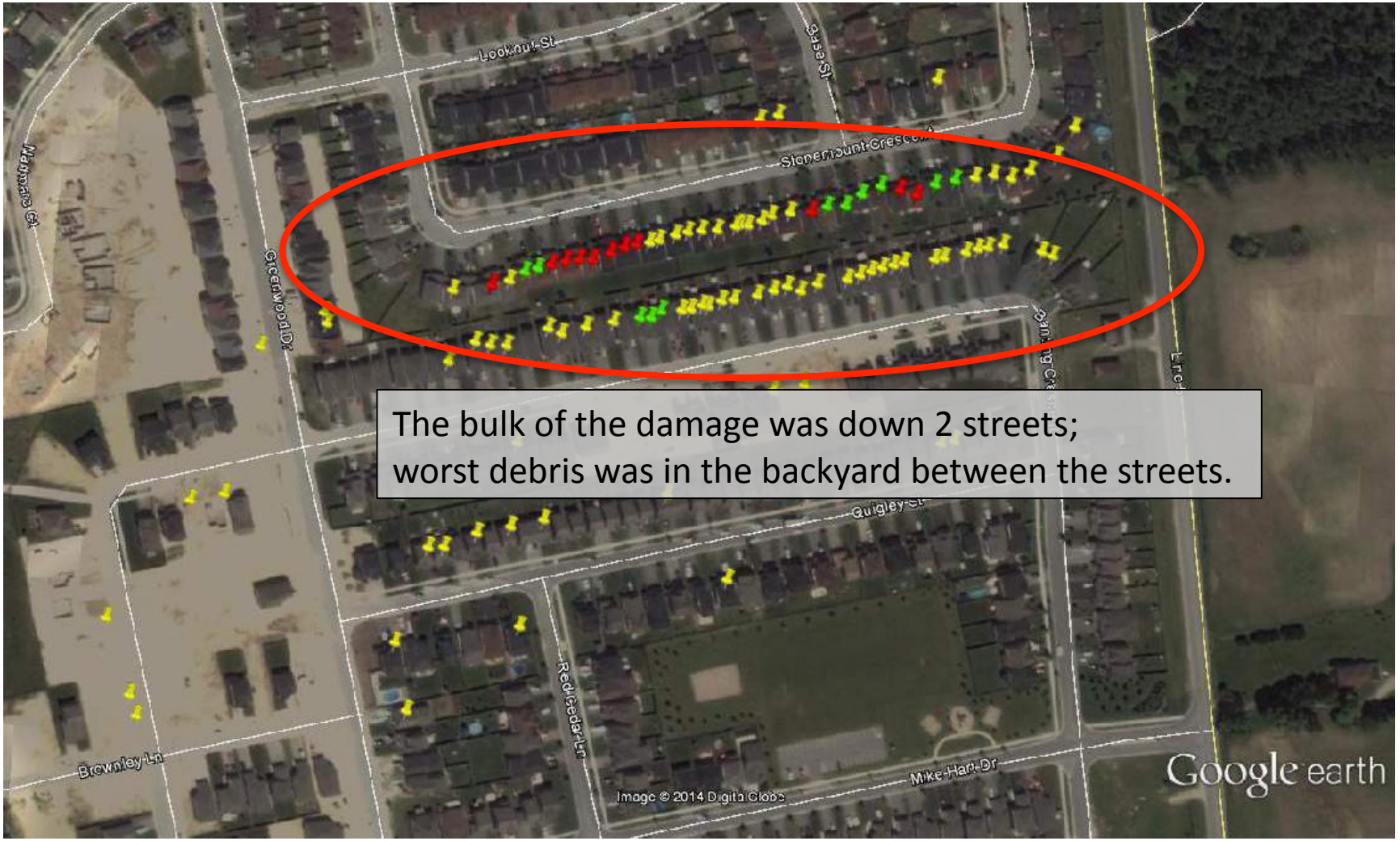
- Overview of damage in Angus
- Patterns of damage/EF-Scale ratings
- Comparisons with damage observations from the 2009 Vaughan Tornadoes
- Discussion about mitigating tornado damage

Damage track of the Angus Tornado

Preliminary track courtesy of Environment Canada

Summary of Damage to Houses

101 houses with damage were identified in Angus:



Google earth

feet 1000

meters 300

Summary of Damage to Houses

101 houses with damage were identified in Angus:

Damage	Quantity
Fascia/Soffits/Eaves	36
Siding	28
Shingles	48
Roof Sheathing	11
Roof Failure (roof-to-wall connections)	11
Walls (structural)	9
Porch Columns	4
Evidence of Debris Impact	18
Garage Doors	9
Broken windows	23
Bricks	4
U-Haul Truck Overturned	1

Summary of Damage to Houses

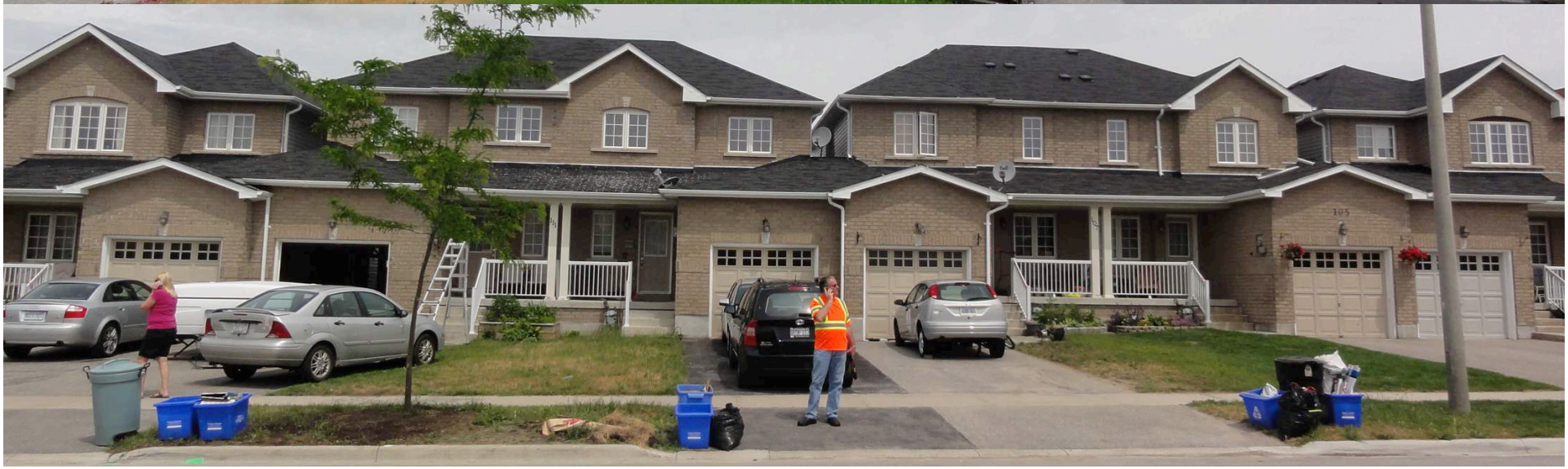
…views from the backyards, between these two streets

Summary of Damage to Houses

Red = houses with roof-to-wall-connection failures (ie, roof is gone)
Green = roof sheathing (ie, small part of roof is gone)
Yellow = everything else.

