Using EDR Delta V in Traffic Crash Reconstruction

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Delta V: The under-utilized tool in recon

- Many recons just look at the speed data and don't consider what they can do with Delta V
- In an older car with ONLY Delta V (no precrash), we can combine Delta V with post-crash travel to get speed at impact
- In a two-car crash, with no EDR in the perpetrator's vehicle, we can get the perpetrator speed at impact using the victim's EDR
- A little bit of math is required – and that scares a lot people from trying to use it. It's not too bad. And there are multiple ways to use Delta V to get another vehicle's speed.

Disclaimer

- Using Delta V takes up about 12 hours in the 40 hour analysis class
- We can’t cover every detail in 1.75 hours
- Half the battle is picking the right value of Delta V to start with from the EDR report!
- To show you the big picture, I’m going to first assume we already have picked a value of Delta V and show you what we can do with it
- Then we will circle back on cautions using Delta V

The Velocity Vector Triangle

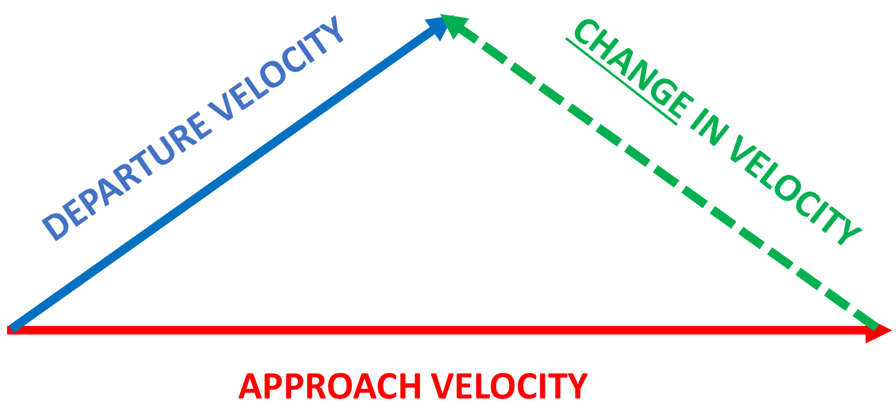
A vehicle in a crash can be described with its VELOCITY VECTORS

There is an **APPROACH** velocity vector.

Crash forces act on the vehicle to **CHANGE** the velocity

Resulting in the **DEPARTURE** velocity vector

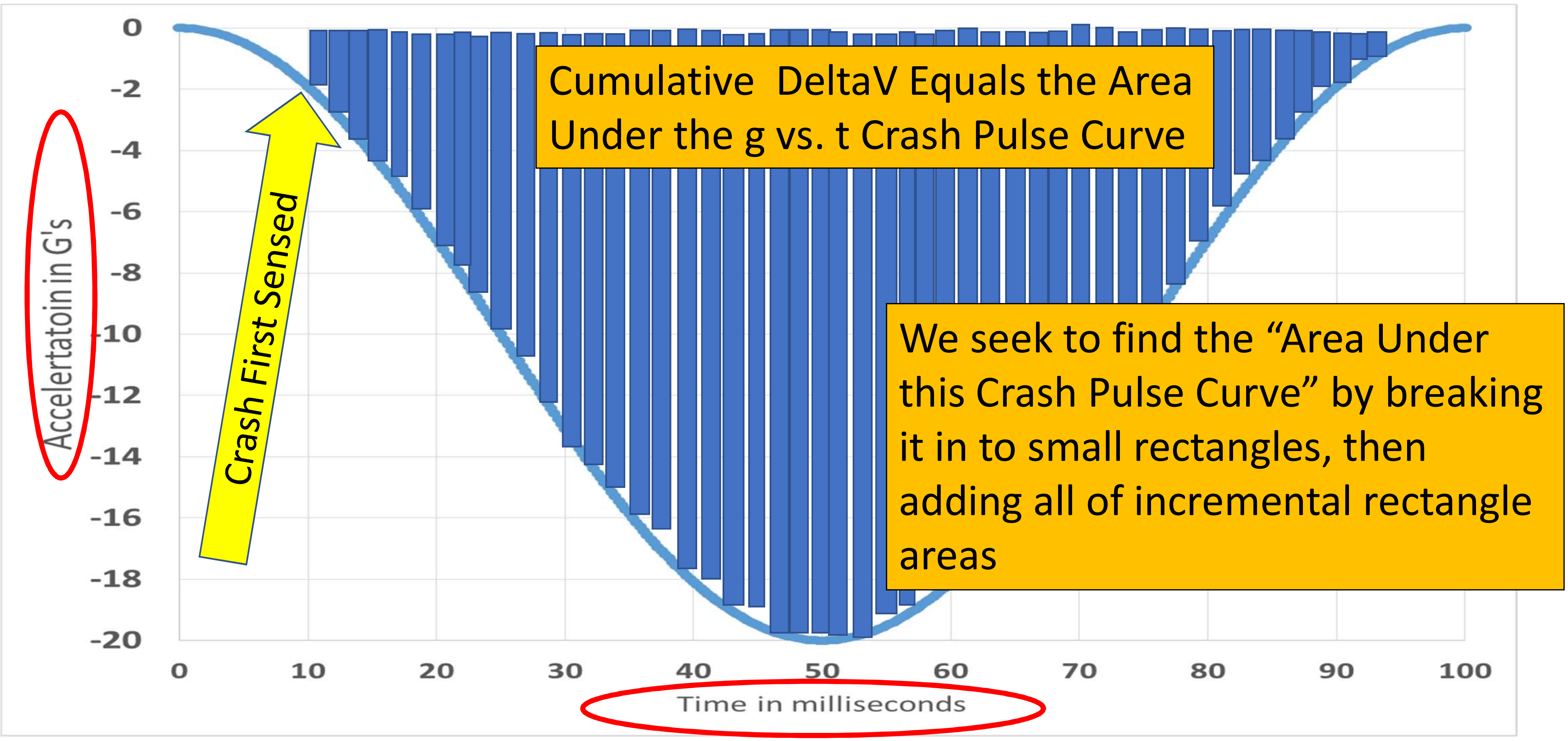
By DEFINITION, the **CHANGE** in velocity is the difference between them



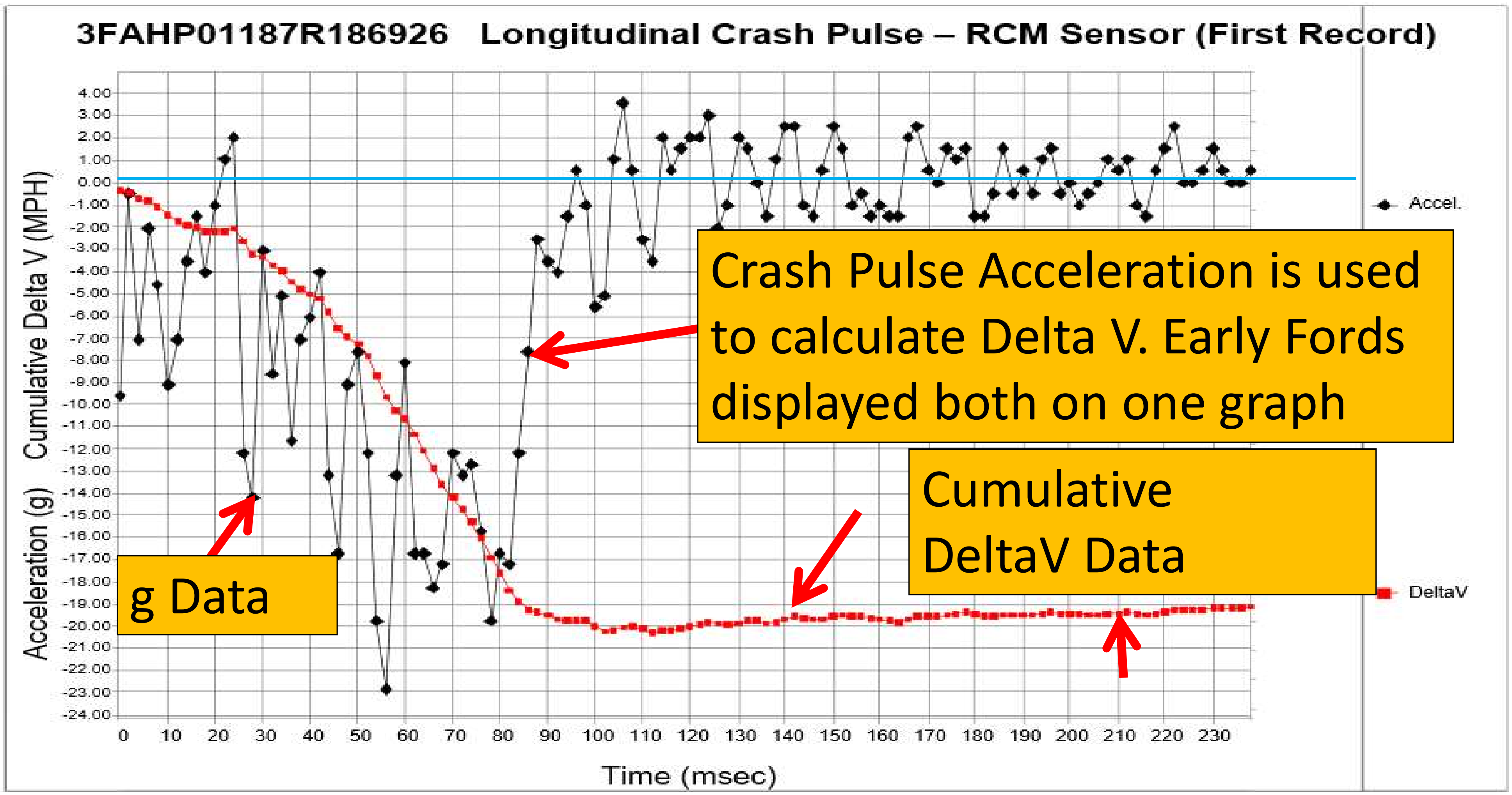
How do we quantify crash forces to get ΔV?

- The speedometer isn't made to capture speed change during a crash (it measure wheel speed, wheels get messed up in crashes)
- Physics tells us that Velocity=Acceleration * time (V=at)
- Airbag modules measure acceleration (aka Crash Pulse)
- For each time interval $\Delta V_{interval} = a\Delta t_{interval}$
- Add up all the ΔV's from each time intervals in the crash pulse, and get the cumulative ΔV.
- This is also known as "the area under the curve"

Generic Crash Pulse (Acceleration) – Graph

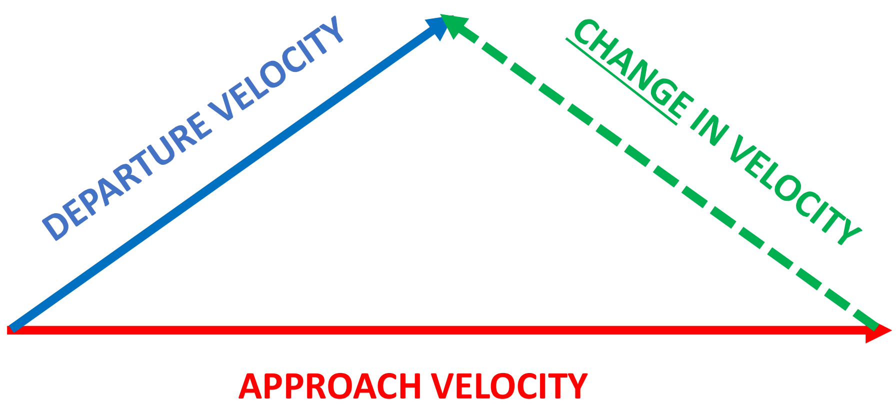


Ford 06+ Fusion Crash Pulse and Cumulative Delta V Data



The Velocity Vector Triangle

So now we know where the measurement of change in Velocity comes from. It comes from measuring acceleration at short time intervals like 1ms, multiplies acceleration times time, and adds it up to get the change in velocity.

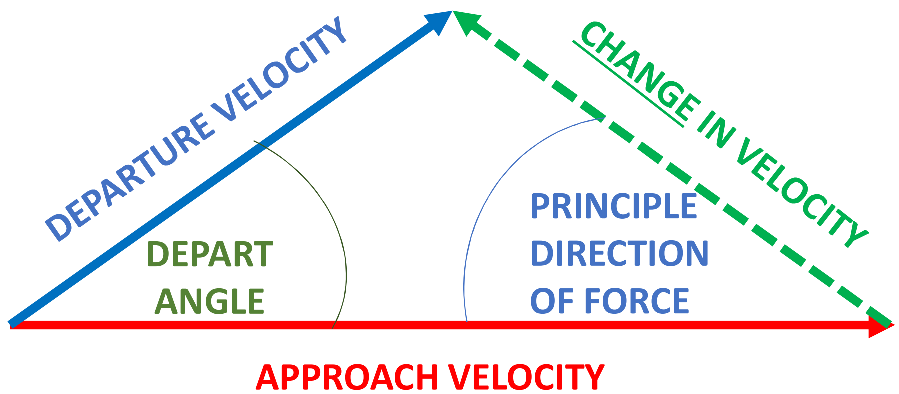


By Definition, they form a TRIANGLE

Triangles have 3 **sides** and 3 **angles**

By DEFINITION, the **DEPARTURE ANGLE** is the difference in direction between the APPOACH VELOCITY and the **DEPARTURE VELOCITY**

By DEFINITION, the **PRINCIPAL DIRECTION OF FORCE (PDOF)** is the difference in direction between the APPOACH VELOCITY and the **CHANGE IN VELOCITY.**



SHORTHAND NAMES

APPOACH VELOCITY = V1

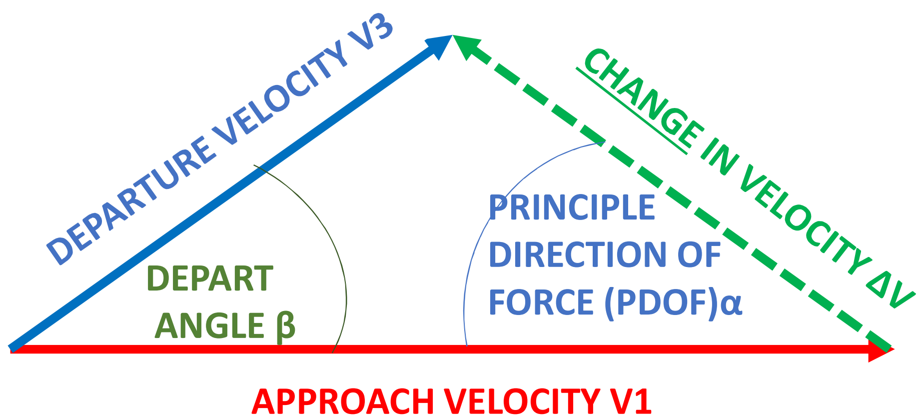
DEPARTURE VELOCITY = V3 (IPTM convention, Northwestern uses V1’)

CHANGE IN VELOCITY = ΔV

DEPARTURE ANGLE = β (“Beta”), the change from approach to depart

PDOF = α (“Alpha”)

SIDES AND OPPOSITE ANGLES (PAIRS) ARE SHOWN IN THE SAME COLOR



SOLVING TRIANGLES

TRIANGLES HAVE 3 SIDES AND 3 ANGLES, OR 6 PIECES OF INFORMATION

YOU MUST KNOW 3 PIECES OF INFORMATION TO SOLVE FOR THE LAST 3

GEOMETRY GIVES US WAYS TO SOLVE TRIANGLES

GEOMETRY DOES NOT CARE THAT THE SIDES OF THE TRIANGLES WE ARE INTERESTED IN ARE VECTORS OR THAT THE VECTORS HAVE REAL WORLD THINGS THAT THEY REPRESENT

GEOMETRY LABELS ANGLES **A**, B, AND C AND OPPOSITE SIDES a, b, and c

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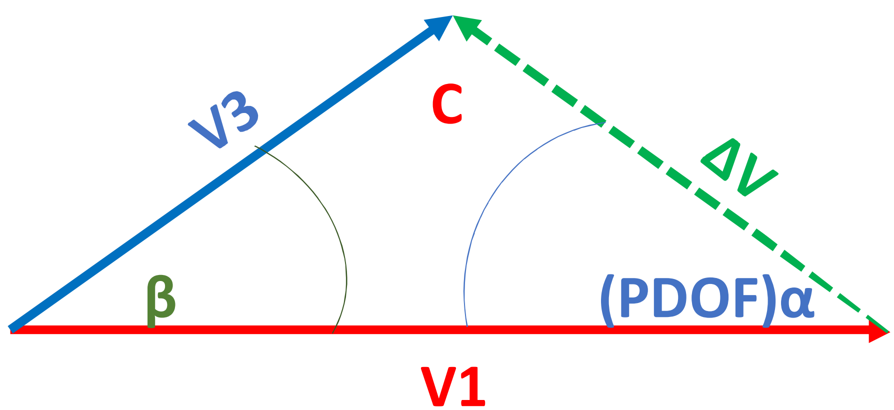

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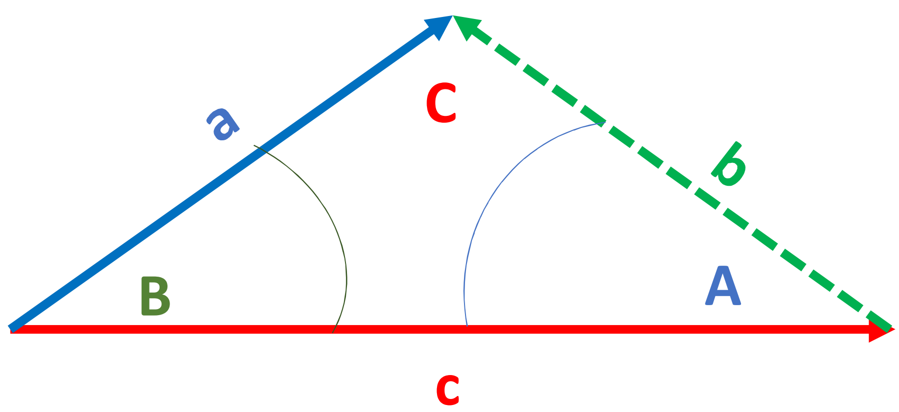
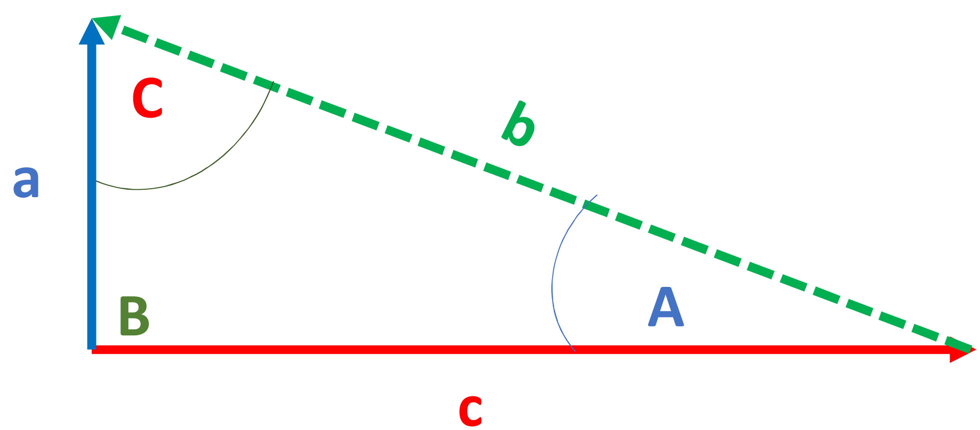


SOLVING TRIANGLES

Right Triangles are the easiest to solve (**B=90º**)

We just use sine, cosine, and tangent functions

If given **b and A**, then **a**=**b**(sin **A**), c=b(cos A), **C**=180-**90**-**A**

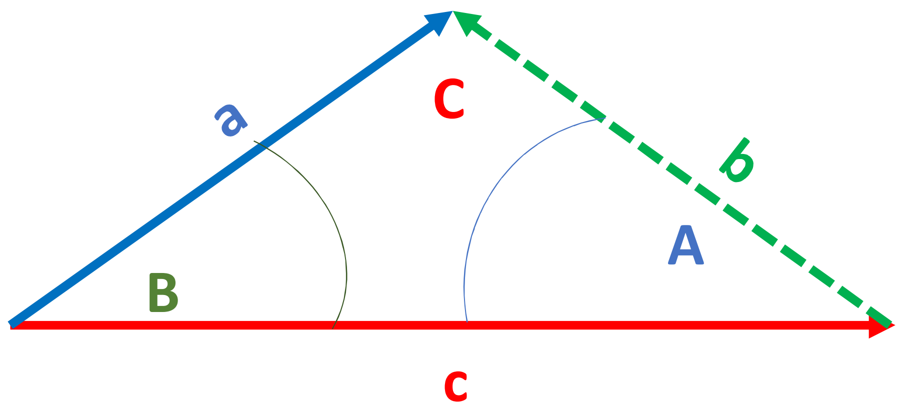


SOLVING TRIANGLES

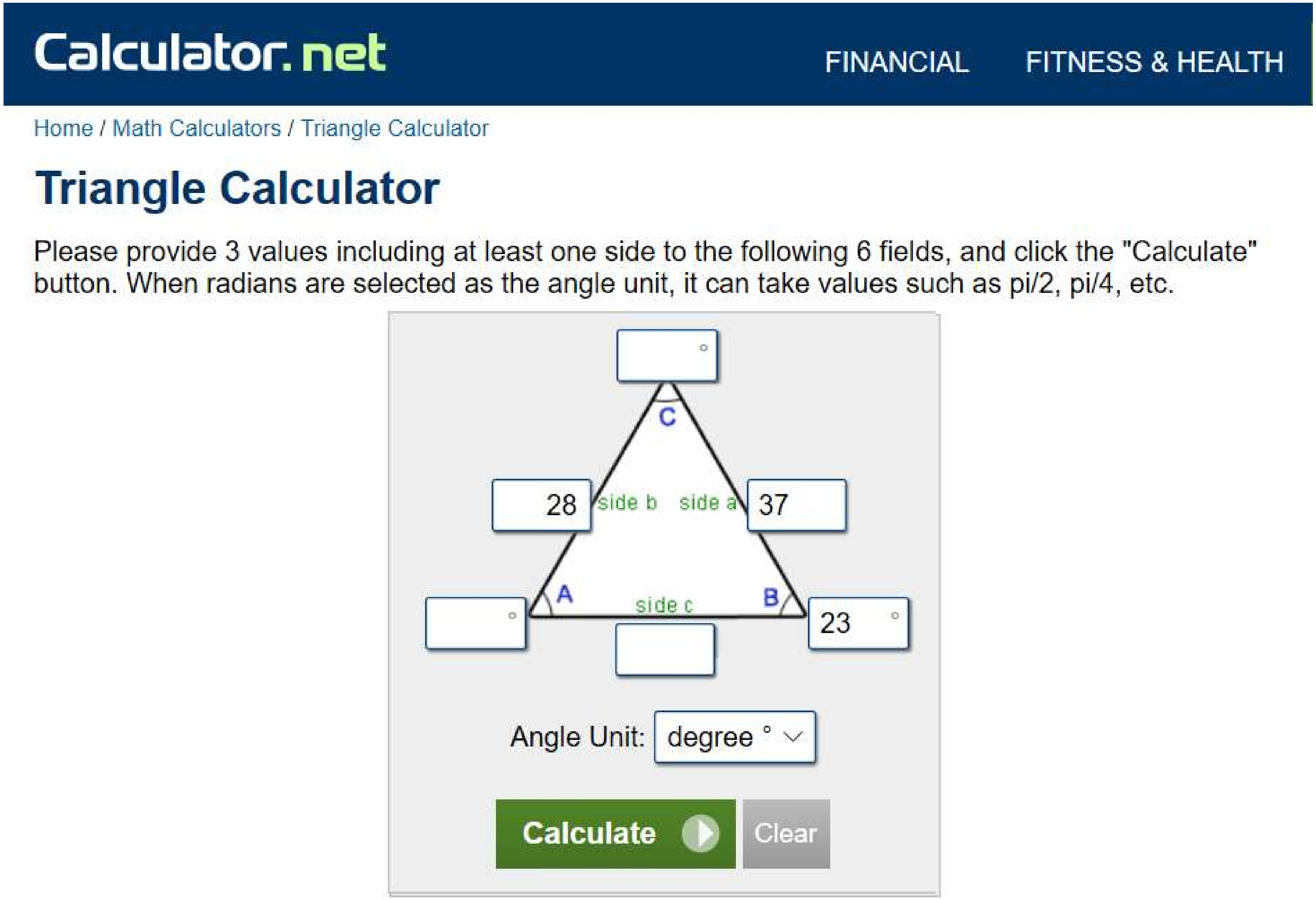
For triangles that are NOT right triangles,

We need 3 tools in our tool belt to solve them:

1. **The law of sines**
2. **The law of cosines**
3. **The 3 angles in a triangle must add to 180 degrees**



Before you panic - There's an APP for that!!!!



