ROHVA Update:
Standards Development and Safety Programs

Presented to
U.S. Consumer Product Safety Commission
Technical Staff
November 10, 2011

Recreational Off-Highway Vehicles

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

- **Only Growing Segment: +15% in 2010**

- **Tens of Thousands of Jobs related to:**
  - Manufacturing
  - Retail
  - Tourism

ROHVA Members

ARCTIC CAT®

BRP

Kawasaki

POLARIS®

YAMAHA

84% of ROVs Represented by ROHVA

ROV Innovation

Additional Entries

Recent Innovations Demonstrate Need To Avoid Design Restrictive Standards

ROHVA's Comprehensive Safety Action Plan

Announced to Chairman Tenenbaum in July 2010

ROHVA
RECREATIONAL OFF-HIGHWAY VEHICLE ASSOCIATION

Vehicle Voluntary Standard

✔ 1. Static *and* Dynamic Stability Performance Requirements

✔ 2. Occupant Retention Performance Requirements

✔ 3. Restraint Warning System

✔ 4. Vehicle Class Expanded to Meet CPSC Area of Interest

Occupant Behavior

✔ 1. Required Helmet and Seatbelt Use

✔ 2. Standardized Warning Labels

✔ 3. E-Course Training

✔ 4. Hands-On Training
Q1 2012

ROHVA Delivered On Commitments To CPSC And Is Continuing Its Work

Vehicle Standards

- **ANSI / ROHVA 1-2010 issued in 03/10**
  - Created initial benchmark
  - Continued to work to address CPSC comments and concerns

- **ANSI / ROHVA 1-2011 issued in 07/11**
  - First-ever dynamic stability standard for OHVs
  - Occupant retention construction/performance standards

Rapid, Significant Progress On Standards

CPSC Comments to ANSI/ROHVA 1-2011

- Support for J-turn and opinion favoring understeer on pavement
- SEA report on CPSC sponsored testing
  - Had hoped to have opportunity to discuss methodology and findings directly with SEA
  - Independently analyzed SEA testing

Carr Engineering, Inc.

James E. Walker, Jr., B.S.M.E., P.E.

ROHVA Engaged Carr Engineering to Evaluate SEA Testing and Conclusions

CPSC/SEA Objectives

1. OVERVIEW

This report contains results from measurements made by SEA, Ltd. for the Consumer Product Safety Commission (CPSC) under contract CPSC-S-10-0014. The objectives of contract CPSC-S-10-0014 are:

…accurate and repeatable…

- To document, study, and compare the dynamic performance characteristics of commonly available recreational off-highway vehicles (ROV's).

This report contains test results for measurements made on nine vehicles. All of the vehicles were selected by CPSC, and all of them can be classified as recreational off-highway vehicles (ROV's). They all have side-by-side seating, and they all use a steering wheel, brake pedal, and throttle pedal for operator control inputs. Eight of the vehicles tested were two-passenger vehicles (Vehicles A-H in this report), and one was a four-passenger vehicle with a second row of side-by-side seating (Vehicle I in this report). The measured curb weights (weights with full fluids and no occupants or cargo) of the vehicles ranged from 1025.0 lb to 1753.4 lb. The measured average maximum speeds of the vehicles ranged from 38.1 mph to 59.2 mph in a loading condition representing Operator plus Passenger loading.

Findings Summary

- **SSF/K_{st} and TTA are static <u>vehicle</u> parameters that can be measured accurately and reliably as long as key test variables are defined and controlled**

- **J-Turn SWA and Ay are dynamic <u>test</u> parameters that cannot be reproduced accurately or reliably due to uncontrollable variations in specific methodologies**

- **On-highway steady-state steering <u>characterization</u> can be performed accurately and reliably, but can change dramatically when evaluated off-highway**

Testing Performed

- **Static Evaluations**
  - ✓ **Static Stability Factor (SSF) Calculation**
  - ✓ **Tilt Table Angle (TTA) for Two-Wheel Lift**

- **Dynamic Evaluations**
  - ✓ **Drop-Throttle J-Turn Minimum SWA**
  - ✓ **Drop-Throttle J-Turn Minimum Ay**
  - ✓ **On-Highway Steering Characterization**
  - ✓ **Off-Highway Steering Characterization**

SSF

SSF Evaluation

- **Measurement of CG and calculation of SSF using SAE suspension method (vs. SEA VIMF apparatus)**

- **Total of 44 individual configurations evaluated**
  - ✓ **Eleven machines**
  - ✓ **Four loading configurations**

- **Total of 27 individual configurations could be directly compared to data generated by SEA**

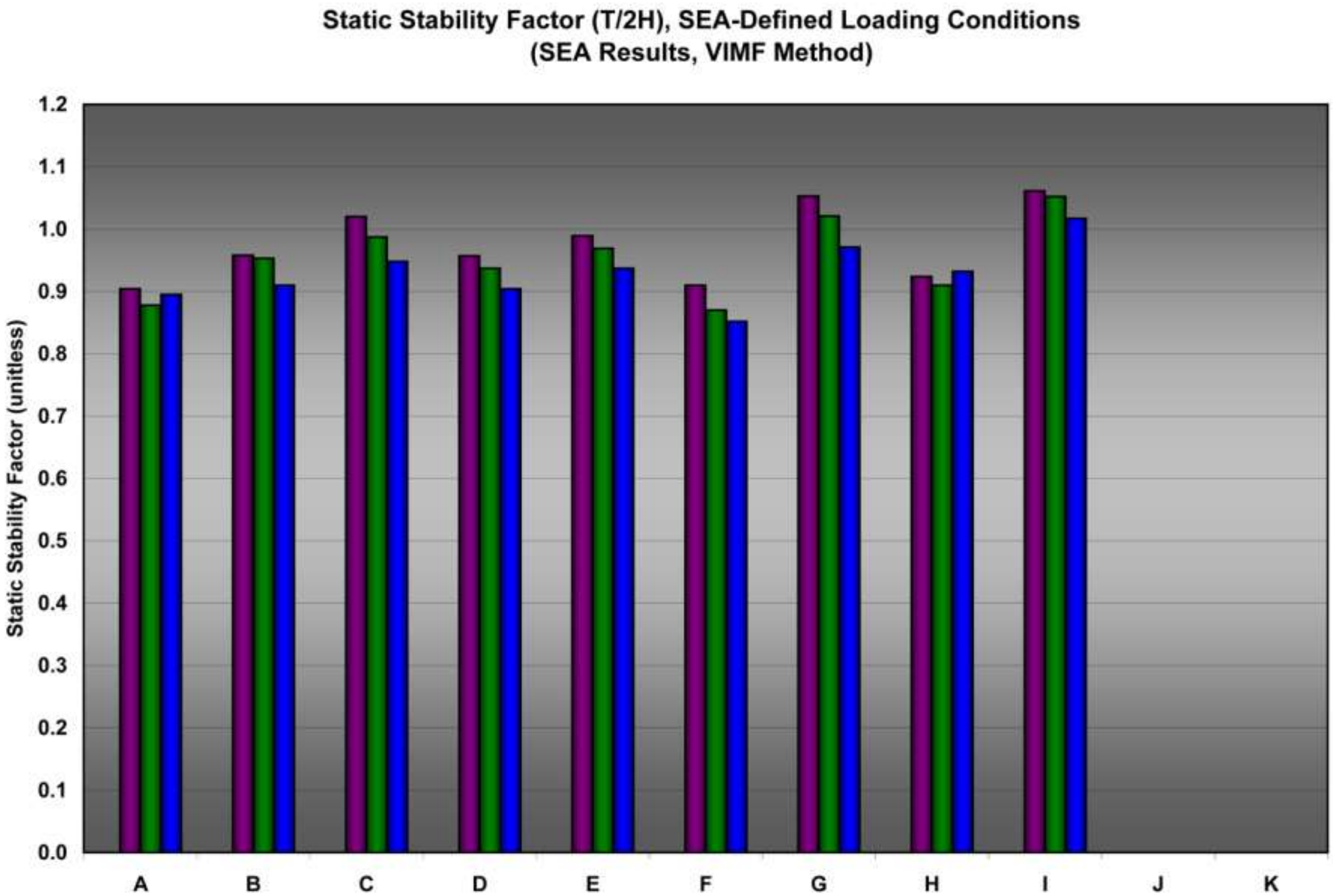
Why Not K_{st}?

…within a value of 0.01…

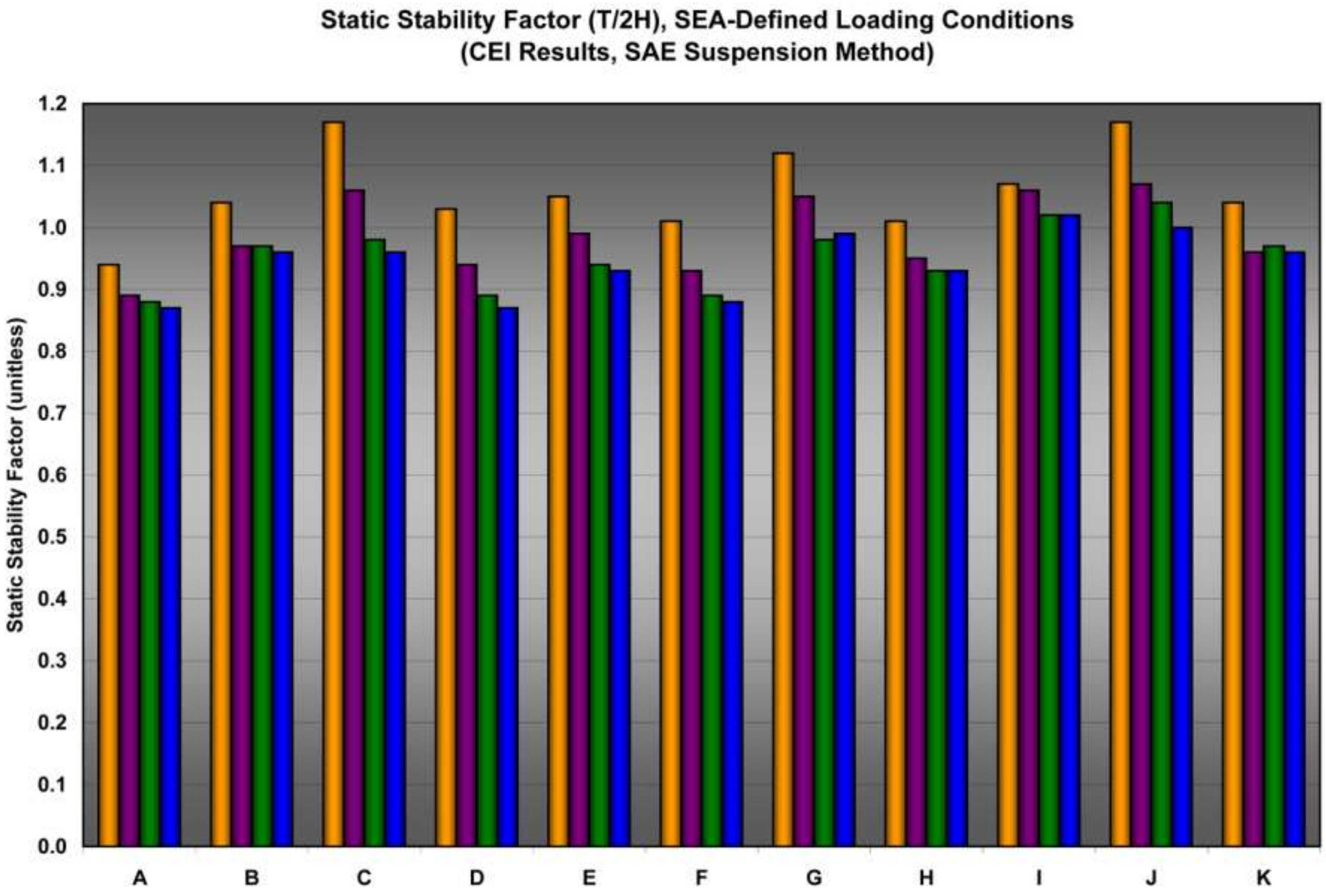
Values for the rollover resistance metric CSV are shown on Page 14. For the Operator and Passenger configurations, the CSV values are higher for the outrigger configurations, primarily because the vehicle roll inertias are higher with outriggers.

TTR results for the driver's side leading tilts, the passenger's side leading tilts, and the average of these two are contained on Pages 15, 16, and 17. For a given vehicle, among the loading configurations the average TTR is generally inversely related to the CG height. Charts comparing driver's side, passenger's side, and average TTR values for the Operator and Passenger configurations are contained on Page 18 and for the Operator, Instrumentation, and Outriggers configurations on Page 19. In general, the variations between the driver's side and passenger's side TTR values are related to the lateral offset of the CG positions for each vehicle and loading configuration. The measured TTR's are generally higher in the direction of tilt opposite of the direction of the lateral offset in CG position. Charts comparing TTA values for the same two loading configurations as Pages 18 and 19 are given on Pages 20 and 21.

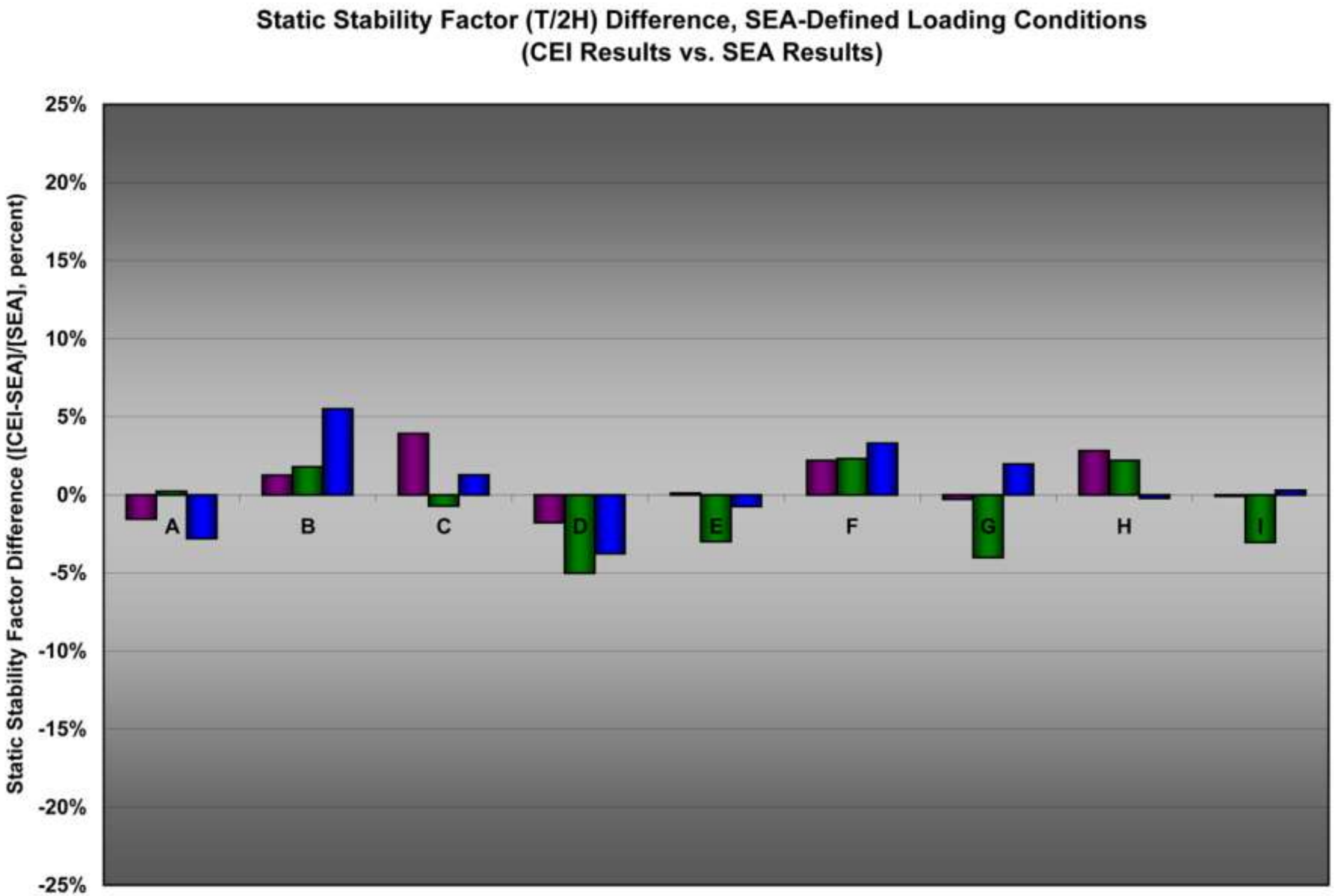
SSF Results


Static Stability Factor (T/2H), SEA-Defined Loading Conditions
(SEA Results, VIMF Method)
Static Stability Factor (unitless)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
A
B
C
D
E
F
G
H
I
J
K

