Electronic Stability Control and it's Impact on Speed Analysis from Yaw Marks

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What is Electronic Stability Control?

- computerized technology that
- improves a vehicle's stability by
- detecting and
- reducing loss of traction (skidding)

Wikipedia

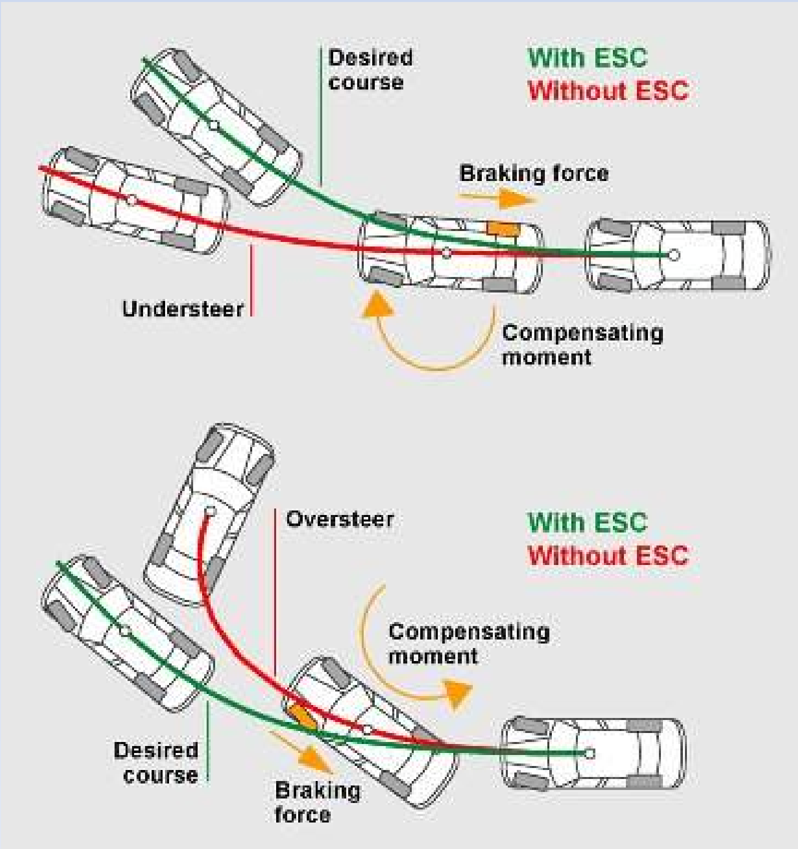
NHTSA and Transport Canada Regulations

- all new passenger vehicles sold in the US and Canada
    - equipped with ESC
    - 2012 model year

How does it work?

- When your steering does not match the direction of your vehicle

- ESC will automatically
  - brake one or more wheels
  - reduce engine power
  - or both
  - for short periods of time



Transport Canada

How does it work?

ESC systems differ by manufacturer

All systems use some or all of the following:

- – Anti-Lock Brake Systems
- – Suspension (Body Control Module)
- – Engine ECM (Retard Throttle)

to assist with regaining stability

How does it work?

- ESC does not improve a vehicle's cornering performance;
- it helps to minimize the loss of control.

Reactive NOT Predictive

Yaw with ESC Characteristics

- Starts of narrow and widens (generally)
- Can see rear out track front
- Mark generally stays consistent
  - Distance between front and rear
- Radius increases

Yaw with ESC Characteristics

- May see rib and groove pattern in some tire marks (compare with vehicle tread pattern)
- May see striation marks within some of the tire marks
- If marks last long enough rear tire mark will move back to proper tracking position

Mercury Marauder ESC

Yaw Mark Characteristics Comparison

Yaw

- Point of separation
  - may or may not be identifiable
- Rear tire
  - out tracks the front tire
- Tire marks
  - Lead tire most prominent
  - Narrow at the onset
  - start close together
  - gradually increases distance of separation
  - Angular Striations
    - May or may not be visible
    - Dependent on surface

Yaw with ESC

- Point of separation
  - may or may not be identifiable
- Rear tire
  - out tracks the front tire
- Tire marks
  - Lead tire may be most prominent
  - May be narrow at onset
  - May be wider at onset
  - May see narrow outside edge at the onset
  - start close together
  - gradually increases distance – then distance stays somewhat uniform until tire marks move back together
  - Angular Striations
    - May or may not be visible
    - Rib/Groove pattern of tire may be visible in some of the marks