The bulk of the damage was along two streets; however, the major structural roof damage (~22 houses) was along only one street


110
112

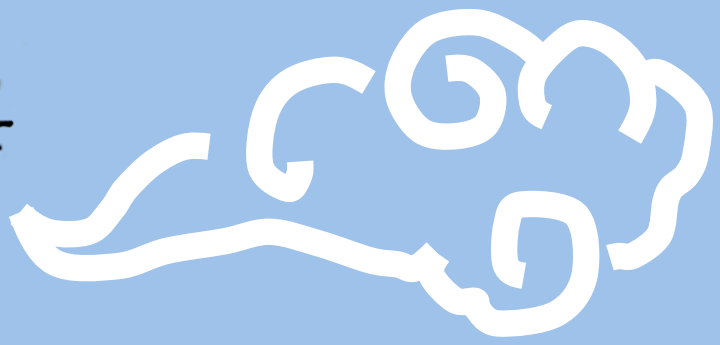


Summary of Damage to Houses – Structural Roof Failures

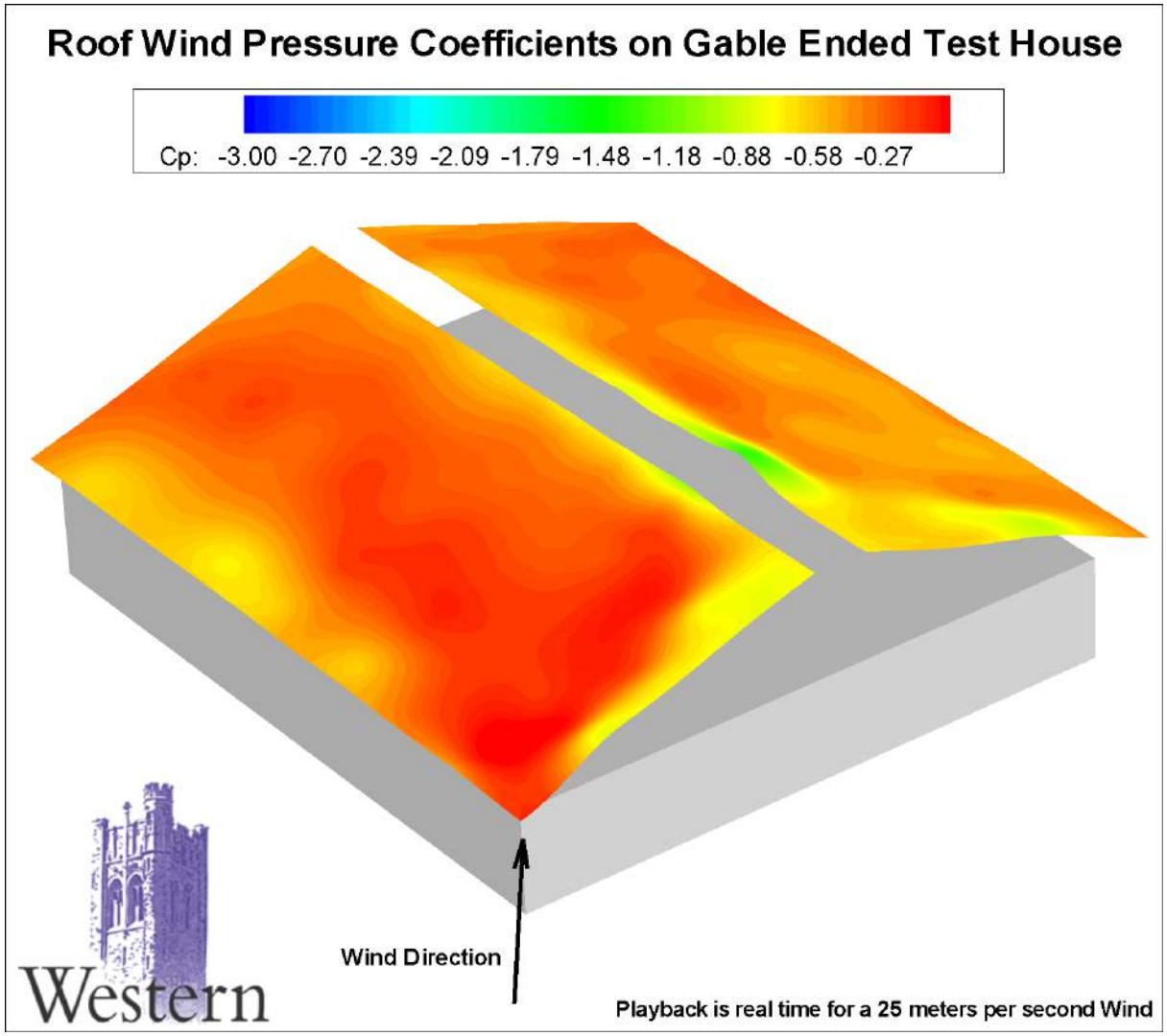
Angus….7 houses in row!

WHAT DOES THE WIND DO TO A HOUSE:

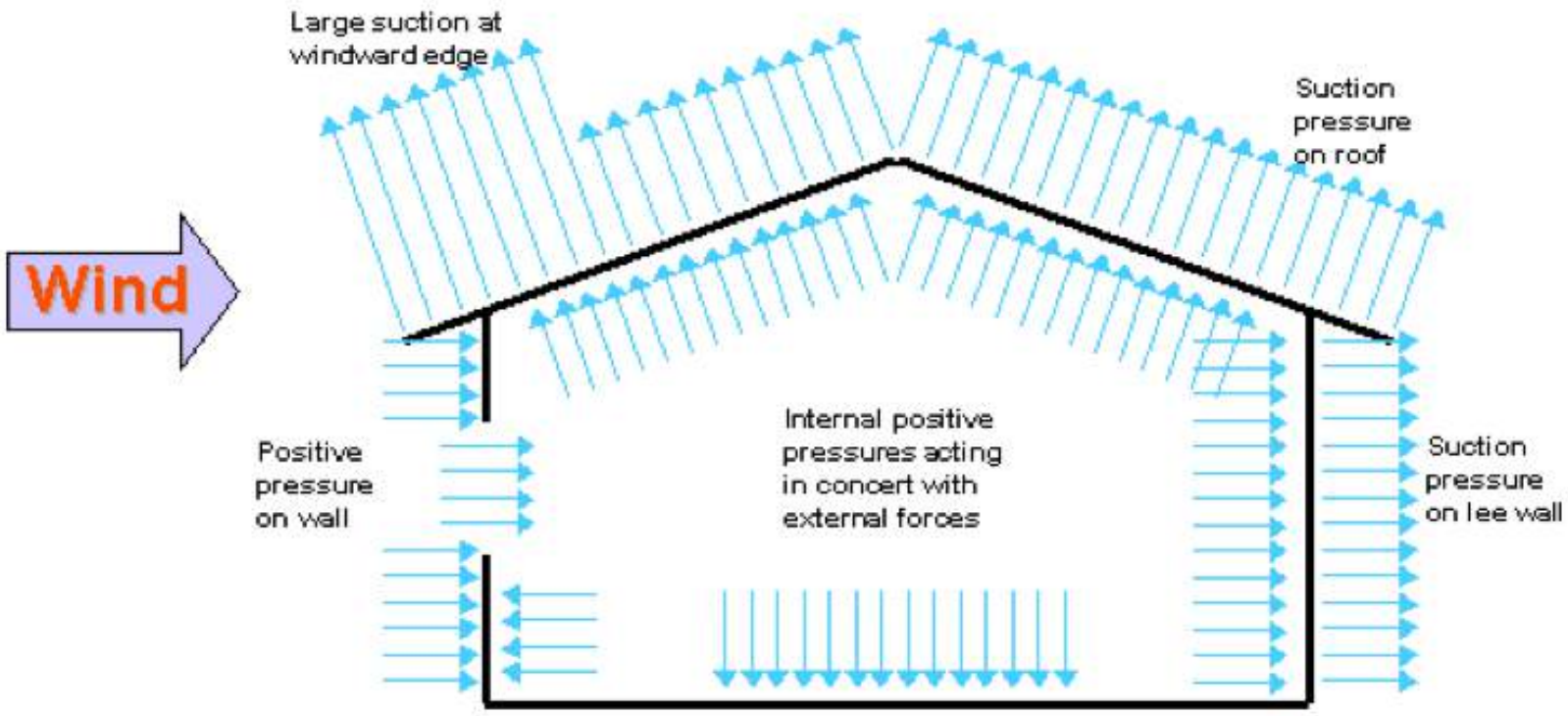
Imagine turning a house upside down…
hanging weights off the roof…
and shaking it…



Wind Induced Pressures on the Roof of a House



Internal Pressurization often leads to roof failures



Peak internal pressures depend on several parameters…basically the positive wall pressure is transferred into the interior volume

Large windward wall opening – internal pressurization – roof failure

VAUGHAN, 2009


These were the correct nails… but there are only 2, not 3
VAUGHAN, 2009


The neighbour's house… very minor shingle damage
VAUGHAN, 2009
159

Summary of Damage to Houses – Structural Roof Failures

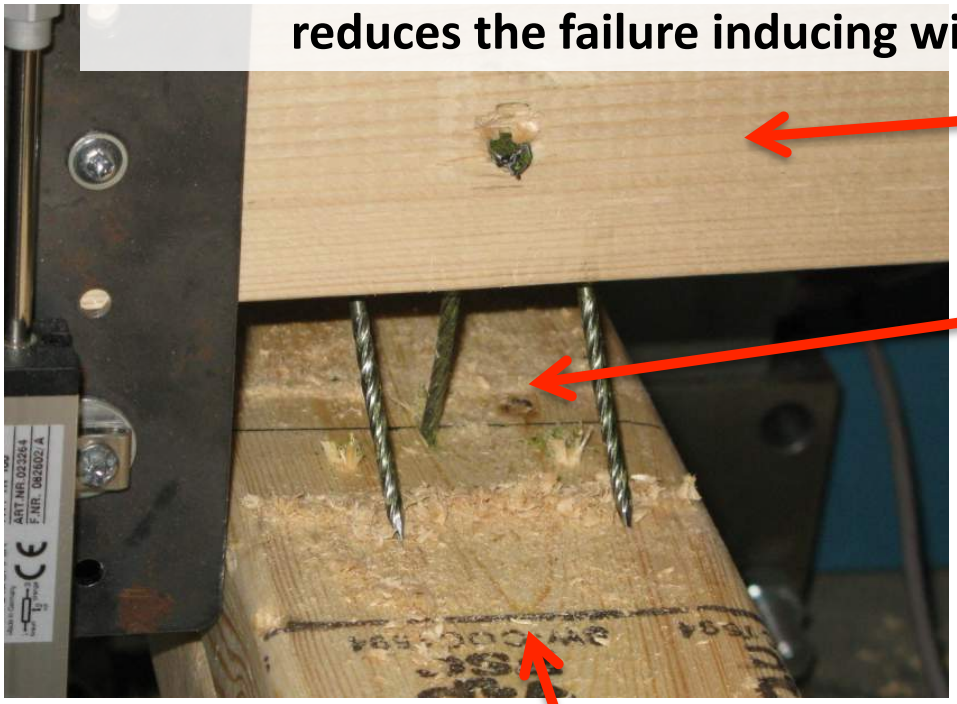
Incorrect toe-nailed, roof-to-wall-connections were prevalent

Full-scale tests at the “3 Little Pigs” project

Summary of Damage to Houses – Structural Roof Failures

Lab tests of toe-nailed connections

Our preliminary analysis suggests that 2 missing nails per connection reduces the failure inducing wind speed by about 40%



Roof truss

A toe-nailed connection (after withdrawal from top plate in lab test).