SSF Results


Static Stability Factor (T/2H), SEA-Defined Loading Conditions
(CEI Results, SAE Suspension Method)
Static Stability Factor (unitless)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
A
B
C
D
E
F
G
H
I
J
K

SSF Results


Static Stability Factor (T/2H) Difference, SEA-Defined Loading Conditions
(CEI Results vs. SEA Results)
Static Stability Factor Difference ([CEI-SEA]/[SEA], percent)
25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
-20%
-25%
A
B
C
D
E
F
G
H
I

SSF Results

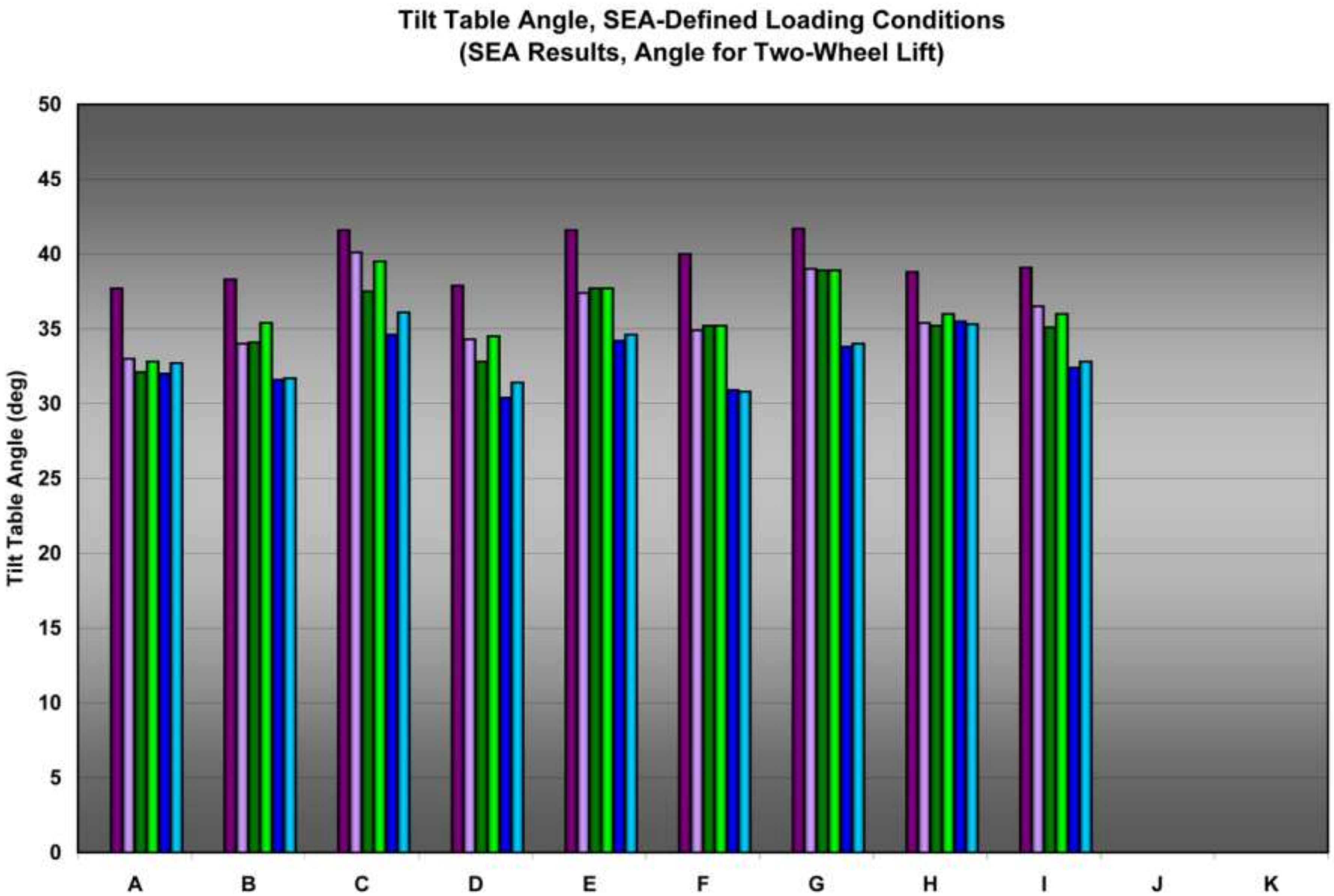
- Maximum difference of ~5% compared to SEA data
- Average difference of ~2% compared to SEA data
- Generally consistent results independent of testing methodology that satisfy CPSC/SEA-stated objective of being both accurate and repeatable
- Generally relates to a machine’s crash avoidance capacity
- Any proposed standard or metric would need to consider test-to-test variability

Tilt Table

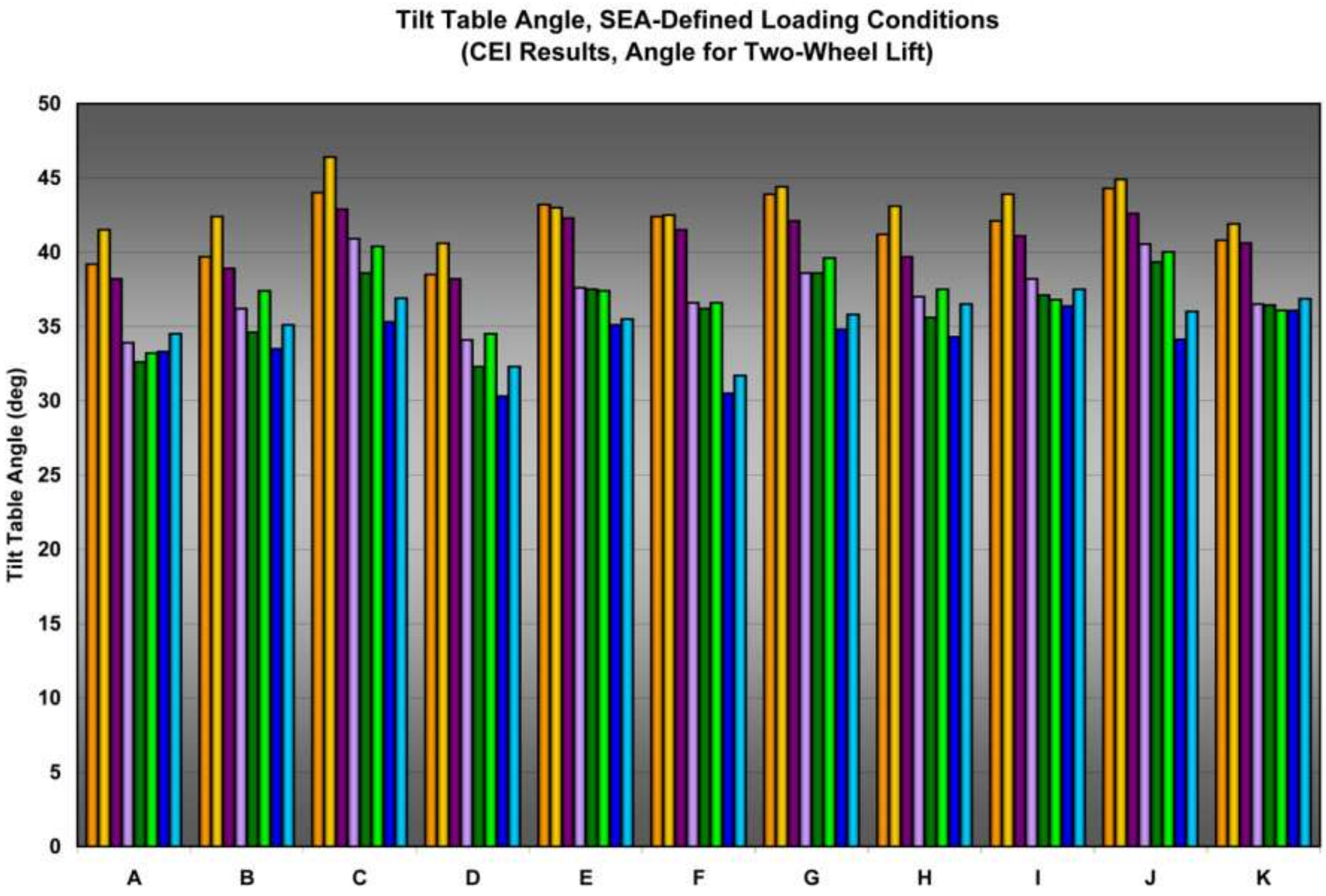
Tilt Table Evaluation

- Measurement of minimum TTA required for two-wheel lift (TWL) on tilt table apparatus
- Total of 88 individual configurations evaluated
  - ✓Eleven machines
  - ✓Four loading configurations
  - ✓Two orientations
- Total of 54 individual configurations could be directly compared to data generated by SEA

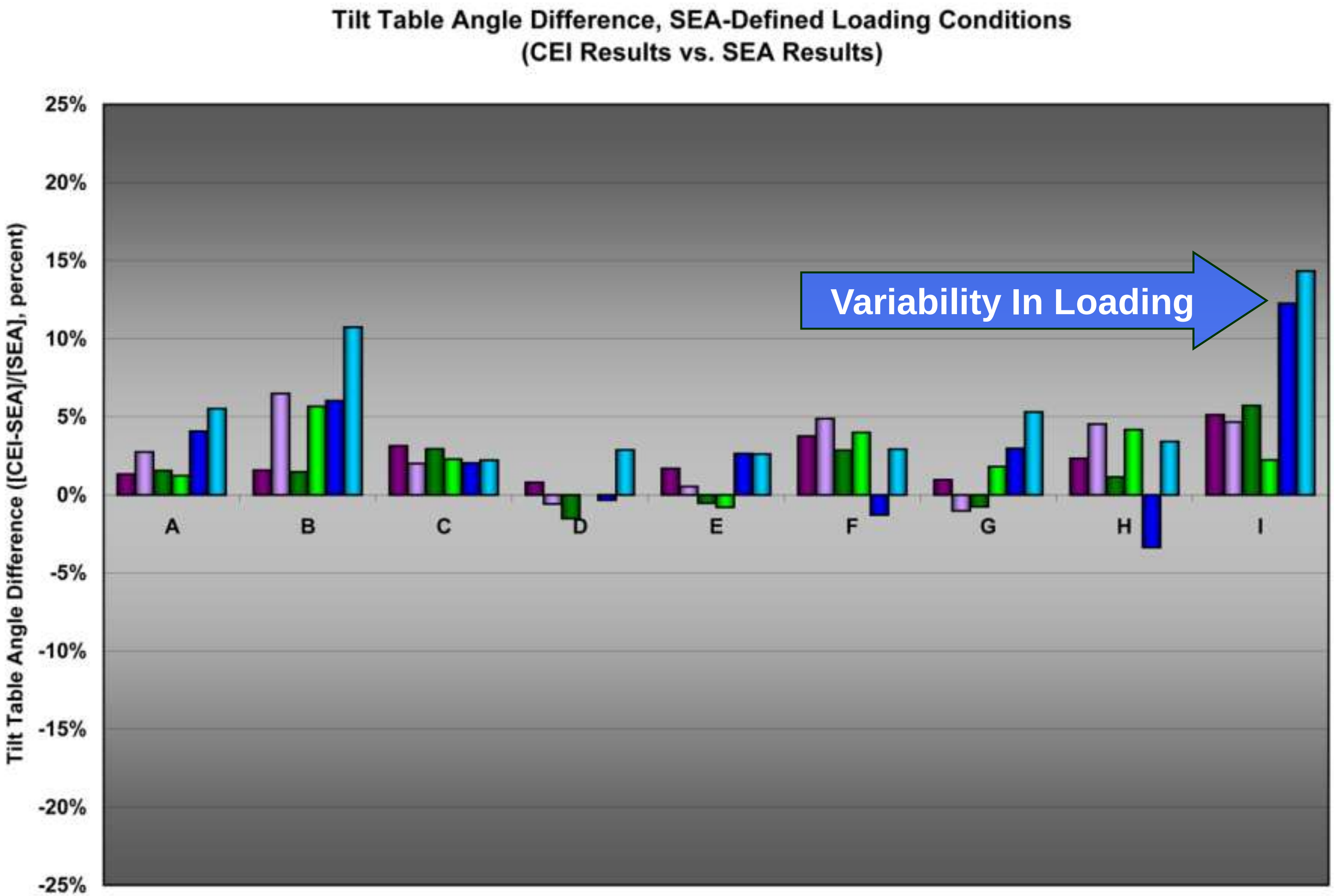
Tilt Table Results



Tilt Table Results



Tilt Table Results



Tilt Table Results

- **Maximum difference of ~14% compared to SEA data**
- **Average difference of ~3% compared to SEA data**
- **Generally consistent results independent of testing methodology that satisfy CPSC/SEA-stated objective of being both accurate and repeatable**
- **Generally relates to a machine's crash avoidance capacity**
- **Any proposed standard or metric would need to consider test-to-test variability**

Drop-Throttle J-Turn
Steering Wheel Angle

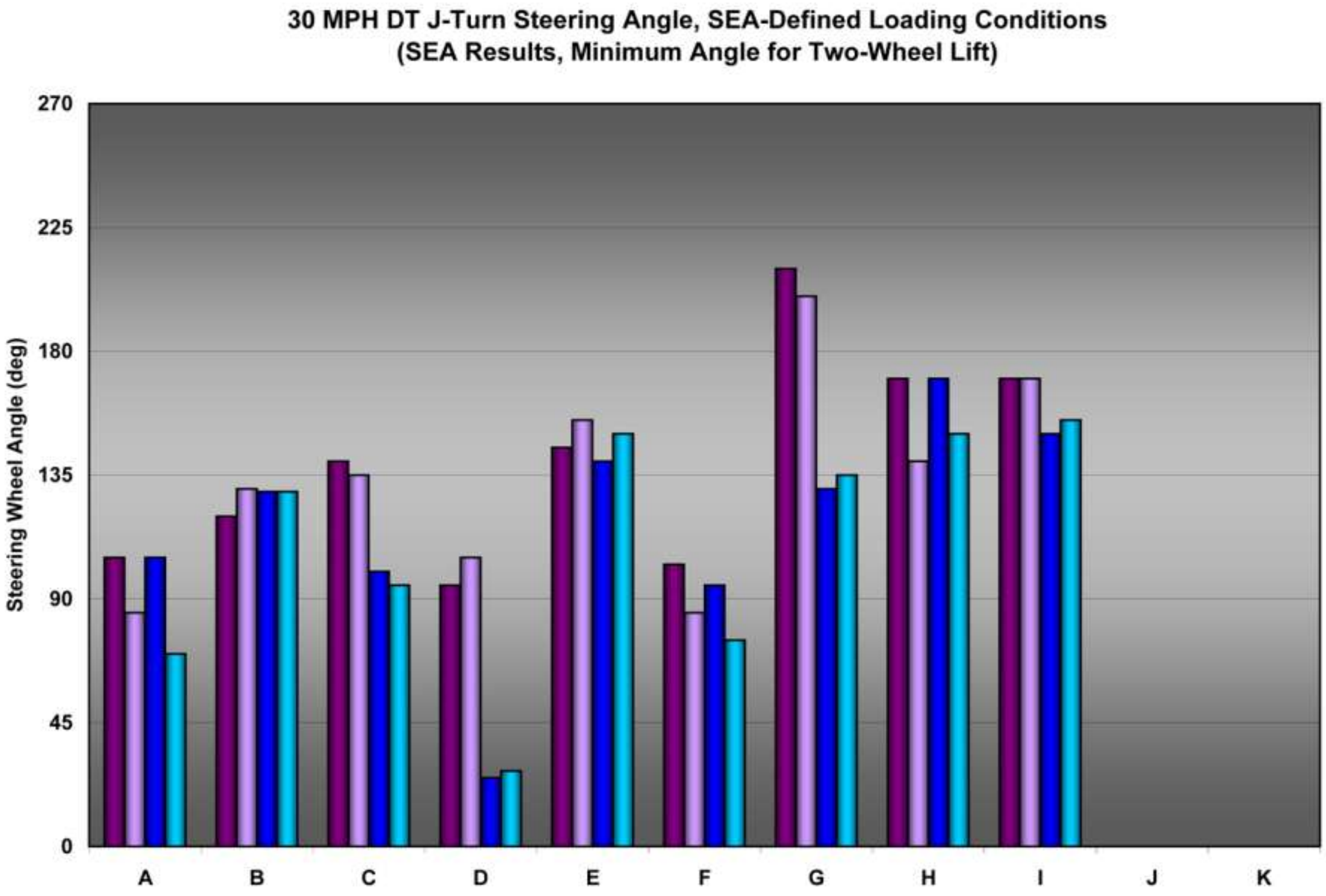
J-Turn SWA Evaluation

- **Determination of minimum SWA required for outrigger contact during aggressive dropped-throttle J-Turn (500°/s @ 30mph) on concrete surface**