Yaw Mark Characteristics Comparison

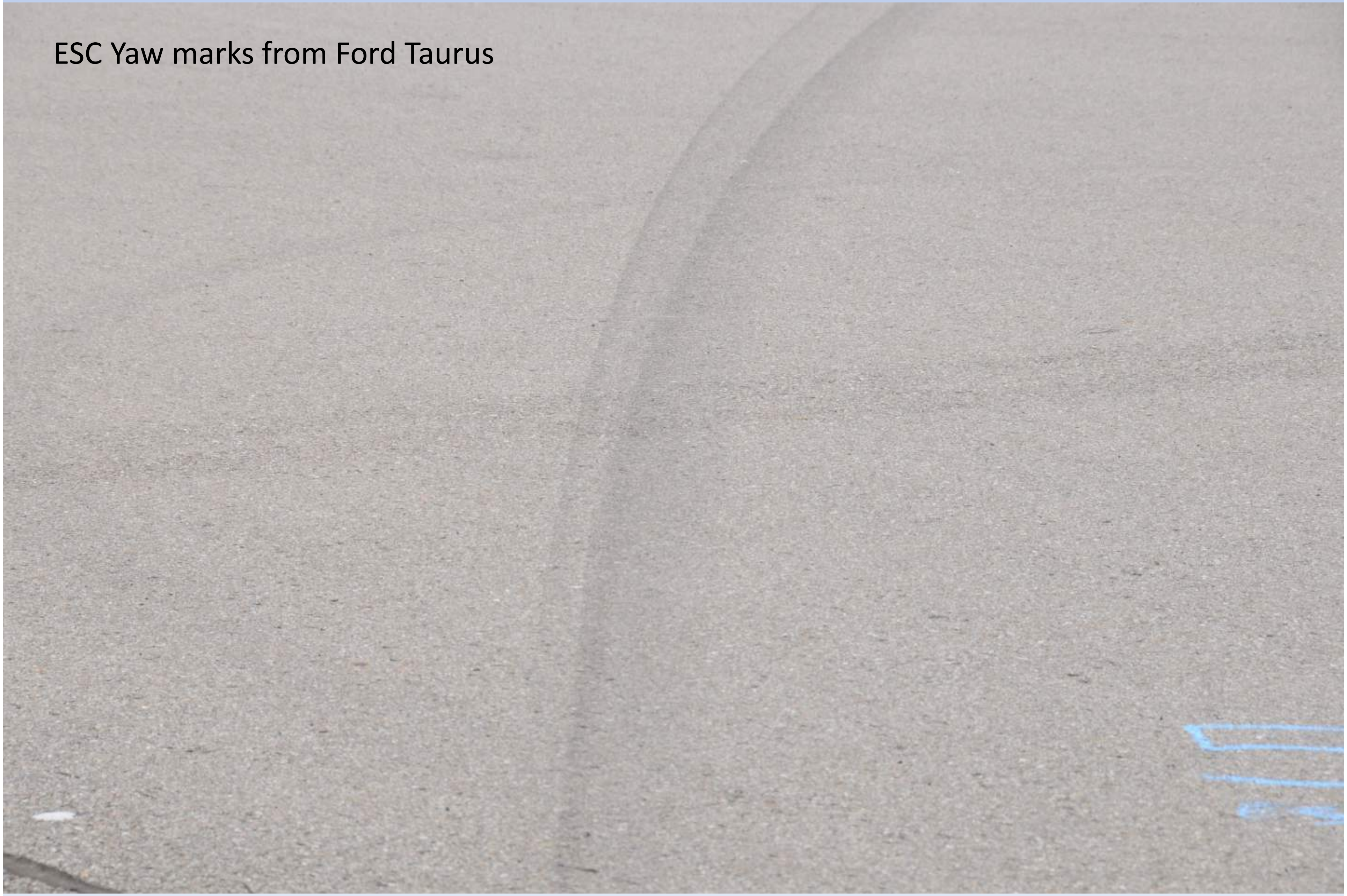
Yaw

- Contrast
  - Lead tire most prominent and darkest
  - All tire marks will get darker throughout the mark (vehicle rotation)
- Radius
  - decreases
  - may see cross over

Yaw with ESC

- Contrast
  - tire mark shading remains similar throughout the mark
- Radius
  - Increases
  - As vehicle regains control tire marks will move back together

ESC Yaw marks from Ford Taurus



ESC Yaw Testing at Blainville

- OPP and Transport Canada participated in ESC Yaw testing
  - PMG Technologies facility in
  - Blainville Quebec in 2015, 2016 and 2016

