Single Vehicle – Loss of Control
the natural motion is to continue in the same direction
weight shifts to outside of turn
weight shifts to outside of turn

INERTIA

friction
a “yaw” occurs when the tires lose traction
WHAT FACTORS AFFECT A LOSS OF TRACTION?

- speed
- friction
- path curvature
TRACKING OF OUTSIDE TIRES IN A YAW
In a controlled turn, front tire tracks outside rear tire.
If the yaw is caused by the inertial motion of the vehicle, and not by other forces, it is called a Critical Speed Yaw or CSY.
Rear tire tracks outside front.
Front, outside tire mark is usually darkest.
crossover
Crossover is not visible
Crossover is not visible
“As a matter of clarity, they do NOT have to see the actual place where the outtracking begins (crossover), just that it has begun.”

Personal email conversation with John Daily, March 29, 2013
“striations”
HOW DO WE DETERMINE R
VEHICLE YAWS OFF ROAD, STRIKES A TREE
Geometry 101:
Finding the radius of a circle:

\[ R = \frac{C^2}{8m} + \frac{m}{2} \]
A yaw mark is not a true circle, but it can be modeled by breaking it into circular segments.
$R_2$
As the yaw continues, the radius decreases.
“The path carved out by a car as it creates a critical speed tire scuff was found to be well modeled by a simple circle.”
Where is the chord-middle ordinate measurement made?
“First, we must identify the location where the outside rear tire tracks outside the corresponding front tire. This will be the location from which we measure the first chord.”

Fundamentals of Traffic Crash Reconstruction, Daily, p. 439
Where is the chord-middle ordinate measurement made?

As close as possible to the start of the yaw.
the most sensitive measurement – defense attack point
Investigation checklist:

Document the yaw mark evidence

STRIATIONS RADIUS MEASUREMENT
More about chord/mid ordinate measurements:

either inside or outside
INSIDE
More about chord/mid ordinate measurements:

either inside or outside

as close to start as possible
Yaw marks
More about chord/mid ordinate measurements:

either inside or outside

as close to start as possible

two measurements
“… a CSY mark should be long enough to measure two chords and middle ordinates. If the marks are too short to obtain two chords and middle ordinate measurements, then the maneuver is not a critical speed yaw.”

p. 441 Daily, Fundamentals of Traffic Crash Reconstruction
More about chord/mid ordinate measurements:

either inside or outside
as close to start as possible
two measurements
chords may overlap
OVERLAPPING MEASUREMENTS
CHORD LENGTH = 30 ft
MIDDLE ORDINATE = 6 in (0.5 ft)
\[ R = \frac{C^2}{8m} + \frac{m}{2} \]

Calculate the radius:

\[ C = 30 \text{ ft} \quad M = 0.5 \text{ ft} \]

\[ R = \frac{30(30)}{8(0.5)} + \frac{0.5}{2} = 225 \text{ ft} \]
DEFENSE:

DEFENSE EXPERT
QUESTIONS CSY
MEASUREMENTS
“Do not be bullied out of your common sense by the expert.”

Oliver Wendell Holmes, Jr.
VEHICLE YAWS OFF ROAD, STRIKES A TREE
DEFENSE EXPERT’S REPORT:

“The evidence used by police to determine speed included only 30 ft of the tire mark, which was assumed to be part of a circle having a total circumference of 2100 ft;
As such less than 2% of the evidence was used by police.
As such, less than 2% of the evidence was used by police.
“An error of as little as 4 inches in the middle ordinate would produce a significant error in the speed estimate.”
“An error of as little as 4 inches in the middle ordinate would produce a significant error in the speed estimate.”
HOW DO WE DETERMINE
Drag factor must be determined in the direction of slip.
direction of slip
Critical Speed Yaw (CSY) equation:

\[ S = \sqrt{15 \times R \times f} \]
Yaw Speed nomograph:

<table>
<thead>
<tr>
<th>yaw radius (ft)</th>
<th>0.40</th>
<th>0.45</th>
<th>0.50</th>
<th>0.55</th>
<th>0.60</th>
<th>0.65</th>
<th>0.70</th>
<th>0.75</th>
<th>0.80</th>
<th>0.85</th>
<th>0.90</th>
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<tbody>
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<td>88.3</td>
<td>91.0</td>
<td>93.6</td>
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<td>88.7</td>
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<td>94.8</td>
<td>97.9</td>
<td>100.9</td>
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<td>77.4</td>
<td>81.2</td>
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<td>88.3</td>
<td>91.6</td>
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<td>100.9</td>
<td>104.1</td>
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<td>102.4</td>
<td>106.0</td>
<td>109.5</td>
<td>112.9</td>
<td>116.1</td>
</tr>
</tbody>
</table>