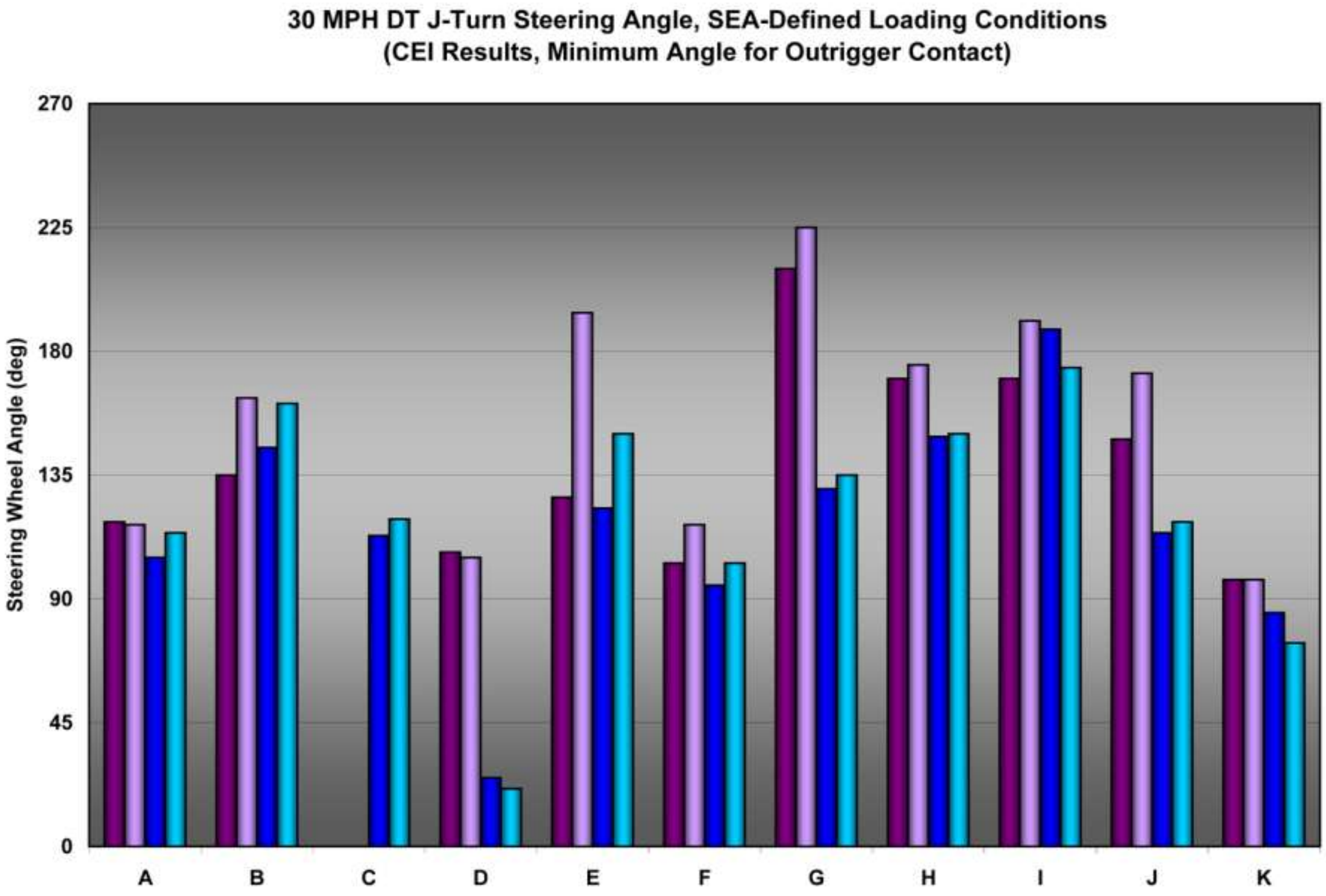
- **Total of 44 individual configurations evaluated**
  - ✓**Eleven machines (A through K)**
  - ✓**Two loading configurations (SEA-defined)**
  - ✓**Two directions (left and right)**

- **Total of 36 individual configurations could be directly compared to data generated by SEA**

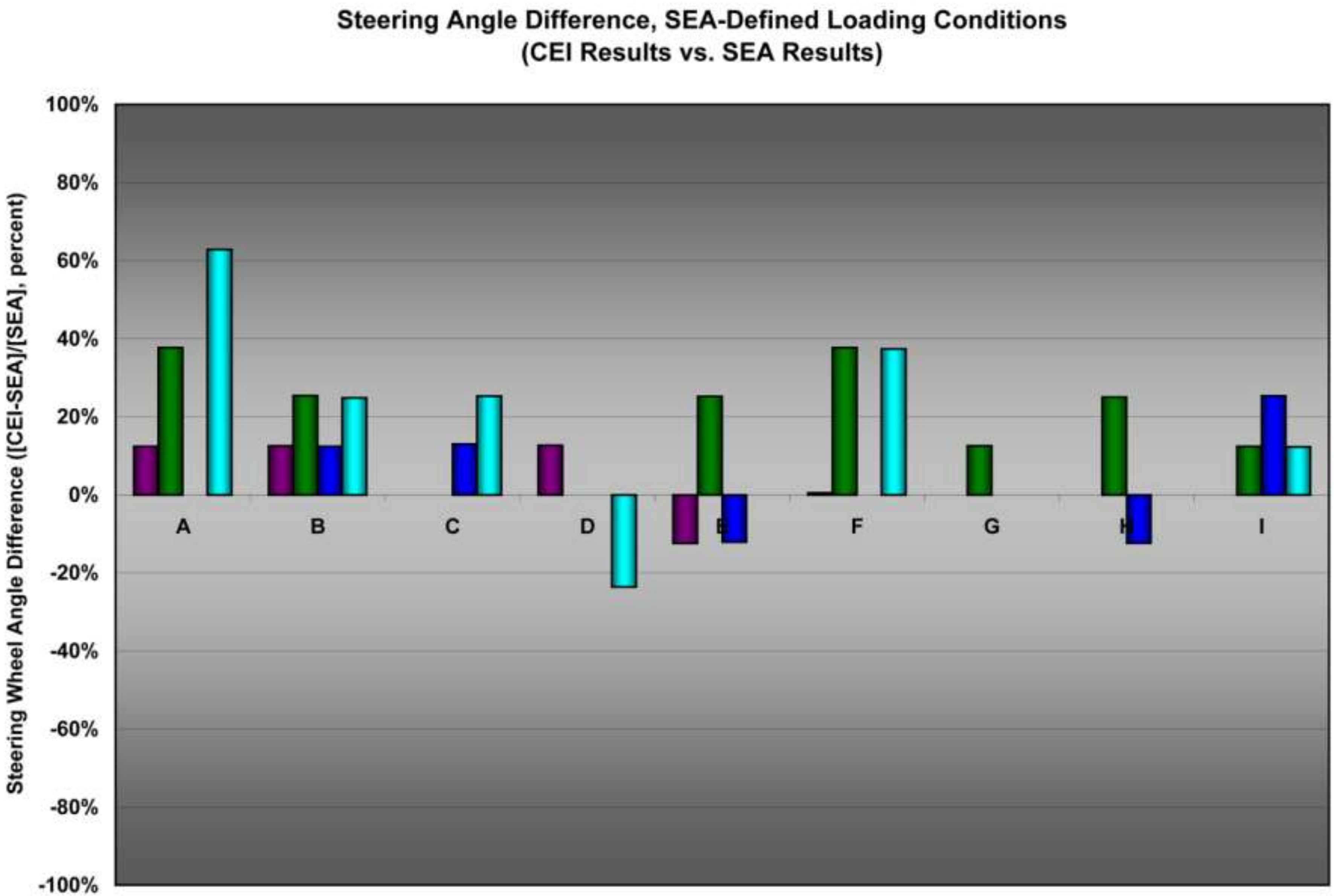
J-Turn SWA Results



J-Turn SWA Results



J-Turn SWA Results

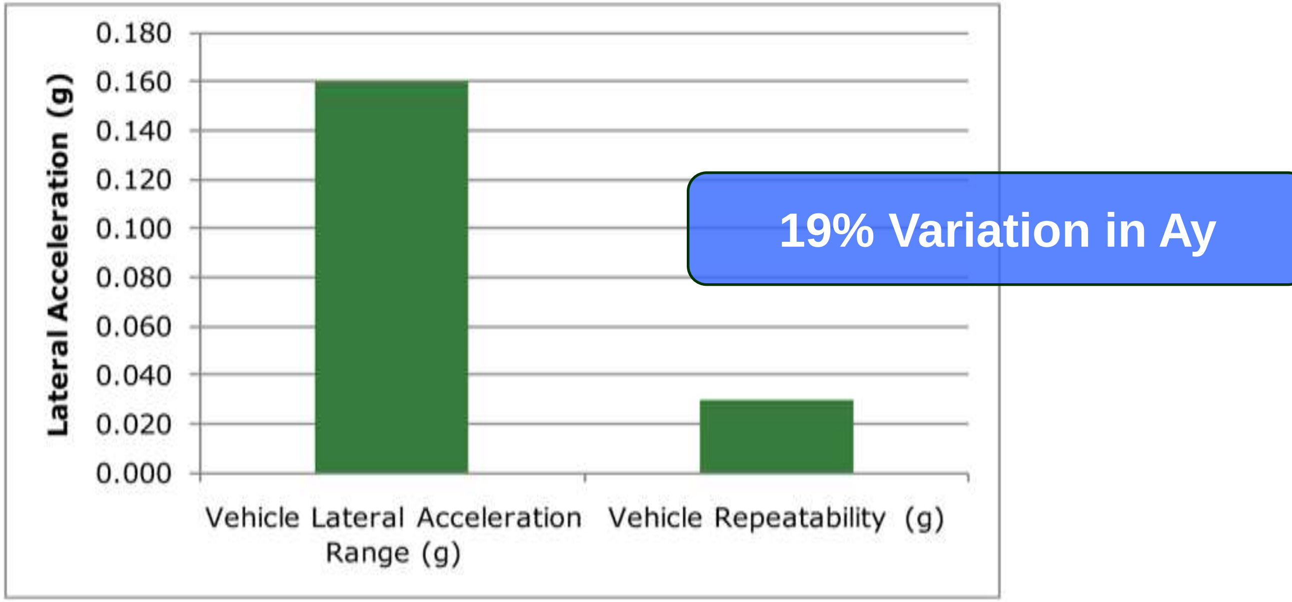


J-Turn SWA Results

- Maximum difference of ~63% compared to SEA data
- Average difference of ~14% compared to SEA data
- Inconsistent results based on specific testing conditions and methodology that do not satisfy the CPSC/SEA-stated objective of being both accurate and repeatable
- Inappropriate for use as a standard or metric due to large test-to-test variability

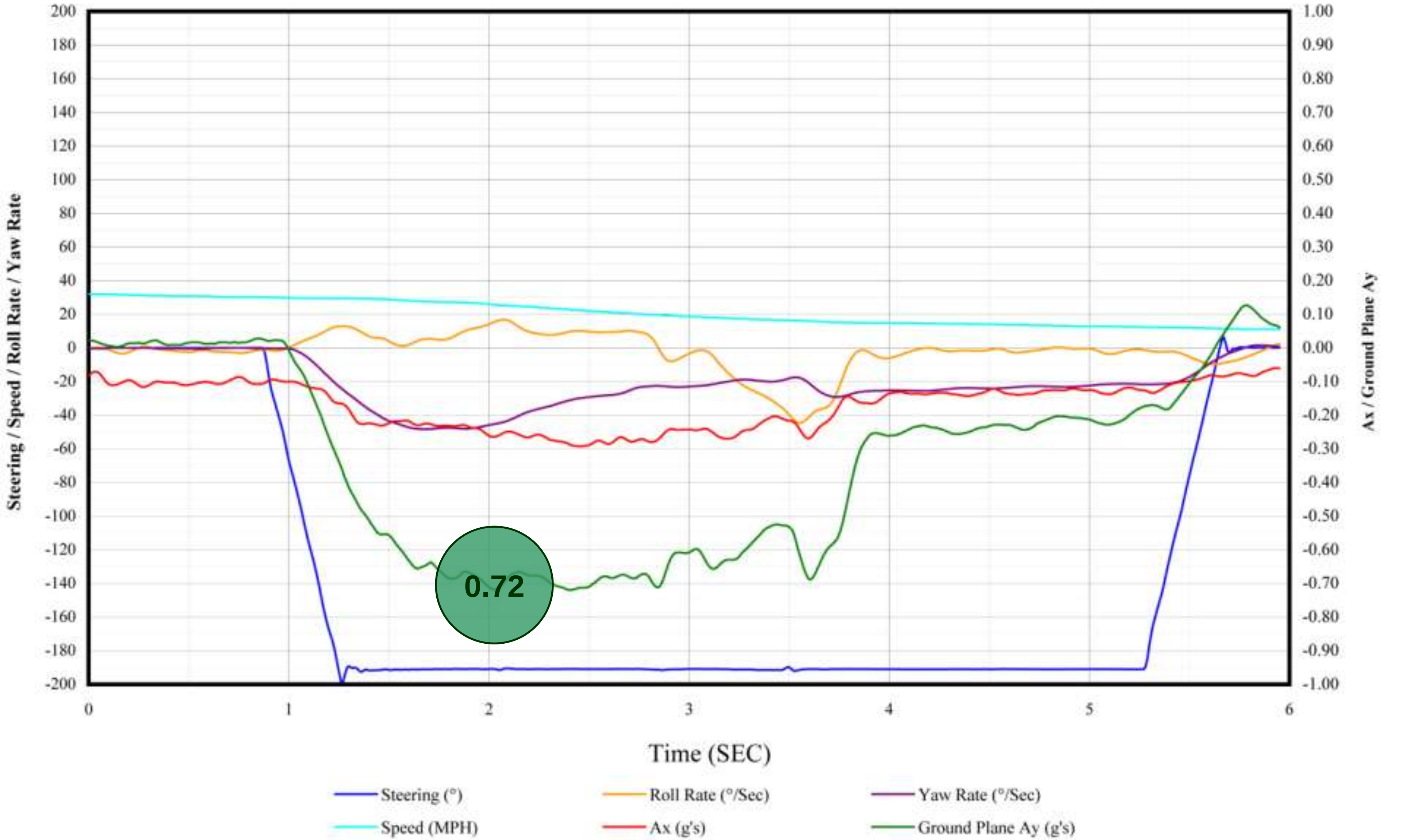
Drop-Throttle J-Turn
Ay Test Variability