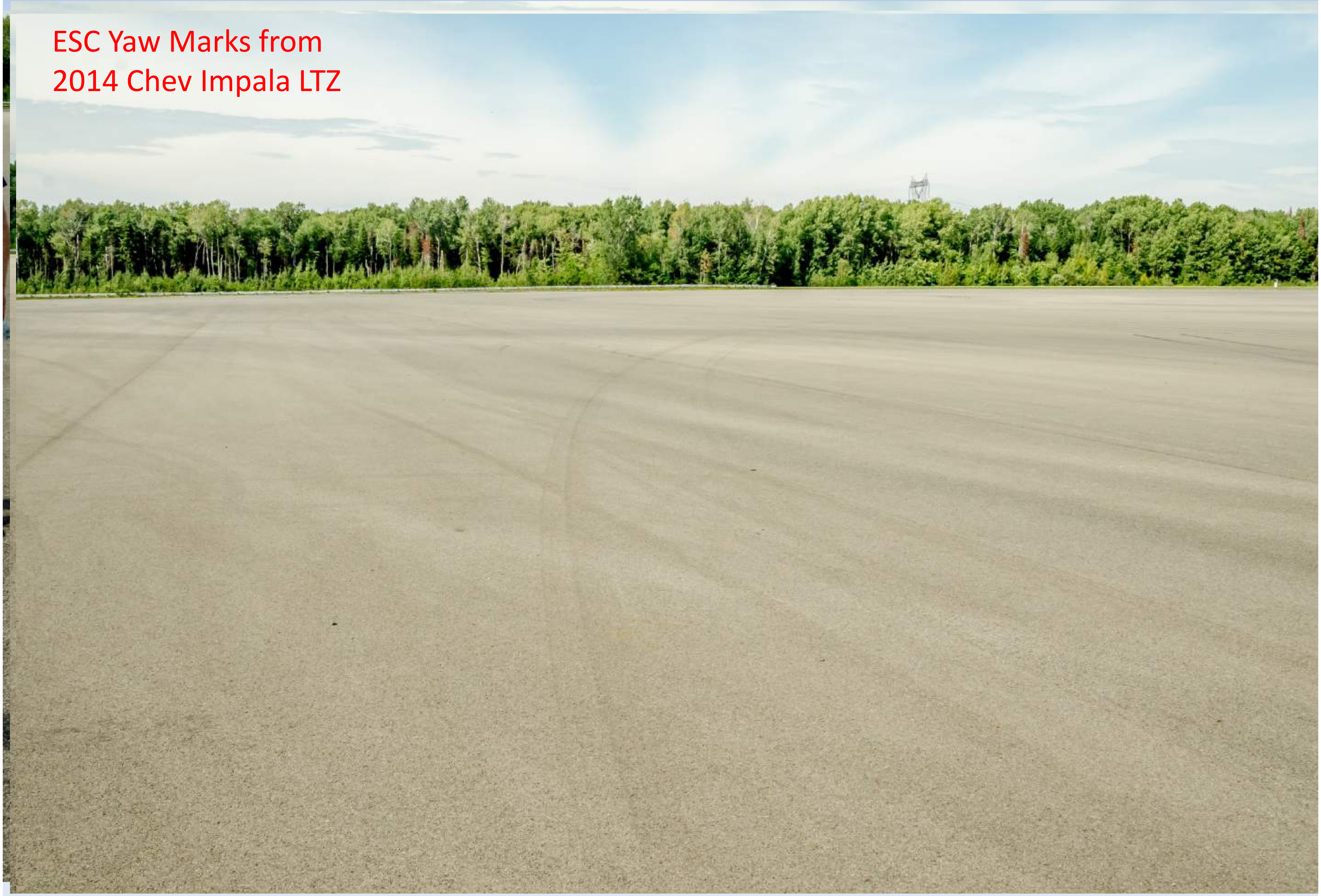
- Study focuses on 2016 & 2017

Team Members

The following investigators were instrumental in the collection of the data:

- Transport Canada:
  - Brian Monk,
  - Jeremy Hamilton, and
  - Eric Meloche
- Crash Data Specialists:
  - Brad Muir,
  - Jon Northrup
- Ontario Provincial Police:
  - Steve Anderson
  - Brian McLaughlin
  - Sue Blacklock
  - Terry Yeomans
  - Chris Prent
  - Mike Chapman
  - Rob Morris
  - Rob Kern
  - Luc Poirier
  - Tyson Braun
  - Marko Harjupanula
  - Mark Wright

ESC Yaw Marks from
2014 Chev Impala LTZ



2015 Chrysler 200 Yaw
with ESC at 131 km/h

2015 Chrysler 200 at 131 km/h

2016

In 2016 a total of 16 ESC Yaw tests were conducted on the following vehicles:

• 2012 Dodge Charger • 2014 Chevrolet Impala LTZ	• 2014 Chrysler 200 AWD

2017

In 2017 a total of 21 ESC Yaw tests were conducted on the following vehicles:

• **2015 Audi A3** • **2014 Chevrolet Impala LTZ** • **2015 Dodge Charger AWD**	• **2017 Hyundai Elantra** • **2015 Mercedes C400 AWD**

Testing

- 37 ESC Yaw tests were conducted
- 2 testing events in 2016 and 2017.