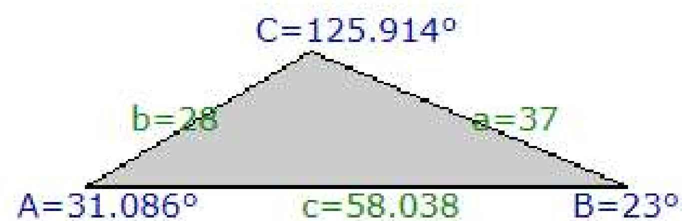
Presto: Instant answers with no math by you

Result

There are two possible solutions:

Possible 1

Obtuse Scalene Triangle



Side a = 37
Side b = 28
Side c = 58.0377

Angle ∠A = 31.086° = 31°5'9" = 0.54255 rad
Angle ∠B = 23° = 0.40143 rad
Angle ∠C = 125.914° = 125°54'51" = 2.19761 rad

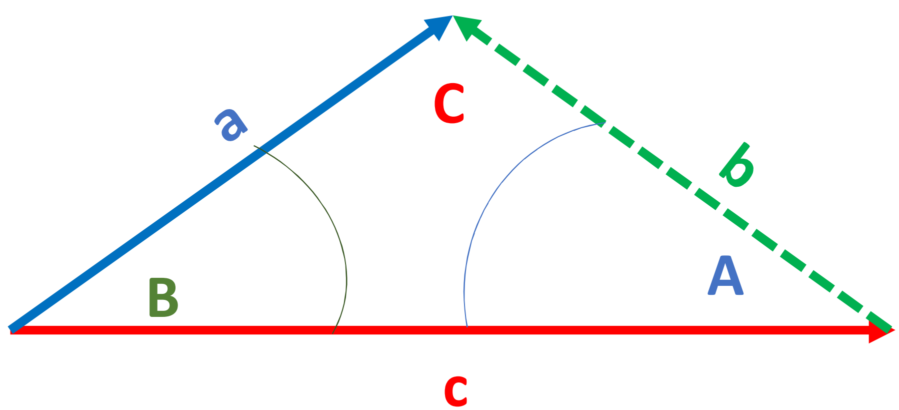
SOLVING TRIANGLES

. In trigonometry, the **law of sines**, is an equation relating the lengths of the sides of a triangle (any shape) to the sines of its angles

The general form is

$$\frac{a}{Sin(A)} = \frac{b}{Sin(B)} = \frac{c}{Sin(C)} \text{ or } \frac{Sin(A)}{a} = \frac{Sin(B)}{b} = \frac{Sin(C)}{c}$$

To use it, you must have an **OPPOSITE PAIR** ***and*** ***half*** ***of the next pair you want to solve*****.**



SOLVING TRIANGLES

The general form can be rearranged to solve for any of the remaining 3

$$a = b\frac{Sin(A)}{Sin(B)} = c\frac{Sin(A)}{Sin(C)}$$

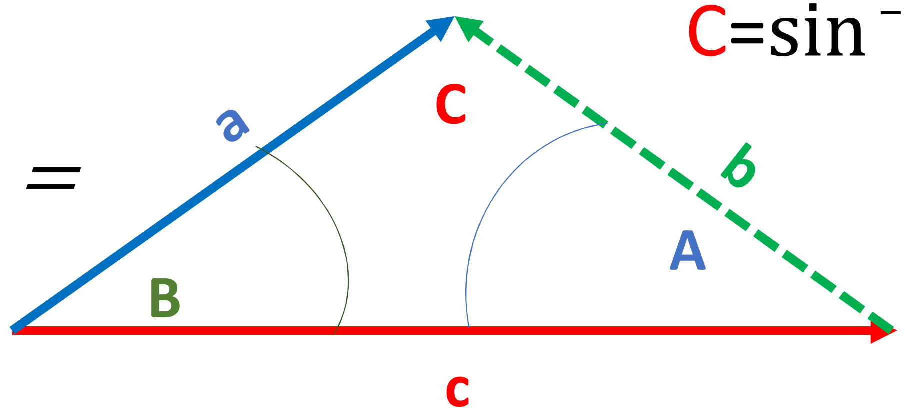
$$A = \sin^{-1}\left(\frac{\boldsymbol{a}\mathbf{Sin}(B)}{\boldsymbol{b}}\right)$$

$$b = c\frac{Sin(B)}{Sin(C)} = a\frac{Sin(B)}{Sin(A)}$$

$$B = \sin^{-1}\left(\frac{\mathbf{bSin}(\mathbf{C})}{\mathbf{c}}\right)$$

$$C = \sin^{-1}\left(\frac{\boldsymbol{c}\mathbf{Sin}(A)}{\boldsymbol{a}}\right)$$

$$c = a\frac{Sin(C)}{Sin(A)} =$$



SOLVING TRIANGLES

You can substitute the physical names for the A's, B's and C's

You will usually be given **ΔV and PDOF by the EDR and won't need to solve for them.**

$$V3 = \Delta V \frac{Sin(PDOF)}{Sin(C)} = V1 \frac{Sin(PDOF)}{Sin(C)}$$

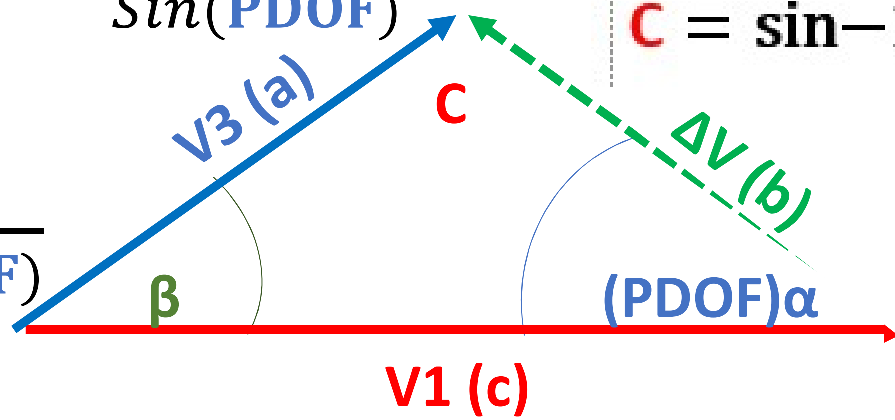
$$\Delta V = V1 \frac{Sin(\beta)}{Sin(C)} = V3 \frac{Sin(\beta)}{Sin(PDOF)}$$

$$V1 = V3 \frac{Sin(C)}{Sin(PDOF)}$$

$$PDOF = \sin\text{-}1\left(\frac{V3\,Sin(\beta)}{\Delta V}\right)$$

$$\beta = \sin{-1}\left(\frac{\Delta V\,Sin(C)}{V1}\right)$$

$$C = \sin{-1}\left(\frac{C\,Sin(PDOF)}{V3}\right)$$



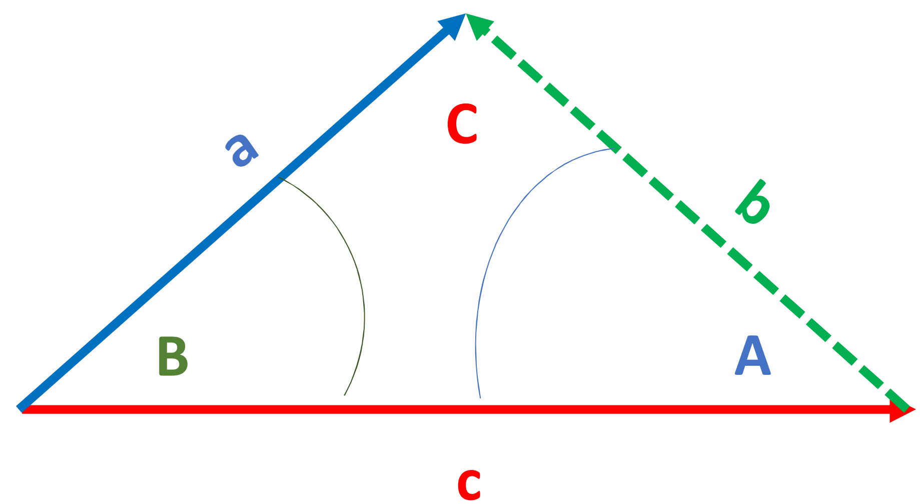
SOLVING TRIANGLES – LAW OF COSINES

If you have *two* SIDES and *one* ANGLE that is NOT AN OPPOSITE PAIR, then you must solve for the third side. This requires using the LAW OF COSINES.

$$a = \sqrt{b^2 + c^2 - (2bcCos(A))}$$

$$b = \sqrt{a^2 + c^2 - (2acCos(B))}$$

$$c = \sqrt{a^2 + b^2 - (2abCos(C))}$$



Once you have the third side, you use law of sines to get the other angles

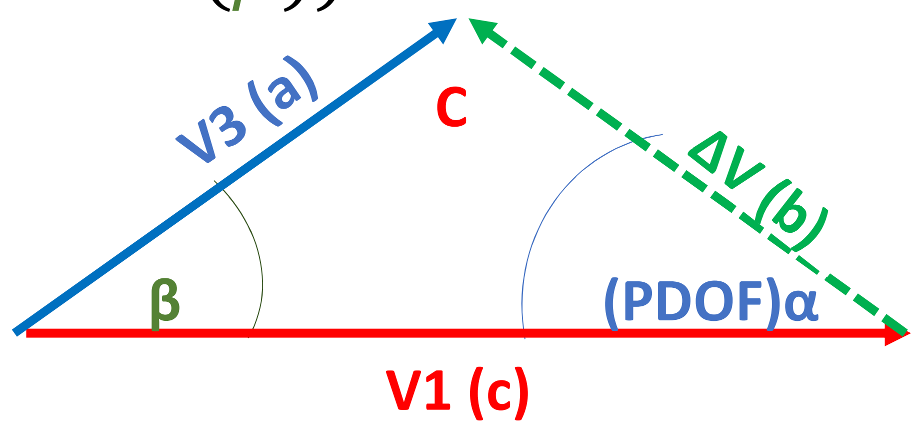
SOLVING TRIANGLES

Substituting the physical names into the general equations yields:

$$V3 = \sqrt{\Delta V^2 + V1^2 - (2 * \Delta V * V1 * Cos(PDOF))}$$

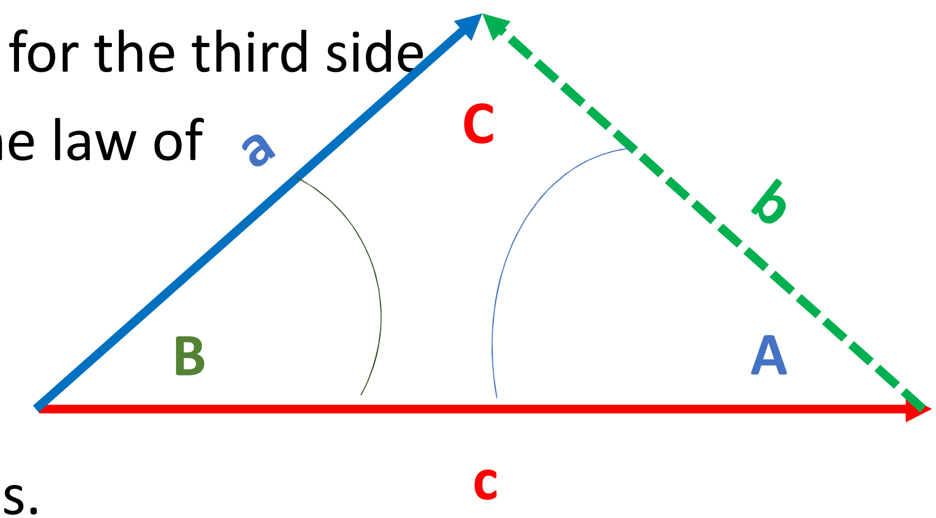
$$V1 = \sqrt{V3^2 + \Delta V^2 - (2 * V3 * \Delta V * Cos(180 - \beta - PDOF))}$$

$$\Delta V = \sqrt{V3^2 + V1^2 - (2 * V3 * V1 * Cos(\beta))}$$



Order of Solution

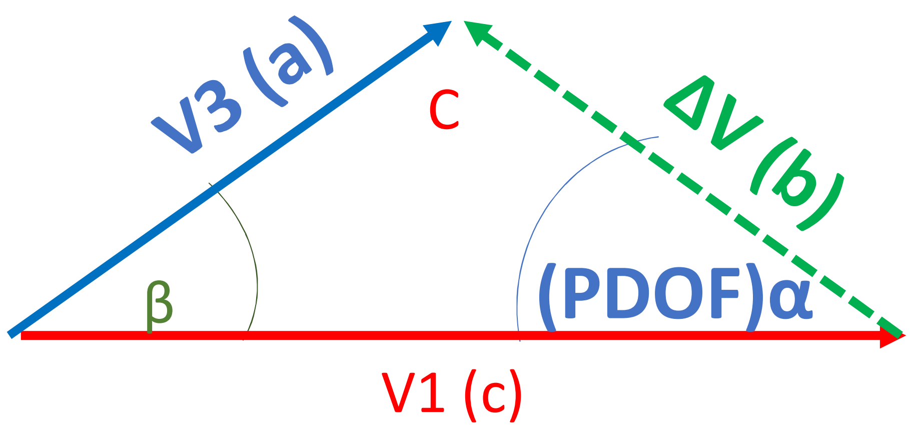
- "SAS" If you have no opposite pairs, but two sides, you must first
  Use the LAW of COSINES to solve for the third side
- Now you have an opposite pair, use the law of
  Sines to get a second angle
- Now with two angles, find the third
  Angle via 180 minus the other two
- Now find the last side with law of sines.



Typical Scenarios

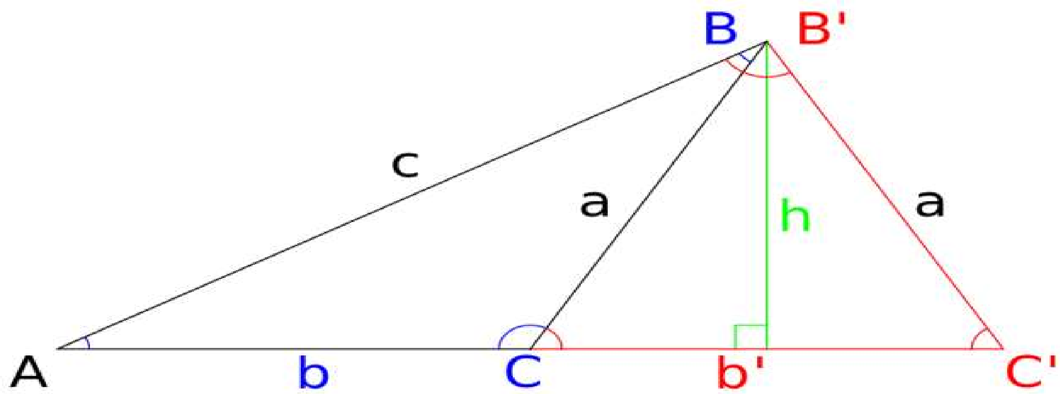
- You have **Delta V magnitude and** PDOF from EDR, and V3 from postcrash travel distance and drag factor
- It is NOT a right triangle
- You DO have an opposite pair
- Use the LAW OF SINES – first to get

  departure angle β
- Then find **C = 180- β- α**
- **Then find V1 with Law of Sines**



Cautions: Ambiguous Triangles

When using the law of sines to find a side of a triangle, an ambiguous case occurs when two separate triangles can be constructed from the data provided (i.e., there are two different possible solutions to the triangle). In the case shown below they are triangles ABC and $AB'C'$.



From Wikipedia

Given a general triangle, the following conditions would need to be fulfilled for the case to be ambiguous:

- The only information known about the triangle is the angle A and the sides a and c.
- The angle A is acute (i.e., A < 90°).
- The side a is shorter than the side c (i.e., $a < c$).
- The side a is longer than the altitude h from angle B, where $h = c \sin A$ (i.e., $a > h$).

If all the above conditions are true, then both angles C or C' produce a valid triangle, meaning that both of the following are true:

$$C' = \arcsin \frac{c \sin A}{a} \text{ or } C = \pi - \arcsin \frac{c \sin A}{a}.$$

From there we can find the corresponding B and b or B' and b' if required, where b is the side bounded by angles A and C and b' bounded by A and C'.

https://www.calculator.net/triangle-calculator.html

Apps help detect ambiguous traingles

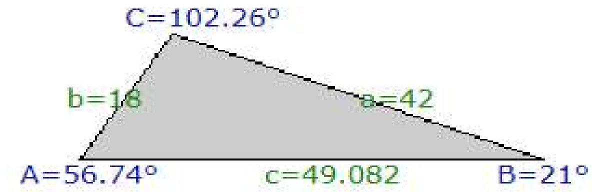
There are two possible solutions:

Possible 1

Obtuse Scalene Triangle

Side a = 42
Side b = 18
Side c = 49.08224

Angle ∠A = 56.74° = 56°44'25" = 0.9903 rad
Angle ∠B = 21° = 0.36652 rad
Angle ∠C = 102.26° = 102°15'35" = 1.78477 rad

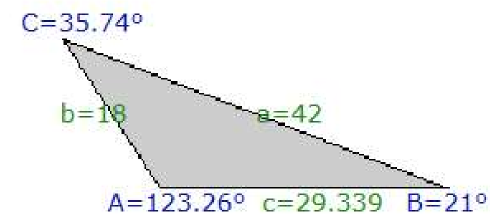


Possible 2

Obtuse Scalene Triangle

Side a = 42
Side b = 18
Side c = 29.33851

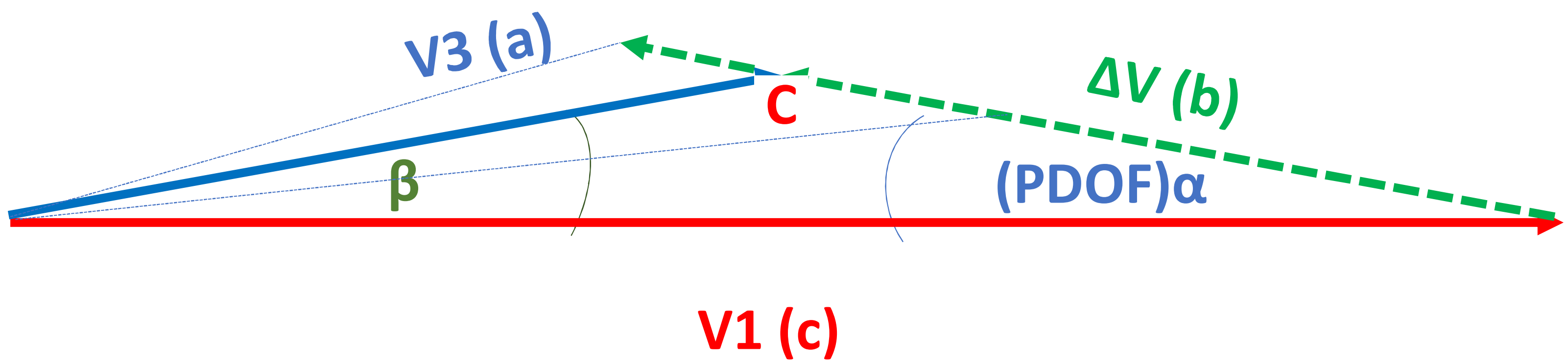
Angle ∠A = 123.26° = 123°15'35" = 2.15129 rad
Angle ∠B = 21° = 0.36652 rad
Angle ∠C = 35.74° = 35°44'25" = 0.62378 rad



SENSITIVITY

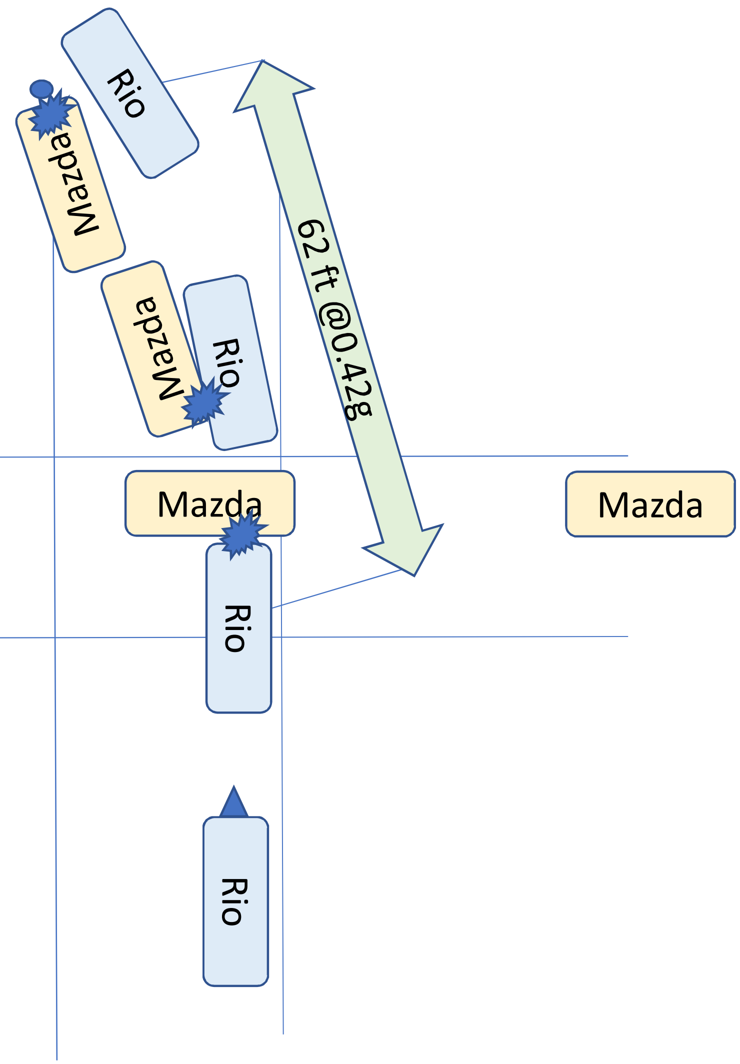
The triangular velocity vector method, like 360 momentum, works great in intersection crashes with PDOF's of 45 degrees.

As a crash approaches inline, the technique becomes sensitive to small changes in the small angles.



Crash Scenario

- Rio driver claims green light & he was going speed limit
- Mazda passenger says red light turned green for them
- Mazda driver dead
- Who's right?



Information Available

- No tire marks noted during on scene investigation
- No gouge marks giving departure angles
- Kia Rio went 62 ft to rest, avg drag factor 0.42, departure angle uncertain due to secondary slap.
- 2013 Mazda 3 EDR data
  - Last reported speed 18 mph
  - X Delta V -8.1 mph
  - Y Delta V +20.5 mph
- No EDR available in 2009 Kia Rio

Calculate the Total Delta V for the Mazda 3

$$TotalDeltaV = \sqrt{DeltaVx^2 + DeltaVy^2}$$

$$TotalDeltaV = \sqrt{20.5^2 + (-8.1)^2} = 22.04mph$$

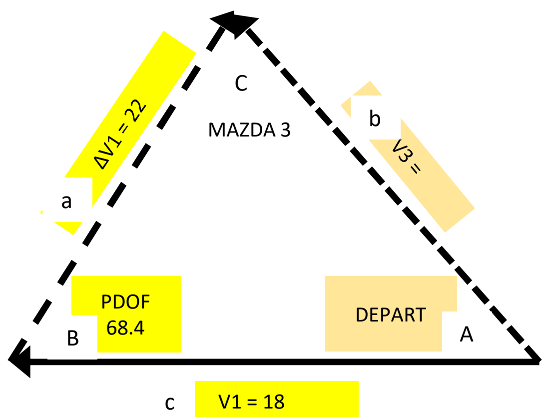
Calculate the PDOF for the Mazda

$$\Theta = \tan^{-1}\left(\frac{DeltaV_Y}{DeltaV_X}\right)$$

$$\Theta = \tan^{-1}\left(\frac{20.5}{-8.1}\right) = -68.4 \deg rees$$

When you get an angle always check to see if it makes sense – sometimes you need the complement of the angle (180 minus what you calculated)

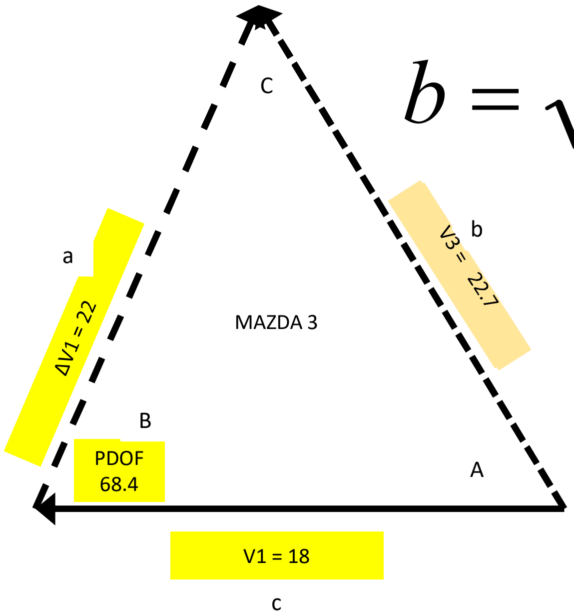
TRIANGULAR VELOCITY VECTOR METHOD
Draw a general shape of a triangle and fill in what you know so far. Label sides and angles.