OPEI Analysis of SEA Data

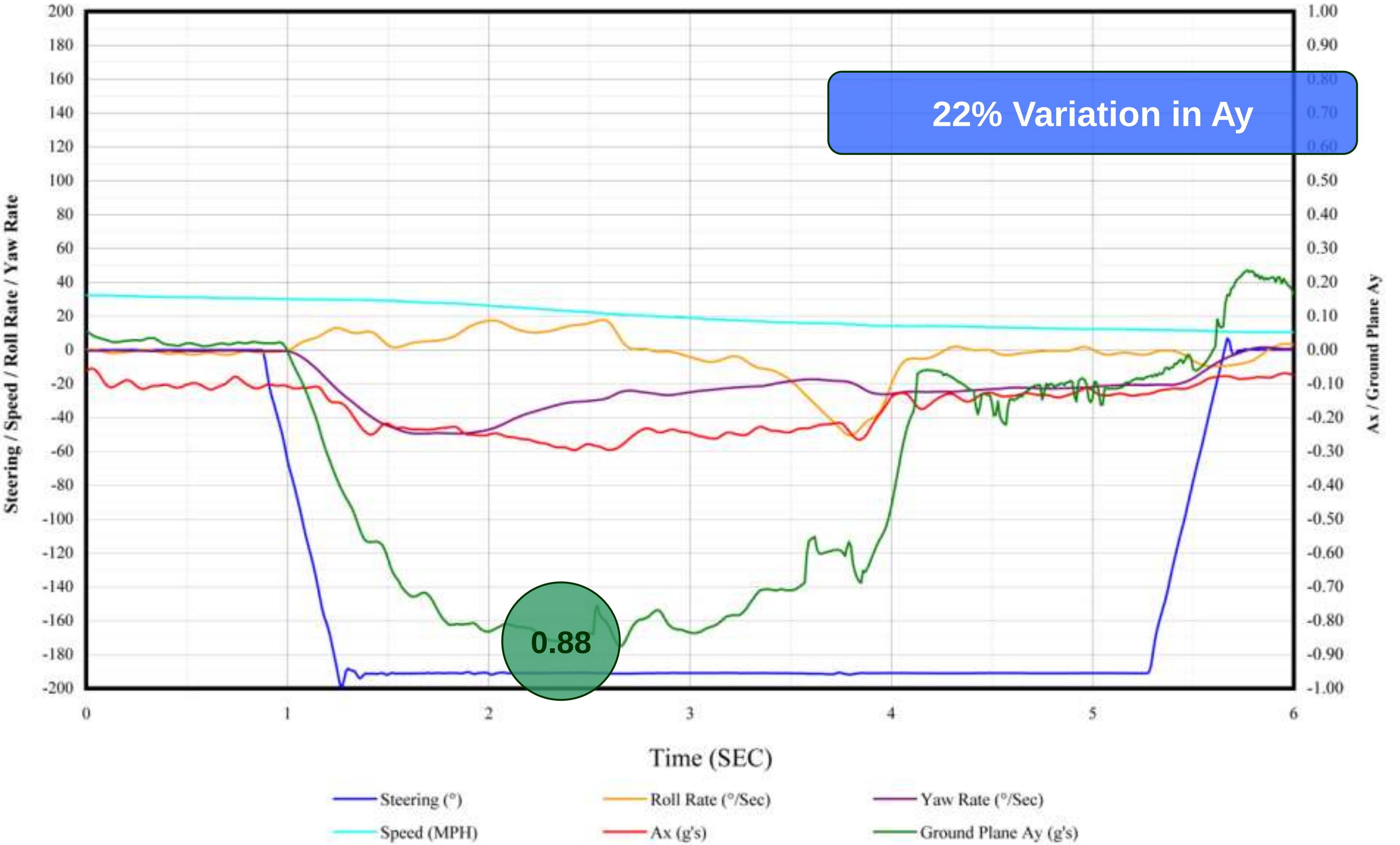


The testing showed that there is a 0.03 range of acceleration values when measuring one vehicle with a common instrumentation set-up. This accounts for 19% of the total range of lateral acceleration at two wheel lift of the 11 vehicles measured by the CPSC. This variation is from a test using the same vehicle with as many of the previously mentioned variables controlled as possible. If other variables are included the variation would conceivably be higher than 19%.

J-Turn Ay Variability / CEI Analysis



J-Turn Ay Variability / CEI Analysis



J-Turn Ay Variability

- **OPEI calculated vehicle variation of ~19% of data range using SEA results**
- **CEI measured ~22% Ay test-to-test variation**
- **The NHTSA does not employ any form of a J-Turn test protocol for either consumer advisory or regulatory purposes**
- **The NHTSA does not employ any form of a lateral acceleration requirement for either consumer advisory or regulatory purposes**

J-Turn Ay Variability

- **Inconsistent results based on specific testing conditions and methodology that do not satisfy the CPSC/SEA-stated objective of being both accurate and repeatable**

- **Inappropriate for use as a standard or metric due to large test-to-test variability**

Drop-Throttle J-Turn
Minimum Ay

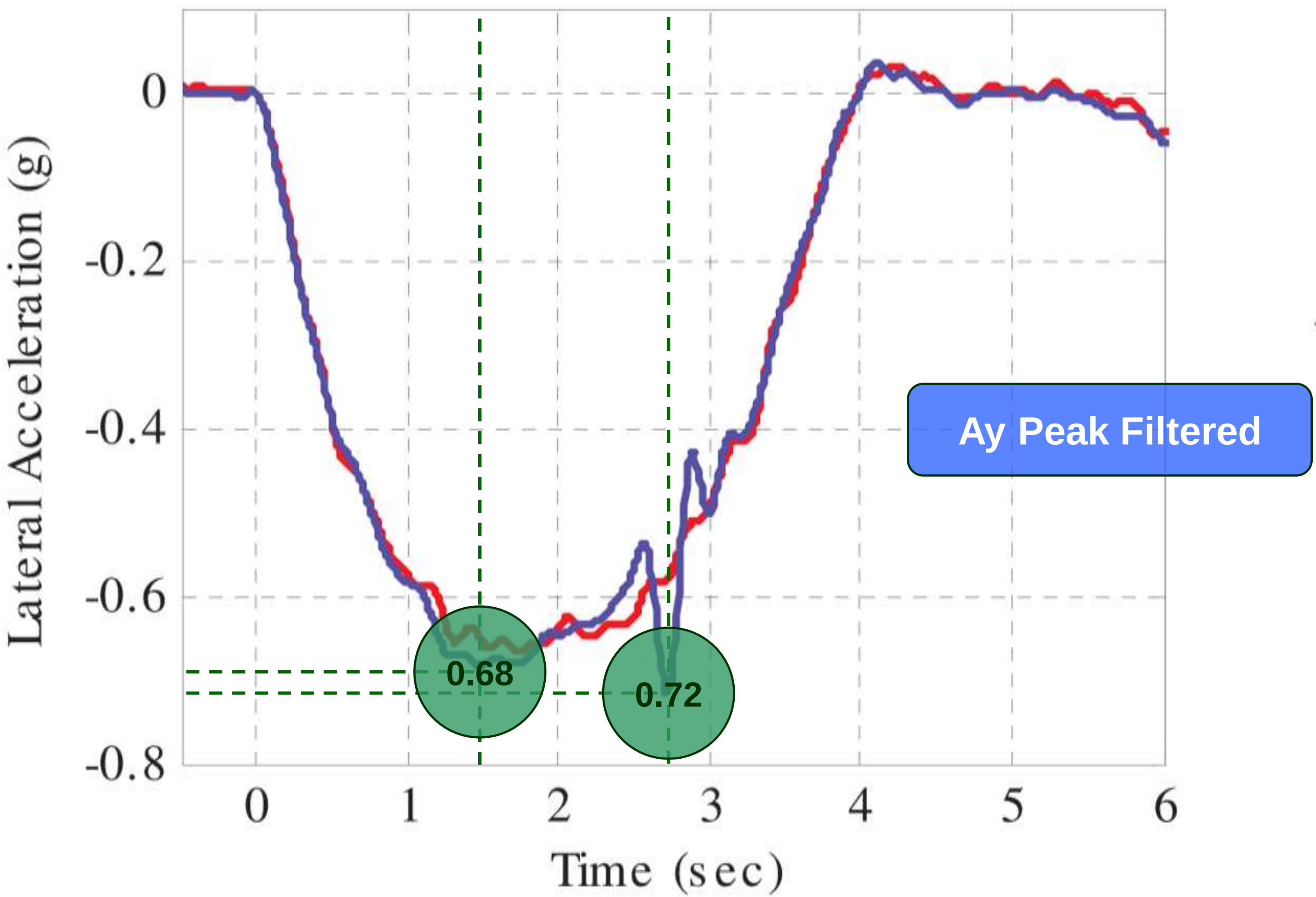
J-Turn Ay Evaluation

- **Determination of minimum Ay required for outrigger contact during aggressive dropped-throttle J-Turn (500°/s @ 30mph) on concrete surface**

- **Total of 44 individual configurations evaluated**
  - ✓**Eleven machines (A through K)**
  - ✓**Two loading configurations (SEA-defined)**
  - ✓**Two directions (left and right)**

- **Total of 36 individual configurations could be directly compared to data generated by SEA**

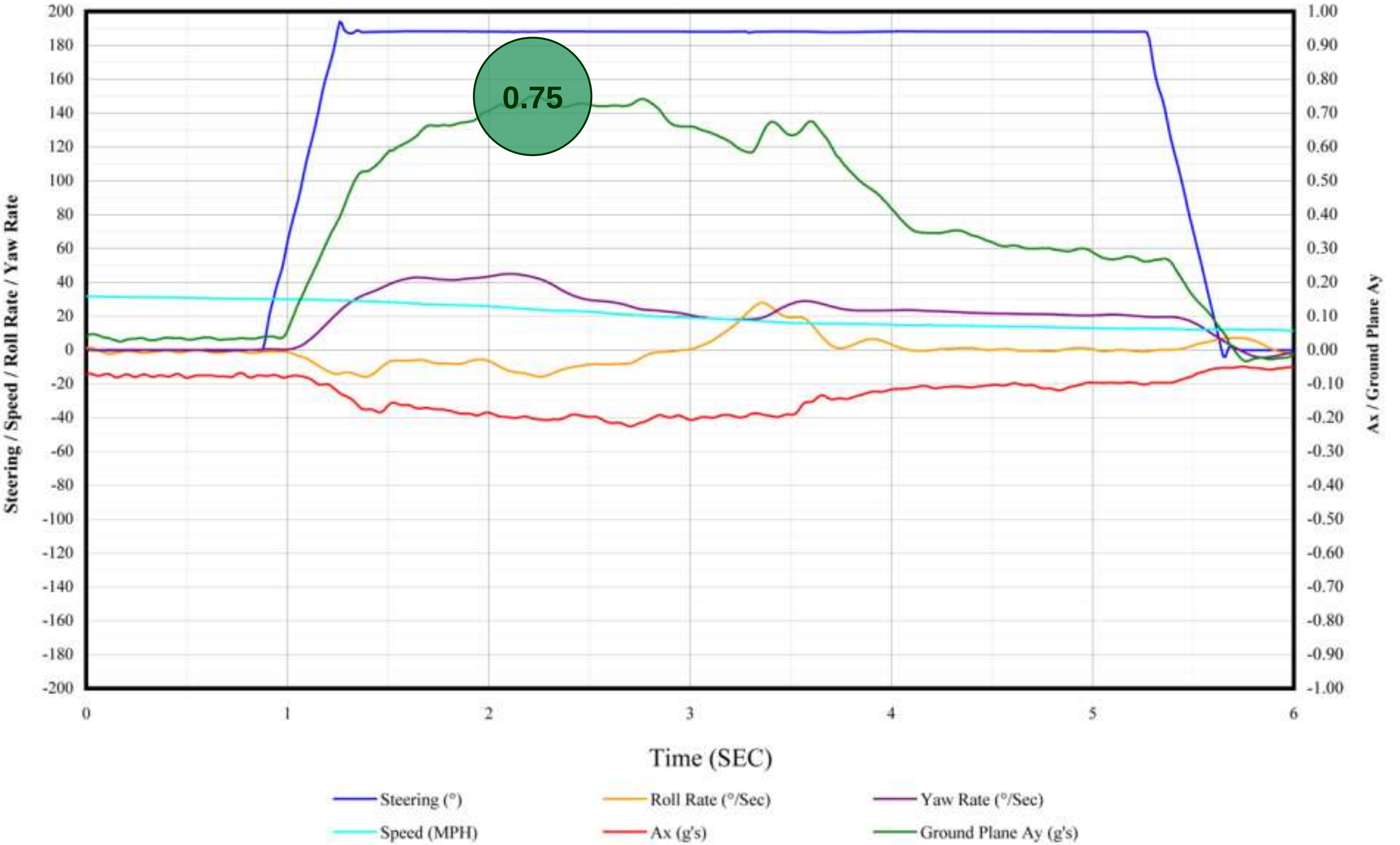
SEA J-Turn Ay Results / Vehicle G



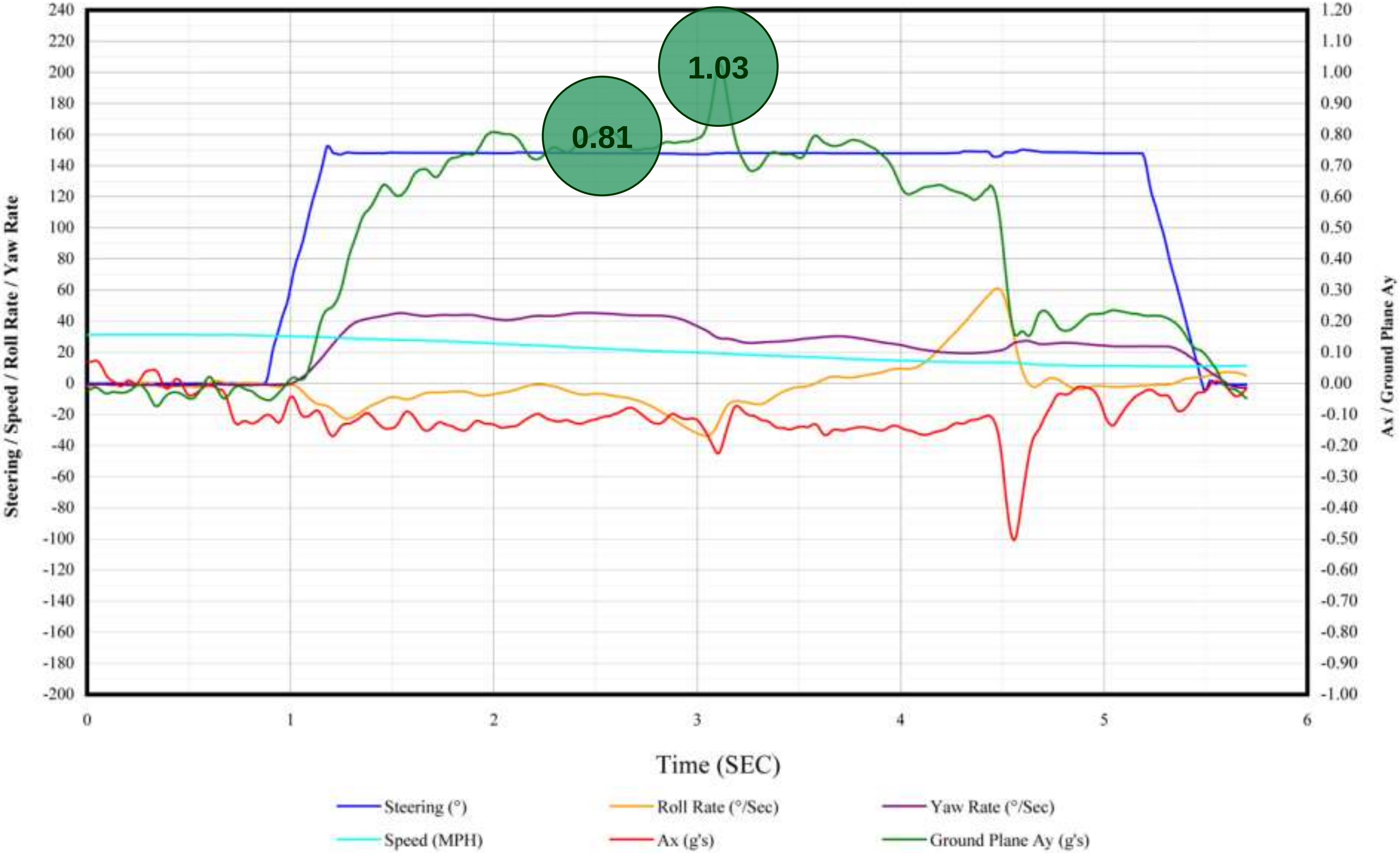
J-Turn Ay Measurement

- Results generated by CEI (using SEA methodology) show a wider range of rolling motions
- Some vehicles displayed rolling motions which prevented an accurate or reliable measurement of Ay
- Ay selected by CEI as local maximum excluding transients generated
- Like SEA, unknown / unquantified effect of outrigger contact during generation of local maximum