- Speed was calculated for each ESC Yaw test using the following critical speed formula

$$S = 11.27\sqrt{\frac{R(\mu + e)}{1 - \mu e}}$$

Test Speed Validation

- Speed was recorded in multiple ways:
  - Radar
  - Video Vbox GPS
  - Garmin Virb video cameras with GPS
  - Racelogic Vbox Sport with GPS
  - Speedometer validation
  - CAN Bus data using Vbox III

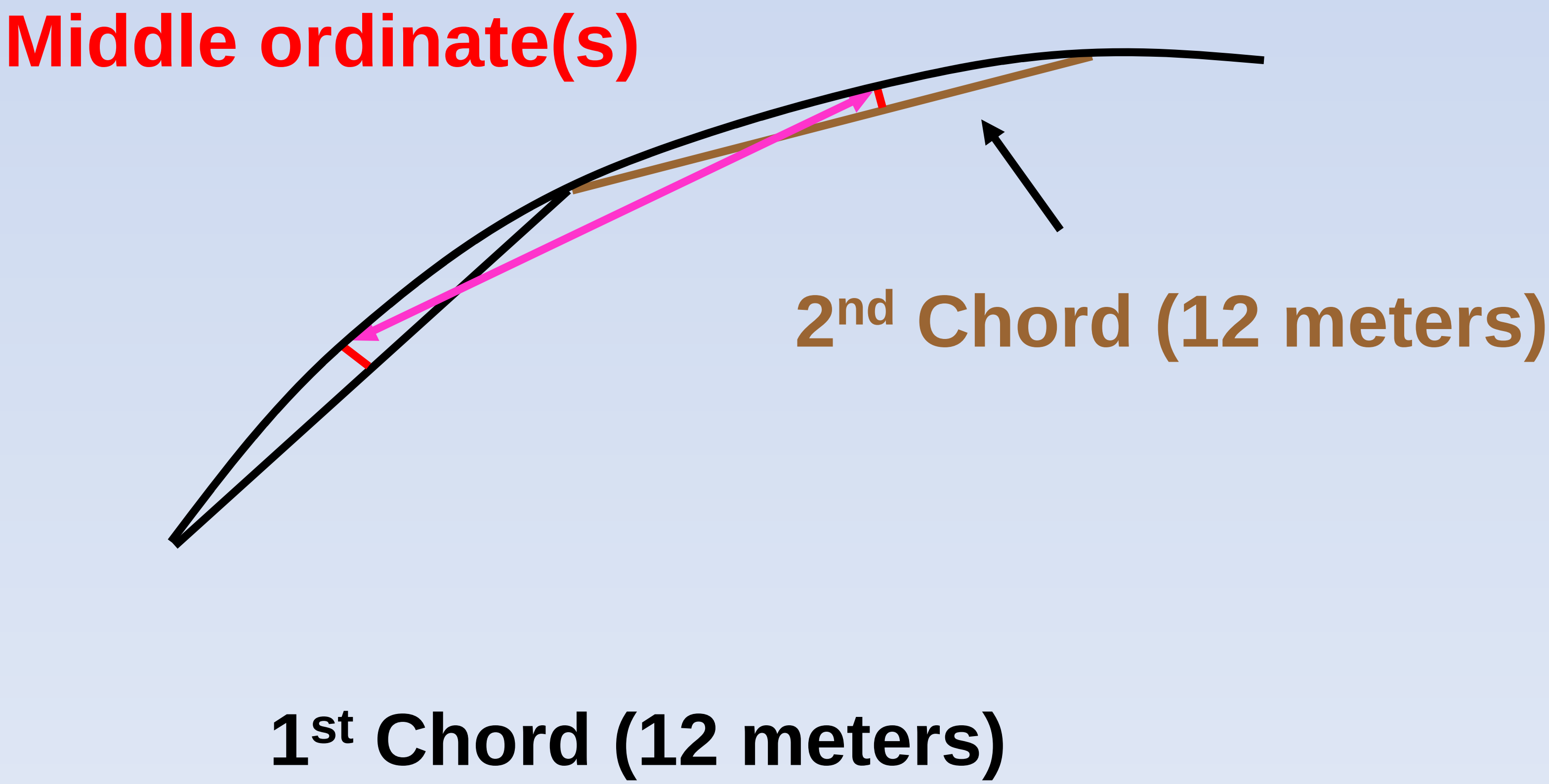
How was radius calculated

12 metre chord method	53
15 metre chord method	21
20 metre chord method	21
Full front tire mark CAD	37
30 metre front tire measurement CAD	37
Full rear tire mark CAD	37
30 metre measurement rear tire CAD	37