Determine what tools you will need to complete the triangle. Ask yourself:

1. Is it a right triangle? NO
2. Do you have any opposite pairs? NO
3. Then what law must you use? LAW OF COSINES (a.k.a side/angle/side) to get the third side

Calculate V3 using Law of Cosines



$$b = \sqrt{a^2 + c^2 - (2acCos(B))}$$

a = ΔV1 = 22.0

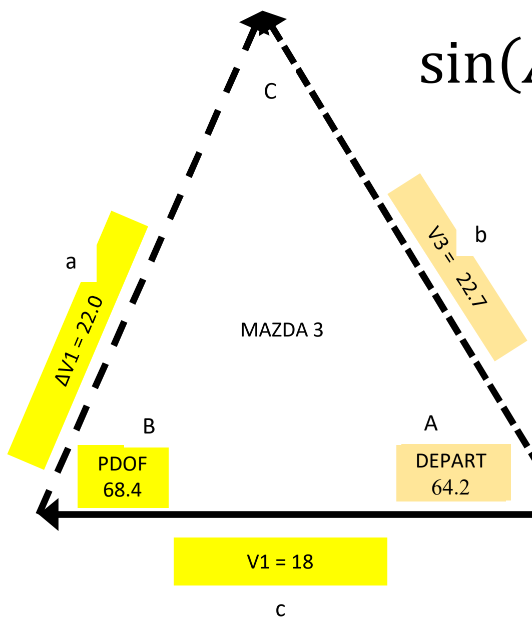
c = V1 = 18.0

B = PDOF1 = 68.4

$$V3 = \sqrt{22^2 + 18^2 - (2 * 22 * 18 * Cos(68.4))} = 22.7$$

Now use law of sines to get the departure angle A

$$\frac{a}{Sin(A)} = \frac{b}{Sin(B)} = \frac{c}{Sin(C)}$$

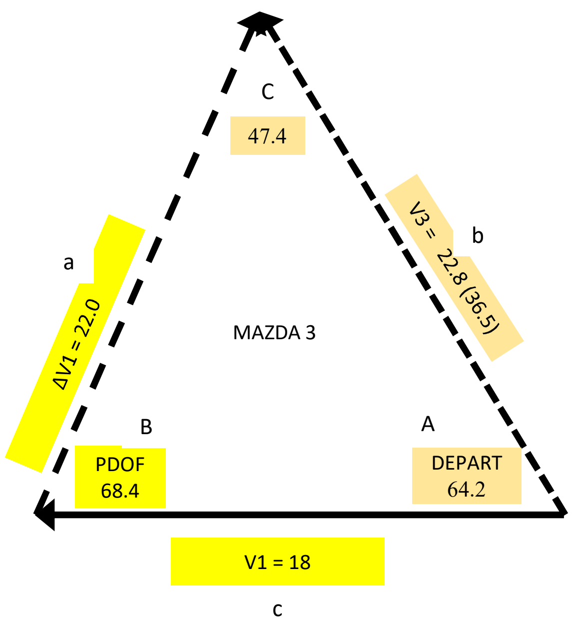


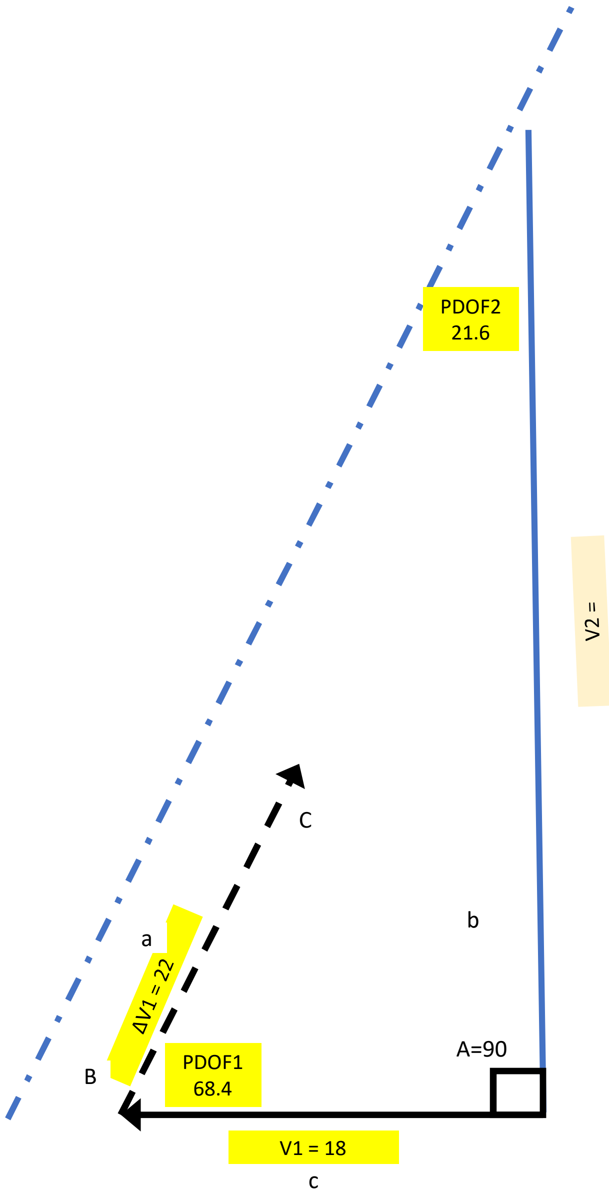
$$\sin(A) = \frac{\sin(B)}{b}a = \frac{\sin(68.4)}{22.7}22.0=0.90$$

$Sin^{-1}(.90) = 64.2$ degrees = A

Now calculate 3rd angle in triangle

- C = 180 – PDOF1-DEPART1 = 180-68.4-64.2 = 47.4

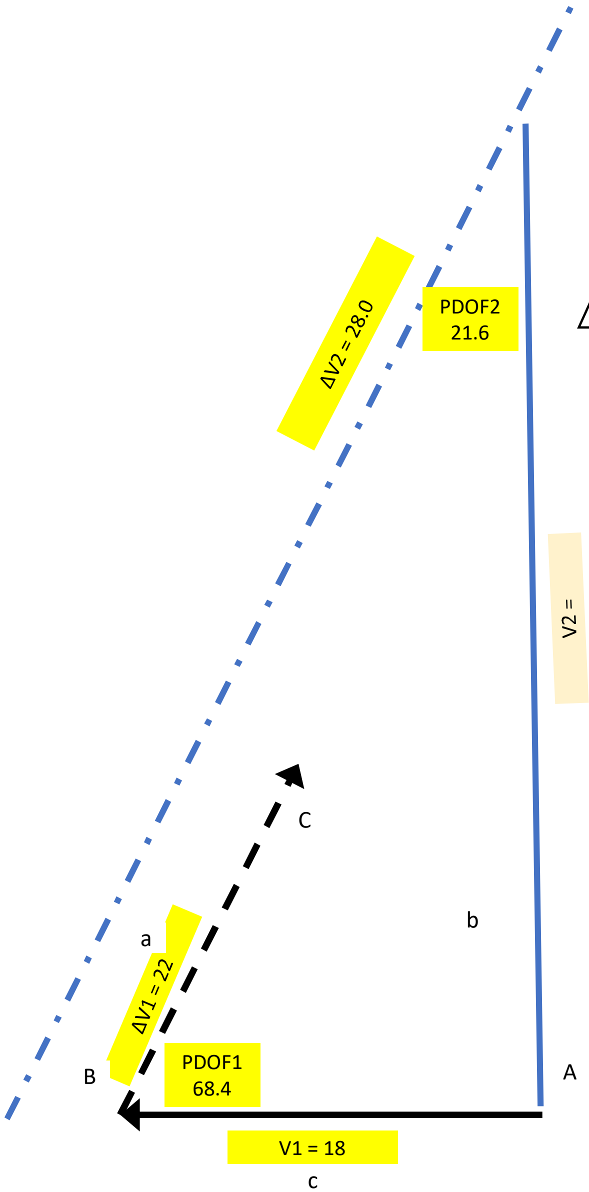




Set up V2 triangle

- Draw the approach vector **<u>direction</u>** line for V2 (*you do not know the magnitude yet*)
- Draw a line parallel to Delta V1 that intersects the V2 direction. Note the triangle created by the dotted line, the V2 direction, and the V1 direction.
- Calculate PDOF2 = 180-(difference in approach angles)-PDOF1 = 180-90-68.4 = 21.6 degrees.

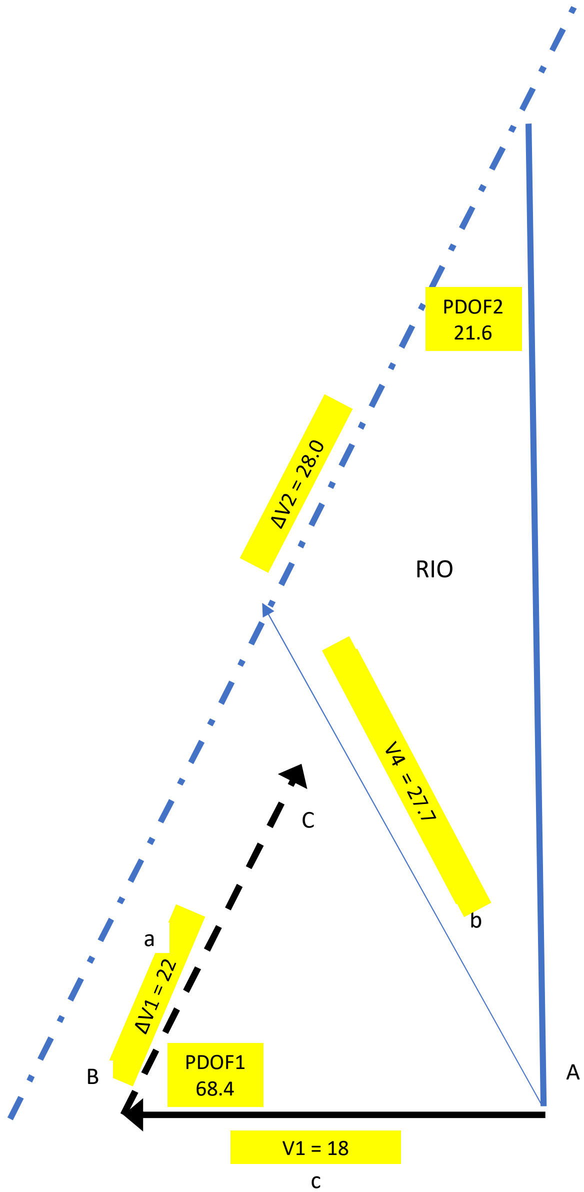
Calculate ΔV2



$$\Delta V_{UnknownVehicle} = -\Delta V_{EDRVehicle} \frac{W_{EDRVehicle}}{W_{UnkownVehicle}}$$

$$\Delta V_{Rio} = -\Delta V_{Mazda3} \frac{W_{Mazda3}}{W_{Rio}}$$

$$\Delta V_{Rio} = 22.0 \frac{3205}{2515} = 28.0 mph$$



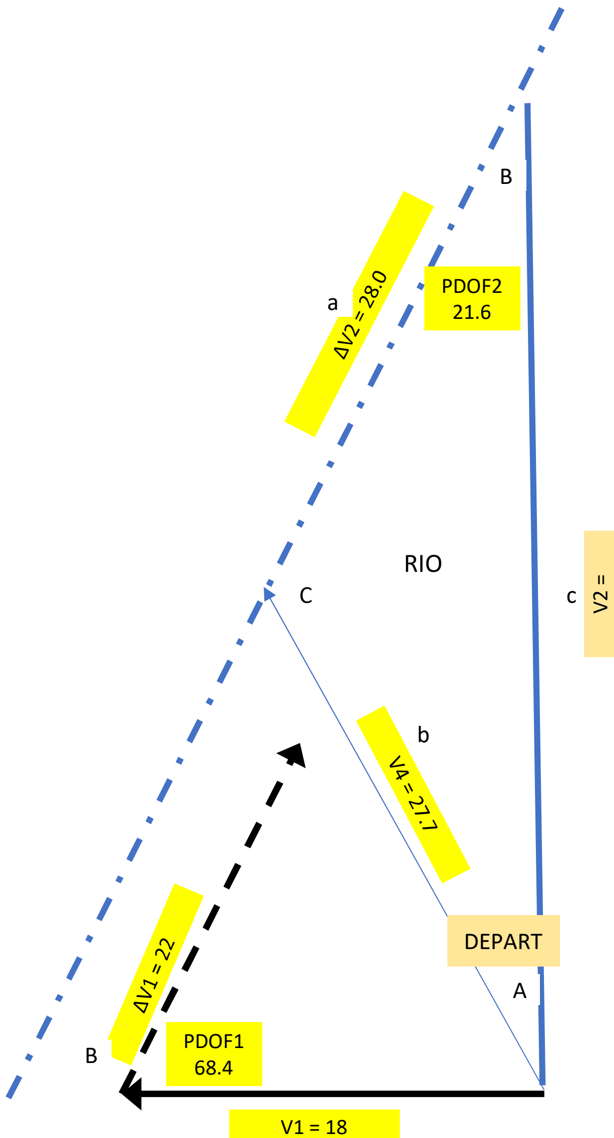
Draw in general line of V4 angle

Calculate V4

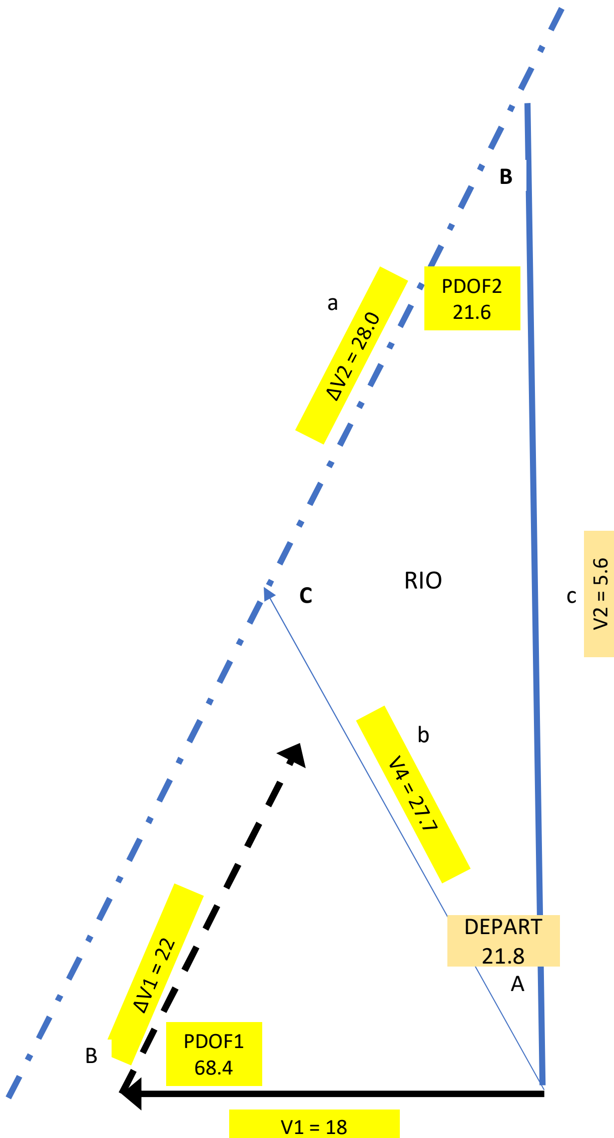
$$V4 = \sqrt{30 * D * f}$$

$$V4 = \sqrt{30 * 61 * 0.42}$$

$$V4 = 27.7$$



- Observe the V2 triangle in its current state.
- Is it a Right Triangle?
- Do you have any opposite pairs?
- Which method do you need to complete the triangle? Regular Trig, ***Law of Sines***, or Law of Cosines?
- You really want V2, but you have to solve for something else first – you can get the opposite pair of ΔV2, the departure angle



Solve for departure angle A

$$\frac{a}{Sin(A)} = \frac{b}{Sin(B)} = \frac{c}{Sin(C)}$$

$$\mathbf{sin}(\boldsymbol{A}) = \frac{\sin(B)}{b}a$$

Sin A= $\frac{\sin(21.6)}{27.7}$ 28.0=**0.372**

Sin^{-1}(.372) = **21.8 degrees =A**

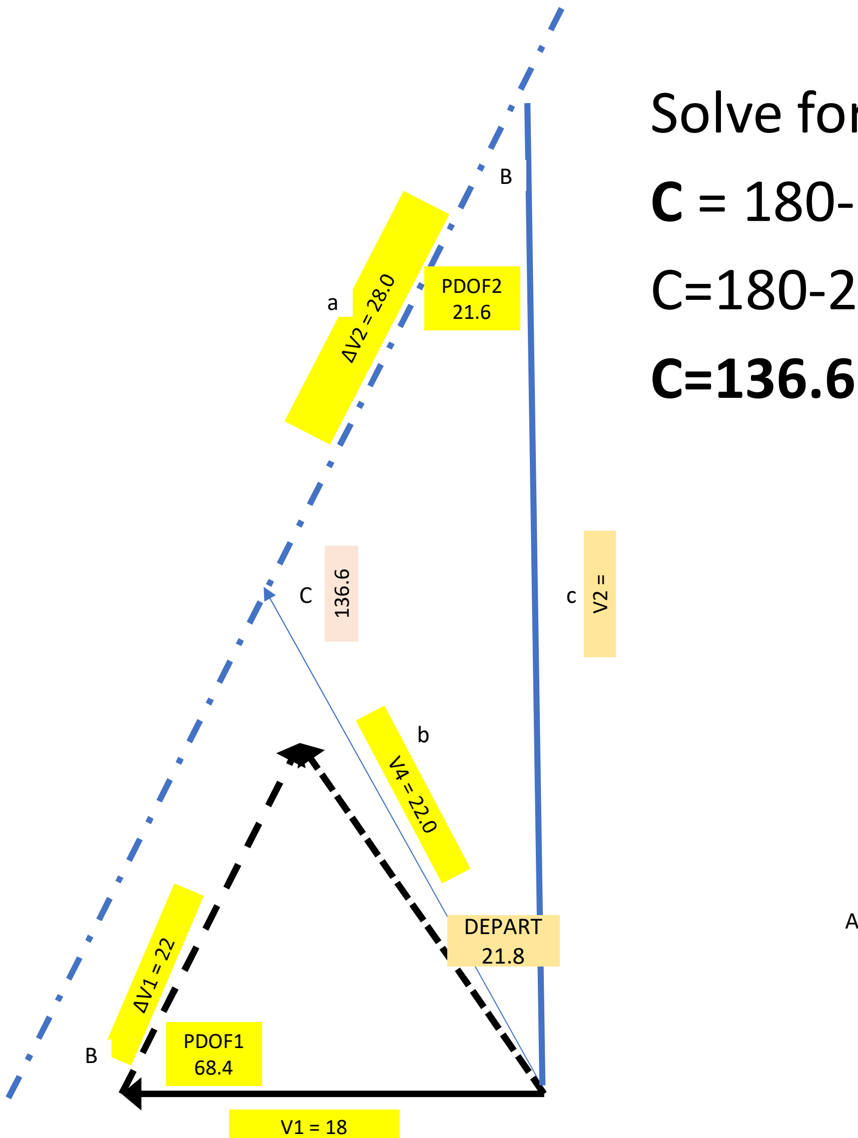
A = departure angle

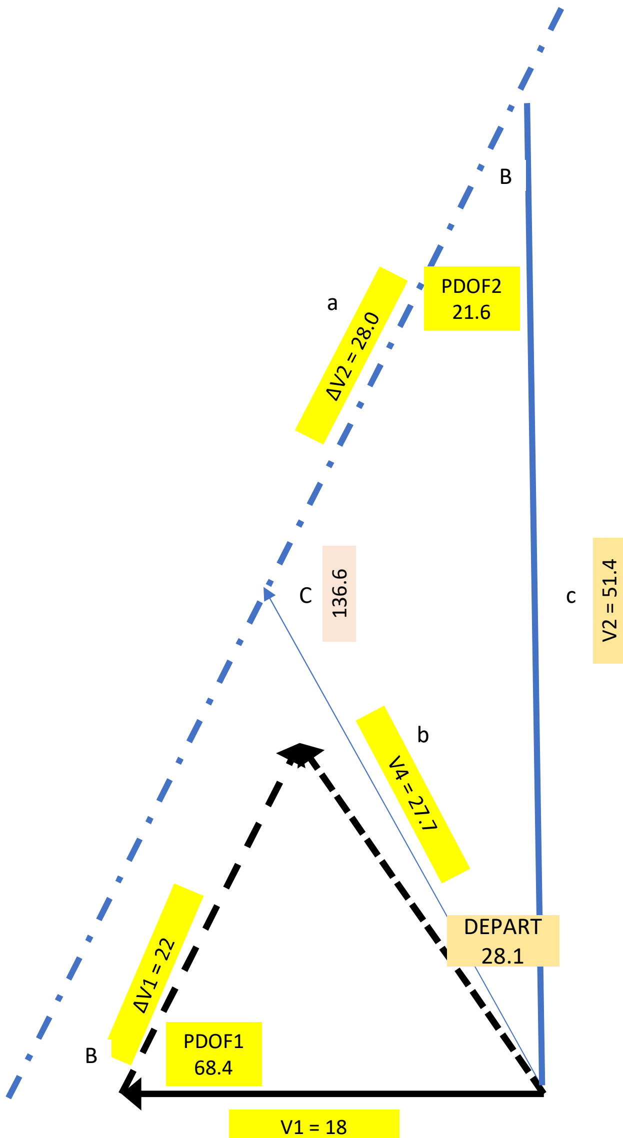
Solve for Remaining Angle

C = 180-B-A =

C=180-21.6-21.8=

C=136.6 degrees





Solve for side c (V2)

$$\frac{a}{Sin(A)} = \frac{b}{Sin(B)} = \frac{c}{Sin(C)}$$

$$c = \frac{\mathrm{b}}{sinB} sinC = \frac{27.7}{sin21.6} sin136.6$$

$$\mathrm{c} = \frac{27.7}{0.37} 0.687 = \frac{(44.6\mathrm{kph})}{0.37} 0.687$$

c = 51.2 **mph**

V2 = 51.2 mph

Recap

- Rio is going 51.2 at impact in a 35mph zone. Speeding=Lying.
- With no EDR in Rio and ABS brakes, Rio could have gone faster then braked.
- Mazda slows from 22 to 12, then gets off brake and onto throttle between -3.0 and -2.5, no sign they ever looked for or saw the Rio coming (thought they had a green light).
- Mazda passenger story consistent with EDR

Pre-Crash Data -5 to 0 sec [2 samples/sec]

(the most recent sampled values are recorded prior to the

Time Stamp (sec)	Speed, Vehicle Indicated (MPH [km/h])		Engine Throttle, % full	Service Brake (On, Off)
-5.0	22 [35]		0	On
-4.5	19 [31]	19	0	On
-4.0	17 [27]	17	0	On
-3.5	14 [23]	14	0	On
-3.0	12 [19]	12	0	On
-2.5	11 [17]	11	25	Off
-2.0	10 [16]	10	61	Off
-1.5	11 [17]	11	63	Off
-1.0	13 [21]	13	64	Off
-0.5	16 [26]	16	64	Off
0.0	18 [29]	17	45	Off
		4		

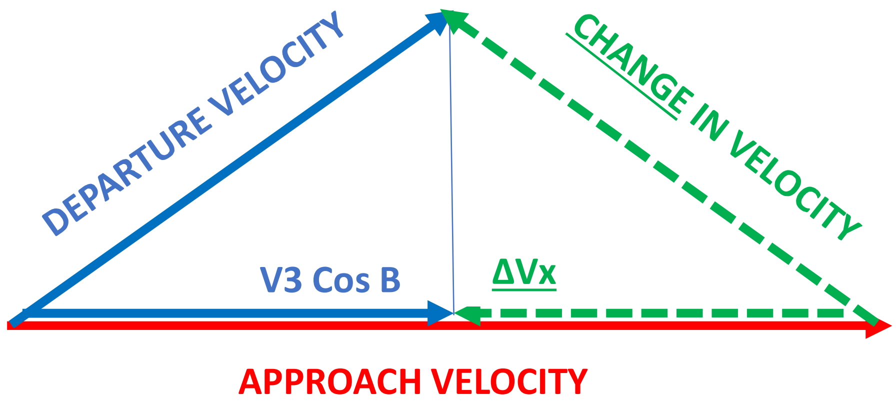
Breaking Down The Velocity Vector Triangle

What if you only had an older EDR with only Delta V x,

But you also knew departure speed V3, and the departure angle???