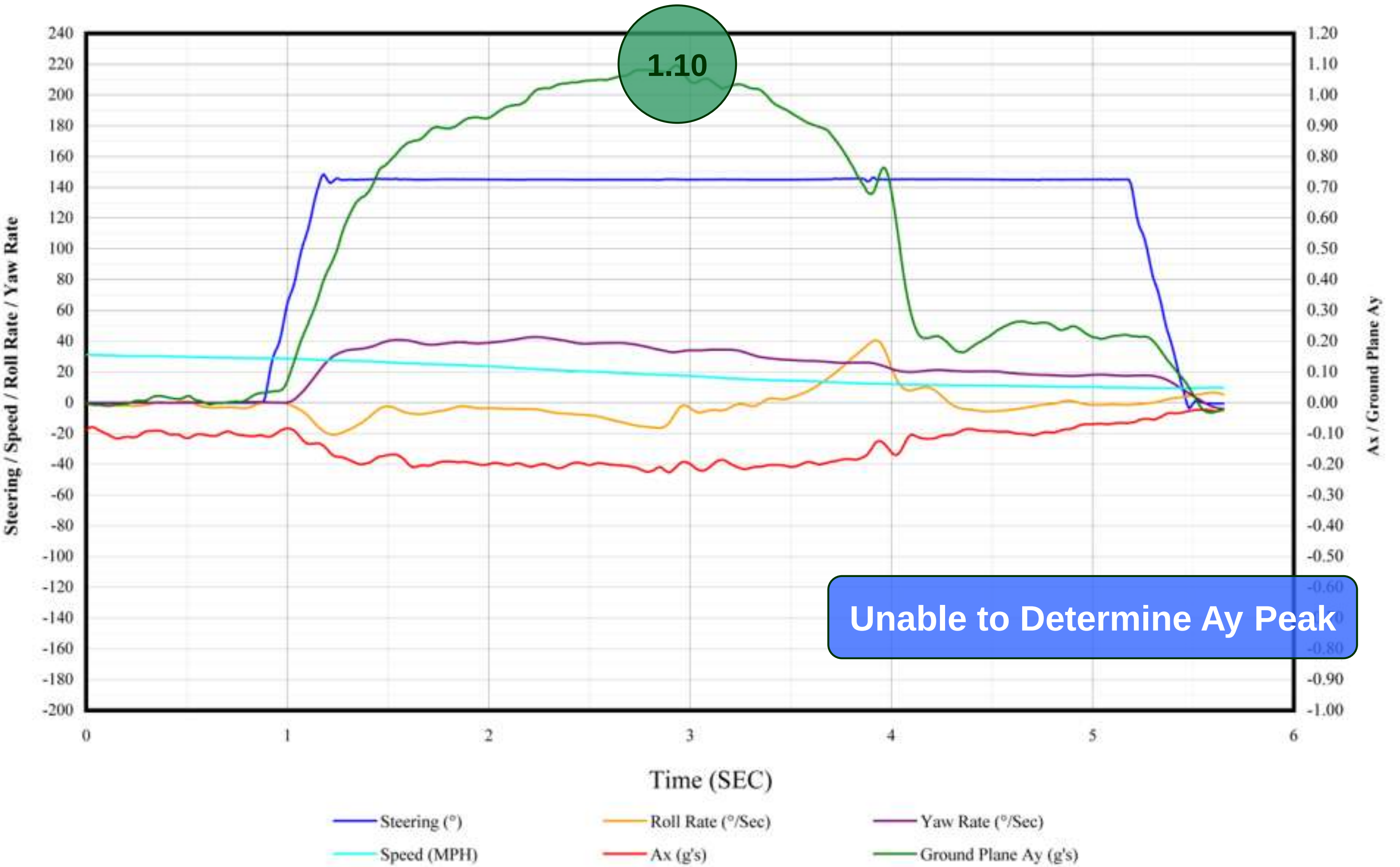
J-Turn Ay Results / Vehicle I



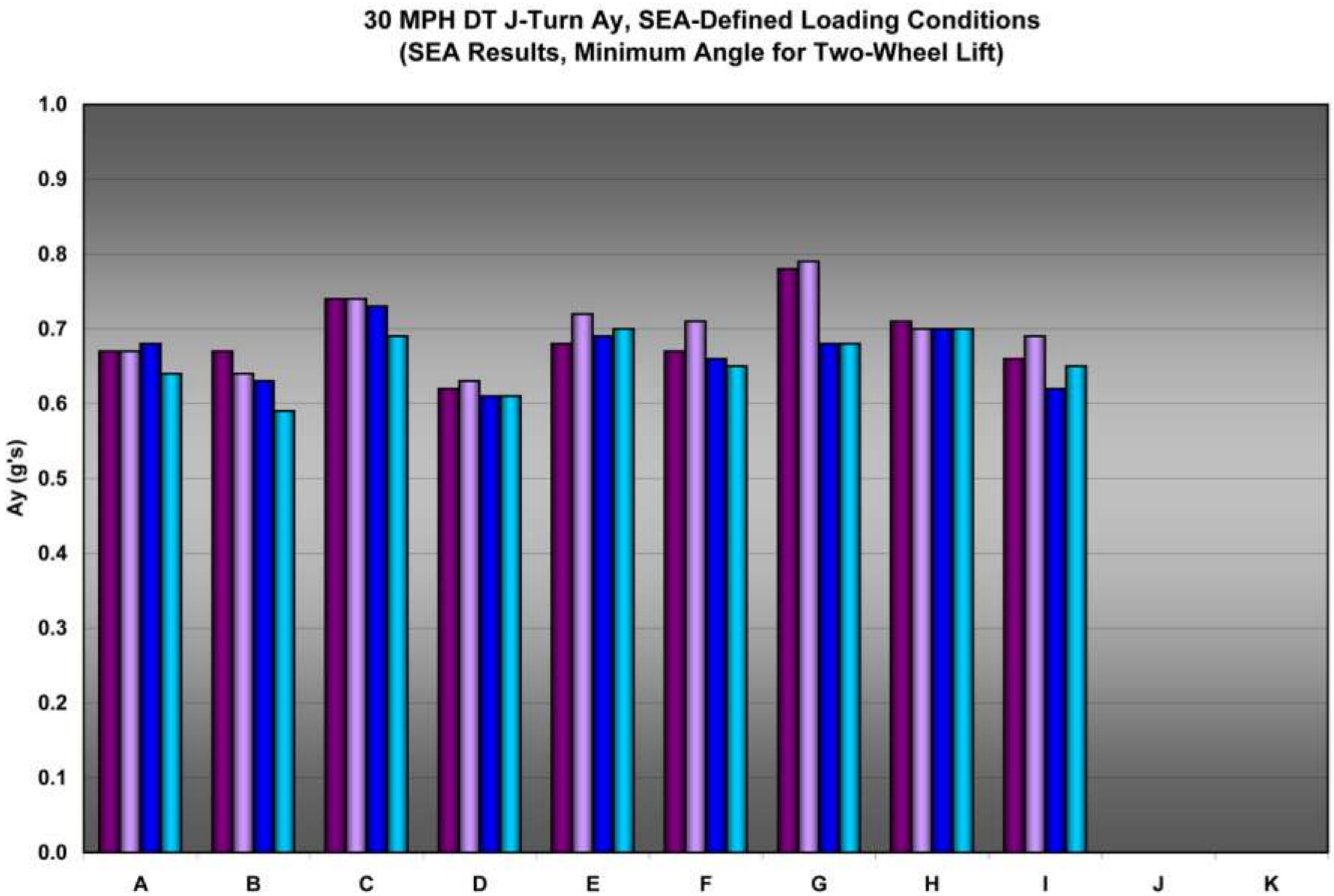
J-Turn Ay Results / Vehicle J



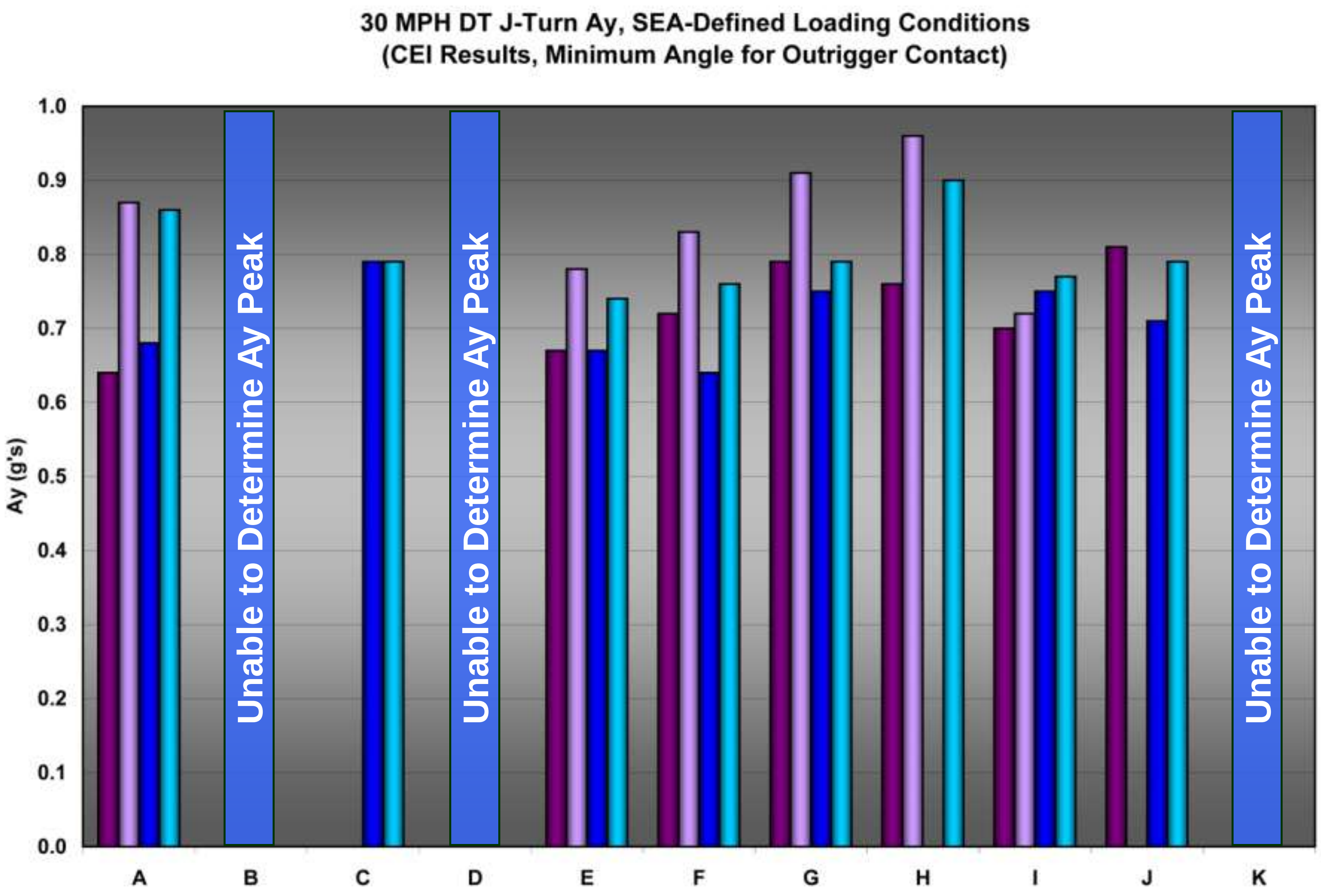
J-Turn Ay Results / Vehicle B



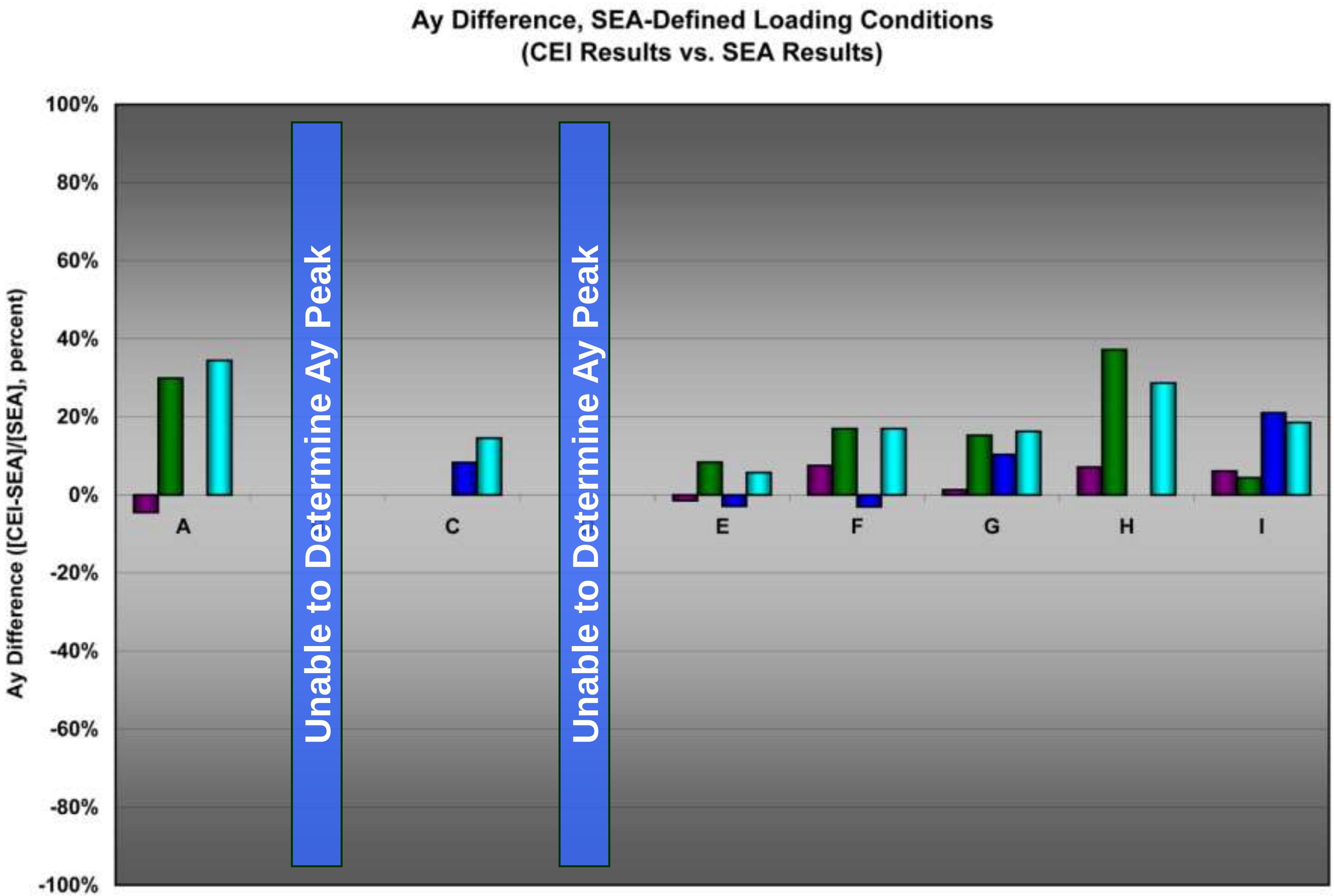
J-Turn Ay Results



J-Turn Ay Results



J-Turn Ay Results



J-Turn Ay Results

- Maximum difference of ~37% compared to SEA data
- Average difference of ~13% compared to SEA data
- Inconsistent results based on specific testing conditions and methodology that do not satisfy the CPSC/SEA-stated objective of being both accurate and repeatable
- Inappropriate for use as a standard or metric due to large test-to-test variability

