RECREATIONAL
OFF-HIGHWAY
VEHICLE
ASSOCIATION

July 31, 2014

Ms. Caroleene Paul
U.S. Consumer Product Safety Commission
Division of Mechanical Engineering
5 Research Place
Rockville, MD 20850

Re: ANSI / ROHVA 1-201X

Dear Ms. Paul,

On behalf of the Recreational Off-Highway Vehicle Association (ROHVA) Technical Advisory Panel, I write in response to your letter regarding the American National Standard for Recreational Off-Highway Vehicles, ANSI/ROHVA 1-201X.

CPSC Staff's Comments

Dynamic Stability

Summary of Draft Provision. The Canvass Draft includes a change to the ANSI/ROHVA 1-2011 standard in Section 8. Lateral Stability, adding a new dynamic test for lateral stability. The added test is a J-turn maneuver performed at 30 mph with a steering wheel angle input of 110 degrees. The performance requirement states that eight out of 10 test runs shall not result in two-wheel lift (a precursor to rollover).

CPSC Staff's Comments. CPSC staff does not believe that the ANSI/ROHVA requirement accurately characterizes the lateral stability of the ROV. Nor can the requirement be used to compare stability performance between two vehicles. Moreover, it is unclear how ROHVA arrived at a proposed 110 degrees of steering wheel input. CPSC staff is not aware of any standards, recognized test protocols, or real-world significance that supports using a J-turn maneuver with 110 degrees of steering input to assess the lateral stability of an ROV.

ROHVA's use of the J-turn does not measure the lateral acceleration at two-wheel lift that produces ROV rollover. Rollover in an ROV begins when the lateral acceleration builds to the point that the vehicle can no longer counterbalance the roll moment generated by the lateral acceleration. [Footnote omitted.] Therefore, staff believes the lateral acceleration at two-wheel lift is the best indicator of the ROV's lateral stability. There is no correspondence between the proposed ANSI/ROHVA dynamic stability requirement and ROV lateral stability because the 110-degree steering wheel input does not correspond to a turning radius and an associated lateral acceleration. For example, an ROV with a low steering ratio will make a sharper turn at 110 degrees of steering wheel input than an ROV with a high steering ratio. [Footnote omitted.] In the proposed ANSI/ROHVA J-turn test, a vehicle with a larger steering ratio will make a wider turn and generate less lateral acceleration than a vehicle with a smaller steering ratio.

As you know, CPSC contracted with SEA Limited (SEA) to evaluate ROVs. SEA's reports are available on CPSC's website (http://www.cpsc.gov/en/Research--Statistics/Sports--Recreation/ATVs/Technical-Reports/). CPSC has previously provided these reports to ROHVA. The results of J-turn tests conducted by SEA on 10 sample ROVs indicate that there is no correspondence between steering wheel input and lateral acceleration at two-wheel lift, as shown in Figure 1. For example, the lateral accelerations at two-wheel lift for Vehicles A, J, and I are 0.670 g, 0.670 g, and 0.675 g, respectively, with a standard deviation of .003 g, which is within 0.45 percent of the average value. If the steering wheel angle input corresponds to lateral acceleration, the steering wheel angles measured at two-wheel lift for Vehicles A, J, and I should be similarly within 1 percent of each other. However, the steering wheel angles measured for Vehicles A, J, and I are 95 degrees, 110 degrees, and 170 degrees, respectively, with a standard deviation of 40 degrees, which is a 32 percent variance from the average value. It is clear that the measured steering wheel angle does not correspond to the lateral acceleration value, and therefore, the steering wheel angle input cannot be used to compare or evaluate the rollover resistance of an ROV.

[Figure 1 omitted.]

CPSC staff is also concerned that ROHVA's proposed test introduces the effects of steering ratio into the outcome of the test. [Footnote omitted.] The steering ratio is set by the ROV manufacturer and varies depending on make and model. Figure 2 shows the steering ratios of the 10 sample ROVs that were measured by SEA. If the dynamic lateral stability requirement is defined by a steering wheel angle input, a manufacturer could increase the steering ratio of a vehicle to meet the requirement rather than improve the vehicle's stability.

[Figure 2 omitted.]

For example, Vehicle A, with 0.670 g of lateral acceleration and 95 degrees of steering wheel angle at two-wheel lift, would fail the proposed ROHVA stability requirement because the steering wheel input at two-wheel lift is less than 110 degrees (see Figure 1). However, if the manufacturer changes the steering ratio of Vehicle A from 13.25 to 15.50, the steering wheel angle at two-wheel lift would increase to 111.6 degrees, and Vehicle A would pass the stability test without an increase in the 0.670 g lateral acceleration at two-wheel lift. Instead of increasing the roll resistance of the ROV, increasing the steer ratio would simply make the driver turn the steering wheel more to make a turn.

In conclusion, CPSC staff does not believe that ROHVA's proposed requirements for dynamic stability are a true measure of rollover resistance because measurement of steering wheel angle input appears to have no unique correspondence to lateral acceleration and introduces the effects of steer ratio into the measurement. Therefore, staff recommends a dynamic stability performance requirement that ROVs demonstrate a minimum lateral acceleration at two-wheel lift of 0.70 g or greater in a J-turn test conducted at 30 mph.

Rationale for CPSC staff's proposed requirement. The National Highway Traffic Safety Administration (NHTSA) developed the J-turn test protocol to measure the lateral acceleration of a vehicle at two-wheel lift and evaluate the vehicle's rollover resistance. [Footnote omitted.] Lateral acceleration is the accepted measure by vehicle engineers to assess lateral stability or rollover resistance. [Footnote omitted.] This value is commonly used by engineers to compare rollover resistance from one vehicle to another.

ROHVA Response

As an initial matter, the CPSC staff's rationale that NHTSA "developed the J-turn test protocol to measure the lateral acceleration of a vehicle at two-wheel lift" is not correct. Further, the reference cited, Forkenbrock et al., "A Comprehensive Experimental Evaluation of Test Maneuvers That May Induce On-Road, Untripped, Light Vehicle Rollover: Phase IV of NHTSA's Light Vehicle Rollover Research Program," DOT HS 809 513 (Oct. 2002), does not support the CPSC's assertion.

The J-turn test protocol developed by NHTSA and described in that report included an entrance speed increasing at 5 mph intervals from 35 to 60 mph, and a specified steering wheel input for each vehicle. The measured end points were whether each particular vehicle reached the 60 mph entrance speed without experiencing two-wheel lift, and if not, at what lower speed two-wheel lift first occurred. While data were also collected on lateral acceleration, along with roll angle, roll rate and yaw rate, no attempt was made to determine a measured value for lateral acceleration at two-wheel lift. In short, the report makes no statement that the NHTSA J-turn was developed for this purpose, and the researchers who developed the J-turn protocol and conducted the testing did not make any attempt to use it in this manner.