You could still calculate the speed at impact

$$\text{Speed at Impact} = \left|V_3\right| Cos(\beta) - \Delta Vx$$

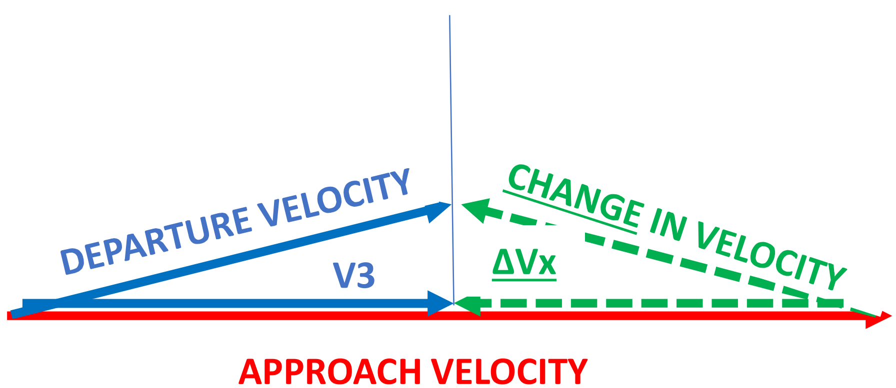


“Inline” Velocity Vector Triangle becomes flat

In fact, as the departure angle approaches zero (an INLINE crash)

The cosine of Beta approaches 1 and the equation simplifies even further

Speed at Impact (INLINE) = V3-ΔVx



Know one Delta V and Weights?

- Newton's laws say crash forces are equal *and opposite*, but Delta V is ***inversely*** *proportional to weights* – got one vehicle, calculate the other!

$$\Delta V_1 = -\Delta V_2 \frac{W_2}{W_1}$$

Equation 12

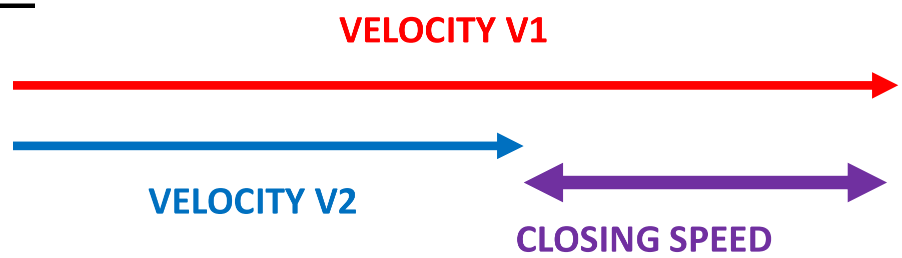
The **negative** sign means the forces are in **opposite** directions, as viewed from a ***SCENE*** *based co-ordinate system*. When viewed from a ***VEHICLE*** *based co-ordinate system* the signs may **not** appear opposite. For example, two vehicles hitting head on **both slow down** which from their vehicle based coordinate system are both negative.

Closing Speed

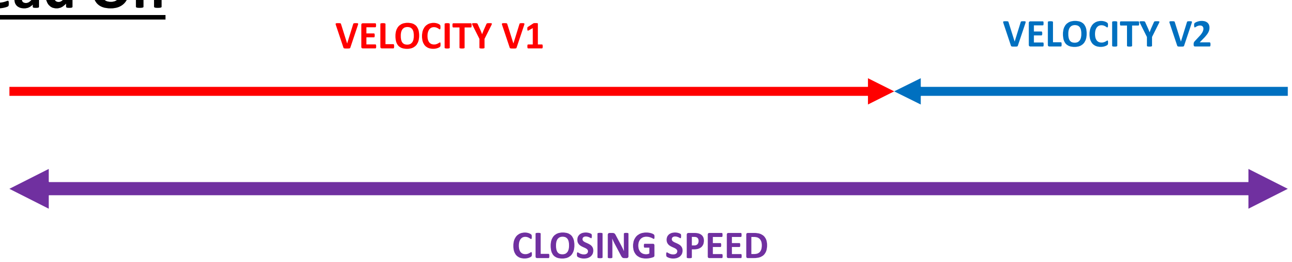
Closing Speed is the difference in the approach vectors of two vehicles

For Inline, V1 = Closing Speed + V2 (V2 is a signed value for inline)

Inline Rear End



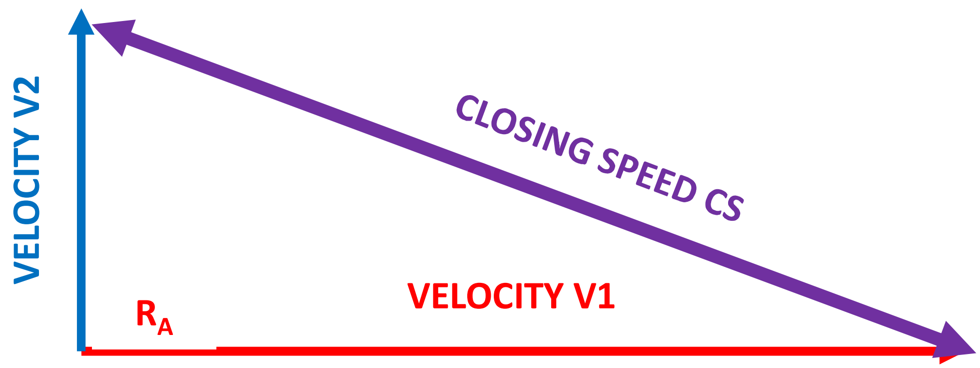
Head On



Closing Speed

Closing Speed is the difference in the approach vectors of two vehicles

Intersection



V1 Can be solved from Closing Speed and V2 if Relative Approach R_A known

Simple trig (sines/cosines/tangents), Pythagorean theorem V1=$\sqrt{CS^2 - V2^2}$ for right triangles

For other triangles law of sines is needed

How to Get Closing Speed

Combine magnitudes of **TOTAL ΔV**'s to get closing speed – with adjustments

The full equation is:

$$\text{ClosingSpeed} = \left[\frac{1}{1+e}\right]\left[\frac{|\Delta V_1|}{\gamma_1} + \frac{|\Delta V_2|}{\gamma_2}\right]$$

Where adjustments are:

e is the coefficient of restitution and
γ (gamma) is the effective mass ratio

Restriction: Vehicles MUST reach a common velocity at the damage centroid or closing speed will be understated.

For **CENTRAL** collisions, γ=1, the equation simplifies to

$$\text{Closing Speed} = \left(\frac{1}{1+e}\right)\left(|\Delta V_2| + |\Delta V_1|\right)$$

Let's start with Central Collisions!!!!!!

First let's look at Restitution [1]

- NCAP 35 mph full barrier collision (Click to Play)
- Approach Velocity is 35 mph
- Q: What is Final Velocity?

- A: Approximately -3.5 mph
- Q: Why does it bounce back? RESTITUTION
- What is the Coefficient of Restitution?
- $e = \frac{separation\ speed}{clsoing\ speed} = \frac{3.5}{35}$ =10%
- Is the Delta V bigger than the closing speed??? YES – we must ADUST ANY RESTITUTION OUT OF DELTA V TO GET ACCURATE CLOSING SPEED

Example Collisions – Restitution Considerations
Restitution is different depending on structure engaged 1

- 40 MPH Barrier End Central Collision (Click to play)

- 40 MPH Barrier End Offset Collision (Click to play)

Example Low Speed Collision – With Restitution

- Low Speed Crash
- (Click to play)
- Closing Speed is 9.4 mph
- Separation Speed is 3.6 mph

$$e = \frac{\text{Separation Speed}}{\text{Closing Speed}} \qquad e = \frac{3.6}{9.4} \qquad e = .38 \text{ or } 38\%$$

Equation 17

Compare this calculated Low-Closing-Speed COR of 0.38 (38%) to a High-Closing-Speed 40 mph crash that had a COR of 0.1 (10%).

- Large Collisions trend toward Plastic (*e* = 0)
- Small Collisions trend toward Elastic (*e* = 1)

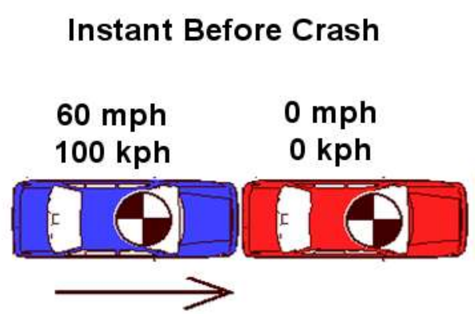
Restitution ADDS to Delta V; it must be ADJUSTED OUT of Closing Speed (imperial)

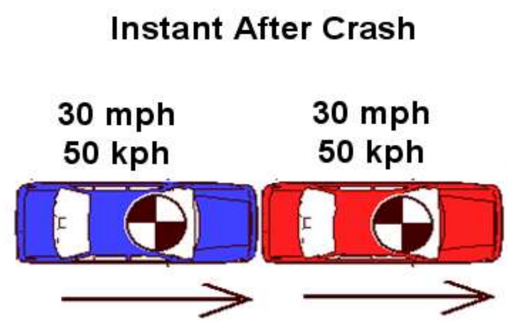
No Restitution

DV_{bullet} = -30 mph

DV_{target} = +30 mph

0 sep/60 close = 0% e





$$\text{Inline Closing Speed} = \left[\frac{1}{1+0}\right]\left[|-30| + |30|\right] = 60mph$$

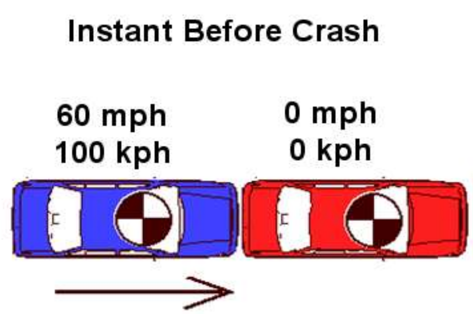
Equation 9

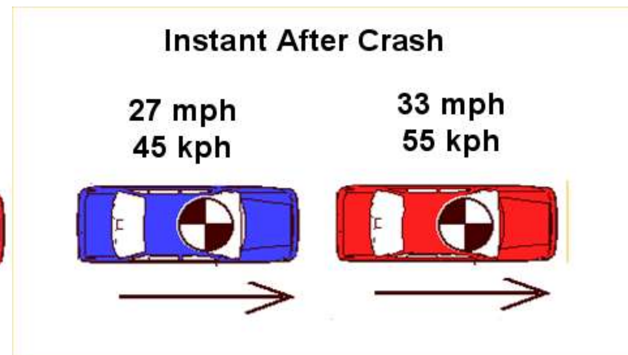
W/Restitution

Dv_{bullet} = -33 mph

DV_{target} = +33 mph

6 sep/60 close = 10% e

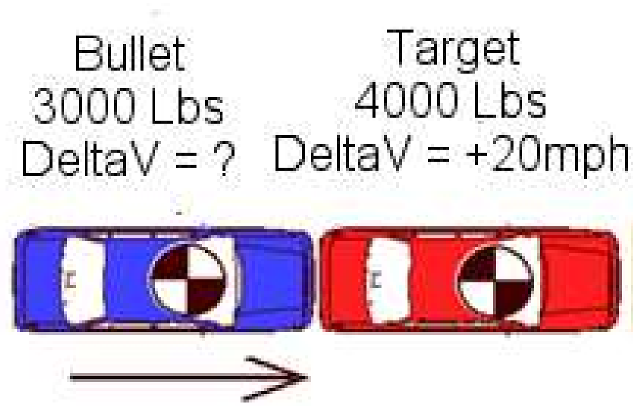




$$\text{Inline Closing Speed} = \left[\frac{1}{1+.1}\right]\left[|-33| + |33|\right] = 60mph$$

Inline Closing Speed – Example Problem

- A 4000 lb target is approaching a red light at 5mph when it is rear ended by a 3000 lb bullet. The EDR in the target measures a +20 mph longitudinal DeltaV. What is the closing speed?
- First since we know the DeltaV of the target vehicle and the vehicle weights we can ***use the inversely proportional DeltaV relationship*** to calculate the DeltaV for the target vehicle with **Equation 12**.



Closing Speed – Example Problem

- First since we know the DeltaV of the target vehicle and the vehicle weights we can use the inversely proportional DeltaV relationship to calculate the DeltaV for the bullet vehicle with Equation 12.

$$\Delta V_{\text{Bullet}} = -\Delta V_{\text{Target}} \frac{W_{\text{Target}}}{W_{\text{Bullet}}}$$

$$\Delta V_{\text{Bullet}} = -(20mph)\frac{4000}{3000}$$

$$\Delta V_{\text{Bullet}} = -(20mph)(1.33)$$

$$\Delta V_{\text{Bullet}} = -26.6\text{mph}$$

Inline Closing Speed – Example Problem

- Restitution in a typical 30mph barrier crash is about 10%
- The Daily/Shigemura recon book says “0 to 15%” in major collisions (depends on how structures engage)
- For this example, use 10% (Law Enf. may have to use 15%)

$$\text{Closing Speed} = \left[\frac{1}{1+e}\right][|\Delta V_1| + |\Delta V_2|]$$

$$\text{Closing Speed} = \left[\frac{1}{1+.1}\right][|20| + |-26.6|]$$

$$\text{Closing Speed} = [.909][20 + 26.6] = .909(46.6)$$

$$\text{Closing Speed} = 42.4\ \text{mph}$$

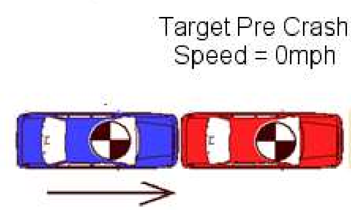
Now combine closing speed with V2 speed

- Closing Speed$_{(e=0.1)}$ = 42.4 mph Next we observe that the target was going 5mph (from its EDR).

Speed V1 = Closing Speed + V2

Speed V1 = 42.4 + 5

Speed V1 = 47.4 mph



Eccentric or OFFSET collisions

- In a **<u>central</u>** collision, the Effective Mass Ratio "gamma" is 1.0, and the term "drops out" leaving us with the simpler **central** collision closing speed formula

$$\text{Closing Speed} = \left[\frac{1}{1+e}\right]\left[\left|\Delta V_1\right| + \left|\Delta V_2\right|\right]$$

Equation for CENTRAL collisions only where the damage centroids reach a common velocity

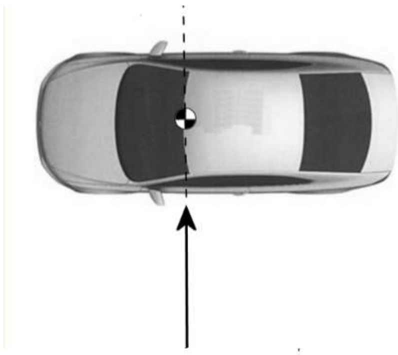
- But the real equation is

$$\text{ClosingSpeed} = \left[\frac{1}{1+e}\right]\left[\frac{\left|\Delta V_1\right|}{\gamma_1} + \frac{\left|\Delta V_2\right|}{\gamma_2}\right]$$

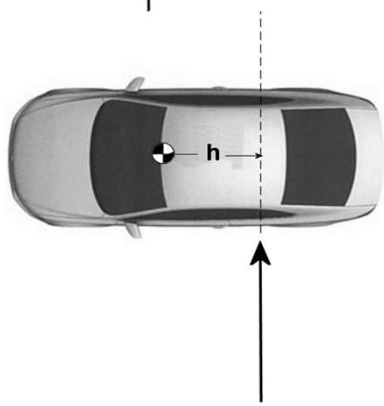
Equation –for <u>any</u> collision where the damage centroids reach a common velocity

- When using Delta V to calculate closing speed, if the offset is not considered, the closing speed will be
  under-estimated.

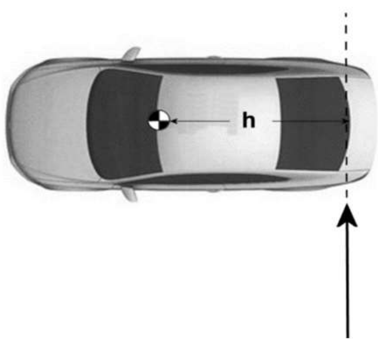
Increasing Eccentricity



Central collision – a crash where an extension of the PDOF passes through the vehicle's center of mass. No rotation post impact

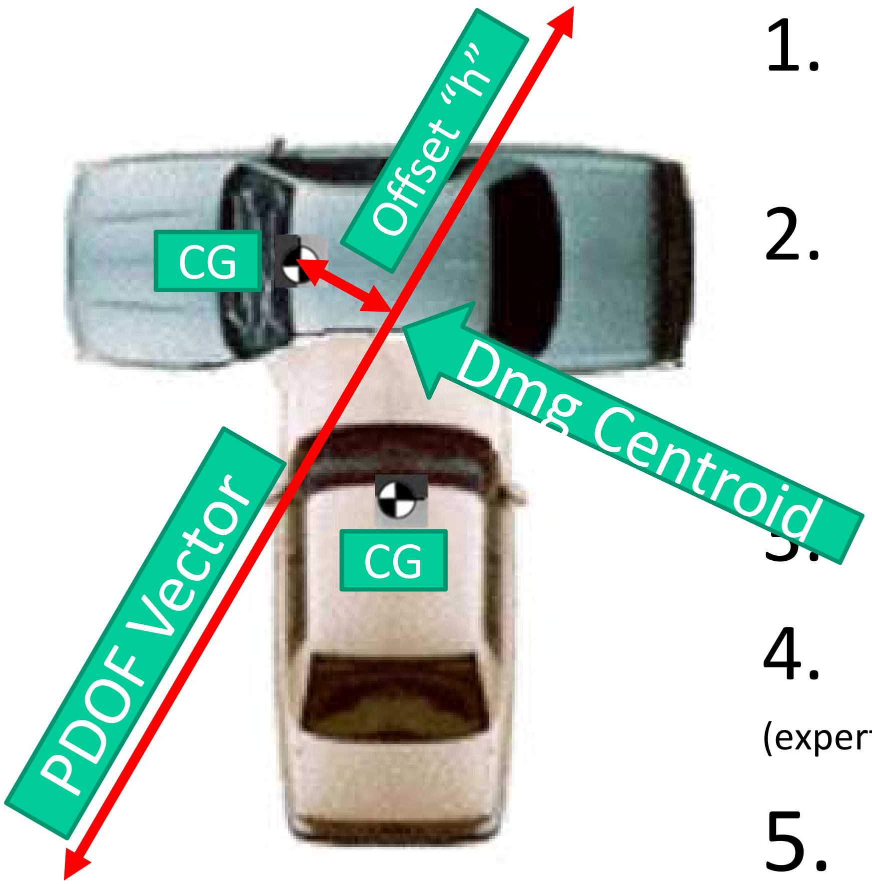


Offset Collision - – a crash where the extension of the PDOF misses the vehicle's center of mass. Some rotation is expected.



Severely Offset Collision - – the extension of the PDOF misses the vehicle's center of mass substantially and significant rotation is expected (depending on impact speed).

Step by Step EMR Process 1



1. Draw vehicles @MAX ENGAGEMENT
   (<u>NOT</u> first bumper touch)
2. Find the DAMAGE CENTROID, the center of the damage AREA
   (NOT the center of the damage FACE)
3. Draw PDOF line thru CENTROID
4. Look up CG and place on diagram
   (expert autostats or Canadian specs, often 4 to 8” behind top of windshield)
5. Measure <u>**perpendicular**</u>
   distance CG to PDOF, lever arm “h”

Step by Step EMR Process 2

6. Calculate **Yaw Moment of Inertia**

$I_{y\text{-}Car}$ = 1.03(weight in lbs) – 1206 * •

Heydinger & Garrott 1999-01-1336 inertial properties, 2010-01-0086 added CG to database

$I_{y\text{-}Pickup}$ = 1.03(weight in lbs) – 1343 *

7. Calculate **K²** (K is *Radius of Gyration*)

$$k^2 = \frac{\text{Yaw Moment of Inertia}(g)}{\text{Vehicle Weight}} = \frac{I_y g}{W}$$

8. Calculate **Effective Mass Ratio** (Gamma) γ

$$\gamma = \frac{k^2}{k^2 + h^2}$$

Don't square k^2 again!

Step by Step EMR Process 3

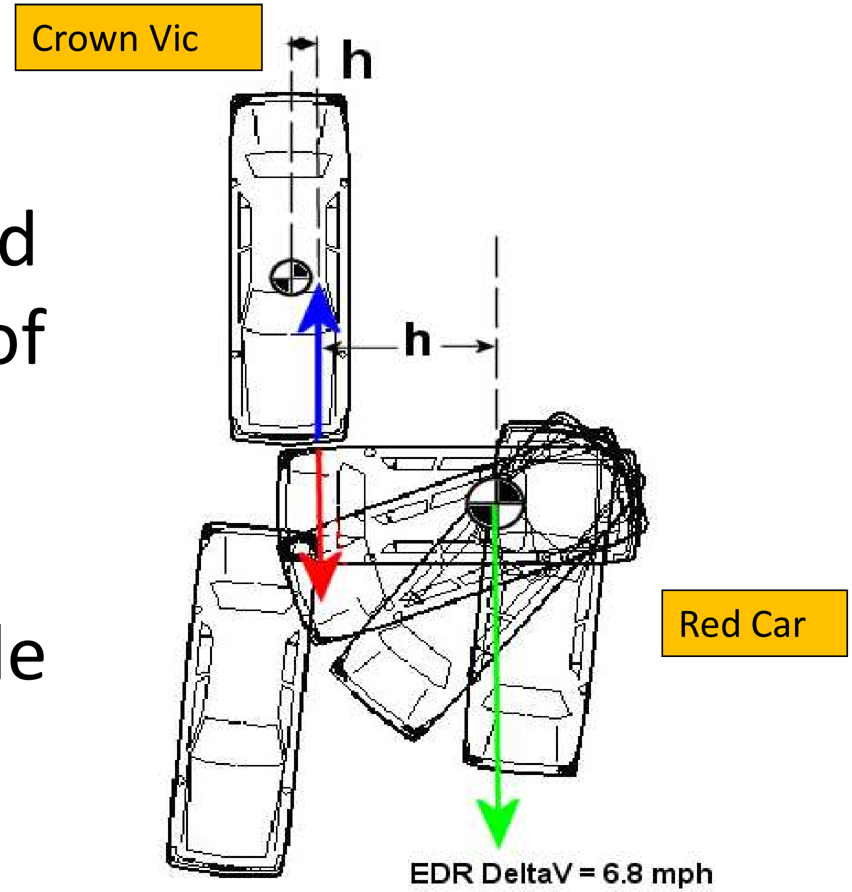
9. Put the Gamma into the closing speed equation

$$\text{ClosingSpeed} = \left[\frac{1}{1+e}\right]\left[\frac{|\Delta V_1|}{\gamma_1} + \frac{|\Delta V_2|}{\gamma_2}\right]$$

Eccentricity Example Problem

Review Video

- Q: The EDR in the 3250 lb red car records a Lateral DeltaV of 6.8 mph
- What is the approach speed for the 4600 lb striking vehicle (Crown Vic)?



Eccentricity Example Problem

- Given the EDR DeltaV in the red car calculate the Crown Vic DeltaV at its Center of Mass (COM)

$$\Delta V_1 = -\Delta V_2 \frac{W_2}{W_1}$$

Substituting $$\Delta V_1 = -6.8 \frac{3250}{4600}$$

$$\Delta V_1 = -4.8\, mph$$

- Next we need to calculate the Closing Speed based on the DeltaVs

Eccentricity Example Problem

We might be tempted to use the Closing Speed equation for **Central** Collisions (Equation 9A w/o restitution)

$$\text{Closing Speed} = |\Delta V_1| + |\Delta V|_2$$

$$\text{Closing Speed} = 6.8mph + 4.8mph$$

$$\text{Closing Speed} = 11.6mph$$

Eccentricity Example Problem

- Add the closing speed of 11.6 mph to the red car speed of 0 to get the approach speed of the Crown Vic IF IT WAS A **CENTRAL** COLLISION.