On-Highway Steering Characterization

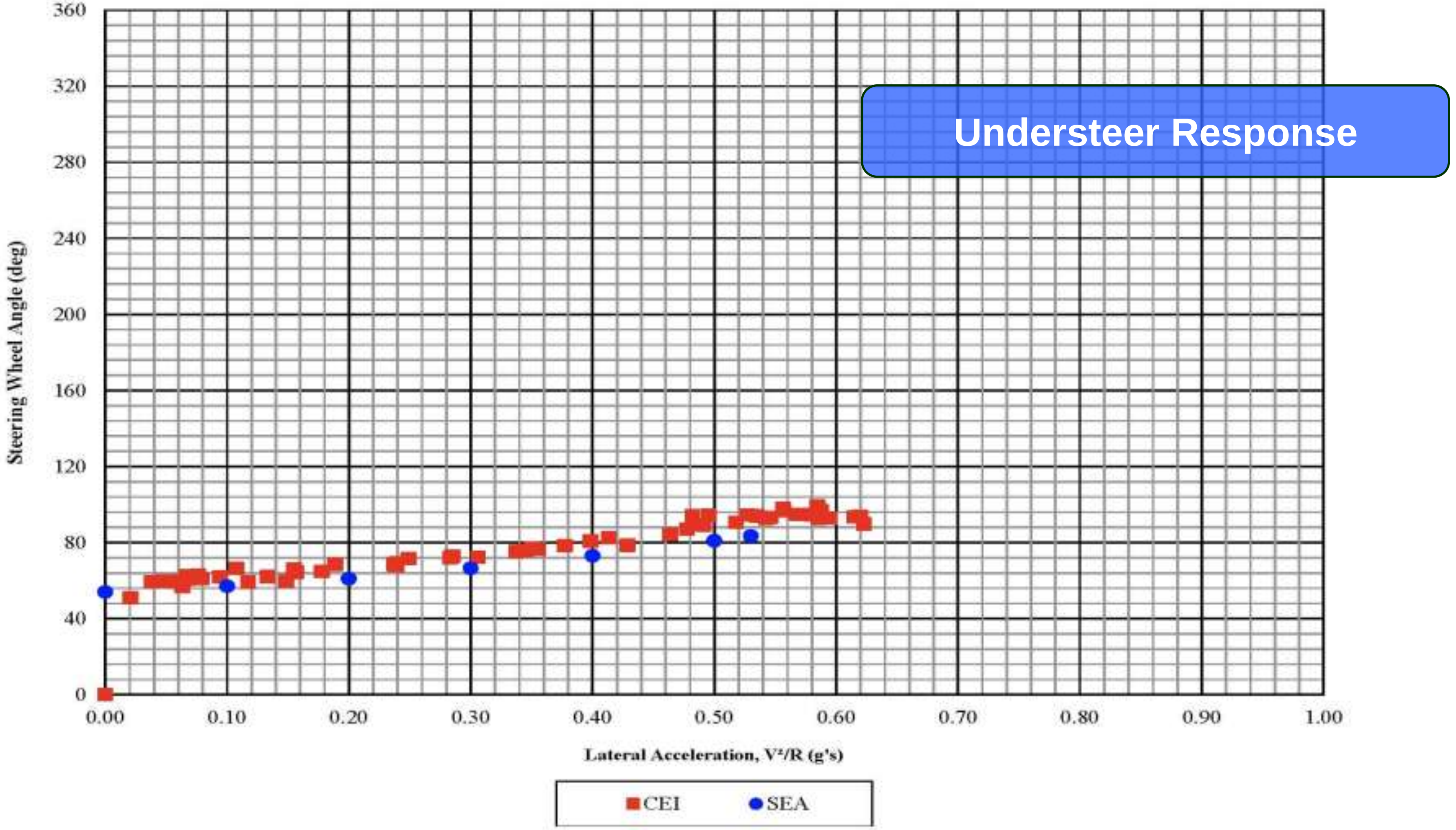
On-Highway Steering Results

- Measurement of SWA as a function of vehicle lateral acceleration on concrete

- Total of 88 individual configurations evaluated
  - ✓Eleven machines (A through K)
  - ✓Two loading configurations (SEA-defined)
  - ✓Two orientations (CW and CCW)
  - ✓Two diameters (50’ radius and 100’ radius)

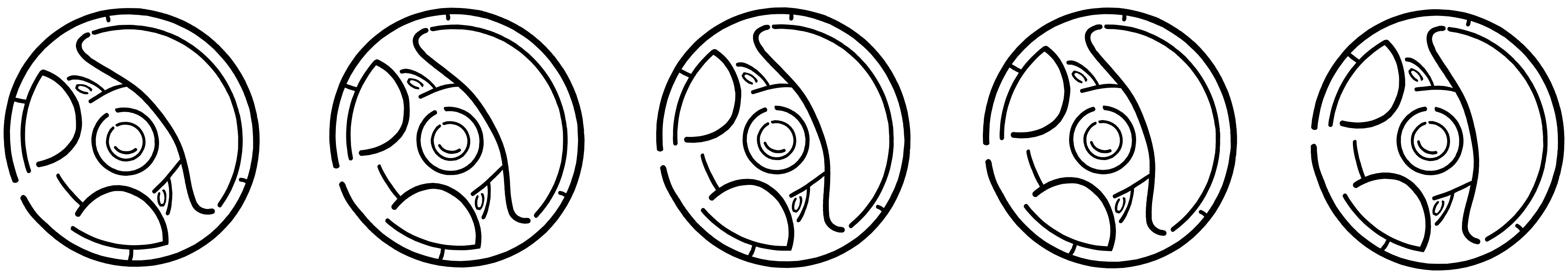
- Total of 36 individual configurations could be directly compared to data generated by SEA

On-Highway Steering / Vehicle C



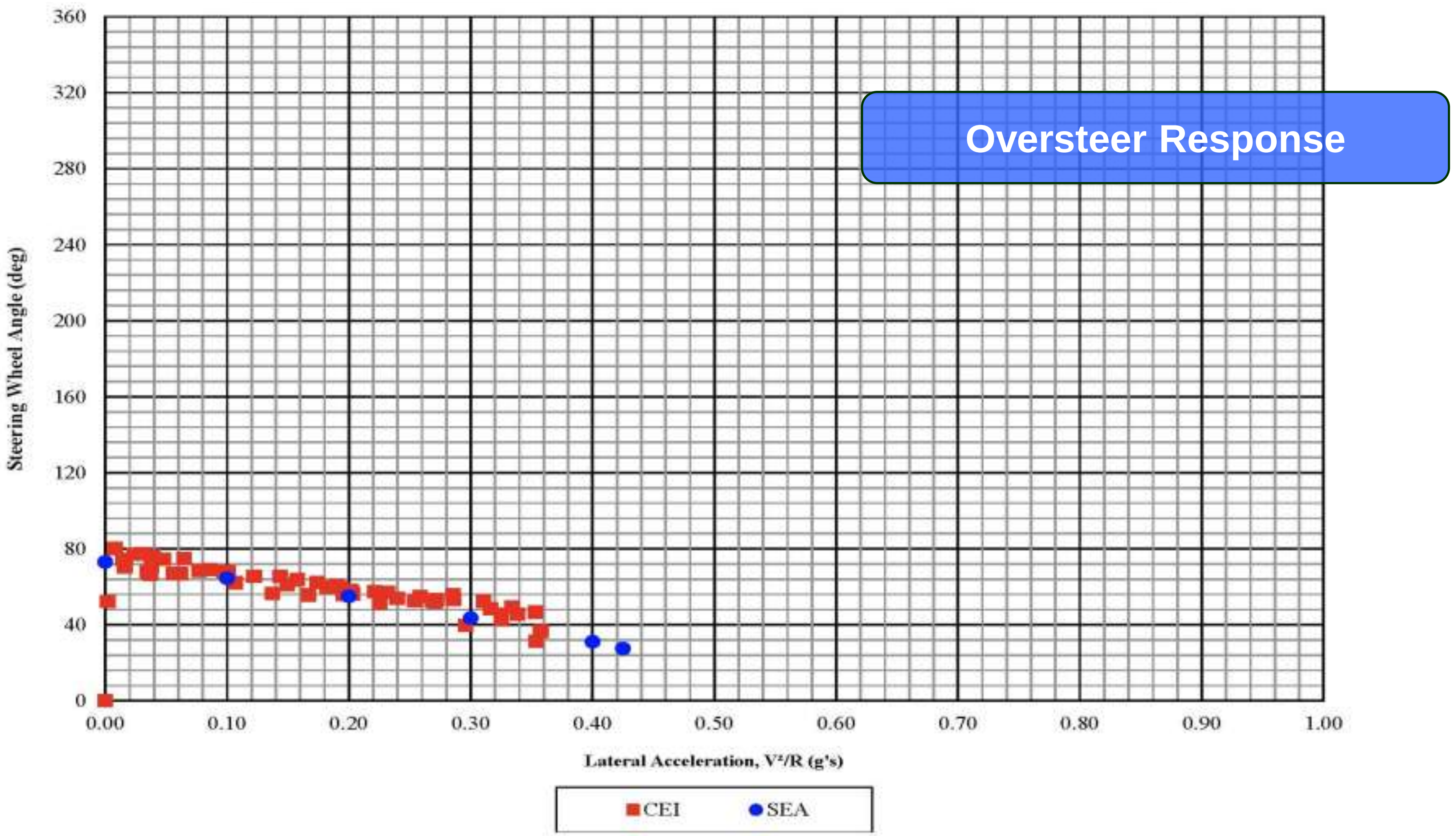
On-Highway Steering / Vehicle C

Two-Wheel Drive on Concrete – Understeer Response



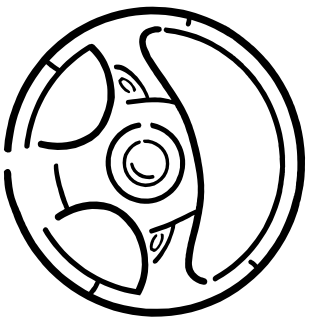
0.00 g **0.20 g** **0.30 g** **0.40 g** **0.50 g**

On-Highway Steering / Vehicle D

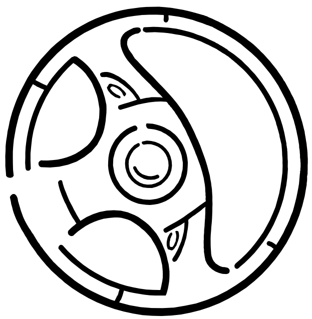


On-Highway Steering / Vehicle D

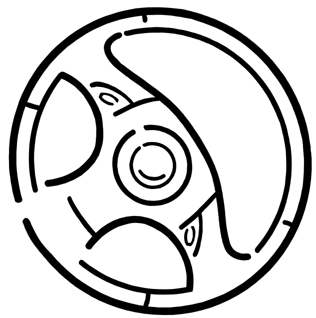
Two-Wheel Drive on Concrete – Oversteer Response



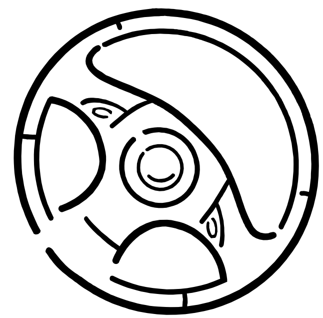
0.00 g



0.10 g



0.20 g

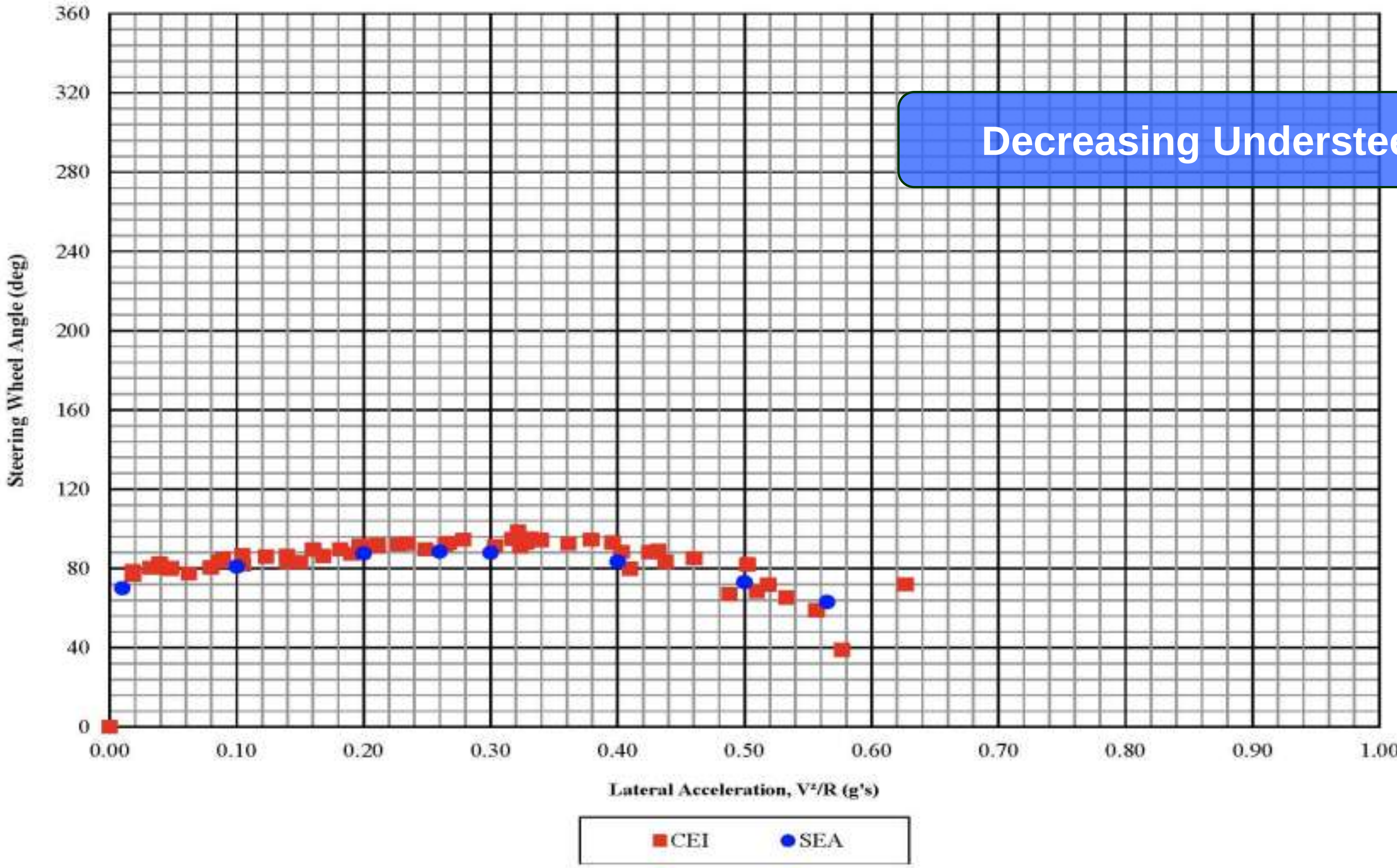


0.30 g

N/A

0.40 g

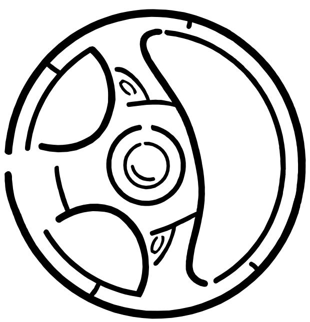
On-Highway Steering / Vehicle A



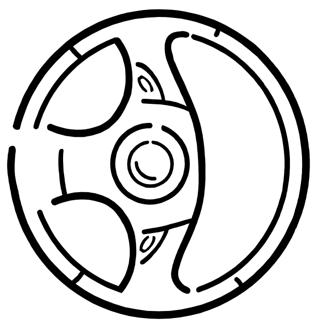
Decreasing Understeer

On-Highway Steering / Vehicle A

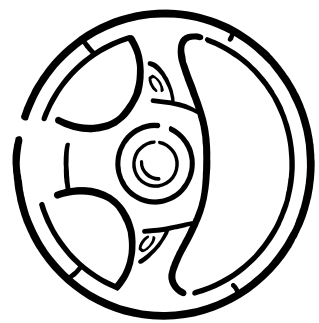
Two-Wheel Drive on Concrete – Decreasing Understeer