Traditional Methodology Measuring Yaw

- Chord and Middle Ordinate
  - Ideally 12 to 14 metre chord
  - Take 1st measurement where you can see
    - Front and rear tire marks
    - Side by side
  - Take 2nd measurements
    - Before rear tire mark comes back in line with front mark

YAW

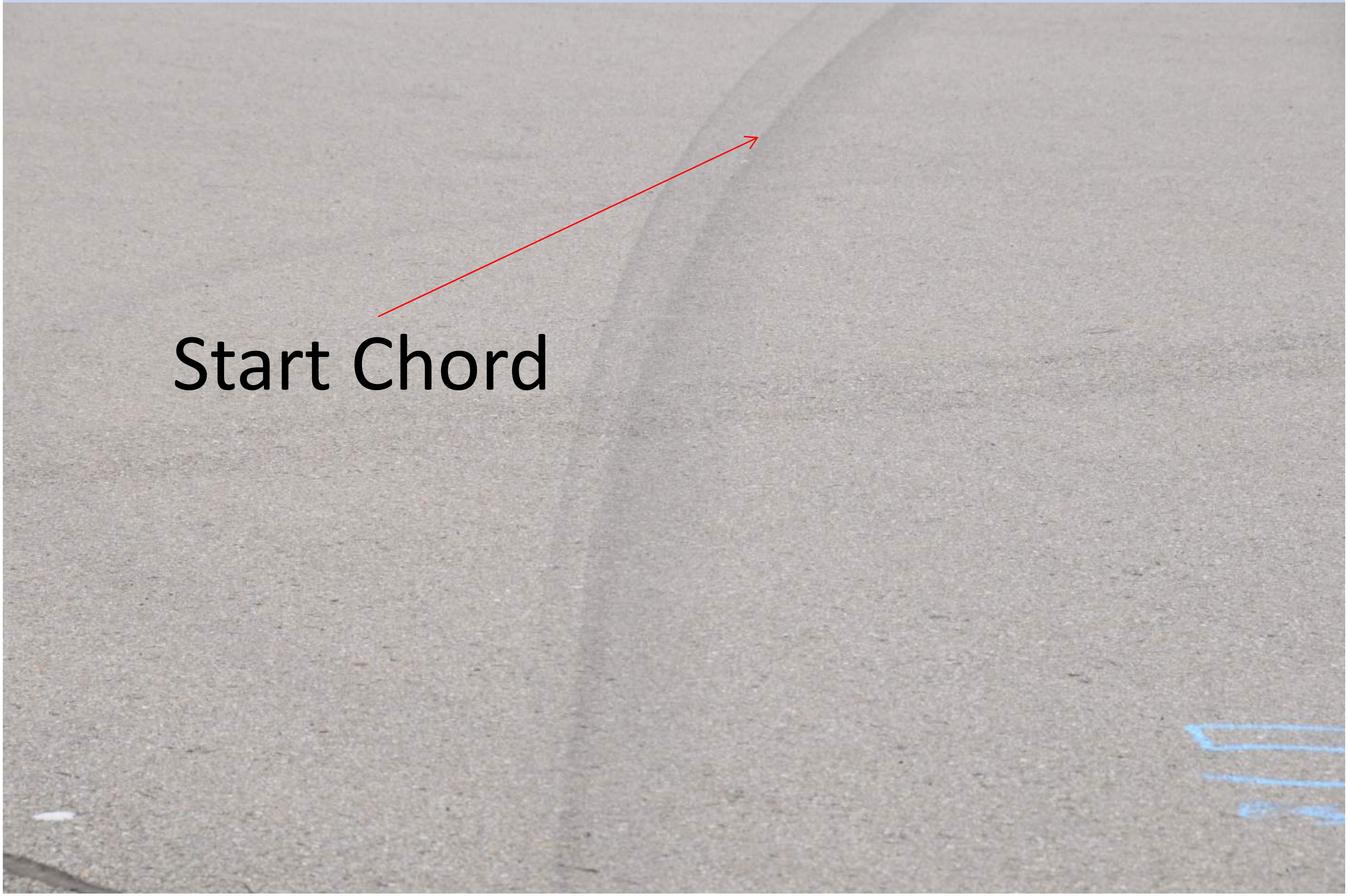


Physical Chord Measurements

12 and 15 metre chord

- Start 1st chord where front and rear tire marks are clearly visible (separate)