Example: 700 ft yaw radius, with drag factor = 0.80, speed = 91.5 mph.
yaw radius = 225 ft
drag factor = .82

What is the speed estimate from the yaw mark?
yaw radius = 225 ft
drag factor = .82

What is the speed estimate from the yaw mark?

\[ S = \sqrt{15fR} = \sqrt{15(.82)(225)} \]
yaw radius = 225 ft
drag factor = .82

What is the speed estimate from the yaw mark?

\[ S = \sqrt{15fR} = \sqrt{15(.82)(225)} \]

52.6 mph
S = 52.6 mph
DEFENSE:

CSY FORMULA IS INVALID

(BASED ON PUBLISHED TESTING)
“The critical speed formula calculations were greater than the measured velocities of the test vehicle in all test results.”
ATTACK: CSY FORMULA IS INVALID.

SAE #950137 Dickerson, et.al.

Testing included double-step steer maneuvers that produced high slip angles. ( NOT CSY MANEUVERS )
ATTACK: CSY FORMULA IS INVALID.
# CSY Test Results

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Corrected Radius $R_1 / R_2$</th>
<th>Drag factor from Skid Test</th>
<th>Longitudinal $f$ Calculated / Measured</th>
<th>Calculated Speed, MPH</th>
<th>Radar or Integrated Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2002</td>
<td>Wisconsin</td>
<td>84.29 / 71.29</td>
<td>0.83</td>
<td>0.18/0.18</td>
<td>32.28</td>
<td>33</td>
</tr>
<tr>
<td>Nov. 2003</td>
<td>Minnesota</td>
<td>123.2/108.9</td>
<td>0.77</td>
<td>0.18/0.181</td>
<td>37.59</td>
<td>38</td>
</tr>
<tr>
<td>Nov. 2003</td>
<td>Minnesota</td>
<td>105.4/92.6</td>
<td>0.77</td>
<td>0.16/0.19</td>
<td>34.77</td>
<td>36</td>
</tr>
<tr>
<td>July 2003</td>
<td>Ohio</td>
<td>73.74/53.01</td>
<td>0.79</td>
<td>0.27/0.26</td>
<td>28.91</td>
<td>29.5</td>
</tr>
<tr>
<td>Oct. 2003</td>
<td>Wyoming</td>
<td>213.6/193.6</td>
<td>0.64</td>
<td>0.21/0.21</td>
<td>45.13</td>
<td>46</td>
</tr>
<tr>
<td>Oct. 2003</td>
<td>Wyoming</td>
<td>112.4/94.5</td>
<td>0.64</td>
<td>0.18/0.20</td>
<td>32.73</td>
<td>33</td>
</tr>
<tr>
<td>April 2004</td>
<td>New Mexico</td>
<td>110.5/100.3</td>
<td>0.77</td>
<td>0.13/0.13</td>
<td>35.61</td>
<td>36</td>
</tr>
<tr>
<td>Oct. 2004</td>
<td>Wisconsin</td>
<td>125.3/116.3</td>
<td>0.89</td>
<td>0.13/NA</td>
<td>40.75</td>
<td>41</td>
</tr>
<tr>
<td>May 2005</td>
<td>Illinois</td>
<td>82.46/71.16</td>
<td>0.78</td>
<td>0.15/0.26</td>
<td>30.96</td>
<td>33</td>
</tr>
</tbody>
</table>

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Defense asserts that the radius is not the radius of the motion of the center of mass of the vehicle.
Adjustment:

\[ R_{\text{CM}} = R_{\text{tire mark}} - \frac{TW}{2} \]
yaw radius = 225 – 2.5 = 222.5 ft
drag factor = .82

What is the speed estimate using the adjusted radius?

\[ S = \sqrt{15 f R} = \sqrt{15(0.82)(222.5)} \]

52.3 mph
A curved tire mark, but *not* a CSY.
1997 Toyota 4Runner SR5 4x2 Automated Rollover Crash Test
CSY will often produce an error in speed during a double-steer maneuver and should not be used.
This is not a CSY – too short.
CAVEATS

ROAD DEFECT (causes yaw)

ROAD DESIGN (sudden weight shift)

MULTIPLE SURFACES

ARTICULATED VEHICLES

YAW CAUSED BY IMPACT
CAUSATION
Was the yaw caused by a road defect?
“Velocity estimates using the speed from yaw marks equation should **never** be used to estimate after-collision velocities.”

Fricke, p. 72-31
MECHANICAL FAILURE AS CAUSATION
“I WAS BEHIND HIM.”

