Single-Vehicle J-Turn Repeatability Study
Vehicle E

Single-Vehicle J-Turn Repeatability Testing Results (Left 174°)
30 mph / 500 deg/s / SEA Operator + Passenger Loading

7% Variation, 10 Runs Without Overturn
0.623 g w/ Outrigger Contact

TEST 110: Vehicle E
SEA Right J-Turn w/ Robotic Steering Controller - SEA Driver & Passenger w/ Outriggers

Same Conditions

Steering (°)  Roll Rate (°/Sec)  Yaw Rate (°/Sec)  Speed (MPH)  Ax (g/s)  Ground Plane Ay (g/s)
TEST 111: Vehicle E
SEA Right J-Turn w/ Robotic Steering Controller - SEA Driver & Passenger w/ Outriggers
TEST 116: Vehicle E
SEA Right J-Turn w/ Robotic Steering Controller - SEA Driver & Passenger w/ Outriggers

0.660 g w/ One-Wheel Lift

Steering (°)  Roll Rate (°/Sec)  Yaw Rate (°/Sec)  Speed (MPH)  Ax (g/s)  Ground Plane Ay (g/s)
0.685 g w/ Outrigger Contact

TEST 117: Vehicle E
SEA Right J-Turn w/ Robotic Steering Controller - SEA Driver & Passenger w/ Outriggers
Multi-Vehicle J-Turn Repeatability Study
SWA Results and Analysis

Steering Wheel Angle for Two Wheel Lift (Left)
30 mph / 500 deg/s / Operator + Passenger Loading

- SEA
- CEI 1
- CEI 2

A: +38%
D: -12%
E: +25%
F: +38%
G: +13%
H: +25%
Ay Results and Analysis

Minimum Ay for Two Wheel Lift (Left)
30 mph / 500 deg/s / Operator + Passenger Loading

- **SEA**
  - A: +30%
  - D: +5%
  - E: +19%
  - F: +17%
  - G: +15%
  - H: +37%

- **CEI 1**
  - A: +8%
  - D: +10%
  - E: +18%
  - F: +4%
  - G: +4%
  - H: +16%

- **CEI 2**
  - A: unable to determine
  - D: +5%
  - E: +10%
  - F: +17%
  - G: +15%
  - H: +37%
CPSC Responses to ROHVA Questions
Q: A review of the dropped throttle J-turn testing for which results are presented in Appendix E of both the April and August 2011 SEA Reports indicates that data from several tests may not have been included in the original Reports. In addition to the runs numbered 116 and 117, 1128 and 1129, and 1326 and 1328, were there any other tests performed where a vehicle (or vehicles) in the operator and passenger loading configuration showed an Ay variability of 0.03 g or greater between runs when tested in the same direction? If so, please list the machine(s) by identifying letter and provide the test results for all such runs.
• A: In Section 4.5 of the April 2011 report SEA states: "...the blue lines are the tests with the minimum steering that resulted in tip-up and the red lines are the tests with the maximum steering that did not result in tip-up." There are no tests with intermediate steering or severity between these two. These blue and red lines are shown for all vehicles in both the right and left steer directions.
Vehicle E

Single-Vehicle J-Turn Repeatability Testing Results (Left 174°)
30 mph / 500 deg/s / SEA Operator + Passenger Loading

Maximum Ay Prior to ORC (g)

Test Sequence Number
• Q: From page 12 of the SEA report, ROHVA understands that “…tip-up events are considered those that produced significant two-wheel lift and in almost all cases outrigger contact.” Please identify the number of drop throttle J-Turn tests performed by SEA where 2-wheel lift was observed without outrigger contact. Please provide this data, by machine, for both loading conditions tested. If the precise number of runs cannot be provided, please provide an approximate anecdotal answer rounding to the nearest 10%.
The statement “For this testing, tip-up events are considered those that produced significant two-wheel lift and in almost all cases outrigger contact,” is describing that the lateral threshold testing of these vehicles resulted in two-wheel lift that would have continued into a 90 degree rollover if the outrigger did not prevent the rollover event from occurring. Therefore, to determine the minimum lateral acceleration required to induce rollover, the tests were repeated at smaller and smaller steer angles until the vehicle exhibited just enough two-wheel lift to measure that minimum lateral acceleration but not enough to make outrigger contact (and thereby incorrectly measure the lateral acceleration caused by outrigger impact with the ground). 100% of the J-Turn tests that measured the minimum lateral acceleration of the vehicle at rollover threshold exhibited 2-wheel lift without outrigger contact since by definition that was how the value was measured.
### Maximum Lateral Accelerations During Dropped Throttle J-Turns