- 12 metre method used 53 times (2016 & 2017)
- 15 metre method used 21 times (2017 only)


Start Chord

Physical Chord Measurements

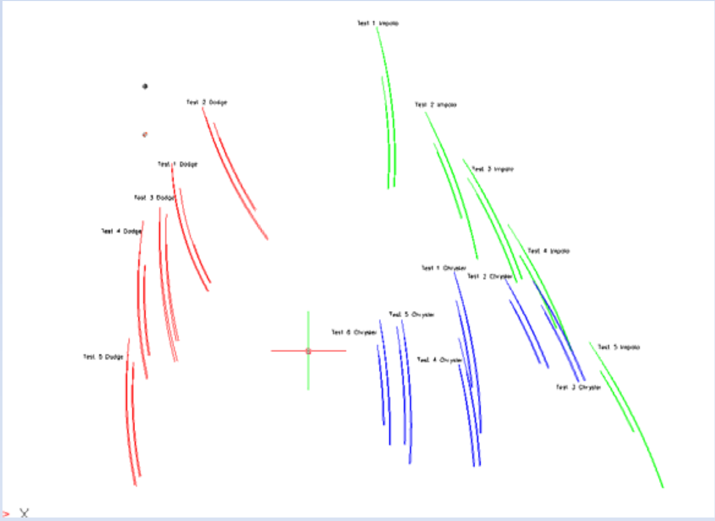
20 metre chord

- Start 1st chord at the start of the tire mark
- Used 21 times (2017 only)