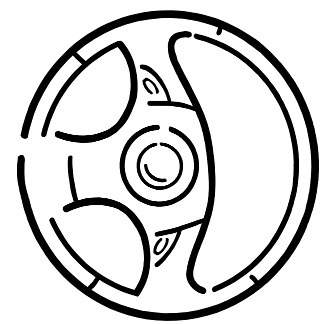
0.00 g



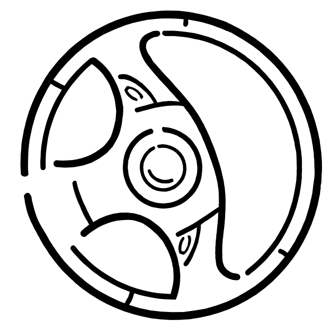
0.20 g



0.30 g

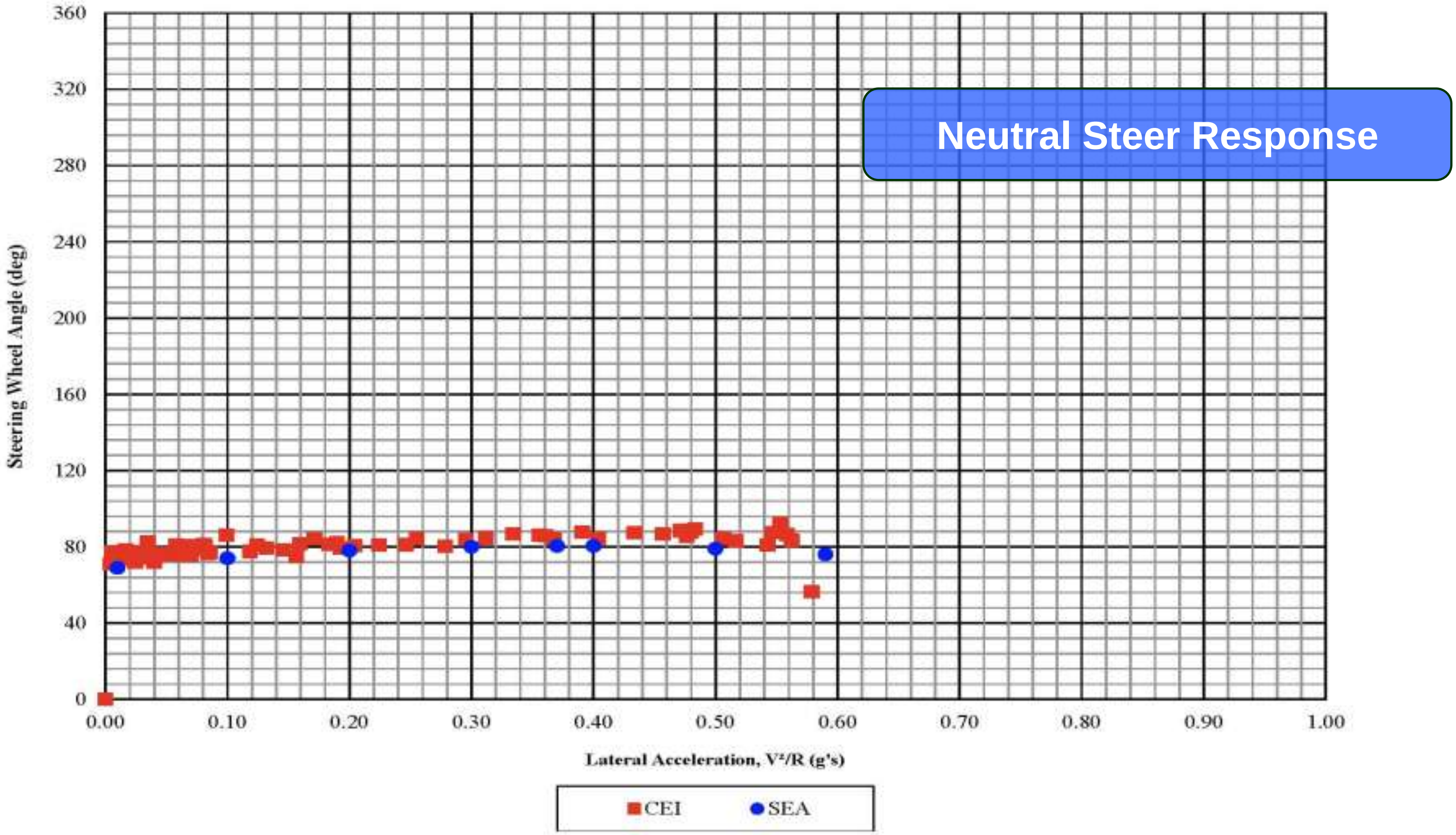


0.40 g



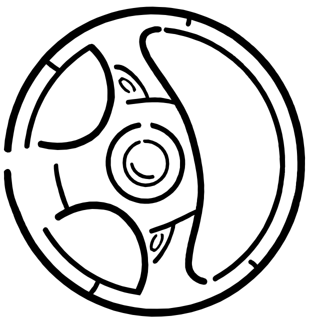
0.50 g

On-Highway Steering / Vehicle D

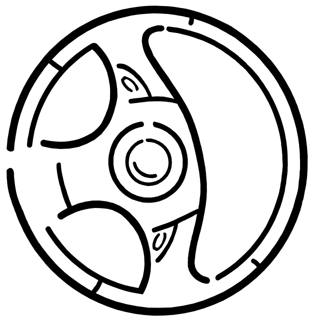


On-Highway Steering / Vehicle D

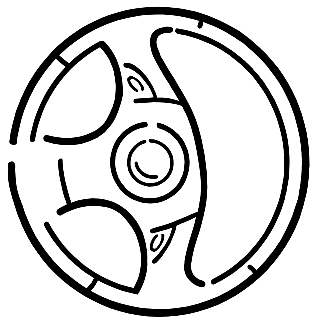
Two-Wheel Drive on Concrete – Neutral Steer Response



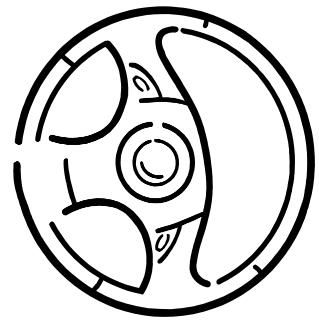
0.00 g



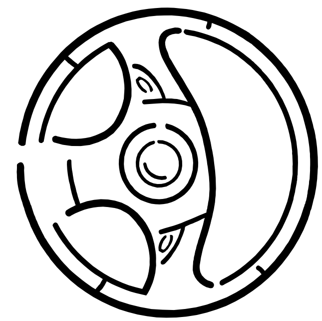
0.20 g



0.30 g



0.40 g



0.50 g

On-Highway Steering Results

- Generally consistent results independent of testing methodology that satisfy CPSC/SEA-stated objective of being both accurate and repeatable

- SWA adjustments are small and do not relate to a machine's crash avoidance capacity

- Inappropriate for use as a standard or metric due to lack of correlation to crash risk or crash involvement

Off-Highway Steering Characterization

Off-Highway Steering Results

- Measurement of SWA as a function of vehicle lateral acceleration on dirt

- Total of 264 individual configurations evaluated
  - ✓Eleven machines (A through K)
  - ✓Two loading configurations (SEA-defined)
  - ✓Two orientations (CW and CCW)
  - ✓Two diameters (50’ radius and 100’ radius)
  - ✓Three driveline modes (2WD, 4WD, 4WDL)

- SEA did not perform testing on off-highway surfaces, so direct comparisons could not be performed

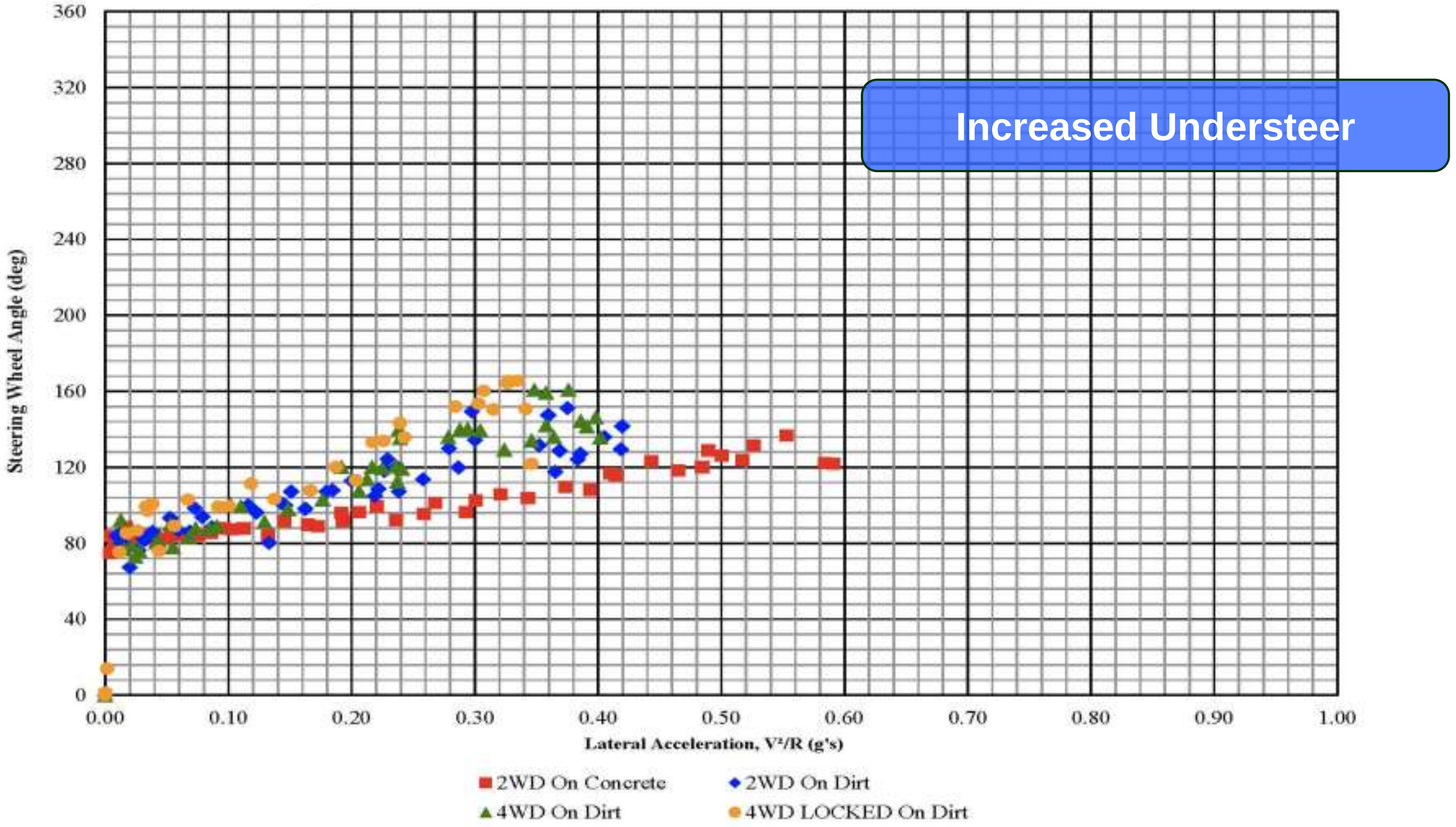
Why Test on Dirt?

- **Testing on on-highway surfaces is a specifically warned-against behavior and is not the intended operating environment for these machines**

- **Testing on off-highway surfaces more accurately reflects the intended usage and utility of the machines**

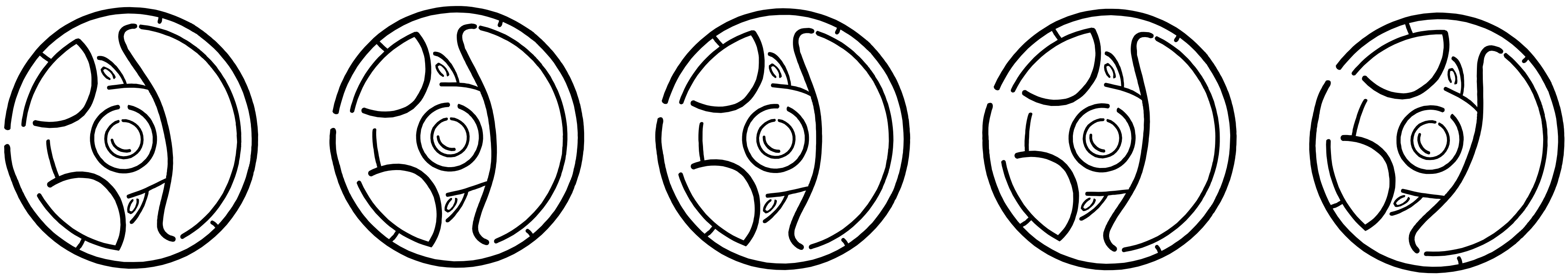
- **Testing in driveline modes with increased tractive effort more accurately reflects the intended functionality of the machines on these surfaces**

Off-Highway Steering / Vehicle E



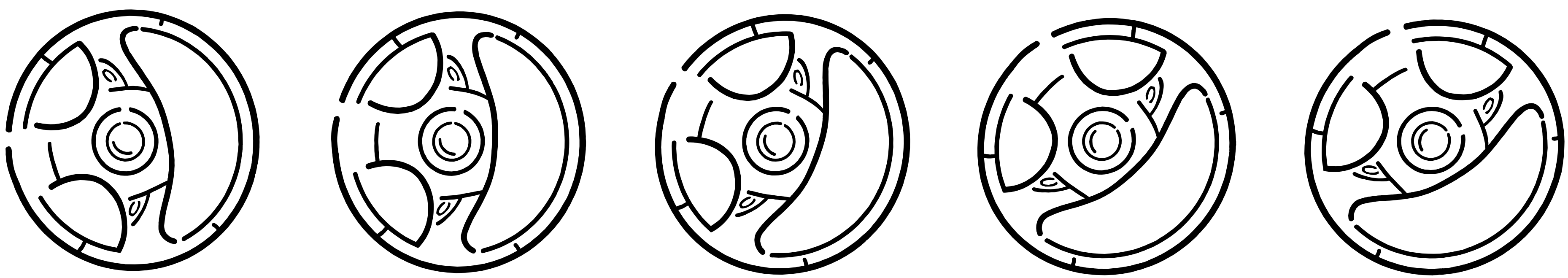
Off-Highway Steering / Vehicle E

Two-Wheel Drive on Concrete – Understeer Response



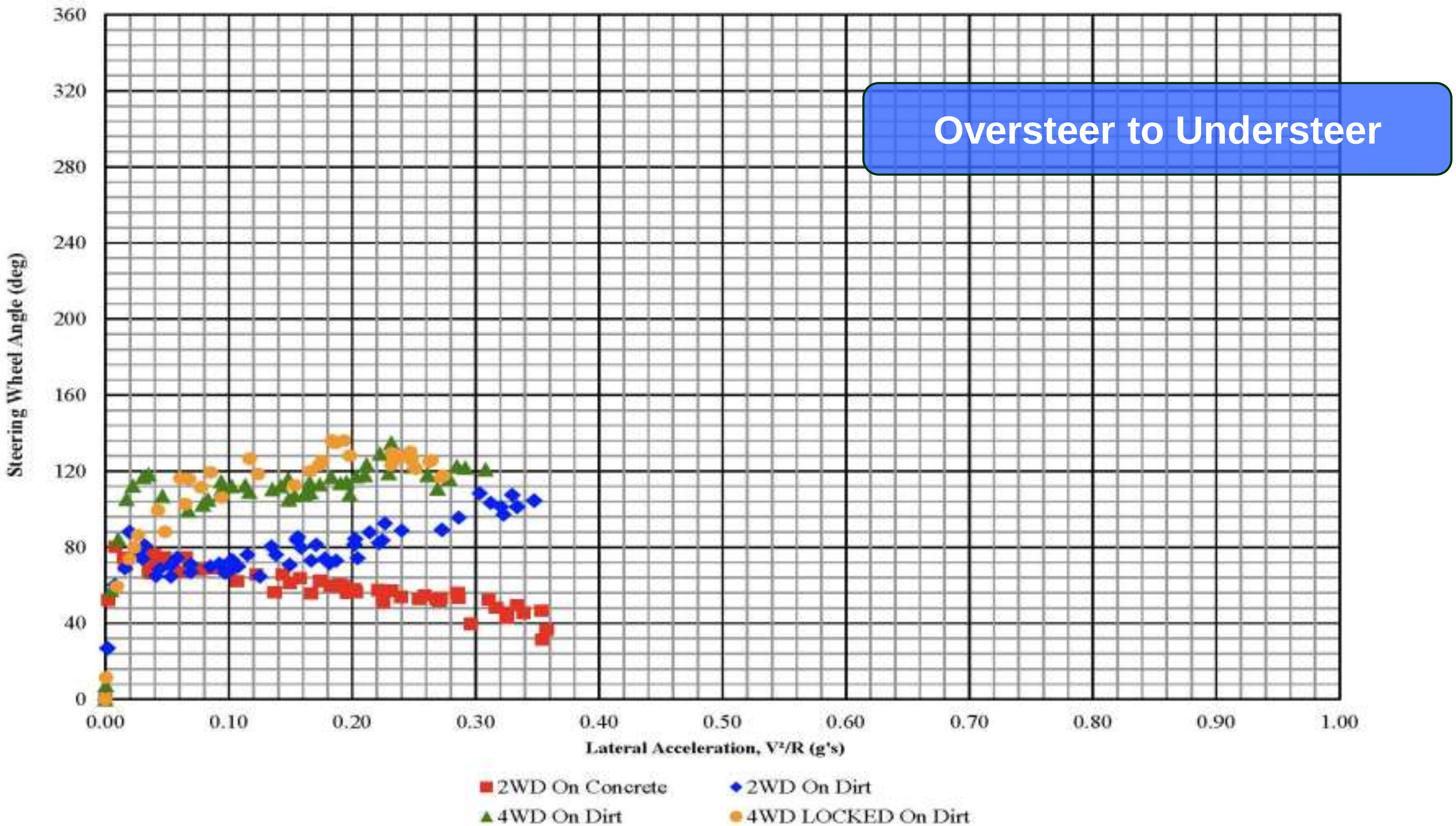
0.00 g | 0.10 g | 0.20 g | 0.30 g | 0.40 g