**Vehicle D – GVWR Loading**

<table>
<thead>
<tr>
<th>Percentage of Steering Required for Two Wheel Lift (%)</th>
<th>Right Steer Maneuvers</th>
<th>Left Steer Maneuvers</th>
<th>Average of Right and Left Maneuvers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steering Angle (deg)</td>
<td>Lateral Accel. (g)</td>
<td>Steering Angle (deg)</td>
</tr>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>25.0</td>
<td>6.3</td>
<td>0.09</td>
<td>-6.9</td>
</tr>
<tr>
<td>50.0</td>
<td>12.5</td>
<td>0.17</td>
<td>-13.8</td>
</tr>
<tr>
<td>75.0</td>
<td>18.8</td>
<td>0.26</td>
<td>-20.6</td>
</tr>
<tr>
<td>87.5</td>
<td>21.9</td>
<td>0.48</td>
<td>-24.1</td>
</tr>
<tr>
<td>100.0</td>
<td>25.0</td>
<td>0.61</td>
<td>-27.5</td>
</tr>
</tbody>
</table>
Understeer Correlation Study
Pages 44 and 45 (Operator and Passenger) and Pages 57 and 58 (GVWR) contain exhibits comparing the laboratory rollover resistance metrics to the lateral accelerations required for tip-ups in the dropped throttle J-turns. Pages 44 and 57 are bar charts of the values, while Pages 45 and 58 are graphs with plots of the rollover resistance metrics versus lateral acceleration at tip-up. Linear fits of the plots are also provided on the graphs. The graphs on Pages 45 and 58 indicate that TTR has a better correlation to lateral acceleration at tip-up than do SSF or CSV. However, none of the static metrics examined correlated very well with the minimum lateral acceleration thresholds. The data for Vehicle I, the four-passenger vehicle, has the biggest outliers from the linear fits for SSF and CSV in both loading configurations.
Quantification of USG

Vehicle A - Circle Tests

CW Transition to Oversteer
At Ay = 0.24292 g

CCW Transition to Oversteer
At Ay = -0.23431 g

CPSC Circle Test Results – Operator, Instrumentation and Outriggers

Appendix C.1 Page #3
USG Correlation on Concrete

SEA Understeer Gradient v SEA J-Turn Max Ay
(100' Diameter Concrete Circle)

- $R^2 = 0.395$ @ SEA Two Passenger
- $R^2 = 0.201$ @ Gross Vehicle Weight
<table>
<thead>
<tr>
<th></th>
<th>SEA Two Passenger</th>
<th>SEA GVW Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>USG (Concrete) v. SEA Max Ay</td>
<td>0.40</td>
<td>0.20</td>
</tr>
<tr>
<td>USG (Concrete) v. SEA TTA</td>
<td>0.27</td>
<td>0.40</td>
</tr>
<tr>
<td>USG (Concrete) v. SEA SSF</td>
<td>0.23</td>
<td>0.02</td>
</tr>
<tr>
<td>USG (Dirt) v. SEA Max Ay</td>
<td>0.00</td>
<td>0.04</td>
</tr>
<tr>
<td>USG (Dirt) v. SEA TTA</td>
<td>0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>USG (Dirt) v. SEA SSF</td>
<td>0.07</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Ay Body Roll
Correction Factor
1. Measured Comp. of AyGP = \((AyGP \cdot \cos(\psi))\)

2. Ay Measured = \((AyGP \cdot \cos(\psi)) + (g \cdot \sin(\psi))\)

3. AyGP = \((Ay Measured - \sin(\psi)) / (\cos(\psi))\) in units of g
Ay Body Roll Correction Factor

\[(Ay \cdot \cos(\psi)) - (Az \cdot \sin(\psi))\]

\[(Ay - \sin(\psi)) / (\cos(\psi))\]

1.0 g convention

0.0 g convention
“Delphi recommended that NHTSA provide greater specificity in the definition of 0 G normal acceleration, because the term 0 G is used inconsistently within the industry (e.g., 0 G is sometimes normalized for the 1 G bias due to gravity). We agree with Delphi’s comments and have revised the definition.”