ROHVA believes that evaluating whether two-wheel lift occurs at a specified steering wheel input angle is a superior way of assessing dynamic lateral stability than measuring peak lateral acceleration at two-wheel lift for several reasons. By specifying a specific maneuver that all vehicles complete without two-wheel lift, it is also more consistent with the nature and purpose of a voluntary design standard.

First, the proposed ROHVA J-Turn is highly repeatable and reproducible, in part, because the test does not force vehicles to their limit and then measure their response. The test is straightforward to conduct and does not require complex measuring or post-processing since the pass-fail metric is whether two-wheel lift occurs. Such characteristics make it appropriate for a pass-fail test.

On the other hand, ROHVA continues to have concerns with a dynamic stability performance test requiring that ROVs demonstrate a minimum peak lateral acceleration at two-wheel lift of 0.70 g or greater in a J-turn test conducted at 30 mph ("Lateral Acceleration J-Turn"). Peak lateral acceleration is not an easy-to-measure, repeatable metric for a pass-fail off-highway vehicle standard test. In contrast to on-highway vehicles, off-highway vehicles have heavily lugged tires, which generate large vibrations on a hard surface and have intense fluctuations in tire contact load. Off-highway vehicles "bring their own bumps" to a smooth pavement test.

As you know, ROHVA has on multiple occasions presented its concerns regarding the repeatability of a Lateral Acceleration J-Turn. See, e.g., "ROHVA Update: Standards Development and Safety Programs," November 10, 2011; "ROHVA/CPSC Technical Discussion," July 19, 2012. These concerns were based on both single-vehicle and multi-vehicle repeatability studies.

During the July 19, 2012 meeting with CPSC staff and a representative of its testing contractor, SEA Ltd., ROHVA learned that the SEA lateral acceleration test data, relied upon by CPSC staff in formulating its opinions regarding a Lateral Acceleration J-Turn, was based on a single test of each vehicle. On October 25, 2012, ROHVA sent CPSC staff a letter, expressing serious concern over the lack of repeatability testing and requesting that a repeatability study be conducted. CPSC staff subsequently agreed to have SEA conduct repeatability testing, which occurred on April 9 and 10, 2013. The September 2013 "CPSC Staff Statement" regarding the SEA repeatability testing concluded that "[t]he results of the repeatability tests indicate that the lateral acceleration at the threshold of vehicle rollover, indicated by two-wheel lift of the inside wheels in a J-turn, can be measured with good repeatability."

The SEA repeatability testing results, however, actually raised *additional* repeatability concerns on the part of ROHVA. Specifically, in connection with this testing, SEA conducted multiple test runs at the "Threshold Steering Input" required to obtain two-wheel lift, as established by SEA in accordance with SEA's methodology. For multiple vehicles, SEA did not observe two-wheel lift at the prescribed steering wheel input, notwithstanding that SEA conducted all test runs at the same time and location. For example, Vehicle D did not reach two-wheel lift in nine test runs once the Threshold Steering Input of 105 degrees was established. See "Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles," SEA Ltd. September 2013, at 66. Similarly, Vehicle E did not achieve two-wheel lift in five runs once the Threshold Steering Input was set at 170 degrees. See SEA (2013) at 74. To compensate for the variations in test outcome, SEA excluded all runs in which two-wheel lift did not occur at the Threshold Steering Input from its Repeatability Study. See SEA (2013) at 4 and 7.

ROHVA is not surprised that there is variation in vehicle behavior at its limit condition. For this reason, ROHVA believes it is inappropriate for a pass-fail test to measure vehicle response at its limit (in this case, forcing the vehicle to rollover).

Moreover, even after filtering the data, the lateral acceleration curve, which is used to determine pass-fail in the Lateral Acceleration J-Turn, is a wavy line that varies between multiple tests. See, e.g., Figure A. This wavy line can change due to several factors such as tire tread, track temperature, equipment used, and where the equipment is mounted.

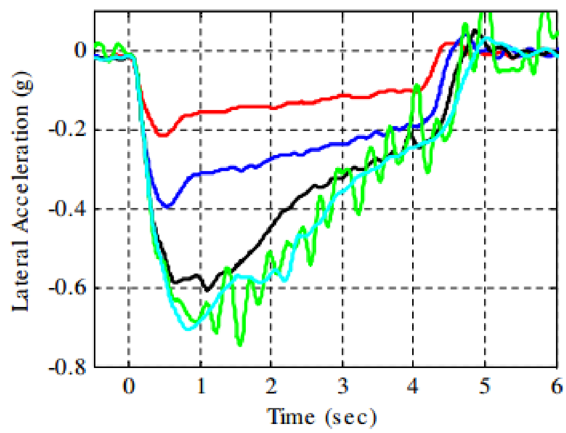

Figure A[1]

In addition, the filter and the subjective filtering technique utilized during the post-processing of the data has a material effect on the precision of the line and ultimately the value selected as the "peak lateral acceleration." For example, in its original ROV testing for CPSC, SEA used a 5 HZ 8th Order Butterworth filter. See SEA (April 2011) at 24. In its lateral stability repeatability testing, in contrast, SEA used a 2 HZ Butterworth filter. See "Repeatability Testing of Four Recreational Off-Highway Vehicles," CPSC Contract CPSC-D-11-0003, SEA, Ltd. Report to CPSC, September 2013 ("SEA (September 2013)"), at 2. The 2 HZ filter averages the actual measurements more significantly than the 5 HZ filter and eliminates the peaks and valleys of the trace. See, e.g., Figure B. This is problematic when "peak lateral acceleration" is the pass-fail metric.

[1] "Vehicle Characteristics Measurements for Recreational Off-Highway Vehicles," CPSC Contract CPSC-S-10-0014, SEA, Ltd. Report to CPSC, April 2011 ("SEA (April 2011)"), at App. E.1, p. 32.