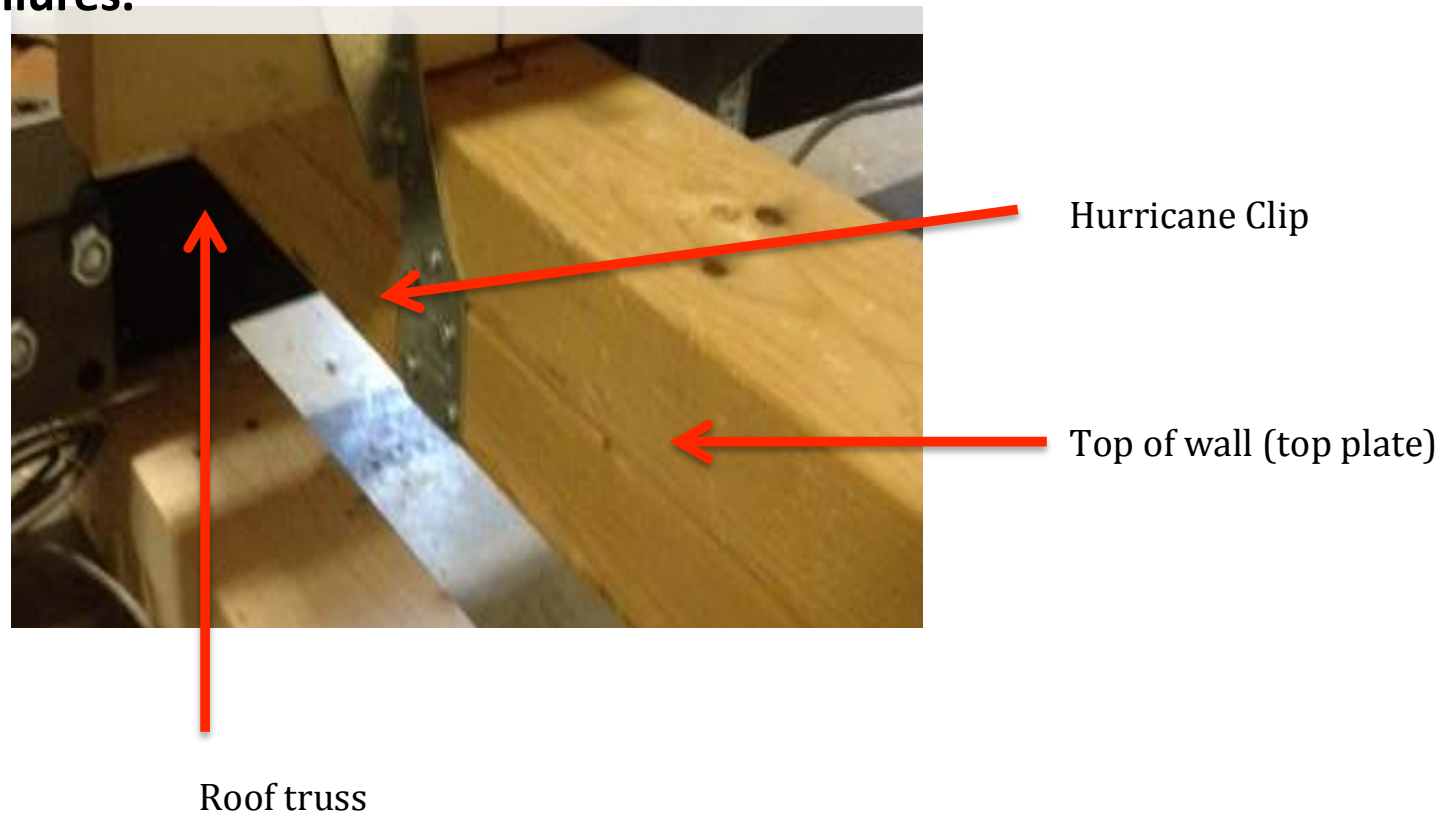
The building code requires 3 nails to connect each roof truss to the top plate of the walls.

Top of wall (top plate)

Summary of Damage to Houses – Structural Roof Failures

In contrast, inexpensive hurricane clips roughly double the capacity.
Our analysis of the Vaughan Tornado suggests that these would have kept the roofs on in these events.

We are still analyzing the wind speeds that may have caused these failures.



Analysis of Roof Damage

Barrie Tornado, 1985

Analysis of Roof Damage

Looking at this Barrie photo...

- Peak coefficient for hip roof is about 0.8. For a two storey gable it is about 1.2 (50% larger)
- Hip roofs have larger capacity due to connections on all 4 walls, compared to two walls for gable.
- These two factors lead to about a 40% difference in failure wind speed, all else being equal.

… although the damage is clearly DOD-6, we are still analyzing the wind speeds that may have caused the Angus roof failures.

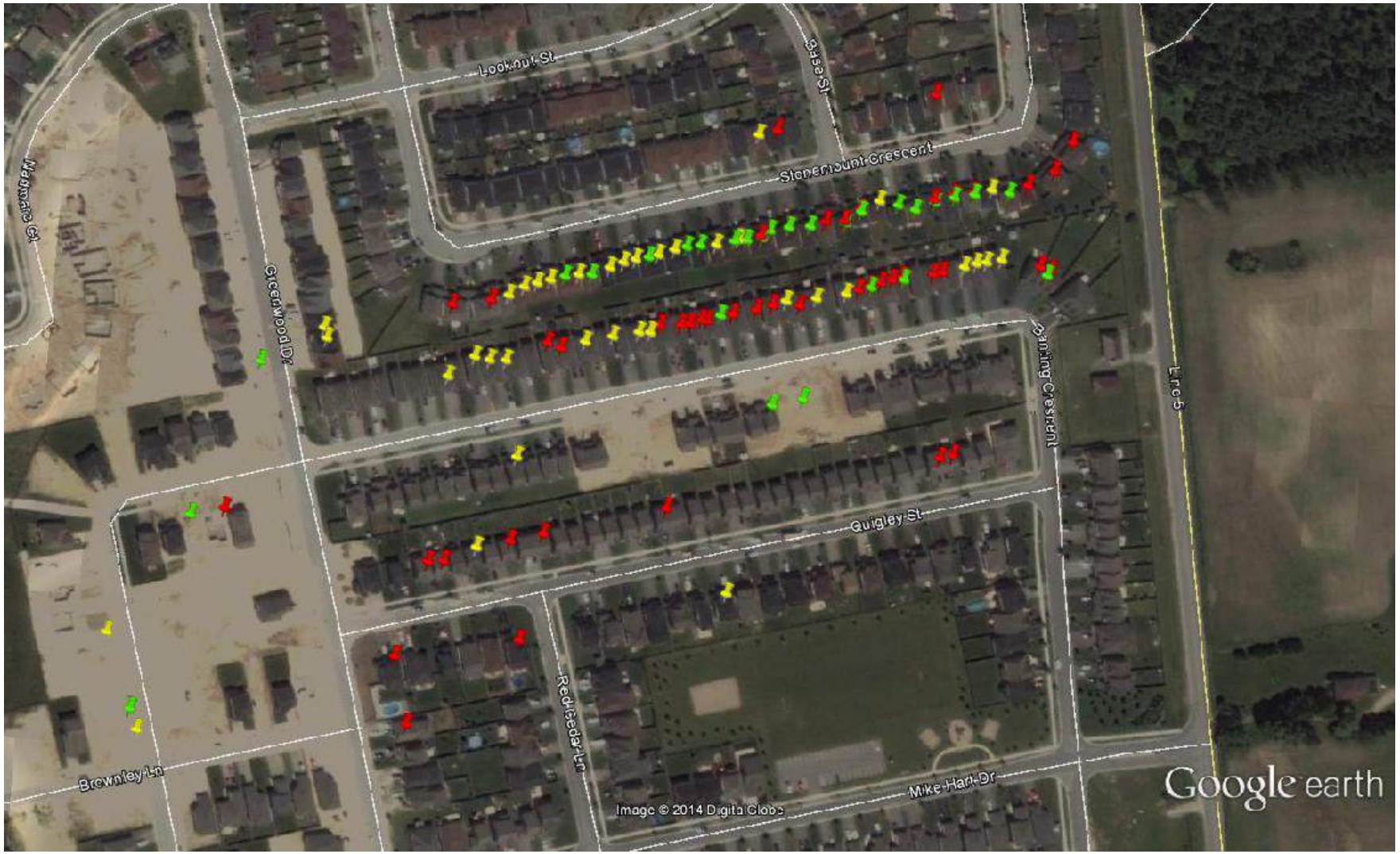
EF-Scale and Degrees of Damage (DOD) for Houses