Speed V1 = Closing Speed +Speed V2

Equation 8C

Speed V1 = 11.6 + 0 = **11.6 mph**

- Unfortunately, this grossly under-estimates the speed of the Crown Vic. The analysis is **not that simple**. We need to **correct** for the eccentric nature of this crash

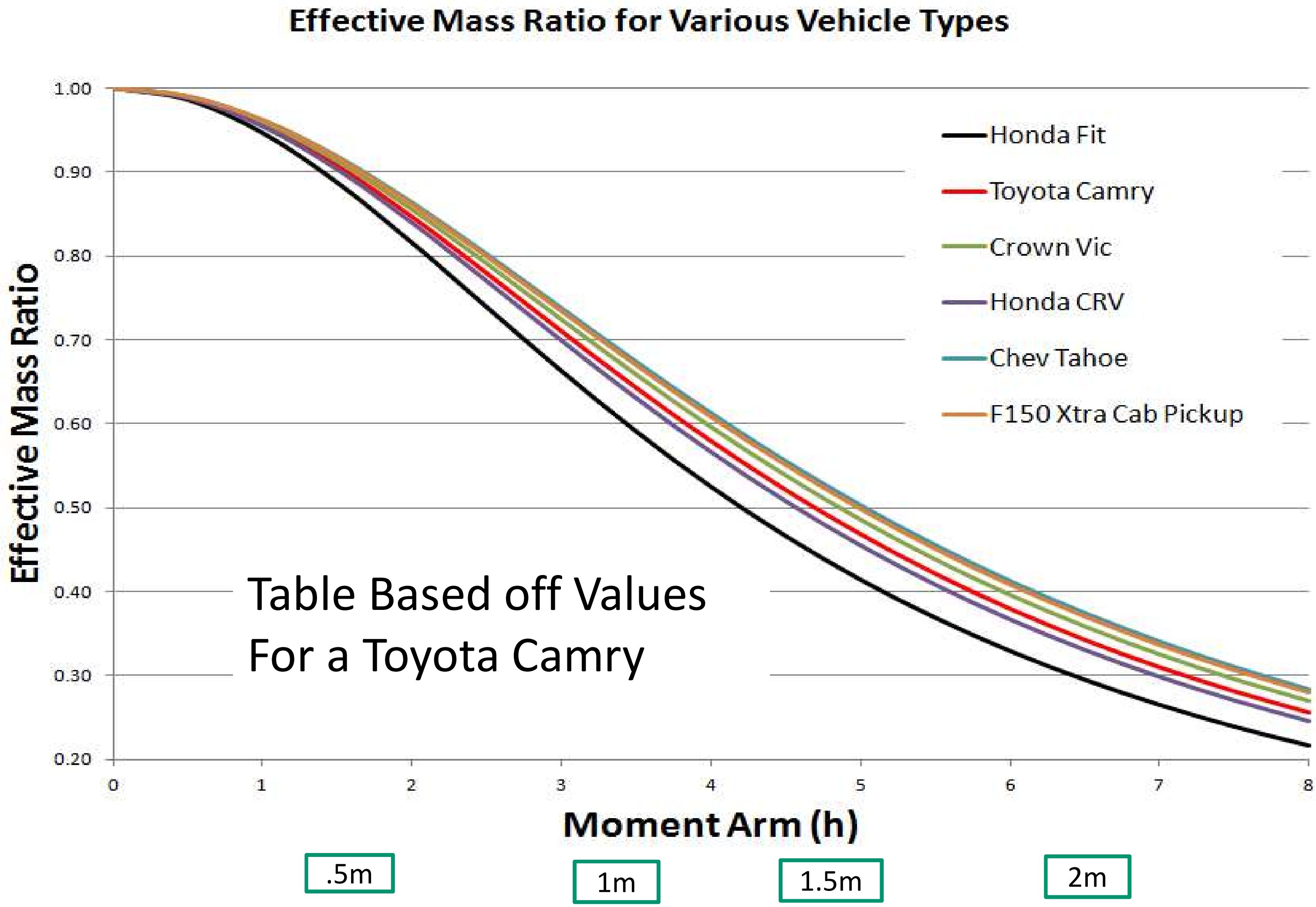
Effective Mass Ratio

- Start with the DeltaV at COM for both vehicles $\Delta v_2 = -\frac{w_1 \Delta v_1}{w_2}$

  (BEFORE we apply the Effective Mass Ratio to either number)
- Then divide each Delta V by the Effective Mass Ratio for that vehicle to TRANSLATE from COM to Damage Centroid where crash occurs
- The Effective Mass Ratio can be calculated from the vehicle weight, and the offset in feet from the PDOF line to the center of mass
- In EDR analysis Level 1, we encouraged you to use the table below where the EMR was pre-calculated for a full-size Toyota Camry. While there are slight differences for lighter and heavier cars, in Level 1 we ignore those differences. Determine or estimate your lever arm or "h" in feet

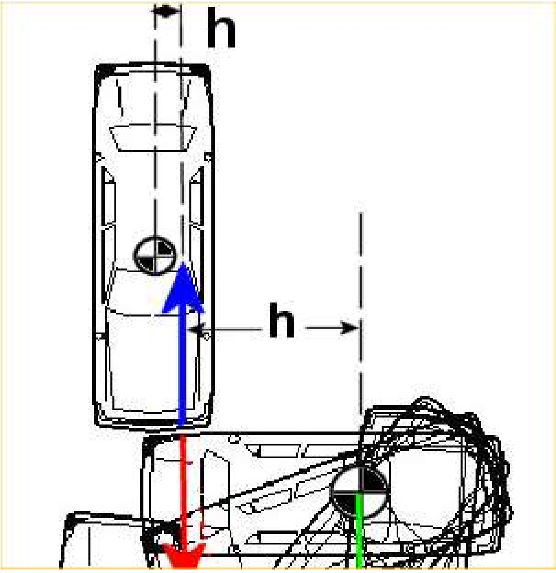
When "h" is	0 Feet	1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet
	0m	0.3m	0.61m	0.91m	1.22m	1.52m	1.83m	2.13m	2.44m
Effective Mass Ratio	**1 (Central Collision)**	**.95**	**.83**	**.70**	**.57**	**.45**	**.37**	**.30**	**.25**

Effective Mass Ratios for Different Vehicles



Eccentricity Example Problem

1. Draw the vehicles at max intrusion
2. Determine the damage centroid.
3. Draw the PDOF line thru the damage centroid.
4. Find the Center of Mass (CG)
5. Measure the perpendicular distance from COM to the PDOF, “h” for both vehicles. In this case the CAD diagram indicates that h was 8 feet for the red car and 1 foot for the Crown Vic.



Use the table to **estimate** the EMR for both vehicles (instead of steps 6 to 8).

When “h” is	0 Feet	1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet
	0m	0.3m	0.61m	0.91m	1.22m	1.52m	1.83m	2.13m	2.44m
Effective Mass Ratio	1 (Central Collision)	.95	.83	.70	.57	.45	.37	.30	.25

- In this case $EMR_{(Red\ Car)} = .25$, and $EMR_{(Crown\ Vic)} = .95$

Eccentricity Example Problem

- Step 9: Since this is an eccentric collision we use the Closing Speed equation with EMR corrections. We just calculated the DeltaVs. Recall earlier we found the EMRs with the table for both vehicles

$$\text{ClosingSpeed} = \left[\frac{1}{1+e}\right]\left[\frac{|\Delta V_1|}{\gamma_1} + \frac{|\Delta V_2|}{\gamma_2}\right]$$

Substituting & assuming e=0

$$\text{Closing Speed} = \frac{4.8}{.95} + \frac{6.8}{.25}$$

$$\text{Closing Speed} = 5.05mph + 27.2mph$$

$$\text{Closing Speed} = 32.25mph$$

Eccentricity Example Problem

- Step 10: V1 = CS + V2 = 32.25 + 0

(the closing speed of 32.25 mph was the actual approach speed of the Crown Vic since the red car was stopped).

- Compare the results with and without the EMR adjustment:

- Closing Speed Without EMR 11.6 mph
- Closing Speed With EMR 32.25 mph

Example: V2 hits parked V1 on side

Given ΔV2 of *10mph @ COM*

V2 = 3000lb, V1 = 3750lbs

Δ V1= ΔV2*(3000/3750) = *8@COM*

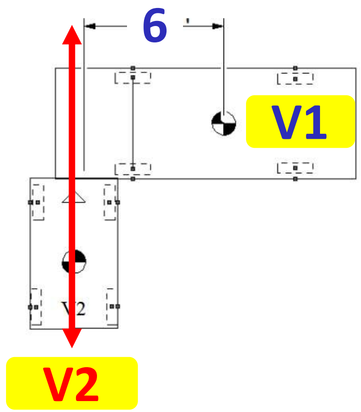
I_{y1}=1.03*3750-1206 = 2656.5

$$k_{v12} = \frac{I_y g}{W} = \frac{2656.5 * 32.2}{3750} = 22.81$$

$$\gamma_{v1} = \frac{k^2}{k^2+h^2} = \frac{22.81}{22.81+6^2} = 0.3879 \text{ unitless}$$

$$CS = \frac{1}{1+e}\left(\frac{|\Delta V1|}{\gamma 1} + \frac{|\Delta V2|}{\gamma 2}\right)$$

$$CS = \frac{1}{1+0}\left(\frac{|8|}{0.3879} + \frac{|10|}{1}\right) = 20.62 + 10 = 30.62\text{mph}$$



Finding CG in Expert Autostats

Expert AutoStats®

2004 CHEVROLET TRAILBLAZER 4 DOOR 4X2 UTILITY

Other Information

Tip-Over Stability Ratio =	1.04	Reasonably Stable
NHTSA Star Rating (calculated)		**

Center of Gravity (No Load):

Inches behind front axle	=	53.11
Inches in front of rear axle	=	59.89
Inches from side of vehicle	=	37.50
Inches from ground	=	29.93
Inches from front corner	=	93.92
Inches from rear corner	=	112.33
Inches from front bumper	=	86.11
Inches from rear bumper	=	105.89

Finding CG from Canadian Specs

Canadian Vehicle Specifications - Version 2018.1

Year: 2018 Make: FORD Model: FLEX

Help

History

MODEL	A WB	B OL	C OW	D OH	E CW	F TF	G TR	WD
FLEX 5DR CUV AWD	51.2 118.2	86.7 202.1	16.5 76.0	37.8 67.8	49.6 4829	38.2 65.8	44.9 65.8	54/46
FLEX 5DR CUV FWD	51.2 118.2	86.7 202.1	16.5 76.0	37.8 67.8	49.6 4459	38.2 65.8	44.9 65.8	54/46

$CG_{\text{from front wheels}} = \%\text{ wt on rear wheels} * \text{wheelbase}$

$CG_{\text{from front wheels}} = 46\% * 118.2\text{ in} = 54.4\text{ in}$

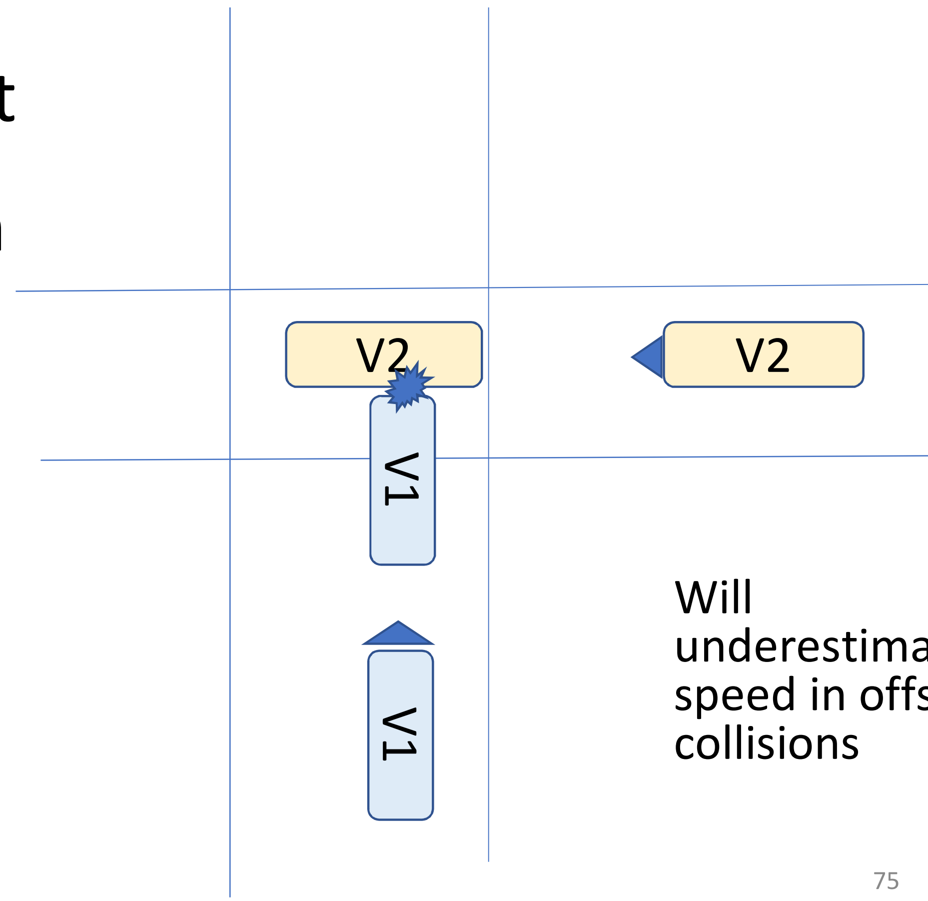
Link: http://www.carsp.ca/research/resources/safety-sources/canadian-vehicle-specifications/

90^{o} intersection central collisions (limited application)

“inline approximation”

- Data recorder in V2 only
- Isolate X and Y axis on V2. First look at V2 DVy only, ignore DV_x. Treat as an inline collision with V2 standing still.
- If = weight, V1 DV_x =V2 Dv_y
- No Restitution
- Closing speed =V1 DV_x + V2 DV_y
- For V2 DVy 20, V1 DV_x=20, Closing speed = 40

V1 = 40 + V2 = 40 + 0 = 40



Will underestimate speed in offset collisions

What Delta V to Use??

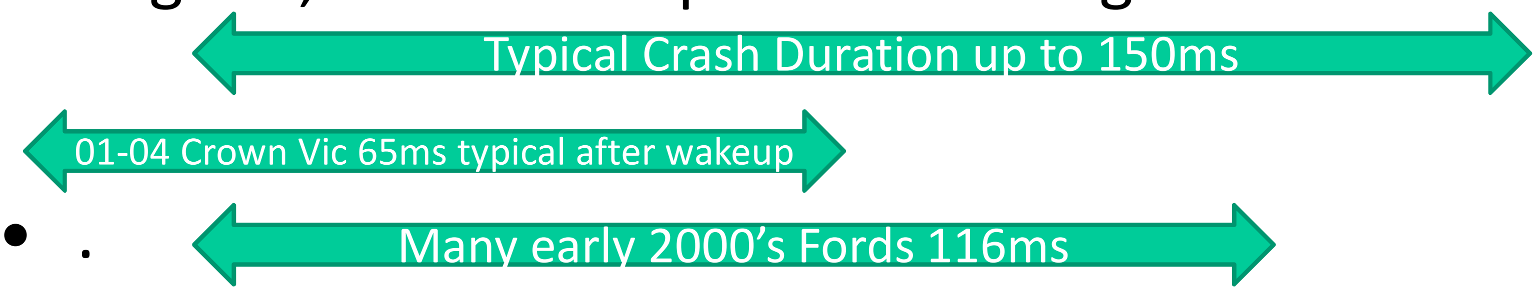
- Late 90's GM with no single value – biggest number on the graph (almost always between 100 and 150ms)
- 2000's GM – use single "Max" value given (more accurate than graph)
- Others-Beware Mfrs may use "max" value that *includes skidding to point of rest* – check for "Part 563" end of crash - ***ΔV change <0.5mph over 20ms*** – typically between 100-150ms

Cautions Using Delta V Information

1. Recorder only captures part of crash
2. Recorder captures data from BEFORE or AFTER crash
3. Missed Delta V before algorithm wake up
4. +offset in accelerometer (Toyota Gen 1 & 2)
5. Missed Delta V due to *sensor clipping*
6. *accelerometer not pointed in direction of travel*
7. *Do I need to consider GROUND FORCES*
8. Unusual DeltaV Curve Shape
9. *Part 563 EDR Regulations*
10. *Small Delta V's*
11. *Car is in yaw at impact, accelerometer not pointed forward*

Cautions Using ***Delta V*** Information
1. **Insufficient Duration**

- Most crashes last 100 to 150 milliseconds, some barrier crashes and head ons shorter, some pole, underride, angular, and sideswipe crashes longer.



- .
- If the duration is not sufficient to capture the entire crash, the ***Delta V will be understated***. You can still use it but any speeds calculated from it must be considered a MINIMUM.

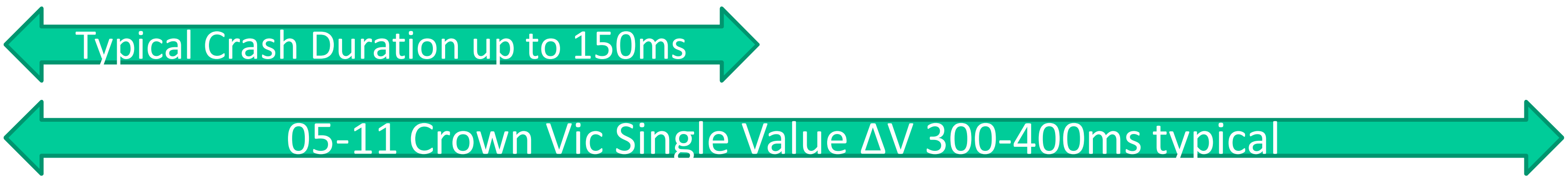
Cautions Using Delta V Information 1. Insufficient Duration

- Classic example: 2001-2004 Crown Vic EDR were designed to capture only 50 ms after deployment, with typical deploy times in those days of 15ms in severe crashes, the resulting 65 ms was seldom enough to capture entire crash pulse.
- Slope of Delta V line must become parallel to x axis or acceleration must settle to near zero to know entire crash has been captured.

Cautions using Delta V Information

2. Excessive Duration

2005-2011 Crown Vic, Grand Marquis, Town Car are the classic example with this issue.



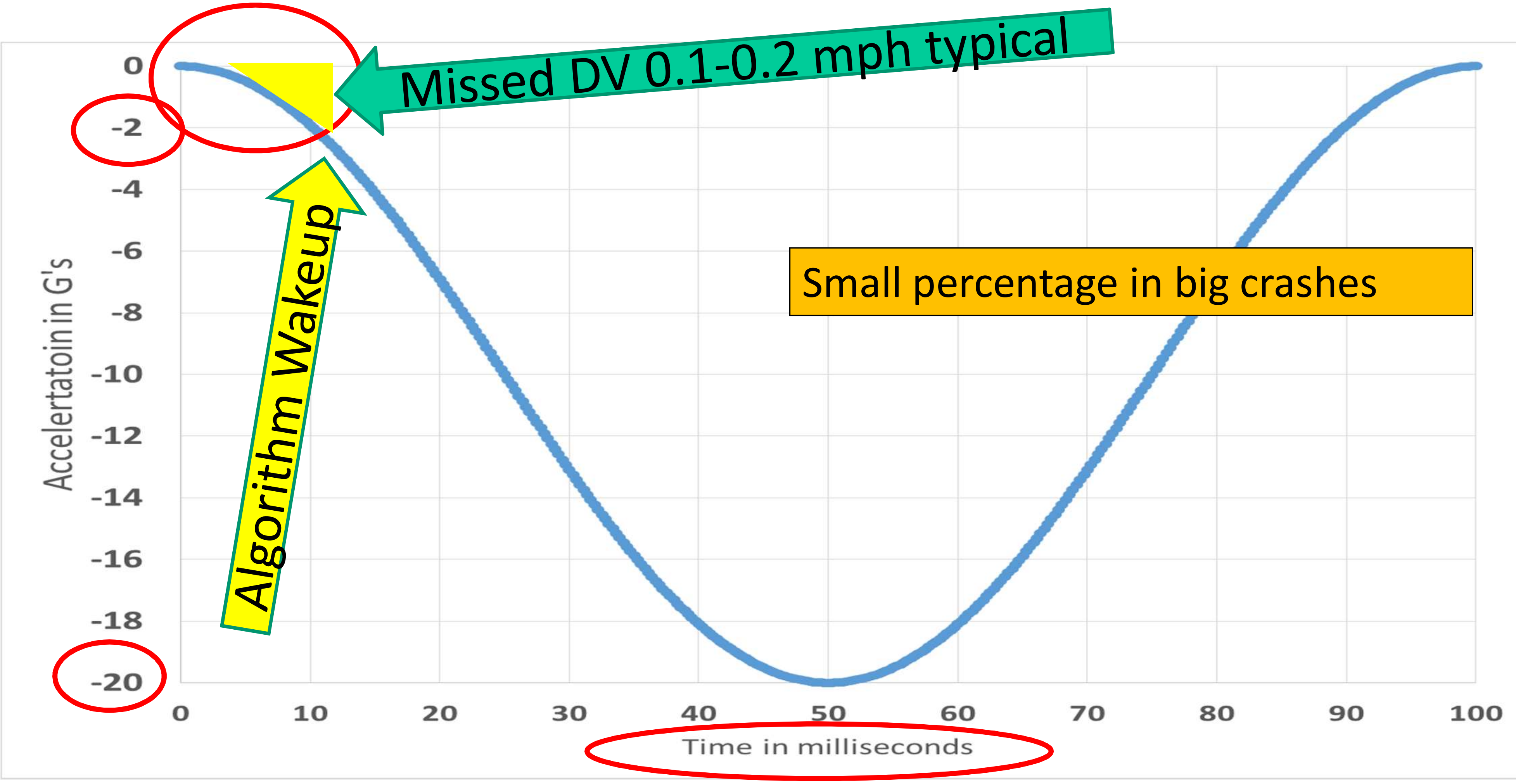
- Crown Vic cumulative longitudinal Delta V register collects data as long as the algorithm runs – typical 300-400ms, worst case seen to date was 1900ms.
- Typical postcrash situation is vehicle skidding to a stop. Use decel rate from your postcrash skid analysis times duration, estimate how much extra Delta V is included in the EDR reported number.

Cautions Using Delta V Information

3. Missed ΔV Before wake up

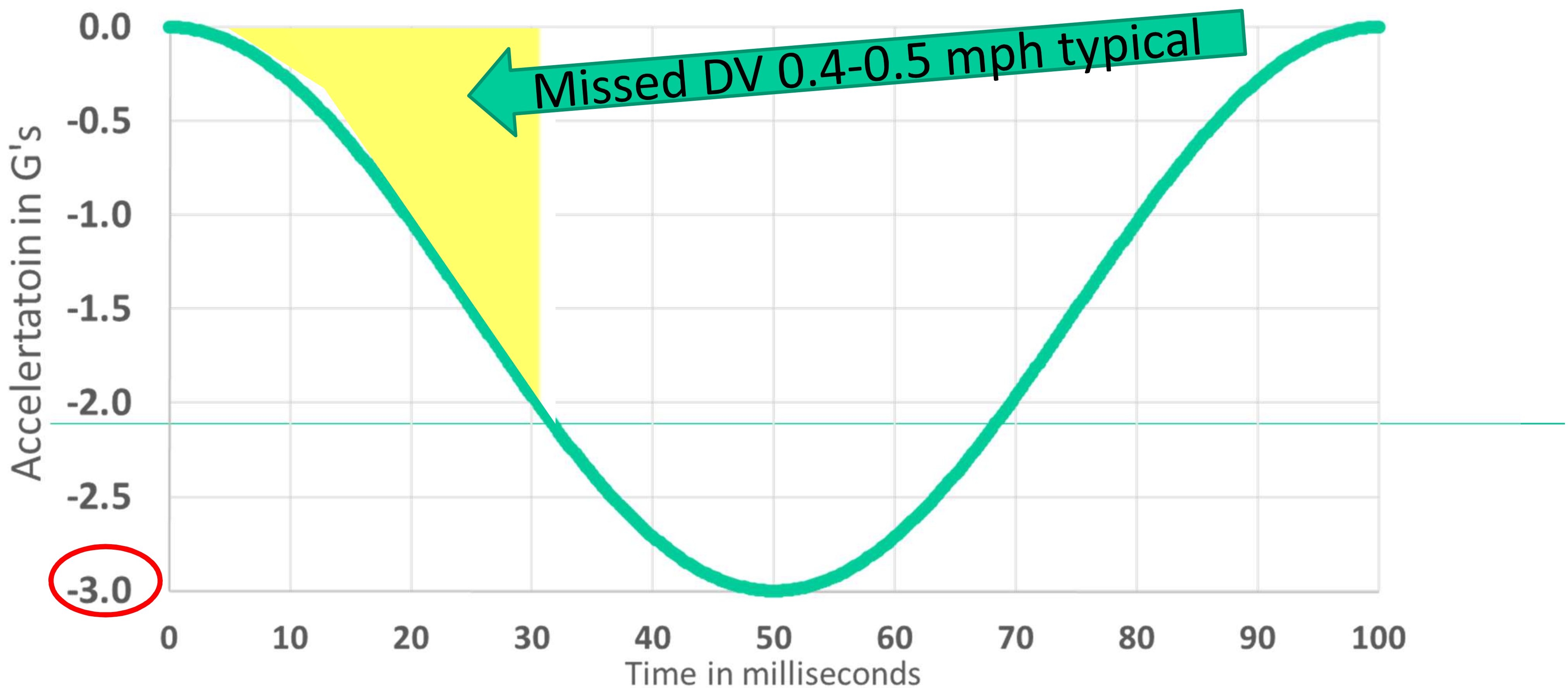
- Generally NOT SIGNIFCANT (typical 0.1 mph) in high Delta V frontals, the algorithm reaches the typical 1-2g wakeup within a few milliseconds.
- SIGNIFICANT in low Delta V events like ped hits where 1-2G is a significant portion of the peak G's. The tail missed (0.4 to 0.5mph) can be estimated based on how sharp the onset of the crash is.
- Not all systems are "wake up" systems. There are "continuously running" systems like Ford Crown Vic that don't have to wake up. These can sometimes be recognized by acceleration graphs that have data shown before time zero or where zero is the time of deployment.
- Post-2013 Toyotas start accumulating Delta V after 0.5mph is reached within 20ms (meaning it does not report the first 0.5 mph).