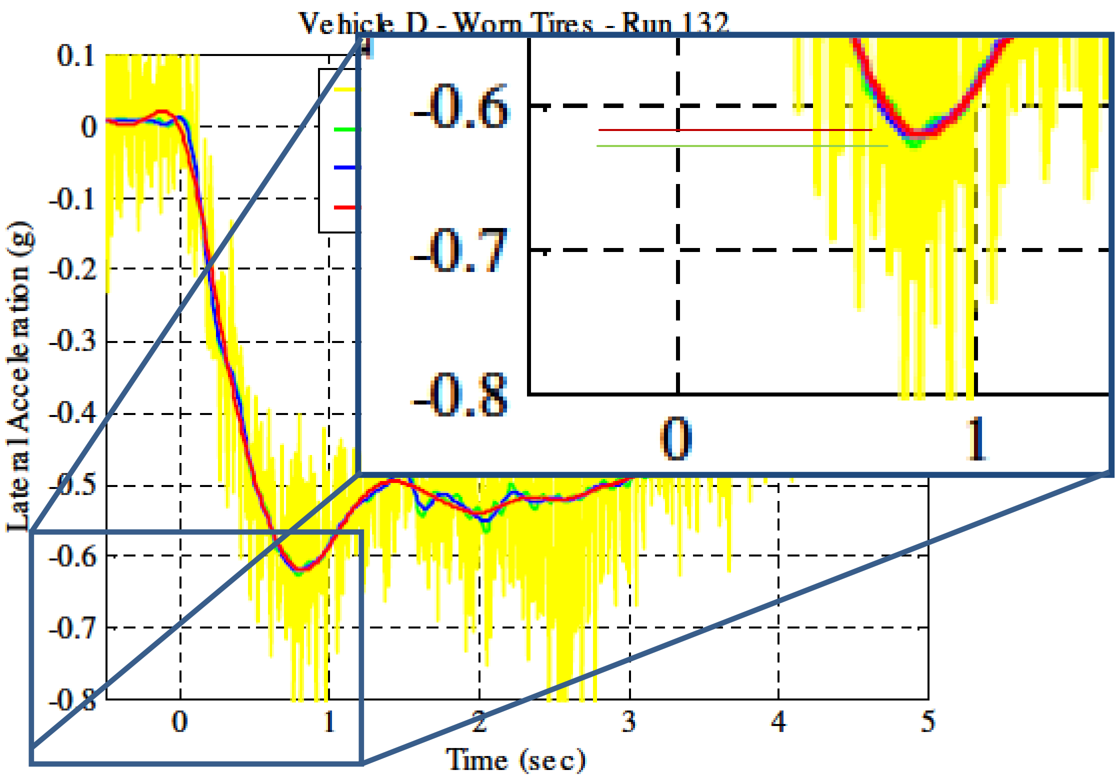

Figure B[2]

In addition to its concerns regarding repeatability, ROHVA does not believe the Lateral Acceleration J-Turn is reproducible. ROHVA has shared with CPSC staff the results of dynamic testing conducted by ROHVA's contractor, Carr Engineering, Inc., which demonstrated that SEA's Lateral Acceleration J-Turn results were not reproducible by Carr Engineering (whereas Kst and tilt table results were reproducible). See "ROHVA Update: Standards Development and Safety Programs," November 10, 2011; "ROHVA/CPSC Technical Discussion," July 19, 2012.[3] In light of these findings, ROHVA requested that CPSC arrange for reproducibility testing of at least 10 test runs per vehicle to be conducted by a different testing entity on a different day and at a different location. See Letter from ROHVA to CPSC staff, dated October 25, 2012, at 2. To ROHVA's knowledge, however, no Lateral Acceleration J-Turn reproducibility testing has occurred, and thus ROHVA's additional concerns over the lack of reproducibility remain.

In the absence of evidence of reproducibility, ROHVA believes that the only way to satisfy a lateral acceleration pass-fail metric would be to have all the testing done at the same location, within a certain temperature and humidity window, using the same equipment and configuration,

[2] Adapted from SEA (September 2013) at App. D, p. 59.

[3] Rather than acknowledging or investigating ROHVA's evidence questioning the Lateral Acceleration J-Turn's reproducibility, CPSC staff, through SEA, simply dismissed it by alleging that Carr Engineering failed to adhere to exacting test methodologies and/or committed errors in processing certain data.

and post-processed with the same software. Requiring, de facto, that all vehicles be tested at a single location by a single vendor is bad policy because such an approach is unrealistic, costly, and would give one test company a monopoly on the market.

Second, the proposed ROHVA J-Turn is reflective of real-world use. 110 degrees reflects a large single steer input without changing hand position on the steering wheel, such as an input that an operator would foreseeably make to avoid an obstacle in the trail. The proposed ROHVA J-Turn is similar to the "Throttle Release & Turn-In Test" conducted by Jaguar Land Rover for vehicles supplied to the United Kingdom Ministry of Defence (TP JLR 00 300).[4] That test is intended to represent an instinctive, poorly-planned maneuver around an unexpected obstacle. The required maneuver, however, is not so severe that an inexperienced driver would expect the vehicle to tip. In a trail or other environment where intricate path-following is important, observation of a large number of operators with widely varying skill levels suggests that unskilled operators limit their steering inputs to avoid entangling their arms, or else significantly reduce their speed. This is not to suggest that larger steering inputs are not possible, merely that more skilled steering techniques such as "single hand palming" or "large rapid crossover" are required to do so, and more skilled drivers generally avoid unplanned maneuvers. The idea that a wide spectrum of drivers have similar initial reactions to an unexpected obstacle is further supported in "Performance of Driver-Vehicle System in Emergency Avoidance", SAE 1977 and "Driver Crash Avoidance Behavior with ABS in an Intersection Incursion Scenario on Dry Versus Wet Pavement", SAE 1999. The magnitude of the response is clearly related to the size of the surprise. As a result, evaluating roll-over resistance at speed with a realistic steering wheel input is a relevant safety metric.

On the other hand, a J-Turn with a lateral acceleration pass-fail metric is not reflective of real-world use. Forcing a vehicle to limit performance (i.e. two-wheel lift) and then attempting to measure or extrapolate peak lateral acceleration at that limit does not evaluate how a vehicle behaves in normal or realistic operating situations. Nor does it predict the likelihood of a rollover incident in off-highway conditions.

Third, even if peak lateral acceleration at two-wheel lift were a repeatable, reproducible and relevant pass-fail metric, there is no reasonable basis for a pass-fail threshold of 0.7g. NHTSA's *100 Car Naturalistic Driving Study* suggests that anything over 0.4g constitutes a "near accident" for on-road driving. In addition, in a study of ROV driving in an off-highway environment, the most experienced test operator during an aggressive run only reached a maximum lateral acceleration of slightly over 0.6g. See Brown, J., Larson, R., Fowler, G. and Kuhn, R., "Recreational Off-Highway Vehicle (ROV) Handling and Control," SAE Technical Paper 2012-01-0239, 2012, doi 10.4271/2012-01-0239.