“HE HAD MOVED INTO THE TURN LANE AND HAD SLOWED DOWN TO TURN.”

“THE TRUCK SUDDENLY FLIPPED OVER.”
TRUCKS WERE BUILT WITH INCORRECT REAR BRAKE ASSEMBLIES.

CONSEQUENCE OF DEFECT:

A TENDENCY FOR REAR BRAKE LOCKUP EXISTS, PARTICULARLY WITH A LIGHTLY LOADED TRUCK.
CHECK FOR RECALLS ON ALL VEHICLES!

www.nhtsa.gov
Check to see if a recall has been repaired
CHECK FOR

TSB’s

(TECHNICAL SERVICE BULLETINS)

www.nhtsa.gov
CHECK FOR COMPLAINTS

www.nhtsa.gov
VEHICLE SUDDENLY STEERS TO RIGHT, COLLIDES WITH GUARDRAIL.
RF WHEEL TOED IN
NHTSA complaint file:

• 845 complaints filed by owners of this vehicle

• More than 70 include language like:
  “when driving, right front wheel completely turned in”
NHTSA complaint file:

- 845 complaints filed by owners of this vehicle
- More than 70 include language like:
  
  "when driving, right front wheel completely turned in"
  
  "subframe assembly on right front had rotted away, control arm assembly had separated from subframe"
NHTSA complaint file:

• 845 complaints filed by owners of this vehicle

• More than 70 include language like:
  “when driving, right front wheel completely turned in”
  “subframe assembly on right front had rotted away, control arm assembly had separated from subframe”
  “right front tire was sideways, my mechanic said subframe had corroded”
free LE subscription for law enforcement
decodethis.com

enter VIN#
A DIFFERENT WAY TO LOOK AT A SINGLE VEHICLE MOTION

CONSERVATION OF ENERGY.
KE = .03376WS²

A VEHICLE IN MOTION HAS KINETIC ENERGY
KE = .03376WS^2

CRASH!
\[ KE = 0.03376WS^2 \]
Conservation of Energy

The kinetic energy of a vehicle is changed to other forms during the collision, but the energy total is conserved.
ENERGY ANALYSIS:

- IDENTIFY EACH ENERGY EVENT
- ISOLATE EACH EVENT
- DETERMINE AN ENERGY EQUIVALENT SPEED FOR EACH EVENT (EES)
- ADD THE SPEEDS
How did this vehicle lose its kinetic energy?
Speed estimate from energy:

**event #1**

Skid/pavement

\[ f = 0.78 \]
\[ d = 69 \text{ ft} \]
Speed estimate from energy:

**event #2**

<table>
<thead>
<tr>
<th>Skid/pavement</th>
<th>Skid/grass</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f = 0.78$</td>
<td>$f = 0.5$</td>
</tr>
<tr>
<td>$d = 69$ ft</td>
<td>$d = 60$ ft</td>
</tr>
</tbody>
</table>
Speed estimate from energy:

<table>
<thead>
<tr>
<th>Event #3</th>
<th>Skid/pavement</th>
<th>Skid/grass</th>
<th>Impact Pole</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$f = 0.78$</td>
<td>$f = 0.5$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$d = 69$ ft</td>
<td>$d = 60$ ft</td>
<td></td>
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</tbody>
</table>
Each event has an equivalent speed:

<table>
<thead>
<tr>
<th>Event</th>
<th>( f )</th>
<th>( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skid/pavement</td>
<td>0.78</td>
<td>69 ft</td>
</tr>
<tr>
<td>Skid/grass</td>
<td>0.5</td>
<td>60 ft</td>
</tr>
<tr>
<td>Impact pole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crush</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
40 mph

Skid/pavement

\[ f = 0.78 \]
\[ d = 69 \text{ ft} \]

Skid/grass

\[ f = 0.5 \]
\[ d = 60 \text{ ft} \]

impact pole

35 mph
CRUSH ANALYSIS

DAMAGE \rightarrow \text{EQUIV. SPEED}
damage analysis yields equivalent speed

35 mph
impact pole
40 mph
Skid/pavement
\[ f = 0.78 \]
\[ d = 69 \text{ ft} \]

30 mph
Skid/grass
\[ f = 0.5 \]
\[ d = 60 \text{ ft} \]

35 mph
impact pole
Combined Speeds Equation

\[ S = \sqrt{S_1^2 + S_2^2 + S_3^2} \]
Combined Speeds Equation

\[ S = \sqrt{40^2 + 30^2 + 35^2} \]

\[ S = 61.0 \text{ mph} \]
A lesson I learned from a defense lawyer in Salt Lake City