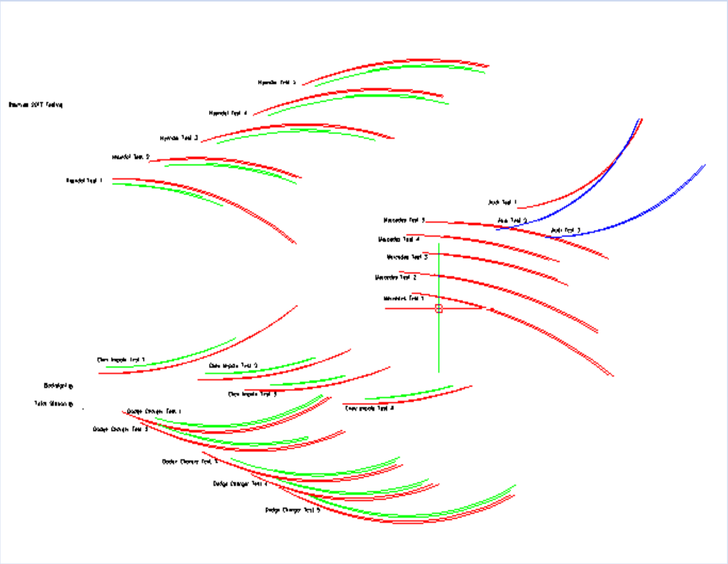

Start 20 Metre Chord

Total Station Measurements

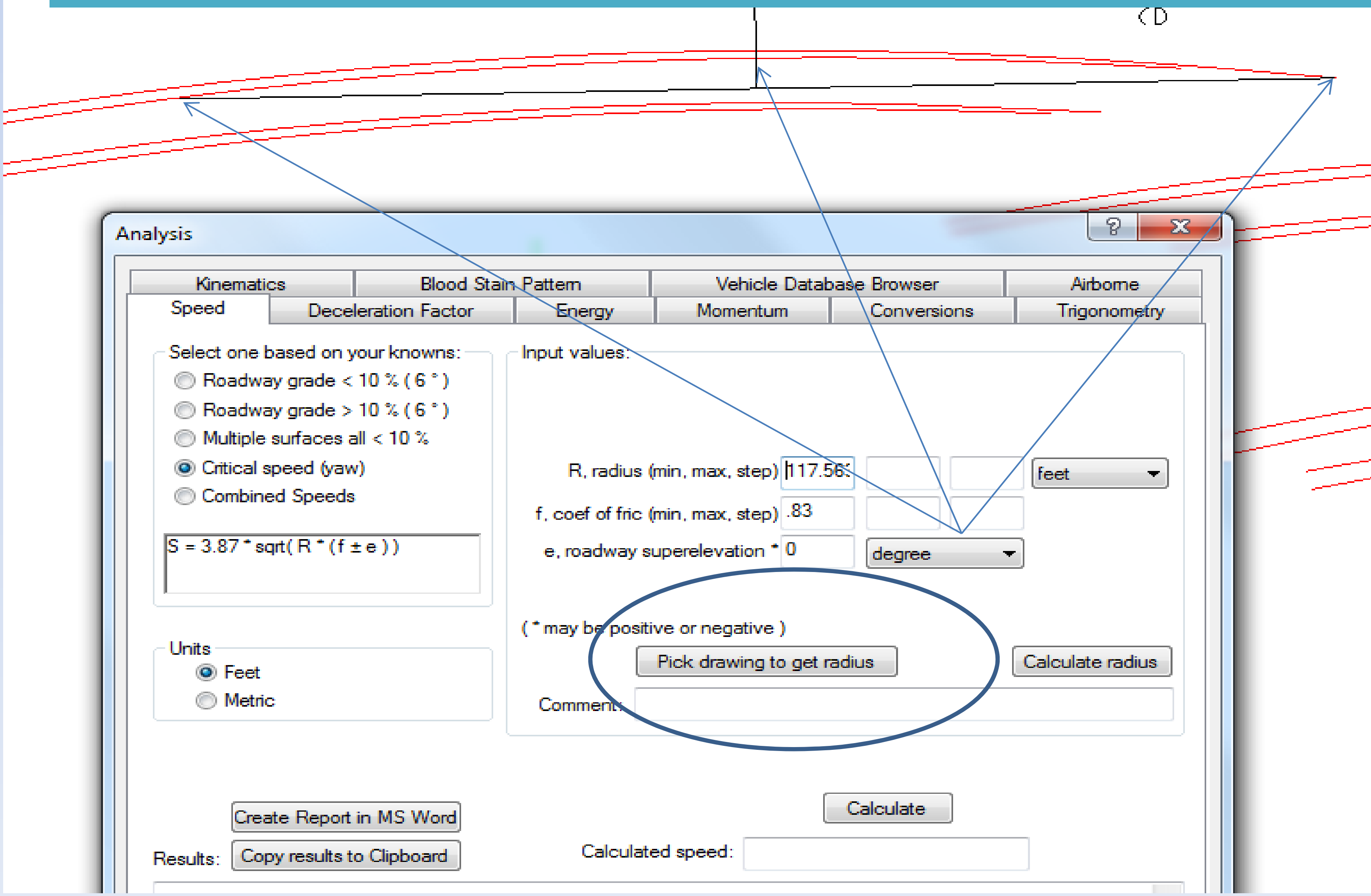
2016 Tests - Blainville



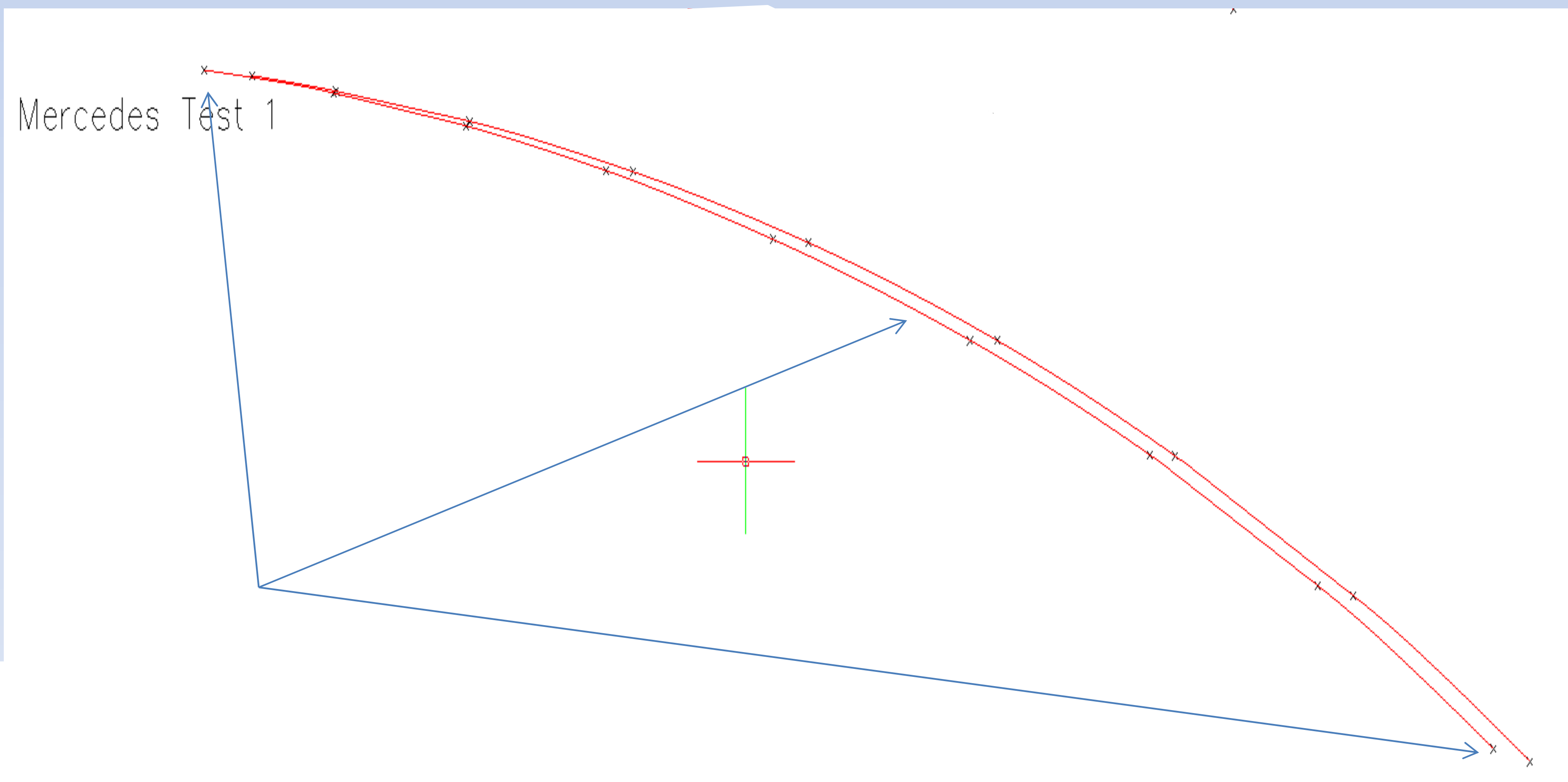
2017 Tests - Blainville



30 Metre Chord within CAD



3 Point Radius – Entire Tire Mark



Summary of Multiple Measurement Methods

Measurement Type	Description of Methodology	Average value to known speed	Standard Deviation	Range % of actual	# of tests	# of measuring groups
12m chord	measurements taken along front lead tire mark starting where 2 distinct tire marks could be seen (i.e. obvious separation)	0.99	0.05	0.94 - 1.04	53	2
15m chord	measurements taken along front lead tire mark starting where 2 distinct tire marks could be seen (i.e. obvious separation)	1.02	0.06	0.96 - 1.08	22	1
20m chord	measurements taken along front lead tire mark starting where the tire marks first become visible	0.99	0.03	0.96 - 1.02	22	1
CAD front tire mark	Total Station measurements taken from the onset of the ESC yaw mark to where the rear wheel tire marks start to move back towards the front tire marks. CAD (IMS Map360) Analysis tool used to select 3 points along the tire mark to determine radius. First point was start of the mark, second point was approximated near the centre of the mark and the third point was the end of the measured portion of the tire mark.	0.97	0.04	0.93 - 1.01	37	2
CAD front 30m	A 30m chord was placed along the front lead side tire mark. CAD (IMS Map360) Analysis tool was used to determine radius. 3 points were selected along the tire mark. First being the start of the tire mark, the 2nds being the point at the middle ordinate and the 3rd being a point on the tire mark at the end of the 30m chord	1.00	0.03	0.97 - 1.03	37	2