Fourth, requiring a vehicle to reach a lateral acceleration of 0.7g at two-wheel lift will result in the unintended consequence of preventing or substantially delaying the development of advanced technology, such as stability control. Some on-road vehicle stability control systems currently in use override operator inputs and slow a vehicle down prior to reaching higher lateral acceleration. To the extent current challenges to deploying such advanced technology in ROVs could be overcome in the future, ROVs that were equipped with this type of advanced safety system could not pass the Lateral Acceleration J-Turn because technology would prevent those

[4] The JLR "Throttle Release & Turn-In Test" requires a steering input of 110 to 150 degrees.

vehicles from ever reaching the specified limit condition. In contrast, the ROHVA J-Turn, which specifies a maneuver that must be completed without two-wheel lift, directly addresses the real world concern of lateral rollovers without restricting the manufacturers' current and future means of limiting those rollovers. In other words, if the goal is preventing two-wheel lift (and ultimately rollovers), the standard should not restrict the means available to a manufacturer (now or in the future) to achieve that goal. Those means include, but are not limited to, mass management, steering and suspension, driveline configurations, and/or stability control technology. By taking a derivative measurement at a limit condition and creating a pass-fail standard, the Lateral Acceleration J-Turn actually prevents the use of technology that could in the future prevent the vehicle from ever reaching that limit condition.

Finally, the concern that a manufacturer would numerically increase a vehicle's steering ratio in order to pass the proposed ROHVA J-Turn is misplaced and entirely speculative. Steering ratios are deliberately chosen as part of a holistic engineering process for the vehicle. See Blundell, M. and Harty, D., *The Multibody Systems Approach to Vehicle Dynamics*, 2004, at 409-14. "Given the fact that steering inputs are the primary means by which the vehicle is guided along its intended path, it is key to have predictable (and reasonably fast) steering response over the range of conditions likely to be experienced by the operator while the vehicle is in use." Brown (2012) at 4. As such, increasing the steering ratio would degrade responsiveness, making such vehicles less desirable to some consumers based on their use patterns.

Even taking the concern over modifying the steering ratio at face value, however, a vehicle with a numerically greater steering ratio, all other things being equal (e.g. speed, CG, driveline, etc.), is less likely to experience two wheel lift in response to a particular steering input and therefore less likely to experience a lateral rollover. As a result, the concern is misplaced.

CPSC Staff's Comments

Hang Tag

CPSC Staff's Comments. CPSC staff believes a hangtag that is displayed at point of sale should provide the consumer with information that helps with the purchase decision. Information on a hangtag should be relevant to the purchase decision because hangtags are typically discarded after a product is purchased. For example, hangtag requirements in the voluntary standard for all-terrain vehicles (ATVs) provide information on the appropriate age recommendation for different sizes of ATVs, as well as information on the category of intended use.

CPSC staff believes the ANSI/ROHVA hangtag requirement should display each vehicle model's lateral acceleration at two-wheel lift, as measured by the J-turn test. The value should be displayed on a progressive scale to allow consumers to compare rollover resistance of each ROV before purchase. This information will allow a useful comparison of ROVs, whereas the draft ANSI/ROHVA provision only duplicates current information. Staff believes the additional statements proposed by ROHVA regarding training, local laws, and hangtag removal do not help consumers with the purchase decision and should be conveyed by some other method than a hangtag.

Rationale for CPSC staff's proposed requirement. CPSC staff believes that a hangtag should allow consumers to make informed decisions regarding the comparative lateral stability of ROVs when purchasing ROVs and should provide a competitive incentive for manufacturers to improve the rollover resistance of ROVs.

NHTSA believes that consumer information on the rollover risk of passenger cars will influence consumers to purchase vehicles with a lower rollover risk and inspire manufacturers to produce vehicles with a lower rollover risk. [Footnote omitted.] In 2001, NHTSA began including rollover resistance information in its New Car Assessment Program (NCAP). [Footnote omitted.] A subsequent study of static stability factor (SSF) trends in automobiles found that SSF values increased for all vehicles after 2001, particularly SUVs, which tended to have the worst SSF values in the years before 2001. [Footnote omitted.] CPSC staff believes that a similar increase in rollover resistance can be achieved in ROVs by making the value of each model vehicle's lateral acceleration at two-wheel lift available to consumers. ROVs that exhibit higher lateral acceleration at two-wheel lift have a higher rollover resistance, and thus, these ROVs are more stable than ROVs with lower threshold lateral accelerations.

ROHVA Response

ROHVA believes that there potentially is value in reiterating the General Warning Label content in a hang tag and thus is adding the specified hang tag to the standard.

ROHVA disagrees, however, with the suggestion that the ANSI/ROHVA hang tag requirement should display each vehicle model's lateral acceleration at two-wheel lift for multiple reasons. Initially, as set forth in detail above, ROHVA believes a pass-fail metric based on lateral acceleration at two-wheel lift is inappropriate and should not be incorporated in the ANSI/ROHVA standard.

In addition, due to the significant variability in lateral acceleration measurements between tests conducted at different times and locations, the only way to incorporate the suggested hang tag would be to have all models tested at a single location in a narrow time window. As set forth above, mandating such a testing monopoly is bad policy for multiple reasons.

Further, providing consumers with a single data point (i.e. peak lateral acceleration at two-wheel lift in a 30mph J-Turn conducted on a paved surface) is both meaningless and potentially misleading. Such information is meaningless in that it does nothing to inform consumers of a vehicle's behavior in an appropriate operating environment (i.e. off-highway terrain) during realistic operating situations (e.g. not intentionally forcing the vehicle to failure). In addition, it is potentially misleading because, by focusing on a single metric, it suggests that other vehicle features such as static stability, ride and handling, suspension, ground clearance, occupant retention systems and other factors are not important considerations in the overall safety and performance of the vehicle. Moreover, focus on such a singular metric fails to appreciate the diversity within the ROV class and the fact that models have varying design features depending on their intended and actual use.

ROHVA also notes that the proposed ANSI/ROHVA hang tag mirrors the hang tag approach taken in ANSI/SVIA 1-2010, which has been adopted by CPSC as the mandatory ATV standard. The additional model category information included in the ANSI/SVIA hang tag is not relevant to ROVs because there are no type/use categories or youth model categories currently included in the ANSI/ROHVA standard.