Missed Delta V Before Wakeup – Big Crashes



Missed Delta V before wakeup – small crashes

(Pre-563 or mfrs who kept low thresholds)



Cautions Using Delta V Information

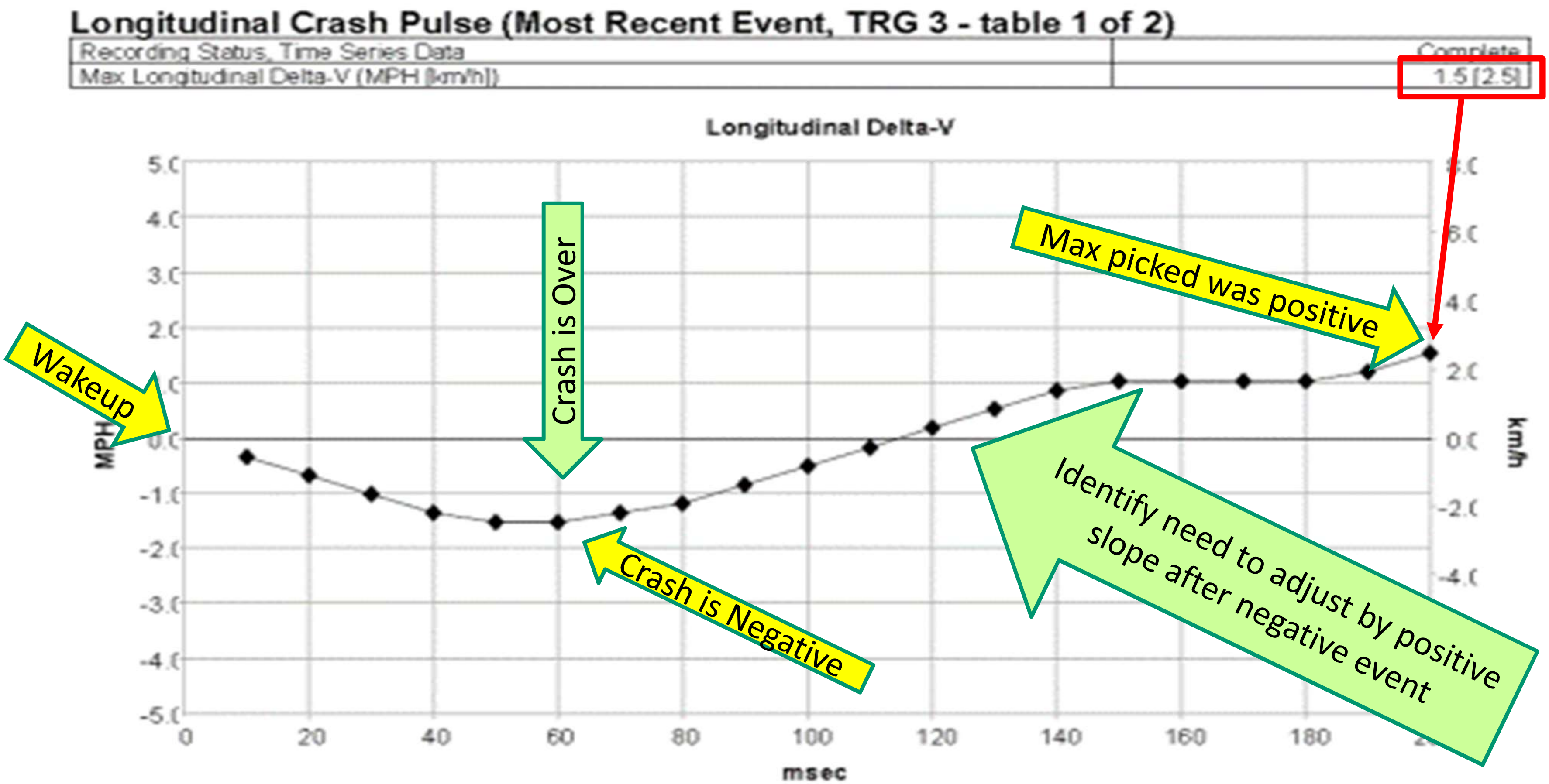
4. +G offset in Delta V Calculation (Toyota)

- Toyota Gen 1 and some Gen 2 vehicles have + 0.39G offset in accelerometers
- Delta V calculated in frontal crashes will be under-reported, Delta V in rear crashes will be over reported
- Fixed midyear 2012 by Toyota in 3rd gen "12 EDR" for Part 563
- Not discussed in Data Limitations at this time. Test data in **SAE 2013-01-1268 quantifies under and over reporting, corresponds to 0.4g in Gen 1. Test data in SAE 2016-01-1496 on 07 Yaris (Gen 2) indicates 0.87G. SAE 2016-01-1495 tests several vehicles, indicates it is vehicle dependent.** Helps explain why Delta V may not correlate perfectly to scene evidence.
- Magnitude of a +0.39G offset on Delta V over 150 ms (reference)

$$\frac{.39g(32.2\text{fps/s})(.150\text{seconds})}{1.466(\text{mph/fps})} = 1.3\text{mph}$$

Cautions Using Delta V Information

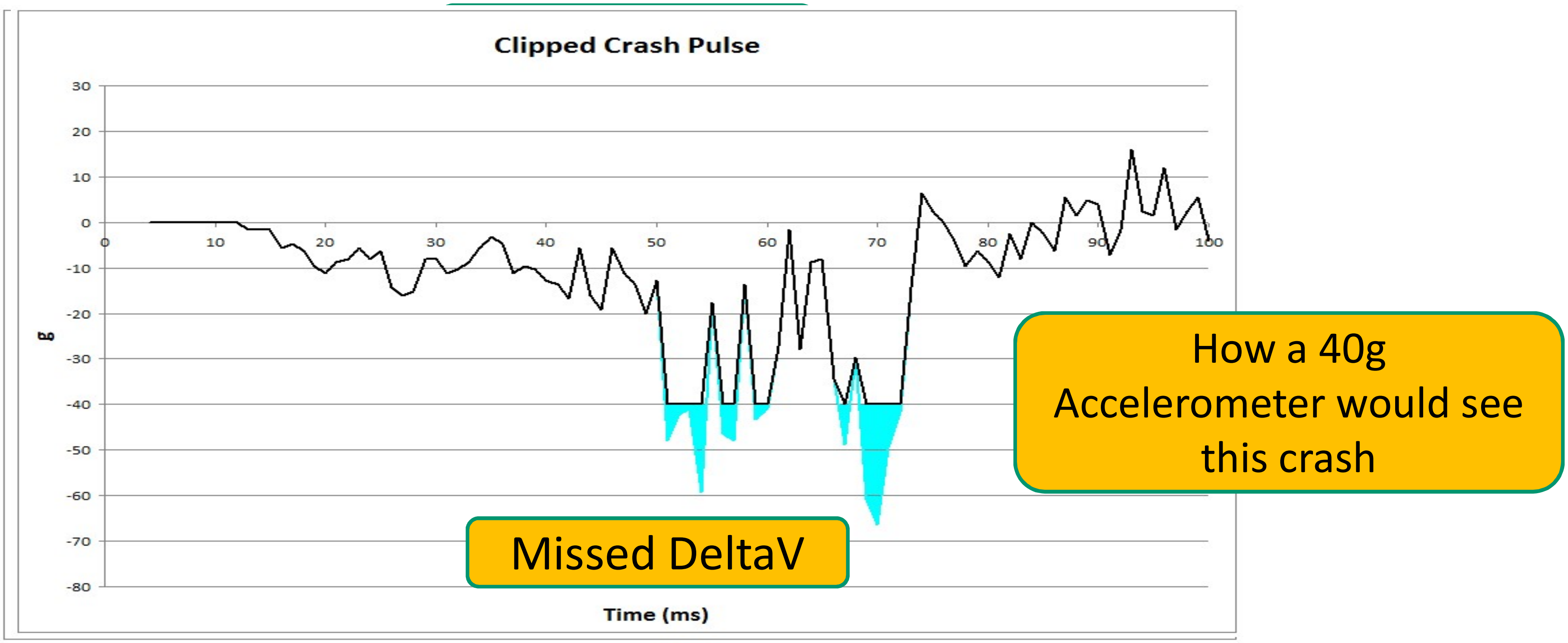
4. +G offset in Delta V Calculation (Toyota)



Cautions Using Delta V Information

5. Clipping [4]

Sensor Clipping – always results in under-reporting

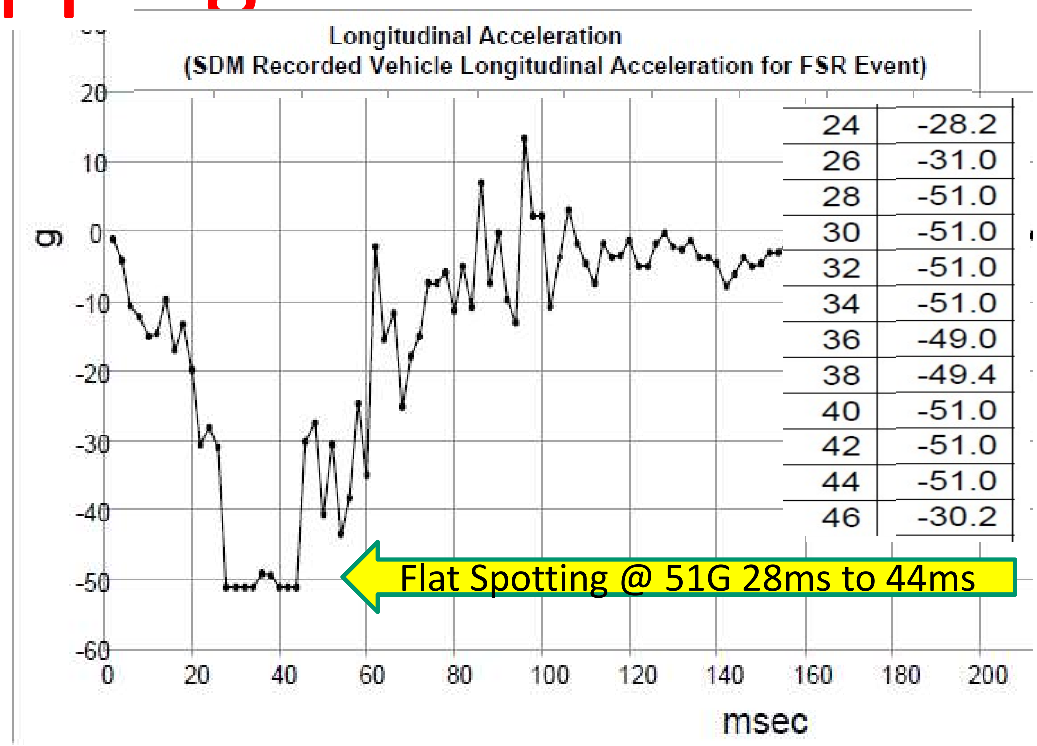


Cautions Using Delta V Information

5. Clipping

How do you identify it??

IF you have an acceleration graph, look for flat spotting at 40, 50, 60, 70, 80 or 100g. Many manufacturers use 50g accelerometers.

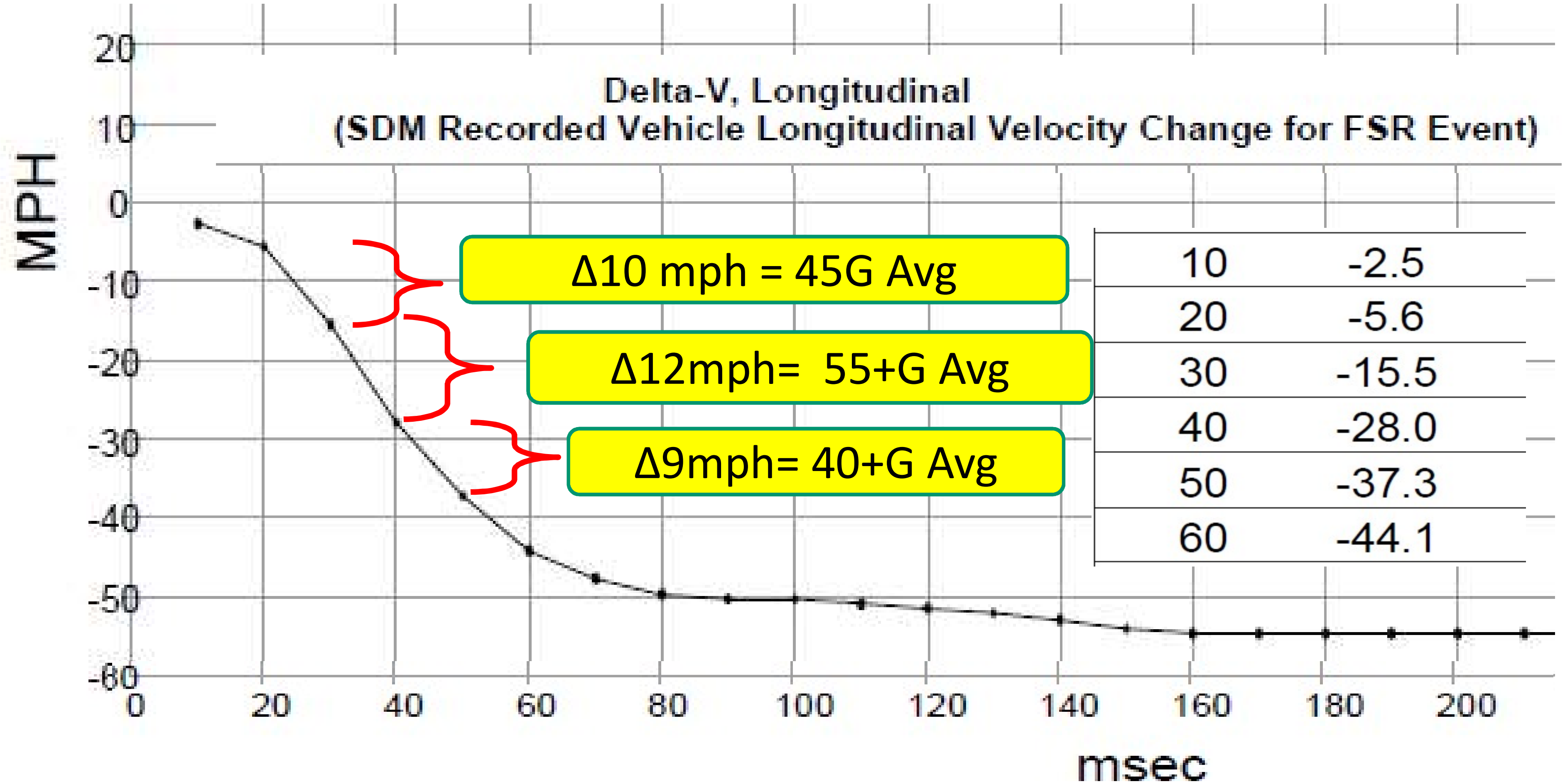


Identifying clipping

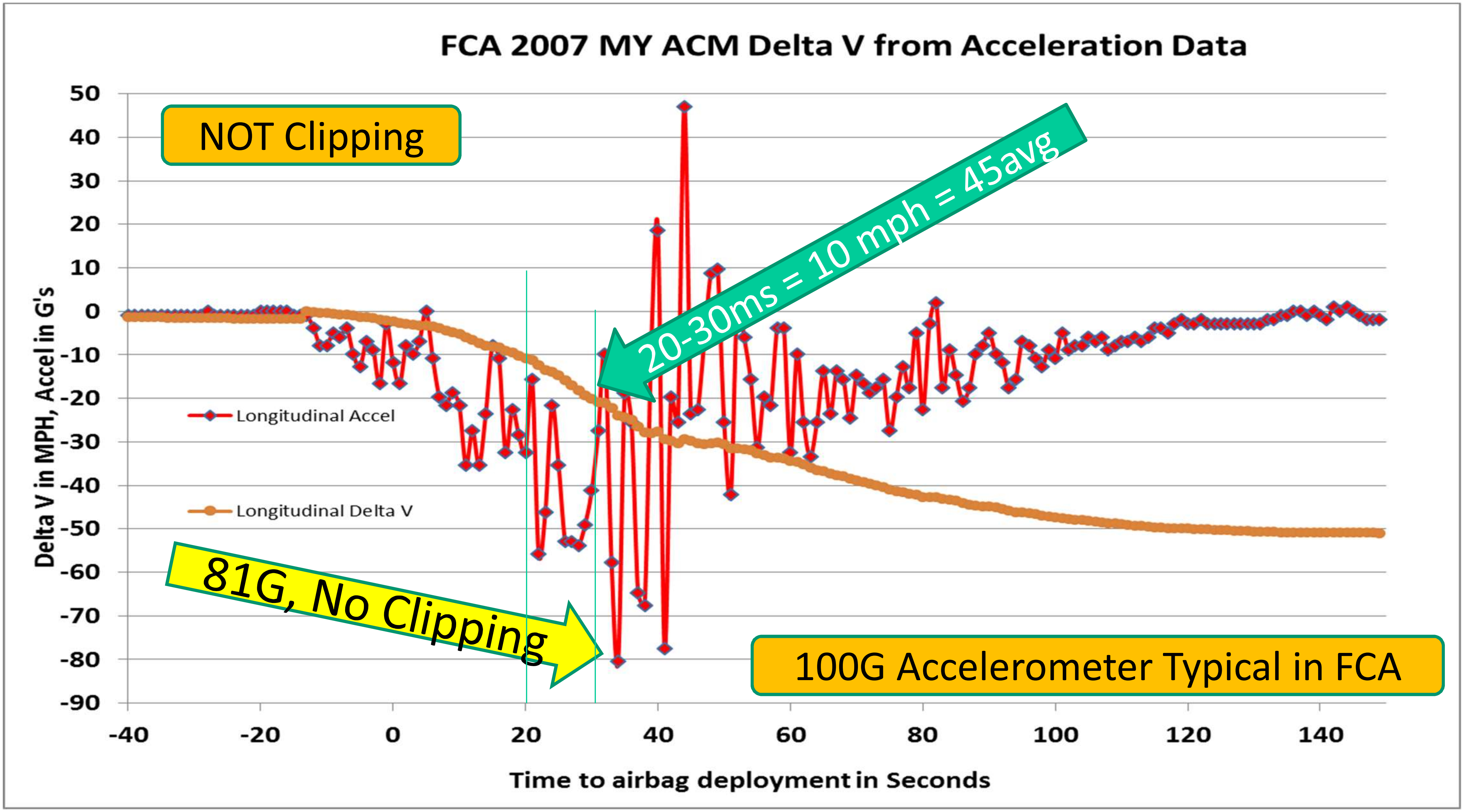
- A steady 50g produces 11 mph of speed change over 10ms (50G*32.2/1.466*0.01 sec)
- If your Delta V is over 35 mph, review the Delta V vs time data table. Subtract consecutive values to get the change over each 10 ms interval. Find the biggest one.
- 11 mph would indicate 50G over the entire 10ms (potentially clipped the entire time), 9mph would indicate spikes over 50G are likely, 7mph or less would indicate any spikes were only for a short time.
- Some ACM's have over 50G accelerometers, this is only a diagnostic to identify <u>possibility</u> of clipping

Identifying Clipping from DV

Subtract consecutive 10ms values of Delta V   11mph = 50G



10	-2.5
20	-5.6
30	-15.5
40	-28.0
50	-37.3
60	-44.1



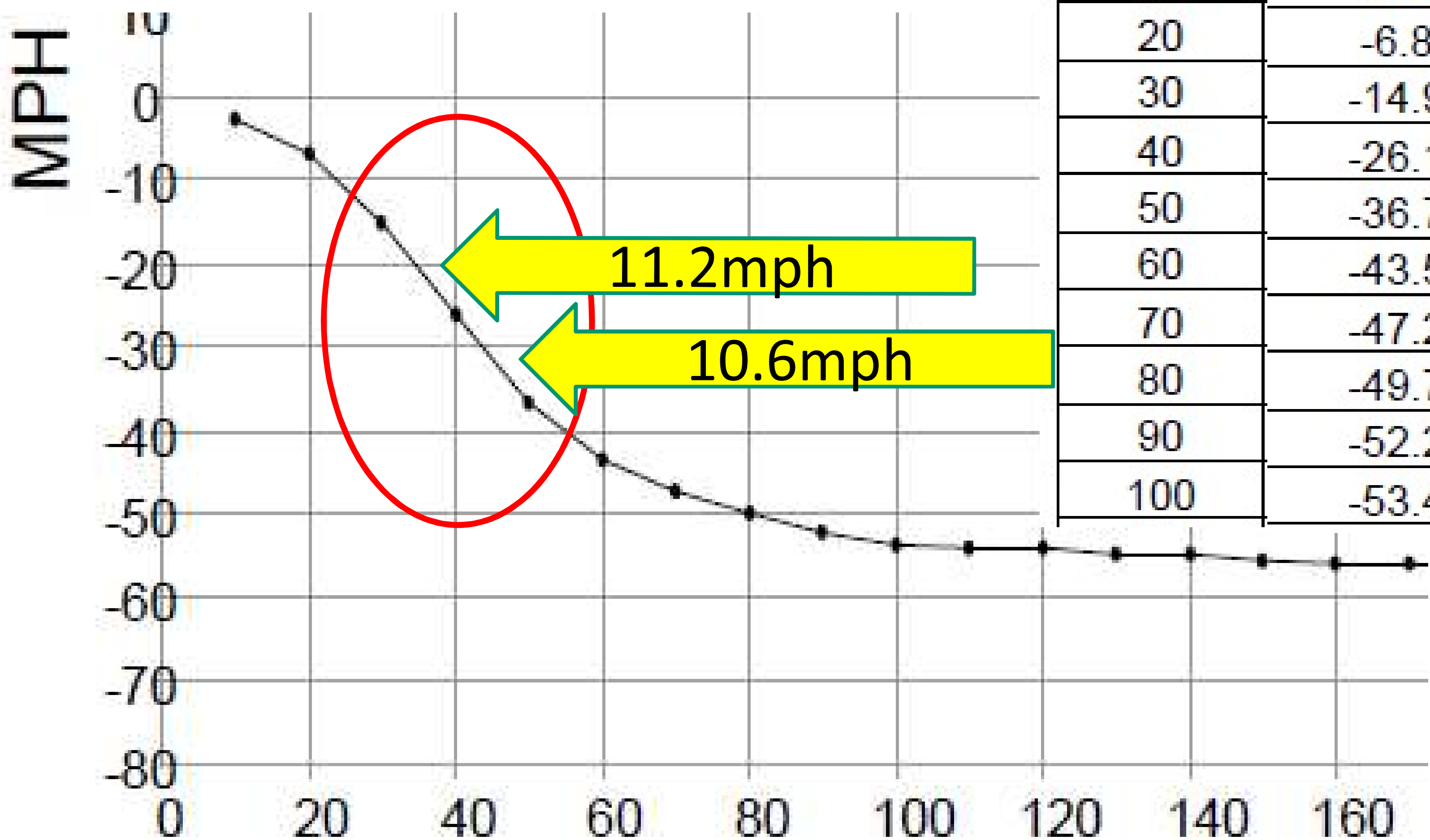
FCA 2007 MY ACM Delta V from Acceleration Data
NOT Clipping
20-30ms = 10 mph = 45avg
Longitudinal Accel
Longitudinal Delta V
81G, No Clipping
100G Accelerometer Typical in FCA
Delta V in MPH, Accel in G's
Time to airbag deployment in Seconds
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-40
-20
0
20
40
60
80
100
120
140

EDR's built after 9-1-14

- NHTSA originally required Delta V to be accurate within +/-10%, but the mfr's said *impossible*
- NHTSA amended the reg to say if manufacturer states *when* clipping first occurred, accuracy would not be enforced after that point.
- Mfrs now display clipping time (Mercedes below)

Maximum Delta-V, Longitudinal (MPH [km/h])	-49.7 [-80]
Maximum Delta-V, Lateral (MPH [km/h])	-10.6 [-17]
Time, Maximum Delta-V, Longitudinal (msec)	163
Time, Maximum Delta-V, Lateral (msec)	153
Clipping Time Longitudinal Sensor (msec)	23
Clipping Time Lateral Sensor (msec)	8