CAD rear tire mark	Total Station measurements taken from the onset of the ESC yaw mark to where the rear wheel tire marks start to move back towards the front tire marks. CAD (IMS Map360) Analysis tool used to select 3 points along the tire mark to determine radius. First point was start of the mark, second point was approximated near the centre of the mark and the third point was the end of the measured portion of the tire mark.	0.95	0.03	0.92 - 0.98	37	2
CAD rear 30m	A 30m chord was placed along the front lead side tire mark. CAD (IMS Map360) Analysis tool was used to determine radius. 3 points were selected along the tire mark. First being the start of the tire mark, the 2nds being the point at the middle ordinate and the 3rd being a point on the tire mark at the end of the 30m chord	0.97	0.02	0.95 -0.99	37	2

Variables

- Coefficient of Friction
  - Used one value based on skid testing
  - Different vehicles provided slightly different dynamic friction values (ABS off)
- Slight variations in recorded speed

Speed Corroboration

- ESC Equipped vehicle likely CDR supported

- Manual Measurements + CAD measurements

  – 20 metre physical

  – 30 metre CAD (if space allows)

Conclusion

A vehicle’s speed can be reliably calculated using Critical Speed Formulae using

- the chord and middle ordinate tape measure approach, and
- through the use of total station measurements and CAD software