CPSC Staff's Comments

Vehicle Handling

CPSC Staff's Comments. The Canvass Draft does not include requirements for vehicle handling. CPSC staff continues to believe that sub-limit oversteer is an undesirable and unstable steering condition for ROVs, and therefore, a requirement for understeer is necessary in the voluntary standard. Staff recommends a performance requirement that ROVs exhibit sub-limit understeer in the range of lateral acceleration from 0.10 g to 0.50 g when tested on a 100 ft. radius circle in a constant radius test, as described by SAE J266, Surface Vehicle Recommended Practice, *Steady-State Directional Control Test Procedures for Passenger Cars and Light Trucks*.

Rationale for CPSC staff's proposed requirement. CPSC staff believes a requirement for sub-limit understeer is necessary to reduce ROV rollovers that may be produced by sub-limit oversteer. As related in SEA's report, tests conducted by SEA show that ROVs in sub-limit oversteer transition to a condition where the lateral acceleration increases suddenly and exponentially. [Footnote omitted.] CPSC staff believes that this condition can lead to untripped ROV rollovers or can cause ROVs to slide into limit oversteer and experience tripped rollover.

Figure 3 shows plots of slowly increasing steer (SIS) tests conducted by SEA that illustrate the sudden increase in lateral acceleration. [Footnote omitted.] The sudden increase in lateral acceleration is exponential and represents a dynamically unstable condition. [Footnote omitted.] This condition is undesirable because it can cause a vehicle with low lateral stability (such as an ROV) to roll over suddenly.

In Figure 3, Vehicle A is an ROV that transitions to oversteer; Vehicle H is the same model ROV but a later model year in which the oversteer has been corrected to understeer.

[Figure 3 omitted.]

When Vehicle A reached its dynamically unstable condition, the lateral acceleration suddenly increased from 0.50 g to 0.69 g (a difference of 0.19 g) in less than 1 second and the vehicle rolled over. In contrast, Vehicle H never reached a point where the lateral acceleration increases exponentially because the condition does not develop in understeering vehicles. The increase in

Vehicle H's lateral acceleration remains linear, and the lateral acceleration increase from 0.50 g to 0.69 g (same difference of 0.19 g) occurs in 5.5 seconds.

CPSC staff believes ensuring sub-limit understeer will reduce rollover events because it eliminates the potential for sudden and exponential increase in lateral acceleration, a phenomenon associated with sub-limit oversteer, that can cause ROV rollovers. SEA test results indicate that half of the 10 sample ROVs tested exhibited sub-limit transitions to oversteer, and the other half exhibited a sub-limit understeer condition for the full range of the test. [Footnote omitted.] CPSC staff believes this demonstrates that ROVs can be designed to understeer in sub-limit operation with minimum cost and without diminishing the utility or recreational value of this class of vehicle.

ROHVA Response

ROHVA previously provided extensive comments in opposition to requiring an understeer bias and in support of its position. See generally DRI Replies to CPSC Letter Regarding December 2010 ROHVA Standard Canvass, dated April 18, 2011. Those comments were prepared by ROHVA consultant Dynamic Research, Inc., which conducts NCAP testing for automobiles on behalf of NHTSA, and are incorporated here by reference.

ROHVA does not agree that (1) a requirement for sub-limit understeer is necessary or appropriate, (2) "ROV rollovers . . . may be produced by sub-limit oversteer," and (3) a transition from understeer to oversteer is unsafe or undesirable.

There is absolutely no data supporting the assertion that understeer provides any safety benefit in an off-highway environment or that sub-limit oversteer is in any way correlated to lateral rollover incidents involving ROVs. Most ROVs have locked rear axles for increased traction in the off-highway operating environment. Locked rear axles tend to produce oversteer, which also may be beneficial off-highway. See Brown (2012) at 4 ("[L]imit oversteer tends to keep the vehicle directed down the trail or path but is associated with more sideslip[.]").

In a recent study of "Recreational Off-Highway Vehicle (ROV) Handling and Control," conducted by Exponent Inc., the authors concluded that novice and experienced operators found ROVs with both understeer (US) and understeer transitioning to oversteer (US-OS) handling characteristics capable of being controlled without difficulty.

> In this investigation, all five operators found the vehicle in all three configurations could be controlled without difficulty when operated in a recreational mode. However, the drivers preferred the maneuverability of the stock (US) and US-OS vehicle over the US+ [heavy understeer] configuration which had a tendency to push to the outside and sometimes diverge from the intended path during cornering on the test course.
>
> All five operators found both the stock (US) and US-OS easiest to control on the test course when operated in an aggressive manner. These configurations provided sufficient feedback to the driver, allowing the driver to predict and respond to the behavior of the vehicle. None of the subjects went off the trail or hit an obstacle when operating the

> vehicle aggressively in these configurations. The US-OS configuration demonstrated the best maneuverability in the tight curves when operated aggressively. The amount of sideslip although, on average, greater than the other two configurations, was found to be controllable as the US-OS vehicle responded quickly and predictably to steering input. On the test course utilized for this study the US configuration would, at times, tend to push to the outside of turns, but it was much easier to overcome with steering and/or throttle input than the US+ configuration.
>
> * * *
>
> The operators found the US and US-OS configurations generally enjoyable to operate, and found the US+ configuration frustrating and less enjoyable.

Brown (2012) at 13.

In addition, ROHVA has explained to CPSC staff its opposition to a pass-fail requirement of sub-limit understeer for two other reasons.

First, the understeer gradient measured on dry pavement is unlikely to represent the behavior achieved on off-highway surfaces. Force variation with load changes character dramatically with surface type – it is not simply a scaled version of the same character, as is the case with passenger car tires on an undeformable surface. See Figure D.

Figure C is taken from "Lateral Tyre Forces on Off-Road Surfaces", El-Razaz, 1988 and shows on the left the typical convex characteristic for dry pavement with an entirely different concave characteristic on, for example, gravel. This complete reversal of the character of load sensitivity means that the handling character measured on dry pavement has at best a tenuous relationship to the handling character achieved off-highway in the intended operating environment.