Four-Wheel Drive on Dirt – Increased Understeer Response



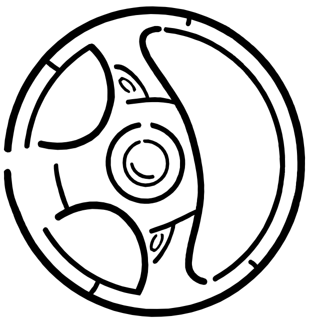
0.00 g | 0.10 g | 0.20 g | 0.30 g | 0.40 g

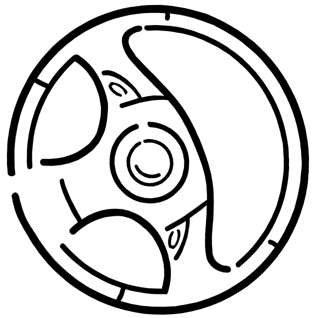
Off-Highway Steering / Vehicle D

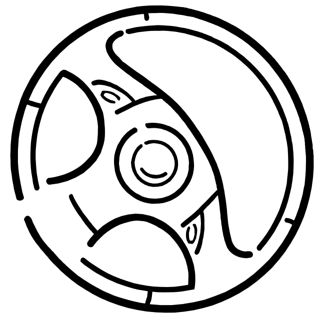


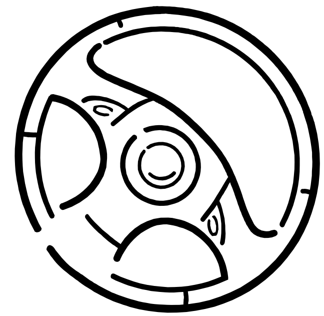
Off-Highway Steering / Vehicle D

Two-Wheel Drive on Concrete – Oversteer Response


0.00 g

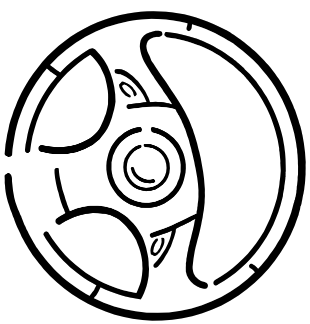

0.10 g

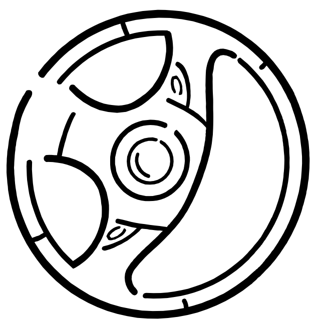

0.20 g

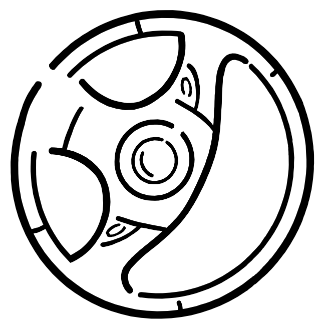

0.30 g

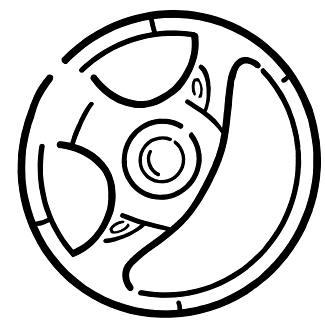
N/A
0.40 g

Four-Wheel Drive on Dirt – Understeer Response


0.00 g

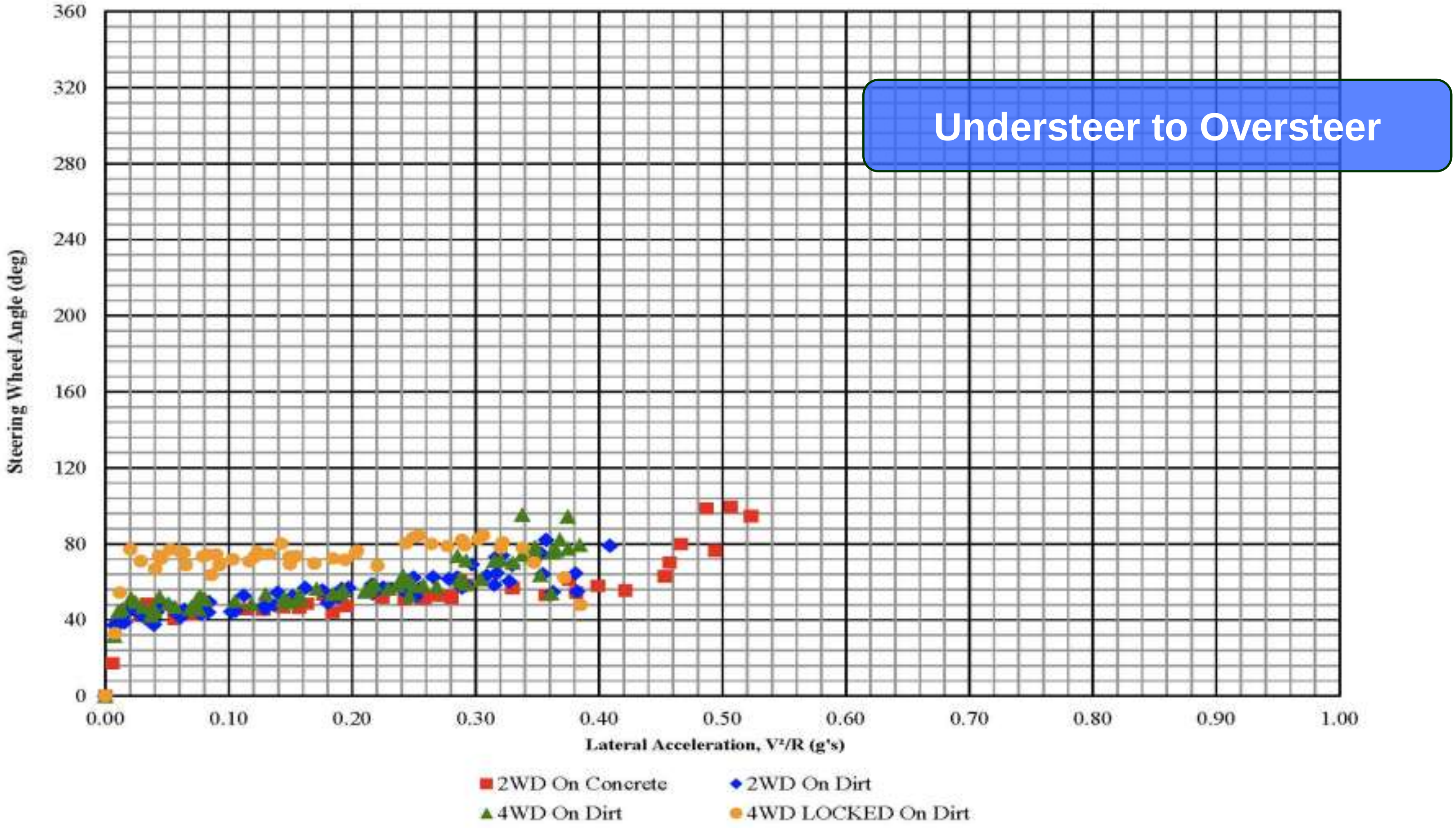

0.10 g


0.20 g


0.30 g

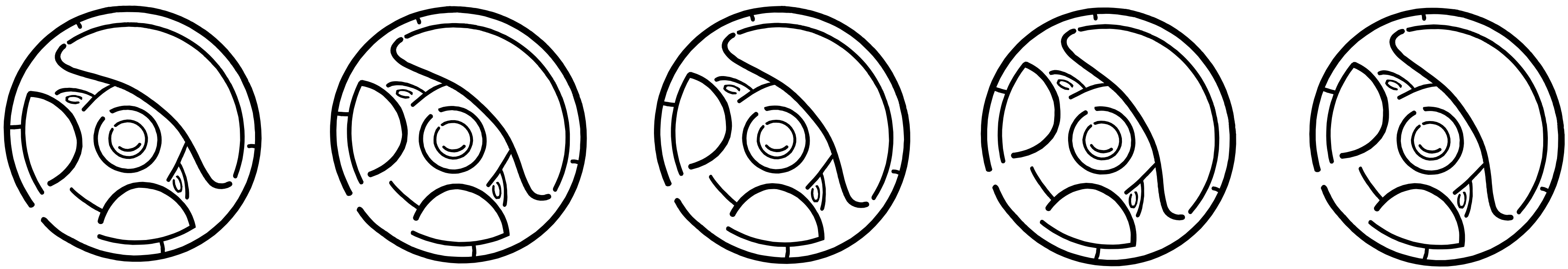
N/A
0.40 g

Off-Highway Steering / Vehicle J



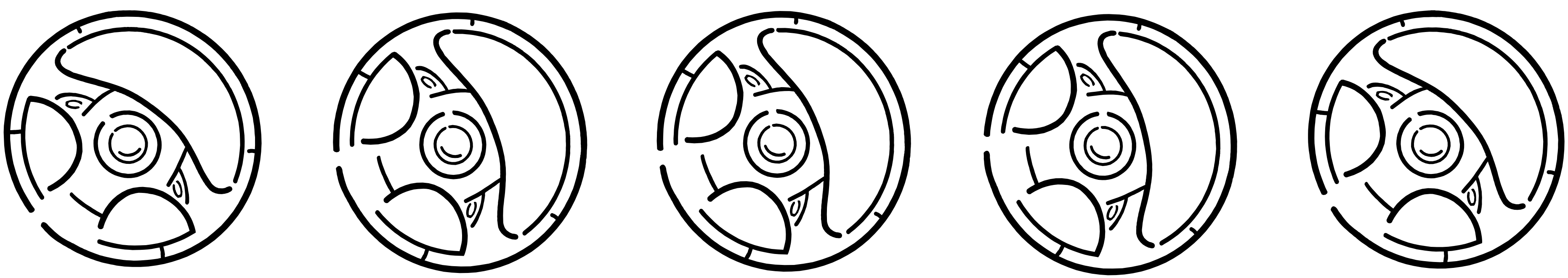
Off-Highway Steering / Vehicle J

Two-Wheel Drive on Concrete – Understeer Response



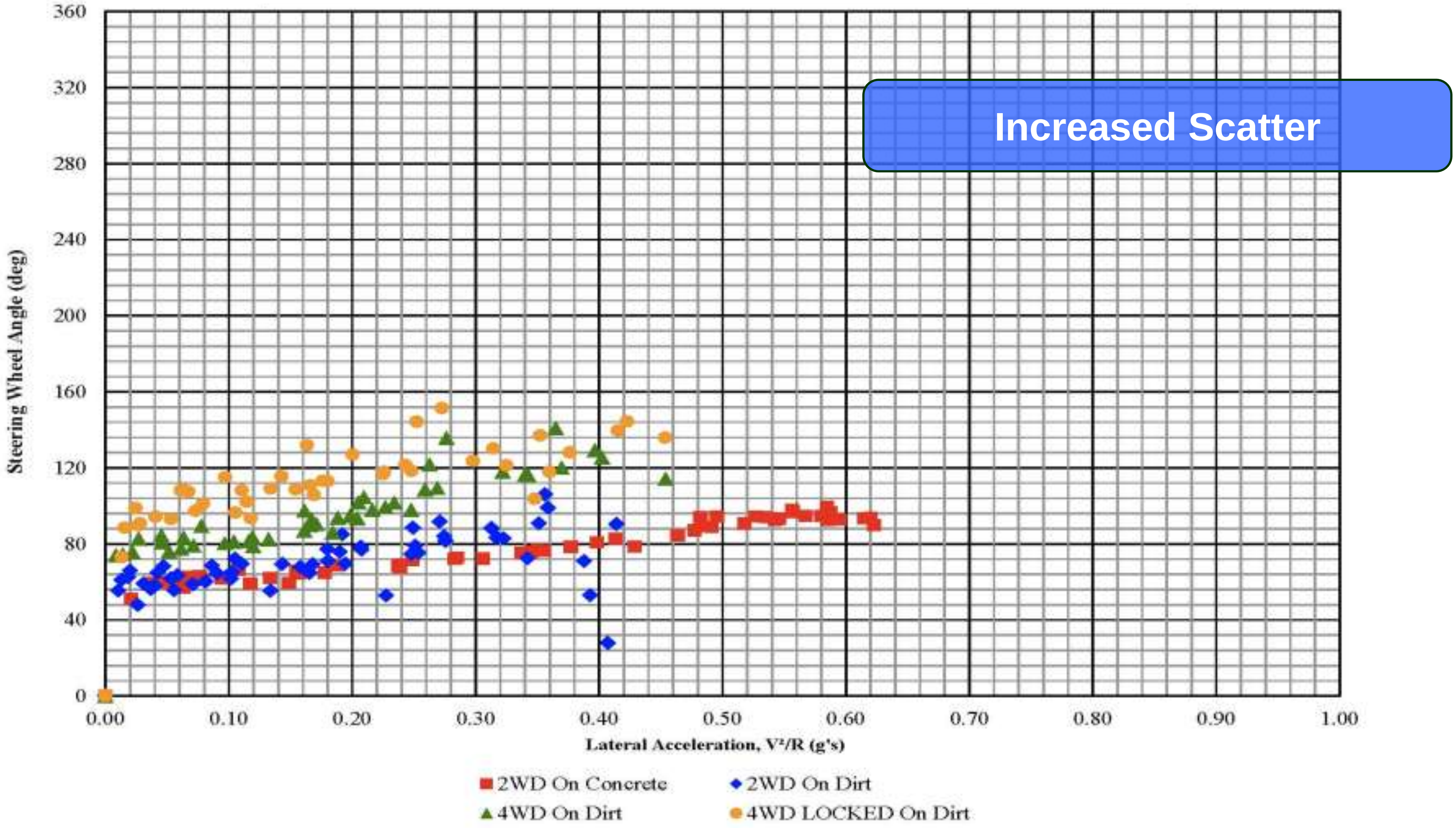
0.00 g | 0.10 g | 0.20 g | 0.30 g | 0.40 g

Four-Wheel Drive Locked on Dirt – Oversteer Response



0.00 g | 0.10 g | 0.20 g | 0.30 g | 0.40 g

Off-Highway Steering / Vehicle C



Off-Highway Steering Results

- **Does not always correlate to a machine's measured on-highway steering characteristic**

- **SWA adjustments are small and do not relate to a machine's crash avoidance capacity**

- **Inappropriate for use as a standard or metric due to lack of correlation to crash risk or crash involvement**

- **May dictate compromises in vehicle design that can reduce utility and/or crash avoidance capacity**

Summary

Summary – SSF and TTA

- SSF/K_{st} and TTA are static <u>vehicle</u> parameters that can be measured accurately and reliably as long as key test variables are defined and controlled

- Generally relates to a machine's crash avoidance capacity

	Average Difference	Maximum Difference
Static Stability Factor (K_{st})	~2%	~5%
Tilt Table Angle	~3%	~14%

Summary – J-Turn SWA and Ay

- J-Turn SWA and Ay are dynamic test parameters that cannot be reproduced accurately or reliably due to uncontrollable variations in specific methodologies

- Inappropriate for use as a standard or metric due to large test-to-test variability

	Average Difference	Maximum Difference
J-Turn Steering Wheel Angle	~14%	~63%
J-Turn Minimum Lateral Acceleration	~13%	~37%

Summary – Steering Characterization

- **On-highway steady-state steering characterization can be performed accurately and reliably, but…**
  - ✓ **The characteristic can change from understeer to oversteer (and vice versa) when evaluated on off-highway surfaces**
  - ✓ **SWA adjustments are small and do not relate to a machine's controllability or crash avoidance capacity**

- **Inappropriate for use as a standard or metric due to lack of correlation to crash risk or crash involvement**