EF-Scale Rating	Wind speed (km/hr)
0	90 – 130
1	135 – 175
2	180 – 220
3	225 – 265
4	270 – 310
5	315 or more

Degree-of-Damage	Damage Description	Expected value (km/hr)	Lower bound (km/hr)	Upper bound (km/hr)
1	Threshold of visible damage	105	85	129
2	Loss of roof covering material (less than 20%), gutters and/or awning; loss of vinyl or metal siding	127	101	156
3	Broken glass in doors and windows	154	127	183
4	Uplift of roof deck and loss of significant roof covering material (20% or more); collapse of chimney; garage doors collapse inward; failure of porch or carport	156	130	187
5	Entire house shifts off foundation	195	168	227
6	Large sections of roof structure removed; most walls remain standing	196	167	229
7	Exterior walls collapsed	212	182	246
8	Most walls collapsed, except small interior rooms	245	204	286
9	All walls collapsed	274	229	319
10	Destruction of engineered and/or well-constructed residence; slab swept clean	322	266	354

Summary of Damage to Houses – Cladding

Red = shingles; Green = siding; Yellow = everything else



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Vehicles – the overturned U-Haul truck

Vehicles are not included in the EF-Scale
…but they were in the original Fujita Scale

Damage observations near overturned U-Haul truck

Repetitive shingle damage (> 20% of roof)

Some garage doors blown in

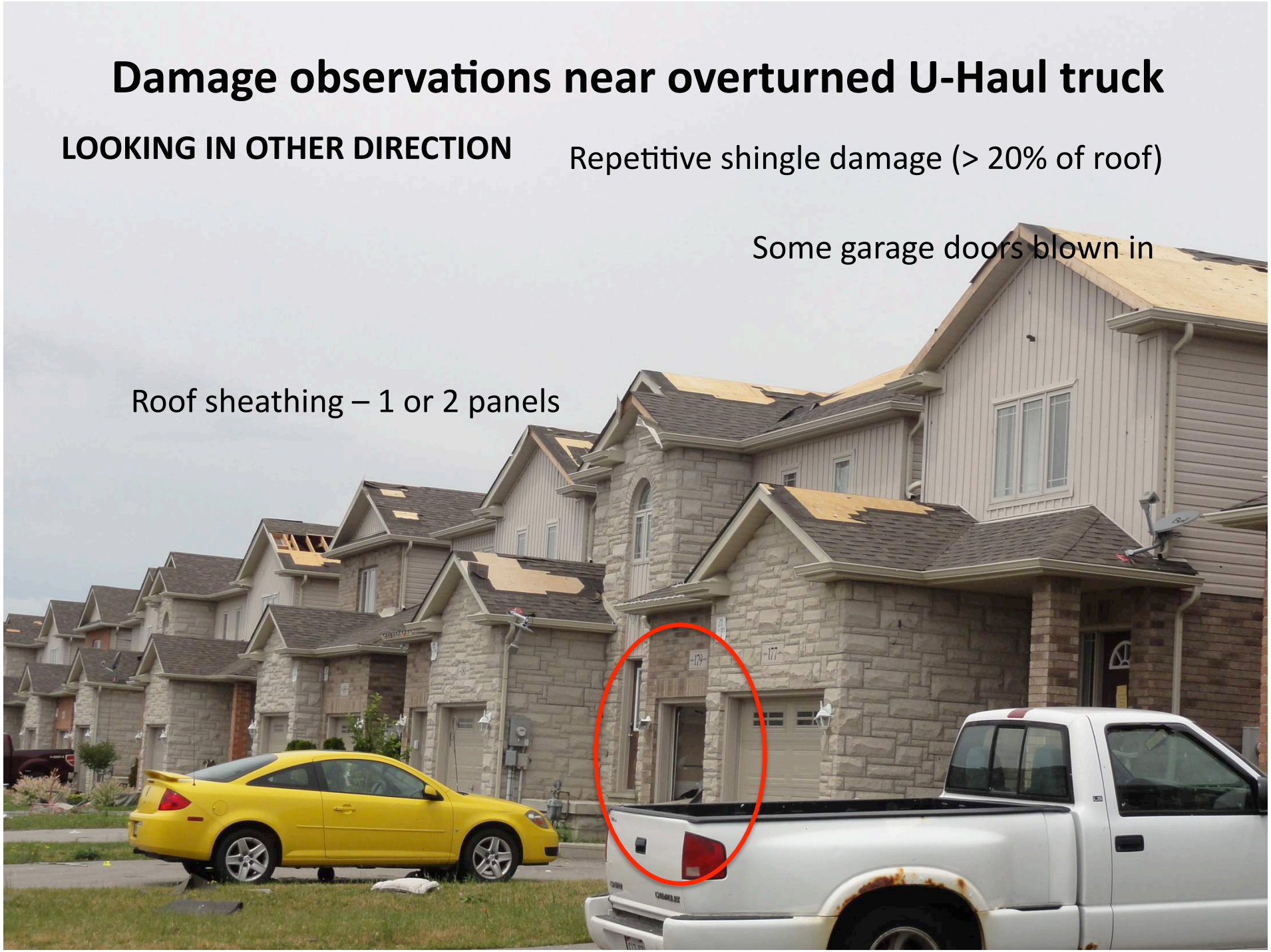
Damage observations near overturned U-Haul truck