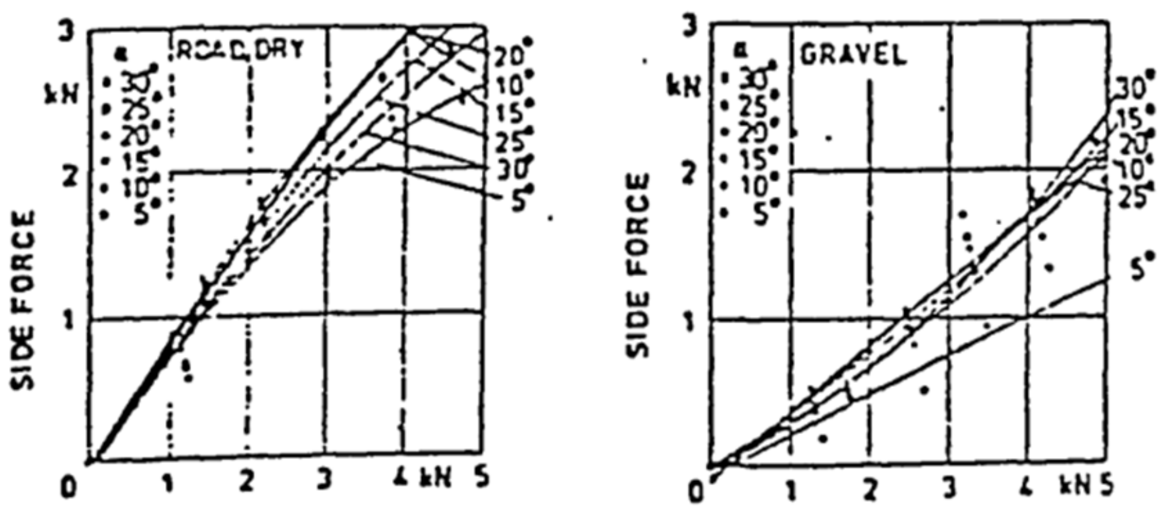

Figure C

If sub-limit understeer gradient hypothetically were relevant to ROV stability, then it should be evaluated in the intended off-highway operating environment, not on pavement.

Second, the real world consequences of different understeer gradients, as measured by the required steering input to stay on path, are minor and, based on Brown (2012), equally appealing to the operator. Figure D, presented to CPSC staff by ROHVA on November 10, 2011, illustrates both the differences in performance by surface and the minor change in required input.

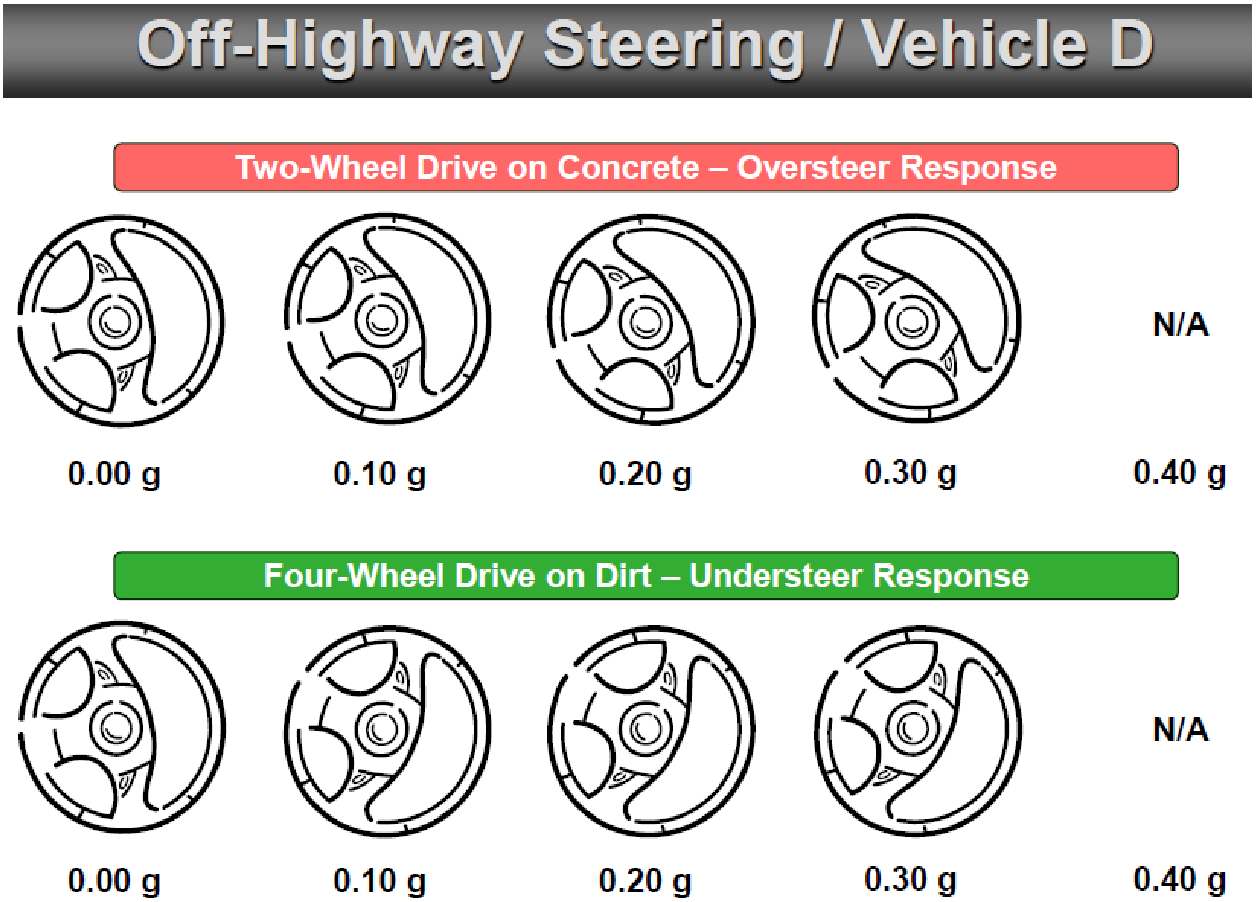

Figure D[5]

[5] "ROHVA Updated: Standards Development and Safety Programs," presented to U.S. Consumer Product Safety Commission Technical Staff, November 10, 2011, at slide 63.