2015 GM Clipping Example – DV



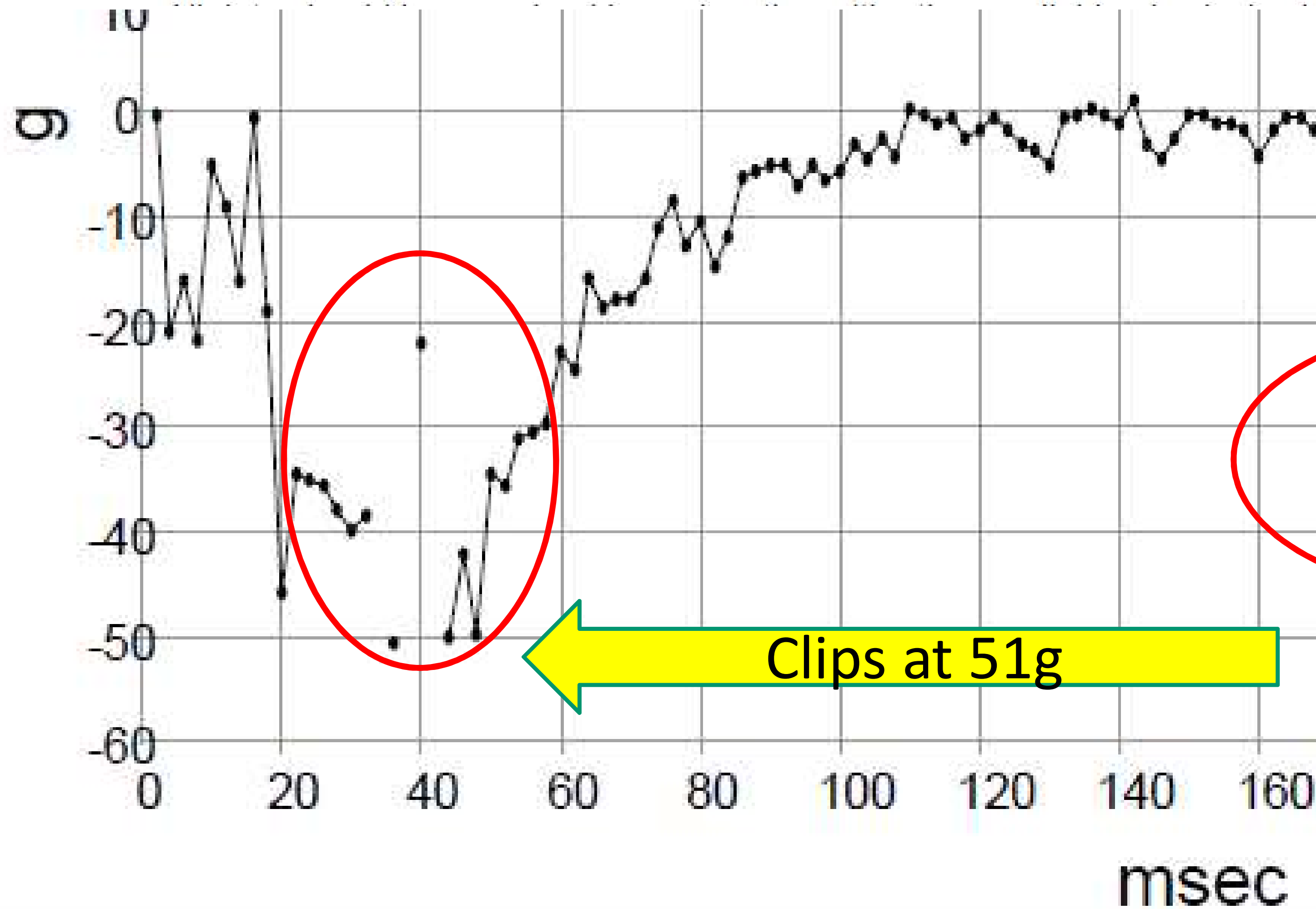
10	-2.5
20	-6.8
30	-14.9
40	-26.1
50	-36.7
60	-43.5
70	-47.2
80	-49.7
90	-52.2
100	-53.4

11.2mph

10.6 mph

2015 GM Clipping Example Accel

-The reported range of the longitudinal and lateral acceleration values is approximately ± 50 g.



20	-45.8
22	-34.6
24	-35.0
26	-35.8
28	-37.8
30	-39.8
32	-38.6
34	Data Invalid
36	-50.6
38	Data Invalid
40	-22.2
42	Data Invalid
44	-50.2
46	-42.2
48	-49.8
50	-34.6
52	-35.8

50.6

50.2

6. *Accelerometer not pointed forward*

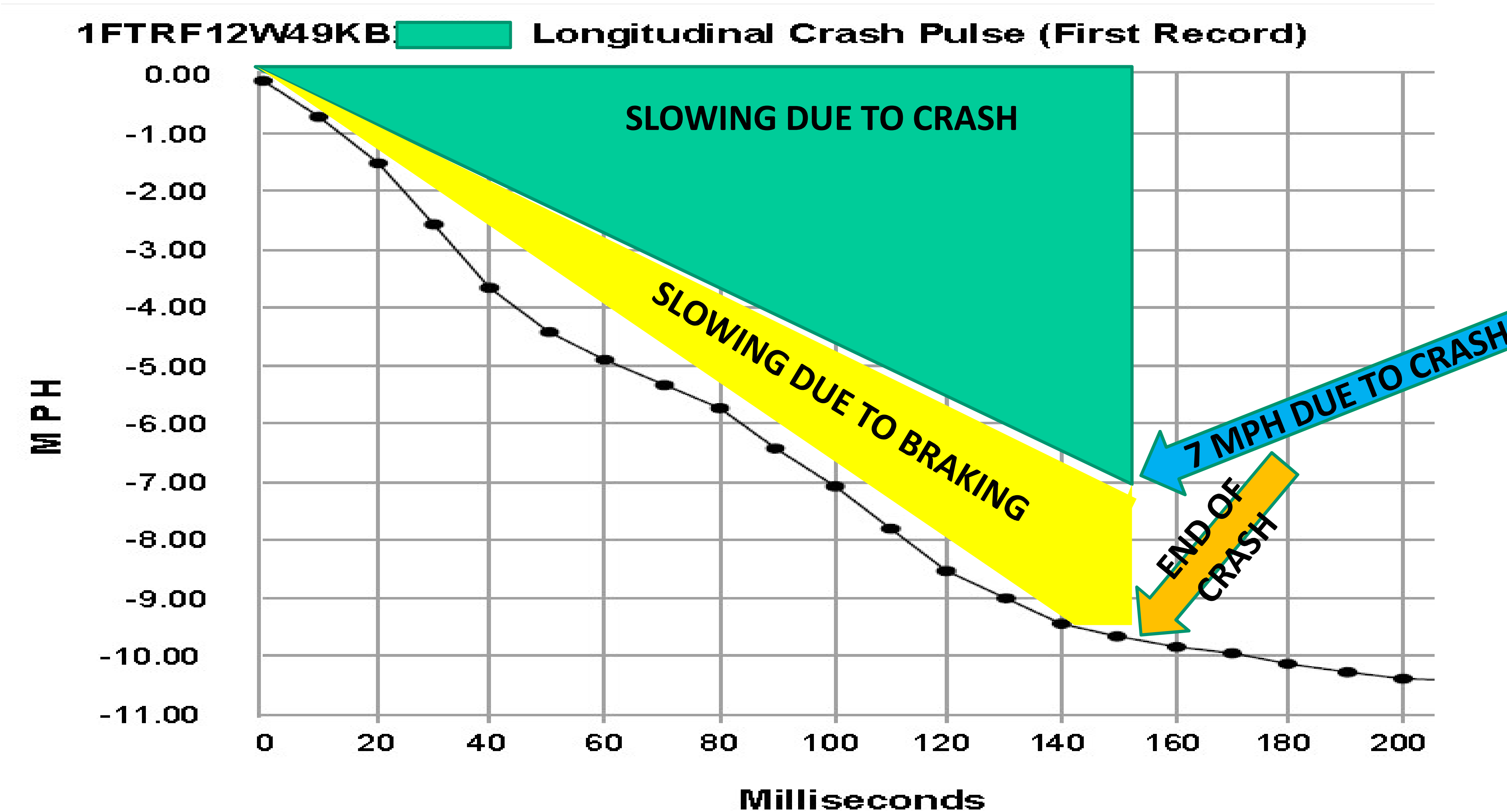
- *Car is in yaw at impact, accelerometer not pointed forward (adjust by cosine of angle)*
- *Car is pitched at an angle at impact*
- *Accelerometer is in crush zone, mounting is reoriented. This is accentuated is there is direct contact between structure and the ACM.*

Cautions Using Delta V information
7a. GROUND FORCES – Subtract them out

- In traditional recon we explicitly IGNORE ground forces during collisions
- In low speed or low Delta V collisions ground forces may be significant.
- Example1: Driver sees ped, slams on brakes, hits Ped resulting in an actual 1 mph DeltaV from ped hit. Slowing due to braking during the crash adds

$$\frac{-0.7g(32.2\text{fps/s})(0.150\text{seconds})}{1.466(\text{fps/mph})} = -2.3\text{mph}$$

- Note: Use ABS drag factor
- So the EDR DeltaV includes slowing due to braking (ground) forces during the collision
- Delta V of Ped Hit = -3.3mph EDR - - 2.3 ground forces = -1.0 mph PED ΔV



1FTRF12W49KB
Longitudinal Crash Pulse (First Record)
SLOWING DUE TO CRASH
SLOWING DUE TO BRAKING
7 MPH DUE TO CRASH
END OF CRASH
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
-9.00
-10.00
-11.00
MPH
0
20
40
60
80
100
120
140
160
180
200
Milliseconds

Cautions using Delta V information

7b. GROUND FORCES – Add them back in

- Example2: A stationary car equipped with an EDR is struck squarely in the side by a motorcycle. The tires are unable to roll and the car is pushed fully sideways. The EDR in the car documents a 10 mph (16 kph) lateral DeltaV.
- In this case, not only does the motorcycle accelerate the car by 10 mph via crash forces, but it must also push the car sideways on a 0.7 f surface during the crash.
- First calculate the ground forces

$$\frac{-0.7g(32.2\text{fps/s})(0.150\text{seconds})}{1.466(\text{mph/fps})} = -2.3\text{mph}$$

Delta V of MC Hit = +10.0mph EDR - - 2.3 ground forces = 12.3 mph Crash ΔV

Cautions Using Delta V information

7b. GROUND FORCES – Add them back in

- Next we recognize that the Motorcycle is the source of both the EDR DeltaV and the forces that were applied to the ground as the car moved sideways during the crash.
- As a result we add the estimated 2.6 mph ground force loss to the EDR documented 10 mph Delta V to have an estimate of the forces brought to the collision from the motorcycle 12.6 mph
- If we wanted to calculate the motorcycles DeltaV we would use the 12.6 mph DeltaV as the DeltaV Target.

$$\Delta V_{\text{Bullet}} = -\Delta V_{\text{Target}} \frac{W_{\text{Target}}}{W_{\text{Bullet}}}$$

- *Warning: Working with small DeltaVs and or great weight or momentum disparity creates highly sensitive calculations for the lighter vehicle*

GROUND FORCE ADJUSTMENT to DELTA V

$$\Delta V_{adjust} = \pm f g \Delta T$$

- Vehicle in Hard Braking hits Ped – Delta V is over reported (subtract adjustment out)

$$\frac{-0.7g(32.2\text{fps/s})(0.150\text{seconds})}{1.466(\text{fps/mph})} = -2.3\text{mph}$$

- Vehicle gets T-boned by Motorcycle – Delta V is Under-reported (add adjustment in)

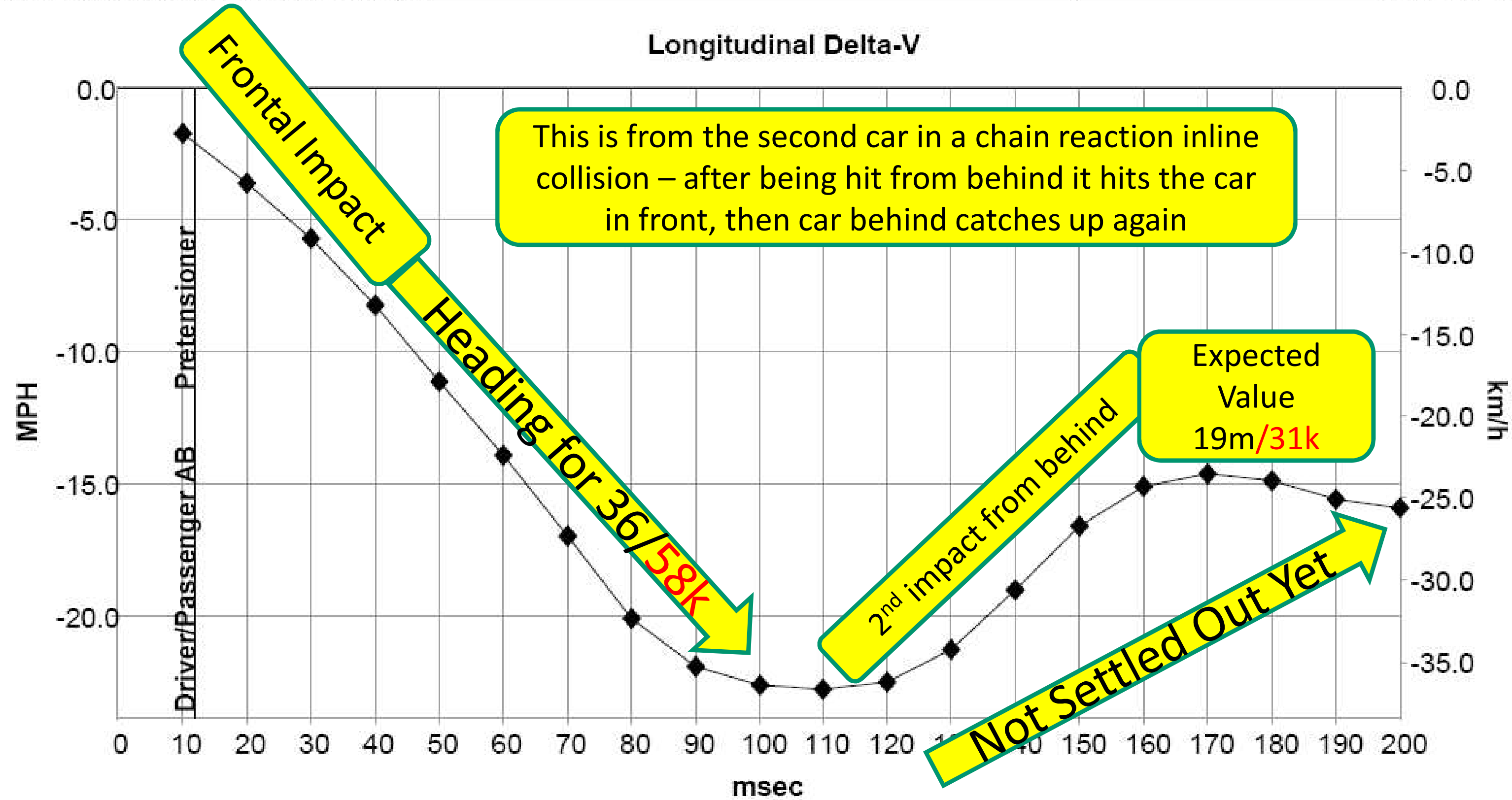
Cautions Using Delta V Information
8. Unusual DeltaV Curve Shape

- Recall that DeltaV is calculated as the area under the Crash Pulse Curve as it is sensed by the Airbag Control Modules accelerometers.
- Sometimes two events in rapid succession can be captured in a single recording, resulting in a “double hump”.
- We should always check to be sure that our Cumulative DeltaV has its familiar shape.
- Non standard curve shape can also be the result of severe rotation, or very small DeltaVs and/or DeltaV resolution.

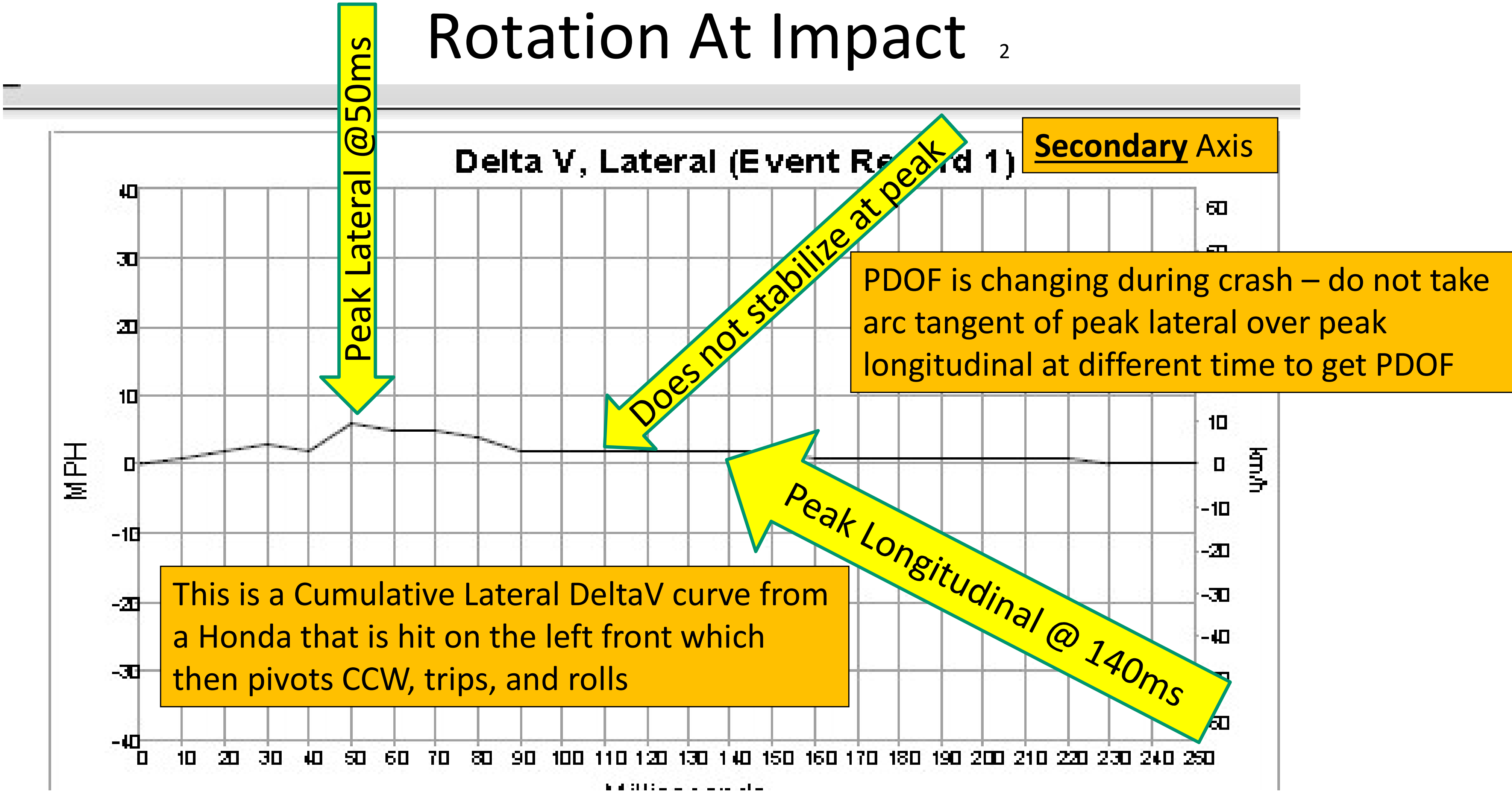
8a. Unusual Delta V Curve Shape – Multiple Impacts

Longitudinal Crash Pulse (Most Recent, TRG 2 - table 1 of 2)

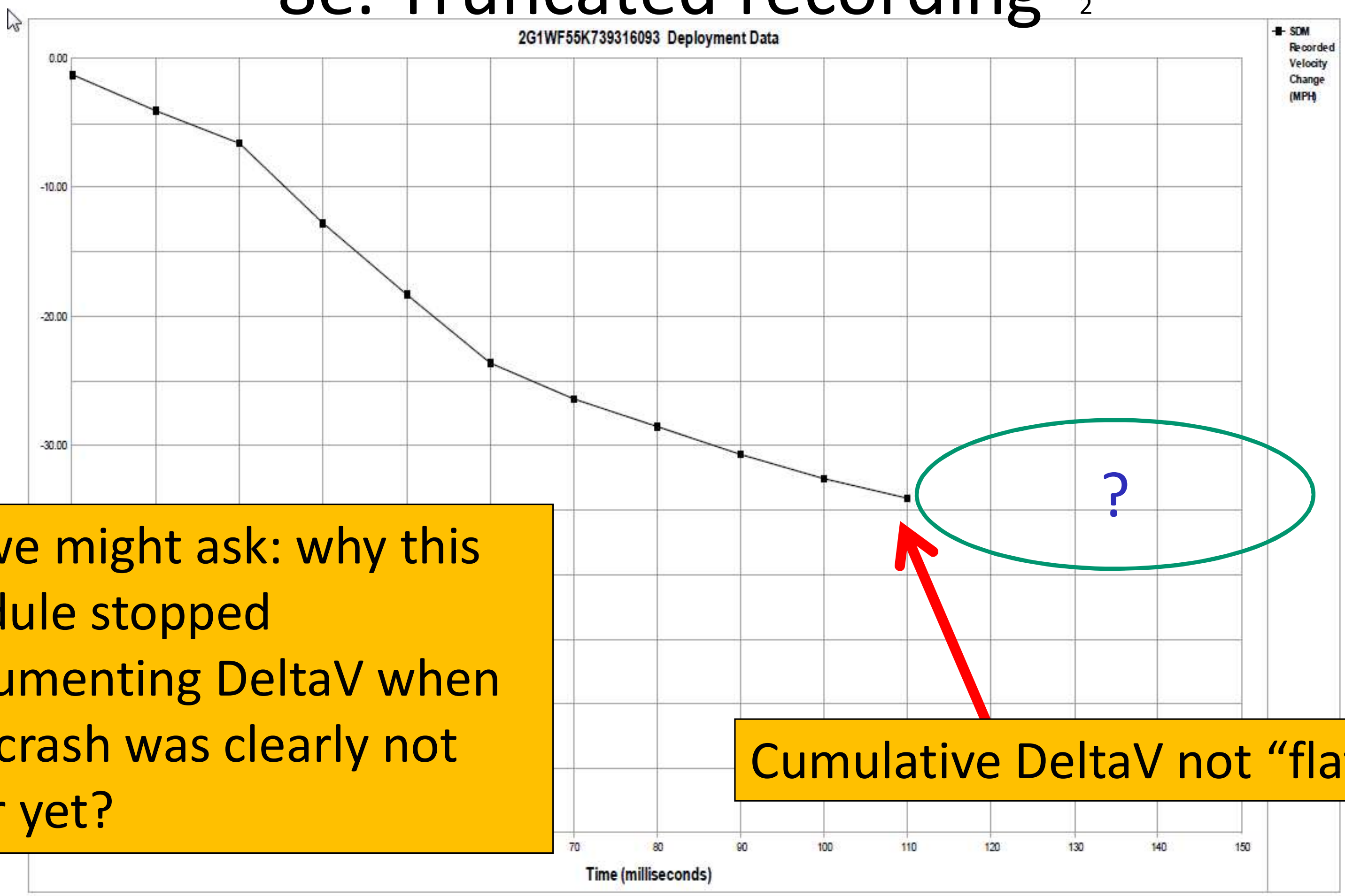
Recording Status, Time Series Data	Complete
Max Longitudinal Delta-V (MPH[km/h])	-22.8 [-36.7]



8b. Unusual Delta V Curve Shape – Severe Rotation At Impact [2]



DeltaV – Unusual Curve Shape
8e. Truncated recording [2]

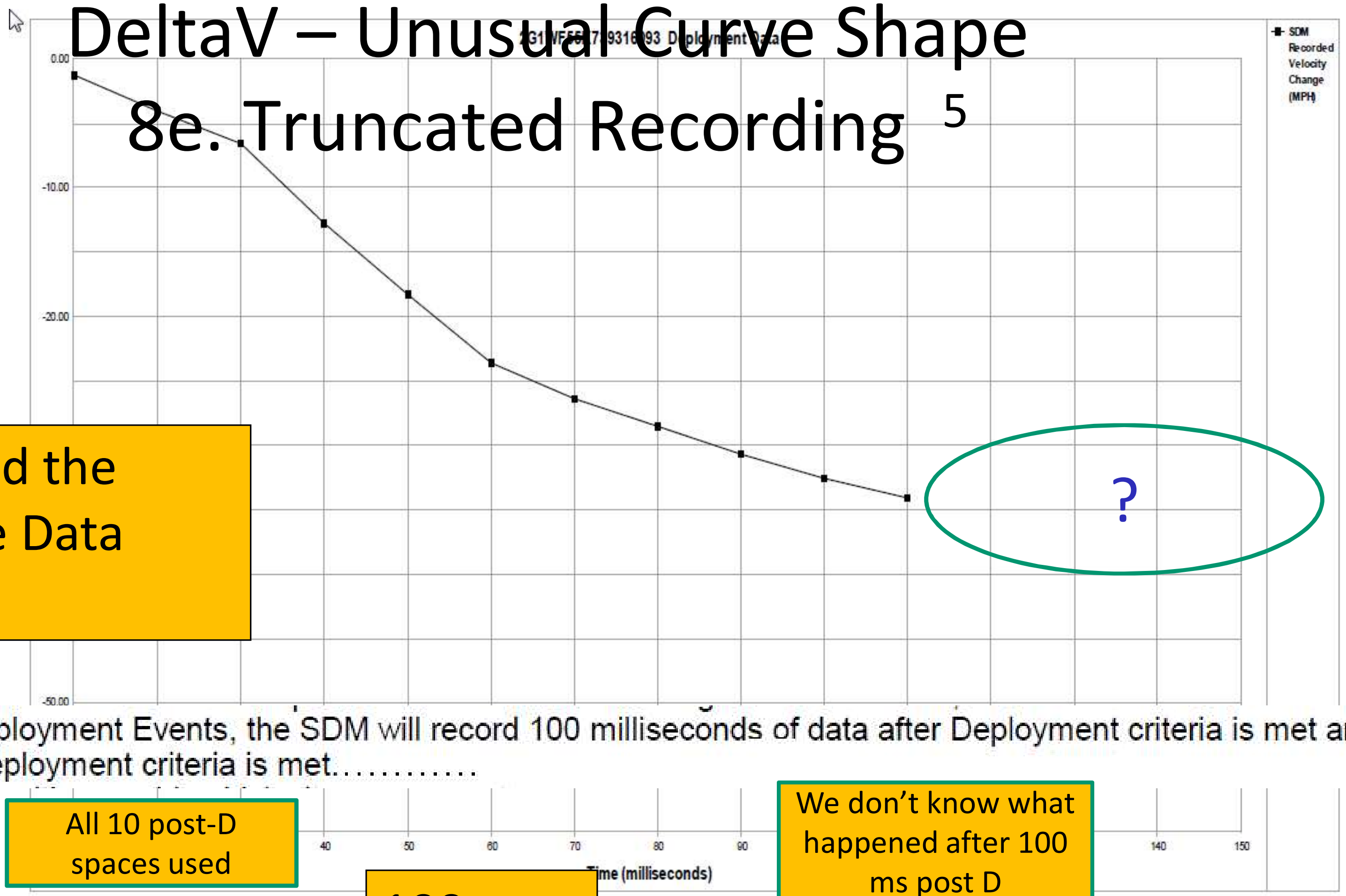


Or we might ask: why this module stopped documenting DeltaV when the crash was clearly not over yet?