LOOKING IN OTHER DIRECTION

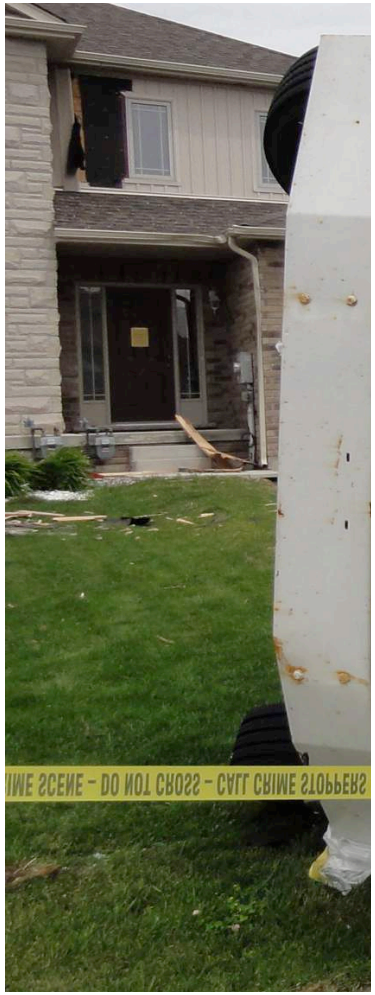
Repetitive shingle damage (> 20% of roof)

Some garage doors blown in

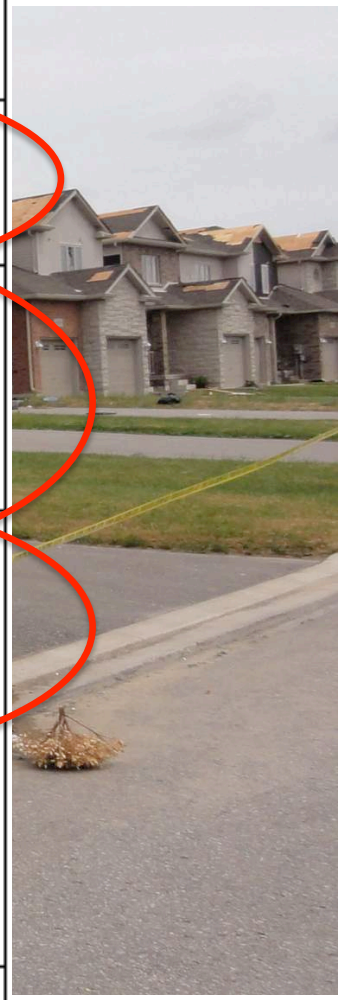
Roof sheathing – 1 or 2 panels



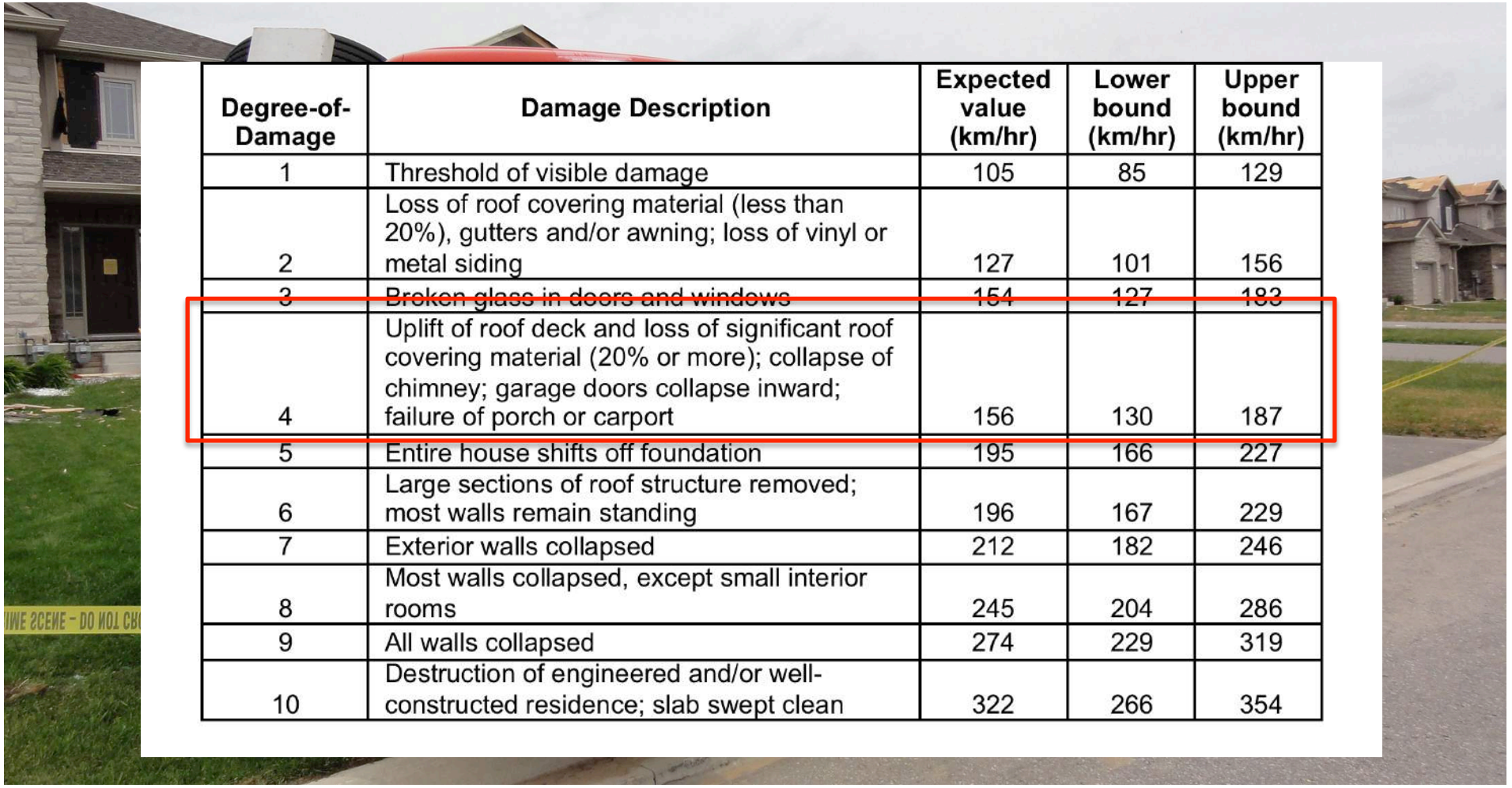
Damag truck



F-scale Category	Estimated Wind Speed Range (mph)	Typical Damage
F0	40 - 72	*Light damage*. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73 - 112 120 – 180 km/h	*Moderate damage*. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113 - 157 180 – 250 km/h	*Considerable damage*. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158 - 206	*Severe damage*. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207 - 260	*Devastating damage*. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261 - 318	*Incredible damage*. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur.