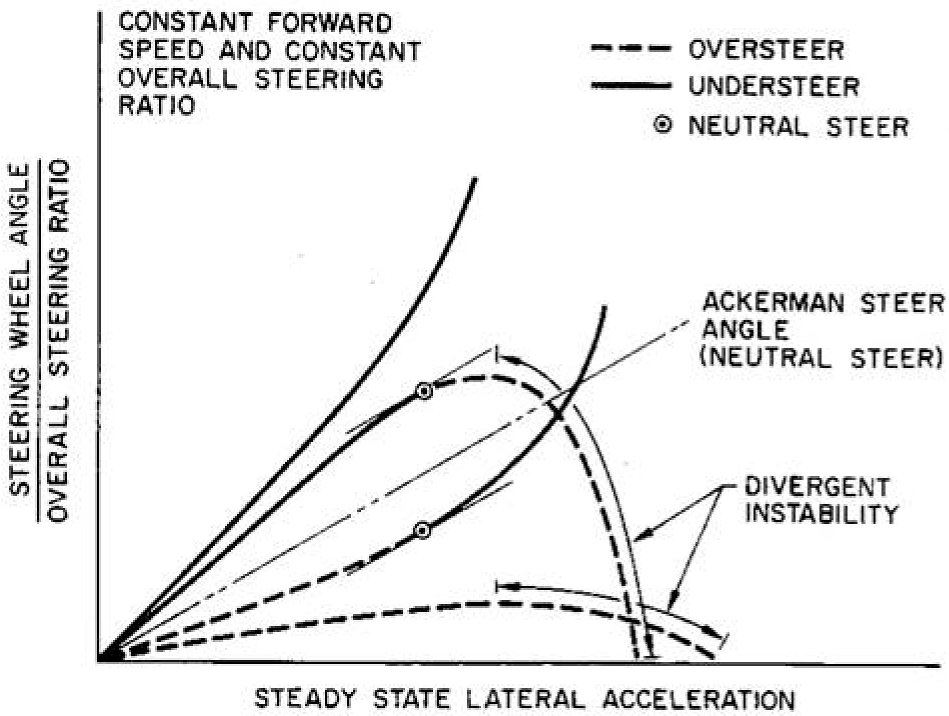

Figure E

For these reasons, ROHVA continues to oppose a pass-fail standard associated with understeer gradient. Compare Figure F (below) with Figure E (above) taken from Gillespie's "Fundamentals of Vehicle Dynamics". This figure is associated with a constant speed test (rather than a constant radius test) and demonstrates that:

i. oversteer vehicles can be stable; and

ii. the transition from understeer to oversteer in any case does not mark the onset of divergent instability, which instead comes at a higher lateral acceleration (this transition being more readily visualized with the constant speed test).

If the objective is to ensure safe handling of vehicles, ROHVA believes that the proposed pass-fail criterion ("always understeer to 0.5g") is inappropriate. The premise for such a pass-fail standard – that oversteer is implicitly connected with divergent instability – is false, as explained by Gillespie.

In addition, ROHVA notes that its J-Turn takes into consideration the vehicle's handling characteristic and evaluates whether it affects rollover stability. Under ROHVA's J-Turn methodology, with a fixed steering wheel input, an oversteer vehicle will make a more aggressive turn than an understeer vehicle. In this regard, to the extent the handling characteristic influences lateral stability, the manufacturer must compensate for that in order to pass the ROHVA J-Turn.

Ultimately, ROHVA believes the critical question should be whether the vehicle rolls over, not whether the vehicle handles in an imperceptibly varying way on a surface (pavement) on which it is not intended to be operated. Vehicle handling is one of many vehicle characteristics, like suspension architecture, wheel base, track width and CG, for which manufacturers exercise engineering judgment to optimize vehicle design and performance for its intended use. In the absence of a confirmed causal correlation to incidents, it would be unnecessarily design restrictive to limit manufacturers' discretion with respect to handling characteristics.

Moreover, measuring and plotting the understeer gradient for an ROV is not precise and generally not repeatable, and thus is not an appropriate metric for a standard. To demonstrate this situation, see Figure F from the report prepared by CPSC's contractor, SEA Ltd. Specifically, the raw data create an erratic trace line. The regression line that subsequently is fitted is the result of the post-processing interpretation of the data, which can vary widely depending on the analysis employed.

As such, understeer gradient is not appropriate for a pass-fail standard. The use of a polynomial function as shown in Figure F is entirely arbitrary and has no known relationship to the behavior of pneumatic tires, see for example "Tire and Vehicle Dynamics", 3rd Edition 2012 by Pacejka, in which complex functions are used to represent the non-linear behavior of vehicle tires on pavement, the vehicle behavior being the sum of the tire forces interacting with the mass and inertia of the vehicle in a readily understood manner, as described in, for example, Milliken & Milliken "Race Car Vehicle Dynamics", 1995. The extremely gentle curvature of the dataset along with the high degree of unavoidable noise in the data (due to tire tread lugs as described previously) mean that the accurate location of a turning point in the underlying data using such a method is susceptible to variations in noise and details of the curve fitting algorithm, as well as the actual function being fitted. These factors create an unsatisfactory level of uncertainty for a pass-fail standard.

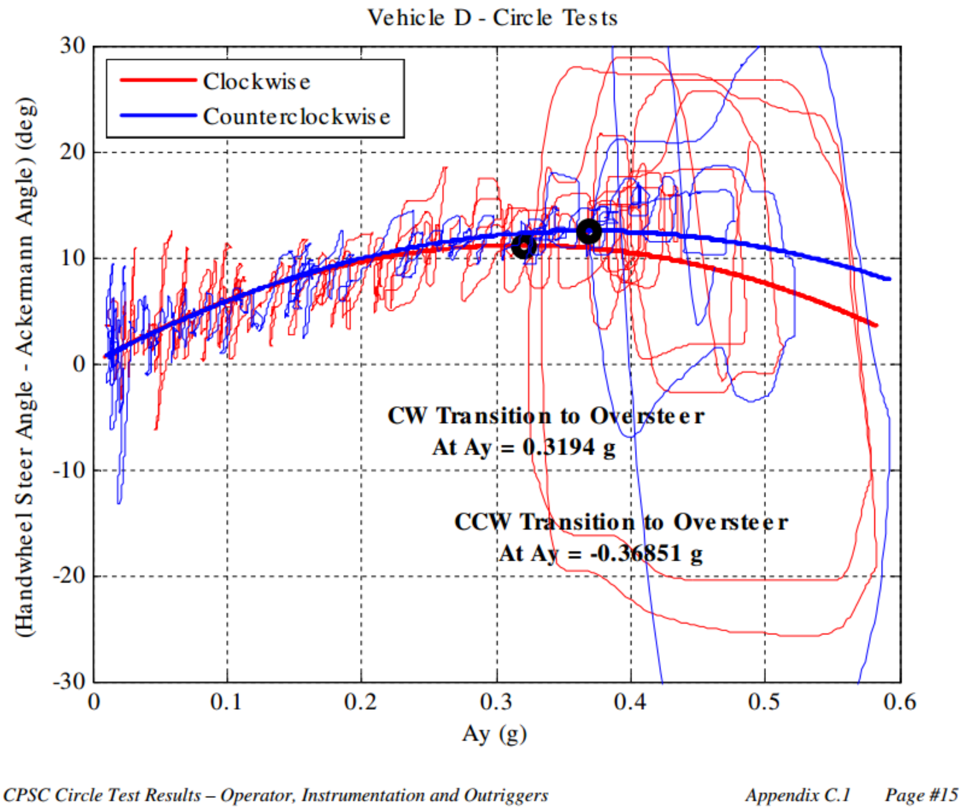

Figure F

CPSC Staff's Comments

Occupant Protection

Summary of Draft Provision. The Canvass Draft includes a significant change to Section 11. Occupant Retention System (ORS), with the introduction of a reminder system that limits the vehicle speed to 15 miles per hour (mph) or less if the driver's seat belt is not buckled. The seat belt reminder requirements can be met by: (1) an audio and visual warning directed at the driver, or (2) a system that limits the vehicle speed.