Cumulative DeltaV not “flat” yet

DeltaV – Unusual Curve Shape

8e. Truncated Recording [5]



In this case we find the explanation in the Data Limitations

………. For Deployment Events, the SDM will record 100 milliseconds of data after Deployment criteria is met and up to 50 milliseconds before Deployment criteria is met………..

4 pre-D spaces not used

DEPLOYMENT

All 10 post-D spaces used

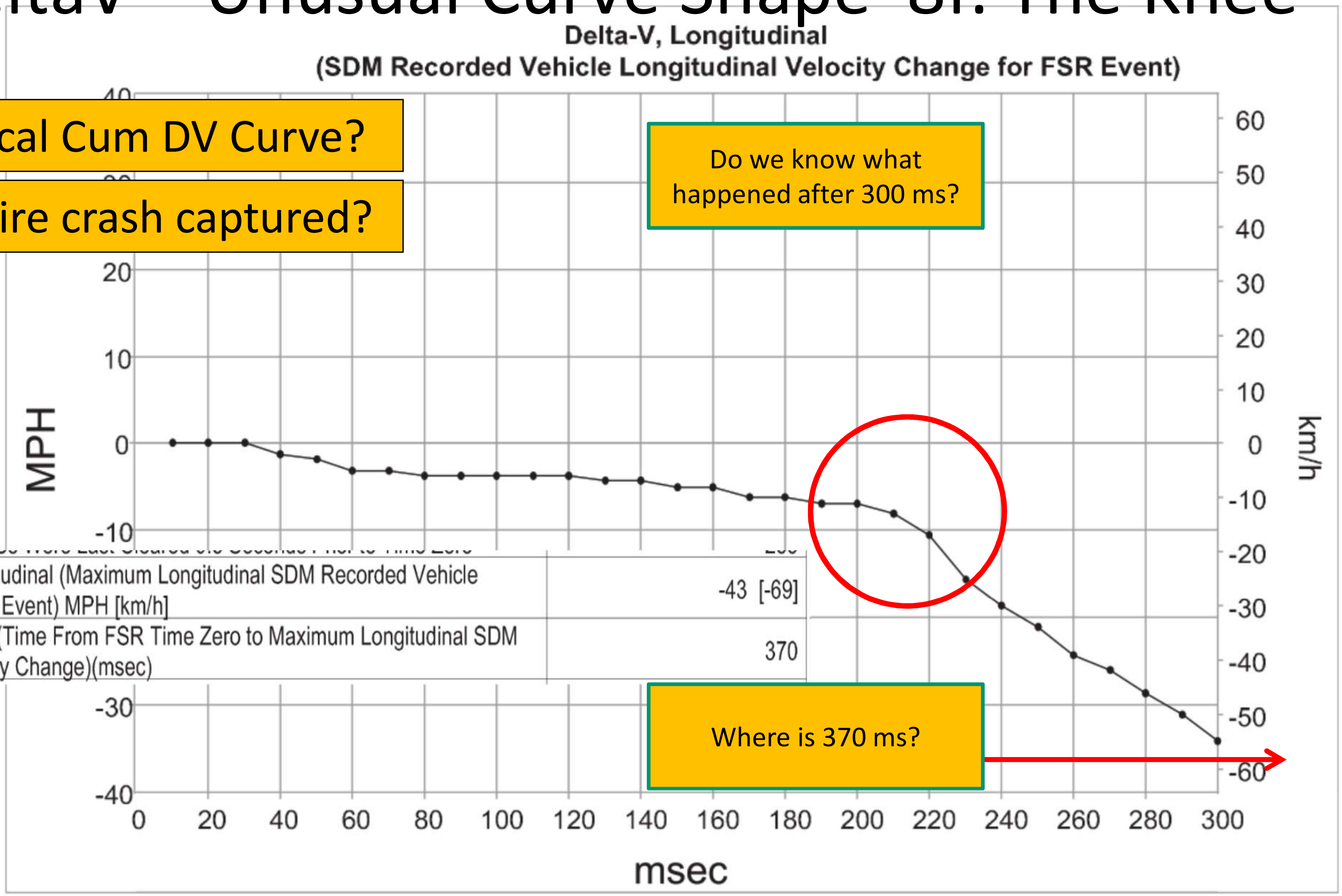
100ms

We don't know what happened after 100 ms post D

DeltaV – Unusual Curve Shape 8f. The Knee

Is this a typical Cum DV Curve?

Was the entire crash captured?



Maximum Delta-V, Longitudinal (Maximum Longitudinal SDM Recorded Vehicle Velocity Change for FSR Event) MPH [km/h]	-43 [-69]
Time, Maximum Delta-V (Time From FSR Time Zero to Maximum Longitudinal SDM Recorded Vehicle Velocity Change)(msec)	370

Delta V – unusual curve shapes 8g. Load shifting or not changing mass of entire vehicle

- In small Delta V's such as motorcycle to car impacts, the initial impact may move the body but due to compliance in the body mounts the chassis does not respond immediately. The Delta V may correct to a lower magnitude when all the mass finally couples.
- In other cases a loose load may initially not change velocity – when it comes to a constraint the full mass Delta V is realized – but this can be delayed until after the end of the Delta V graph and not be recognized.

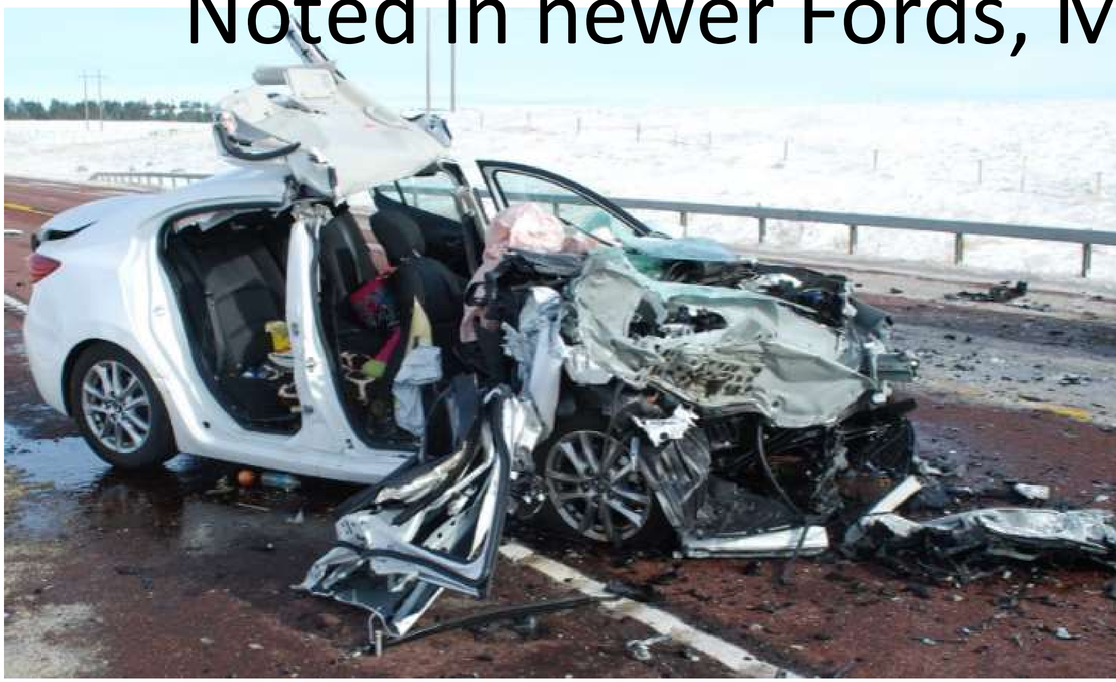
Cautions using Delta V information

9. Unintended consequences of Part 563

CFR 49 Part 563 regulates how Delta V data is recorded. It requires recording a time series every 10ms from 0 to 250ms after algorithm wake up (typically displayed on a graph), and that it keeps track of cumulative maximum Delta V *up to* 300ms from wakeup.

If the algorithm wakes up on a curb but the car goes on to hit a tree at past 300ms while the algorithm is still running, it may show only the curb hit on the graph. NHTSA does not require the manufacturer to include Delta V after 300ms in the single value max Delta V. It does require the manufacturer to report the ***time*** of the maximum Delta V. If the time = 300ms be suspicious some portion of the event was still going on. If the time is >300ms, the manufacturer keeps recording until the algorithm stops.

Algorithm woke up early, missed later event
Noted in newer Fords, Mazda & Kia/Hyundai



System Status at Event (Event Record 1)

Safety Belt Status, Driver	Belted
Safety Belt Status, Right Front Passenger	Unbelted
Occupant Size Classification, Front Passenger	Adult
Frontal Air Bag Warning Lamp (On, Off)	Off
Ignition Cycle, Crash	1892
Multi-Event, Number of Events (1, 2)	No. 1
Complete File Recorded (Yes/No)	Yes
Ignition Cycle, Download	1893
Maximum Delta-V, Longitudinal (MPH [km/h])	1.2 [2]
Time, Maximum Delta-V, Longitudinal (msec)	297.5
Maximum Delta-V, Lateral (MPH [km/h])	-1.2 [-2]
Time, Maximum Delta-V, Lateral (msec)	297.5
Time, Maximum Delta-V, Resultant (msec)	297.5

Deployment Command Data (Event Record 1)

Pretensioner Deployment, Time to Fire, Driver (msec)	250
Pretensioner Deployment, Time to Fire, Right Front Passenger (msec)	250
Frontal Air Bag Deployment, Time to Deploy/First Stage, Driver (msec)	250
Frontal Air Bag Deployment, Time to Deploy/First Stage, Right Front Passenger (msec)	250

Max Value
Mazda

Signs of “early” wakeup

- Ford devotes TWO bytes to deploy time, if deploy time is higher than 300ms the deploy DV is not captured in the printed max.
- Kia/Hyundai max deploy time is 253ms (anything 250-255 should be suspicious)

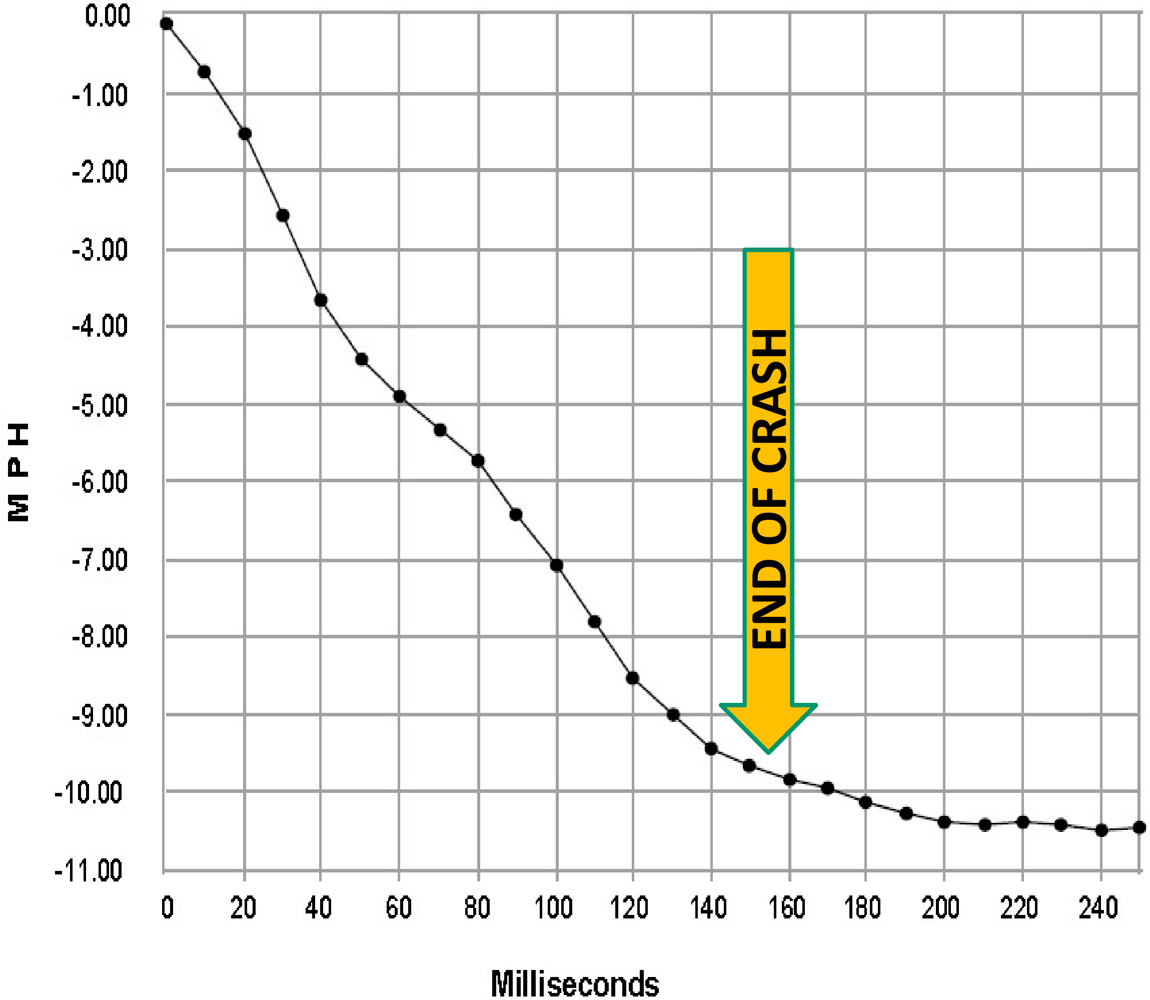
Cautions using Delta V information
9. Unintended consequences of Part 563

CFR 49 Part 563 defines end of event as when cumulative delta-V within a 20 ms time period becomes 0.5 mph or less, or algorithm shutoff.

This usually does a good job of determining end of event, but under rare circumstances, it fails. Recent case: 115 mph impact, 49 mph ΔV, but as car skids to rest ΔV is still being measured over 0.5 mph/20ms – recorder reports ΔV as 56 mph at 300ms but crash was over at 100ms.

Always review the Delta V graph to make sure the end of event choice for the single value was rationale.

1FTRF12W49KB Longitudinal Crash Pulse (First Record)



Longitudinal Crash Pulse (First Re

Time (msec)	Delta-V, longitudinal (MPH)
0	-0.10
10	-0.73
20	-1.53
30	-2.56
40	-3.66
50	-4.42
60	-4.90
70	-5.35
80	-5.75
90	-6.41
100	-7.08
110	-7.80
120	-8.53
130	-9.02
140	-9.45
150	-9.67
160	-9.83
170	-9.95
180	-10.13
190	-10.27
200	-10.38
210	-10.43
220	-10.39
230	-10.43
240	-10.47
250	-10.44

END

<0.5

Cautions in Using Delta V Information
9. Unintended Consequences of Part 563 [1]

- Mfr MUST record if ΔV_x >5mph within 150 ms. Manufacturer MAY record at lower threshold (Nissan, Hyundai), most don't.
- For vehicles with ΔV_Y, must record if either DVx or DVy exceeds 5mph within 150 ms. (Toyota records side impacts at a lower threshold)

Small and low DeltaV impacts <5mph may not recorded (unless mfr kept a lower threshold).

Most pedestrian strikes will not be recorded.

Cautions in using Delta V information

9. Unintended Consequences of Part 563

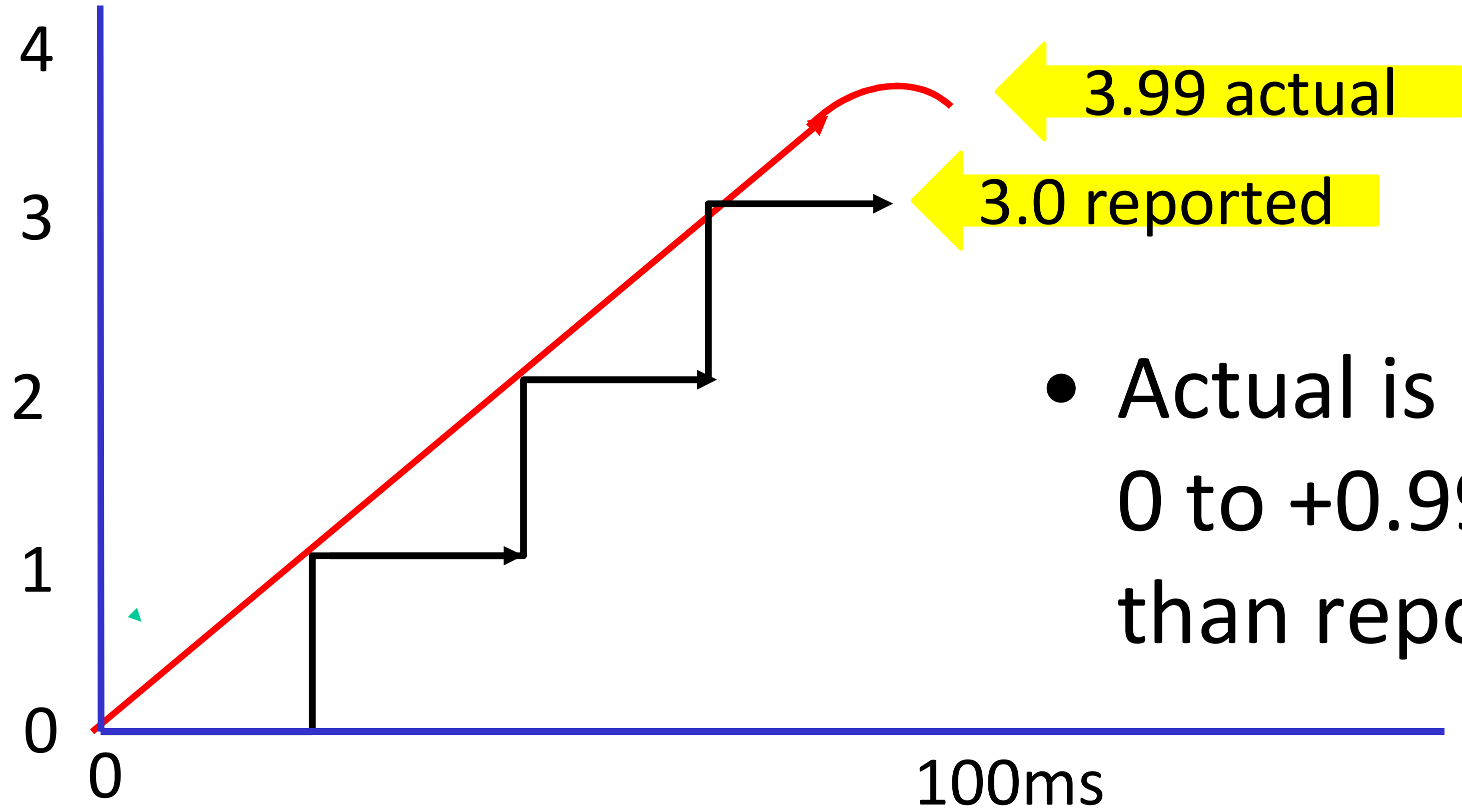
- *Time zero* means whichever of the following occurs first:
- (1) For systems with "wake-up" air bag control systems, the time at which the occupant restraint control algorithm is activated; or
- (2) For continuously running algorithms,
  - (i) The first point in the interval where a longitudinal cumulative delta-V of over 0.5 mph is reached within a 20 ms time period; or
  - (ii) For vehicles that record "delta-V, lateral," the first point in the interval where a lateral cumulative delta-V of over 0.5mph is reached within a 5 ms time period; or
- (3) Deployment of a non-reversible deployable restraint.

This part of 563 defines the beginning of the crash pulse.

10. Small Delta V’s

- Small Delta V accuracy is affected by the RESOLUTION of the place it is stored
- Some manufacturers TRUNACATE the Delta V to the NEXT LOWER WHOLE KPH, and then have CDR ***round*** it to the nearest mph. It is more precise to start with the kph value. Others may report to a precision of 0.01 mph – we don’t need to worry about those!
- If an EDR reports a small Delta V of 3kph, we need to be aware it may have measured 3.00 to 3.99. Both would be reported as 3. If the small Delta V is important, you can “range it” from the value shown to the next higher value.

Small Delta V Accuracy with 1mph or 1 kph Resolution of Delta V



- Actual is a range 0 to +0.99 more than reported

DeltaV Accuracy +/-10%

Parameter	Full Scale	Resolution	Accuracy	How Measured	When Updated
ΔV	± 55.9 mph	0.4 mph	~ ± 10%	integrated acceleration	recorded every 10 msec, calculated every 1.25 msec.
Vehicle speed	158.4 mph	0.6 mph	± 4 %	Magnetic pickup	vehicle speed changes by ≥ 0.1 mph
Engine Speed	16383 RPM	1/4 RPM	± 1 RPM	Magnetic pickup	RPM changes by ≥ 32 RPM.
Throttle Position	100% Wide open throttle	0.4 %	± 5%	Rotary potentiometer	Throttle position changes by ≥ 5%.

Recording Automotive Crash Event Data (1999)

Augustus "Chip" Chidester, National Highway Traffic Safety Administration

John Hinch, National Highway Traffic Safety Administration

Thomas C. Mercer, General Motors Corporation

Keith S. Schultz, General Motors Corporation

Delta V Accuracy

1999 Chidester Paper (w/GM authors) stated

"Accuracy is **+/-10%**" - **generally accepted**.

NOTE: +/-10% does *NOT include clipping or other special circumstances. It applies primarily to accelerometer accuracy and reporting resolution during moderate severity crashes.*

Some papers report high DV tests as being more than -10%, those are suspected of being cases of clipping.

Also, for very small accelerations and DV's, accelerometer RESOLUTION is 0.5G typical, so 0.9G may report as 0.5G resulting in more than 10% error.

Analog accelerometers present in 1999 have largely been replaced by digital accelerometers, and may have higher ranges. Manufacturers advise the +/-10% margin still applies to the newer digital accelerometers. GM now uses 113G accelerometers.

Ped Impact Considerations

- Many vehicles have 5mph recording threshold that won't capture ped crashes at all. Exceptions old GM, old Ford, Nissan, Mazda, possibly Kia/Hyundai
- If using inversely proportional Delta V formula to get closing speed, big weight ratios make answer sensitive.
- Did ped fully mass couples to car – full forward projection?
- Missed Delta V before wakeup 0.4-0.5mph?
- Accelerometer resolution may be 0.5g, not visible to you
- ΔV Resolution of 1kph on many 2013+ models will result in large range of vehicle speeds
- Hope you have speed in EDR and are only working Detla V to confirm recording is from your crash!!!!

QUESTIONS???

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