Damage observations near overturned U-Haul truck



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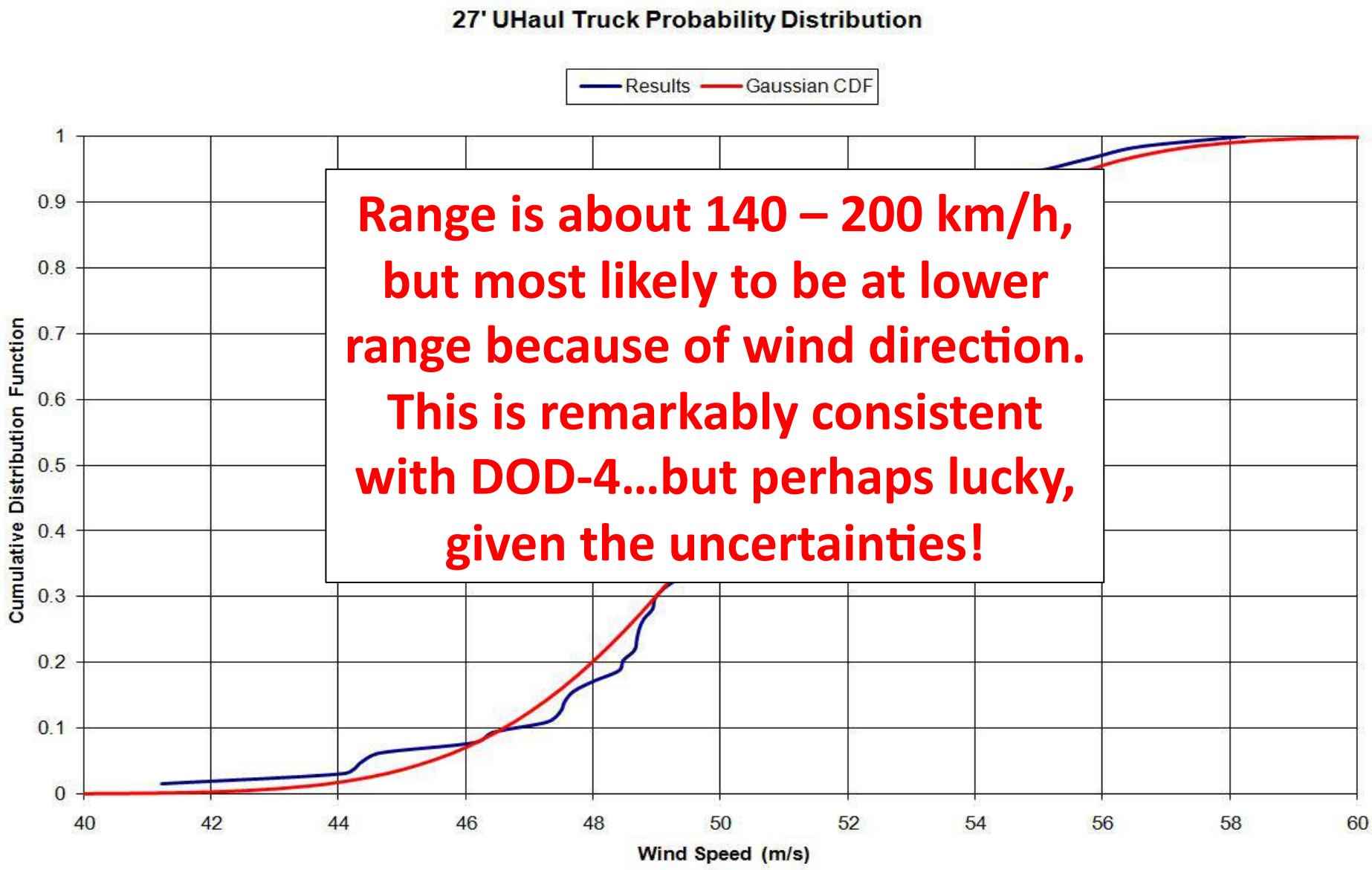
The overturned U-Haul correlates with DOD-4: 130 – 187 km/h