CPSC Staff's Comments. CPSC staff is encouraged that ROHVA introduced specific performance requirements for in-vehicle technology that limits the maximum speed capability of the ROV until the driver's seat belt is buckled. However, staff believes that the vehicle speed limitation requirement for seat belt reminders should be mandatory, without the option of only an audio and visual warning. Based on staff's analysis of ROV-related incidents where victims were not wearing seat belts, staff also believes the requirement should include the seat belt status of front passengers as well as the driver.

In Annex A of the Canvass Draft, ROHVA states that a key consideration in evaluating a seat belt reminder system is its effectiveness in leading vehicle occupants to use their seat belts. ROHVA also states that studies and data indicate that continuous/repeating audible and visual reminders are effective in increasing seat belt use in automobiles. CPSC staff believes the automobile studies prove a more general point that seat belt reminders must be aggressive and acceptable to be effective. In the open environment of ROVs, staff believes engine noise and helmet use would reduce or negate the effectiveness of an audio warning. In addition, staff believes the visual reminder is ineffective because it is the least aggressive method of reminding a person to use their seat belt.

In conclusion, CPSC staff believes ROHVA's introduction of a reminder system that limits the maximum speed of the ROV until the driver's seat belt is buckled is a positive step toward increasing seat belt use in ROVs. However, staff also believes that ROHVA's optional requirement for only an audio and visual warning will be ineffective in the open environment of ROVs; therefore, staff believes a reminder system that limits the vehicle speed should be required.

Rationale for CPSC staff's proposed requirement. As stated in CPSC staff's letter of August 29, 2013 to ROHVA, staff analysis of ROV-related incidents indicates that 91 percent of fatally ejected victims and 73 percent of all victims (fatal and nonfatal) were not wearing a seat belt at the time of the incident. [Footnote omitted.] Without seat belt use, occupants experience partial to full ejection from the ROV, and many victims are struck by the ROV after ejection. Staff believes that many of the ROV deaths and injuries can be eliminated if occupants are wearing seat belts. Most of the ROV victims who were injured or killed (66 percent) were in a front seat of the ROV, either as a driver or passenger. Therefore, staff believes a system that limits vehicle speed if occupied front seat belts are not buckled should be a mandatory requirement for all ROVs.

ROHVA Response

ROHVA agrees with CPSC staff that many ROV deaths and injuries could be eliminated if occupants regularly wore seat belts. For that reason, ROHVA emphasizes the importance of all ROV occupants wearing seatbelts in on-vehicle warning labels, the new on-vehicle hang tag, the ROV Safety Rules, the ROV Basic *DriverCourse*, and in all of its other safety messages. ROHVA also includes a provision mandating seat belt use in its Model State Legislation. ROHVA welcomes CPSC's assistance in promoting this critical safety message.

In addition, ROHVA is enhancing the requirements for seat belt reminder systems to include either an FMVSS 208-style audible alert or a speed-limiting interlock connected to the driver's seat belt.

With respect to the former, ROHVA notes that, in connection with the development of ANSI/ROHVA 1-2011, CPSC stated:

> CPSC staff does not believe the proposed eight-second reminder light will be as effective in changing user behavior as the seat belt warning requirements for passenger cars in the Federal Motor Vehicle Safety Standards (FMVSS) Standard No. 208 *Occupant Crash Protection*. FMVSS 208 requires an active seat belt reminder that is dependent on the

> latch status of the seat belt; the user is motivated to latch the seat belt to remove the reminder. In comparison, the eight-second light requirement proposed in the Canvass Daft has no feedback to educate or motivate the users to latch the seat belts.

Letter from CPSC staff to ROHVA, dated March 10, 2011, at 3. Given its endorsement of an audible alert system and its request that ROHVA require such a system in the ANSI/ROHVA standard, ROHVA is perplexed that CPSC staff now suggests that such a system is inadequate.

With respect to a driver's side speed-limiting interlock, ROHVA notes that, through Model Year 2014, one manufacturer has incorporated such technology in its vehicle. In recognition of this innovation, and CPSC staff's interest in it, ROHVA has made incorporating such a system an option for manufacturers. To be clear, however, challenges to implementation of a speed-limiting interlock remain, such as technological barriers (including throttle control systems that do not support it), intellectual property rights and customer acceptance concerns, to name a few. In addition, ROHVA notes that, not only are there no speed-limiting interlocks on passenger automobiles in the United States, federal law prohibits NHTSA from mandating interlocks. Nonetheless, ROHVA sought to be responsive to the suggestion contained in CPSC staff's August 29, 2013 letter to ROHVA, and thus included the driver's side speed-limiting interlock option.

ROHVA believes, however, that it would be a mistake to tie a speed-limiting interlock to the status of passenger seat belts. ROV drivers maintain responsibility for operation of the vehicle and must maintain the exclusive ability to control it. By tying a speed-limiting interlock to a passenger seat belt, a degree of vehicle control is transferred from the driver to the passenger. It is not difficult to imagine that an inopportune unlatching of a passenger seat belt could lead to catastrophic results since a loss of engine power constitutes an even more significant hazard to vehicle control in an off-highway environment, as compared to on-highway. It can generate, for example, an uncommanded yaw rate change in a corner or result in a loss of control on a slope.

In addition, including an interlock on a passenger seat adds complexity (e.g., requires weight sensors) and increases the likelihood of system failure. Moreover, ROHVA is unaware of incident data that suggests the failure of a passenger to fasten a seat belt while a driver's belt is fastened is a significant hazard pattern.

ROHVA's new seat belt reminder provisions represent a significant enhancement in occupant retention standards. As is the case with the entire voluntary standard, ROHVA remains committed to continuing to monitor technological advancements and customer experience, and to updating these provisions as appropriate in the future.

Regards,

Thomas S. Yager
Vice President