→ This falls into the EF-1 range

Wind tunnel tests of U-Haul trucks

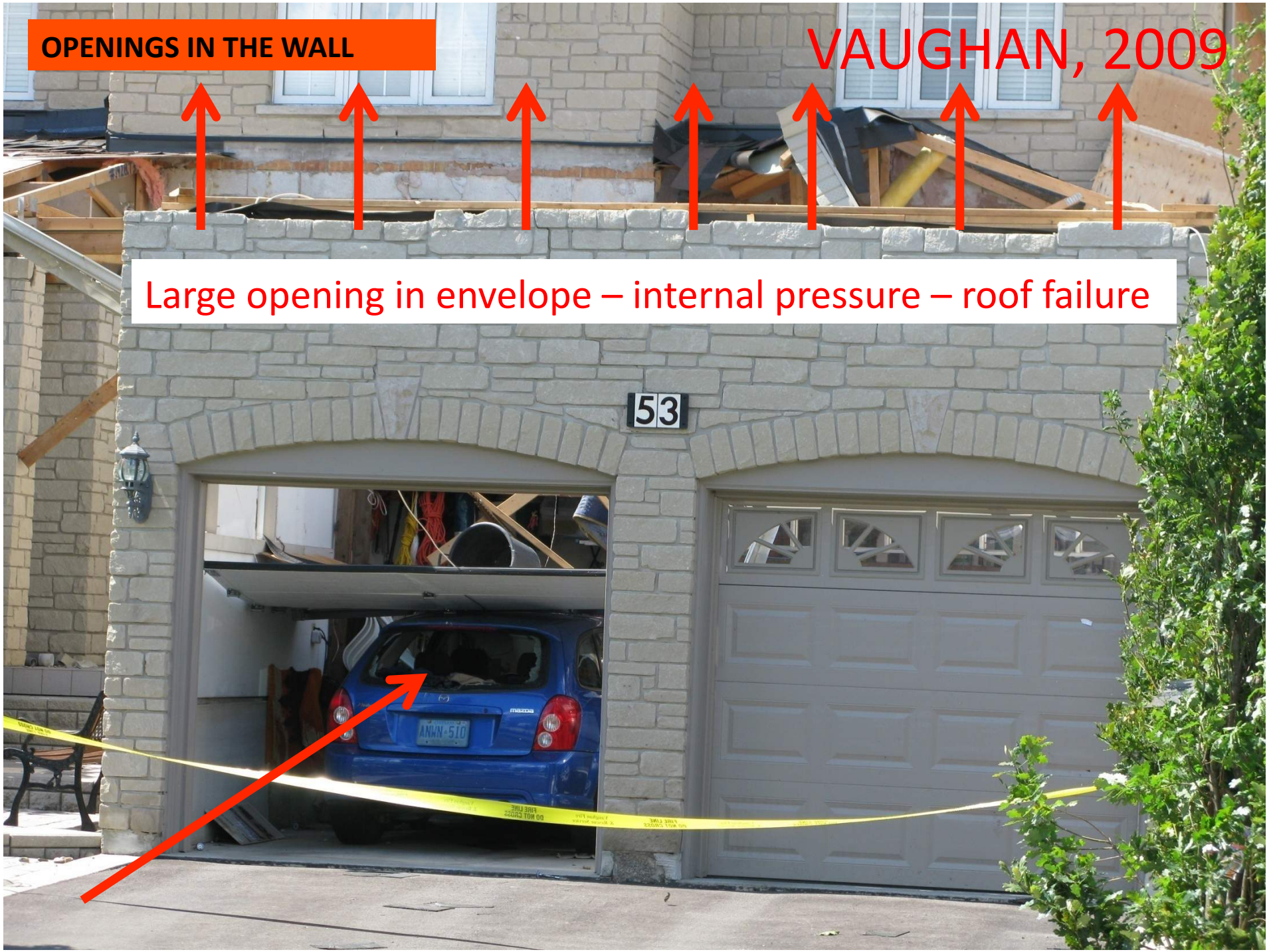


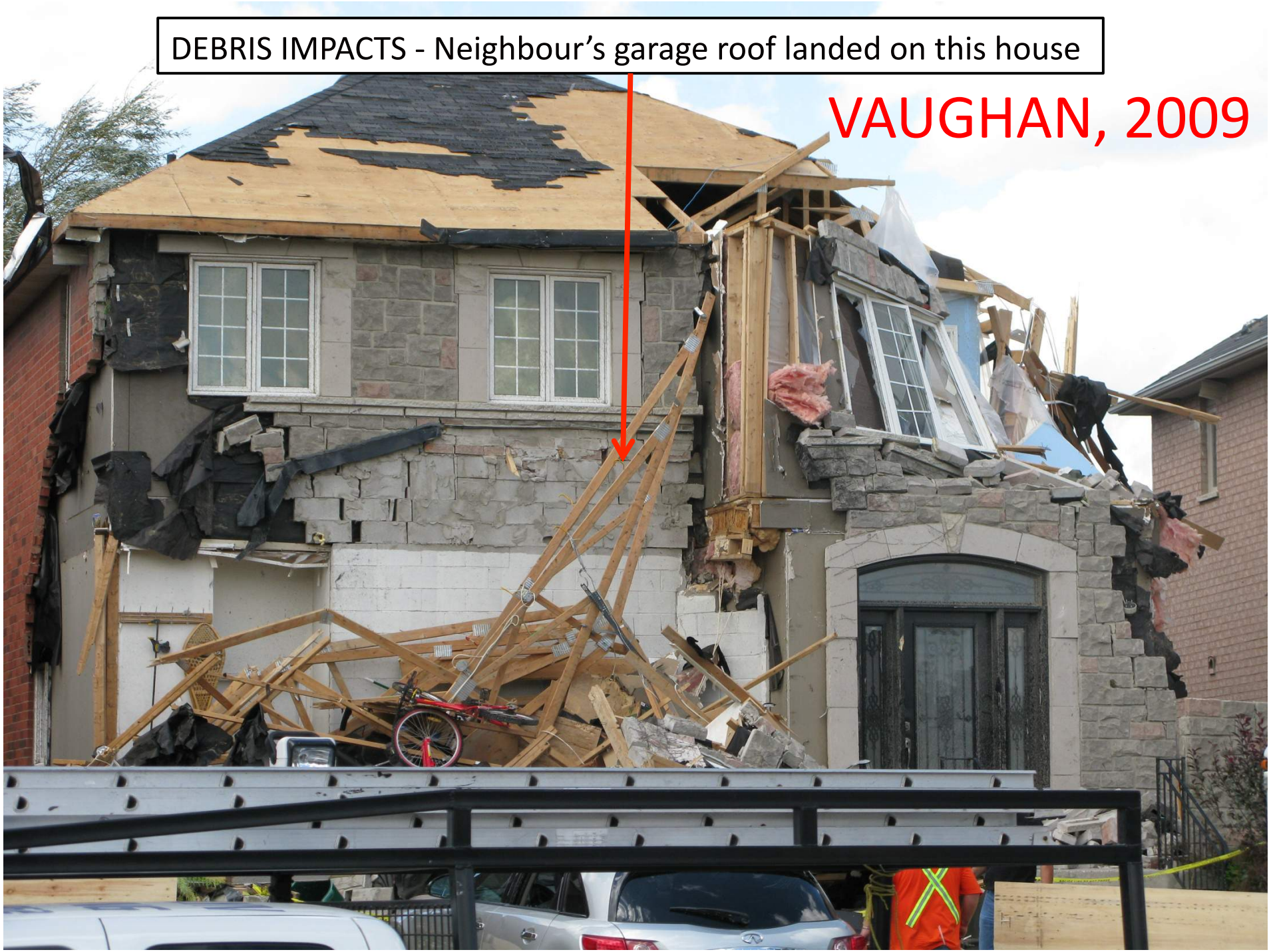
Wind-borne debris

Goderich, ON, F3, August 2011


Wind-borne debris

Wind-borne debris


OPENINGS IN THE WALL
VAUGHAN, 2009
Large opening in envelope – internal pressure – roof failure
53


DEBRIS IMPACTS - Neighbour's garage roof landed on this house
VAUGHAN, 2009

Wind-Borne Debris Impacts

Wind-Borne Debris Impacts

Wind-Borne Debris Impacts

Wind-Borne Debris Impacts

Red = debris impacts; Yellow = everything else.

Wind-Borne Debris Impacts

Preliminary analysis: Red = debris impacts; Yellow = everything else.

Debris impact damage is strongly correlated with **Structural Roof Damage**

Wall Failures

Wall Failures

For Want of a Nail

For want of a nail the shoe was lost.
For want of a shoe the horse was lost.
For want of a horse the rider was lost.
For want of a rider the message was lost.
For want of a message the battle was lost.
For want of a battle the kingdom was lost.
And all for the want of a horseshoe nail.

Questions?

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