

## THE AUSTRALIAN TERRAIN VEHICLE ASSESSMENT PROGRAM (ATVAP)

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### ABSTRACT

Around 12 to 14 people are killed and 1400 injured annually in Australia resulting from Quad bike (All-Terrain Vehicle - ATV) and Side by Side Vehicle (SSV) incidents. The Australian Terrain Vehicle Assessment Program (ATVAP) consumer safety star rating system has been developed on the basis of a series of tests assessing a vehicle's static stability, dynamic handling and rollover crashworthiness and is being proposed as a method to reduce these serious and fatal injuries mainly resulting from Quad bike rollovers.

The ATVAP objective is to introduce a robust, test based rating system, in order to provide consumer based incentives for informed, safer and appropriate vehicle purchase, highlighting 'Fit For Purpose' criteria, with corresponding incentives and competition amongst the Quad-bike and SSV industry for improved designs and models. This paper presents an overview of the testing basis on which the proposed rating system was developed.

### INTRODUCTION

#### Background

In Australia, the term for vehicles commonly used on farms over rougher terrains is Quad Bikes or Side-by-Side Vehicles (SSVs) depending on their size and farming task. Quad bikes (Figure 1: top left frame) are distinguished from SSVs (Figure 1: top right frame) in Australia by their design, namely the Quad bike's straddle seating, steering via handlebars with a small thumb operated throttle on the right side and low pressure tyres. This compares to the SSV's operator configuration which is more akin to a traditional car where seating is upright, a steering wheel is used to direct the vehicle, brakes and accelerator are operated by the drivers right foot and wheel tyre pressures are higher.

The Quad bike is called an All-Terrain Vehicle or ATV in the United States of America (USA). However, both an Australian Coroner and the USA Federal Government's Consumer Product Safety Commission (CPSC) have indicated that the term 'All-Terrain Vehicles' is misleading and may result in false assumptions as to the terrain that such vehicles can safely traverse [1, 2]. Hence, there is considerable resistance by Australian safety stakeholders in regards to the use of the term All-Terrain Vehicles or ATV. In this paper the term Quad bike will be used throughout to describe this vehicle type as shown in top left frame of Figure 1.

The SSV shown in the top right frame of Figure 1 is also referred to as a Recreational Off-Highway Vehicle (ROHV) in the USA. In this paper the term SSV will be used throughout to describe this vehicle type. Another term sometimes used in the USA for SSVs is Utility Task Vehicle (UTV). SSVs are distinguished from various larger four wheel drive or sports utility vehicles (SUV) off-road vehicles by their limited width, limited gross vehicle weight rating and limited engine capacity. However, the term All-Terrain Vehicle or ATV is sometimes used in Australia inadvertently to describe a SSV. One potential confusing factor in Australia is the continuing use of the terms 'Quad', 'Quad bike', 'ATV' and 'All-Terrain Vehicle' by the media, by accident investigators, by Coroners, and by others, which has often been used to refer to both Quad bikes and Side-by-Side Vehicles.

It is estimated that there were approximately 270,000 Quad bikes (ATVs) and SSVs in use in Australia in 2010 [3]. This compares to an estimated 80,000 Quad bikes and SSVs in use in New Zealand agriculture in 2010 [4]

and an estimated 10 million Quad bikes and SSVs in use by 16 million individuals in 2008 in the United States (US) [5]. However, SSVs are increasingly being used on farms and workplaces in place of Quad bikes, and are part of the 'Fit For Purpose' vehicle selection for farming and workplace environments being promoted by the Quad bike safety stakeholder groups. Some advantages of SSVs when compared to Quad bikes are: greater carrying capacity; standard driving configuration (e.g. steering wheel and pedals); no specific physical capacity for performing "active riding" as required with quad bikes; roll cages or rollover occupant protection systems; and, occupant restraint systems.

A detailed study of Australian fatalities from the Australian National Coronial Information System (NCIS) involving Quad-bikes and SSVs from 2001 to 2012 was carried out to establish injury mechanisms associated with their usage [6]. Around 141 fatalities were identified of which 109 were relevant to the study described here, and were studied in detail by the authors. Approximately 75% occurred on farms. A rollover occurred in 71% of all cases and of these 85% of the work related fatal cases involved a rollover compared to 56% of recreational cases. Around 28% involved mechanical asphyxia where 50% were 'pinned' by the Quad bike and for the 53 farm cases identified 68% were 'pinned'. Regarding Quad bike & SSV injuries, based on hospital and other injury databases [7], it is estimated that there are approximately 1,400 presentations per annum at hospitals in Australia, from minor to severe injuries.

In response to the incidence of fatal and serious injury rollovers involving Quad bikes it has been proposed by some authorities and other safety stakeholders that, as a minimum, Operator Protection Devices (OPDs) such as those devices highlighted by the Authors in a previous paper [8], be installed on all workplace Quad bikes. That proposal is based mainly on the observation that a two post Rollover Protection System (ROPS) fitted to old and new tractors has resulted in a marked reduction of tractor fatalities [9, 10, 11] and hence, by analogy, might be effective in reducing Quad bike rollover harm.

While in principle it appears that such systems may have a protective benefit in some rollovers, it is also clear that fitment of OPDs will not prevent rollovers from occurring in the first instance and OPDs may not be effective in all rollover situations [12], as active separation or ejection still occurs and impact or crush by stiff areas on the Quad bike or the OPD itself may result. Other than the reports by the Authors, Australian research on the 'in service' effectiveness of OPDs based on fatality and hospital data has yet to be done. Some USA research has been done and published based predominantly on computer simulations and some limited field rollover tests on full ROPS designs [13-19], but similarly no US cohort studies have been carried out to assess the effectiveness of OPDs in the field or laboratory tests of Quad bikes fitted with an OPD.

Thus, there has been little agreement on the way forward in improving Quad bike safety in regard to rollover [20]. The Australian Industry manufacturers represented by the Federal Chamber of Automotive Industries (FCAI) policy position for Quad bikes is that while some design and safety performance measures have been standardised and introduced (mandatory under US law), they remain focused on rider training, active riding and administrative controls such as personal protection equipment (PPE), e.g. such as helmets [8].

The Authors note that in the hierarchy of control measures for managing risks, engineering controls which design out the hazard are considered a more effective control measure than training courses which seek to change human behaviour. The authors note from Australian regulations covering mobile plant and structures in Australia, that persons with management or control of plant at a workplace are required to prevent mobile plant from overturning or the operator from being ejected from the plant. This person(s) must ensure, so far as is reasonably practicable, that a suitable combination of operator protective devices (OPD) for the plant is provided, maintained and used. A person who neglects their 'duty of care' to prevent mobile plant from overturning or the operator from being ejected from the plant, can be criminally charged in the event of serious injury or death of an employee.

Increasing rollover resistance and enhancing rollover crashworthiness design, should be one of the first components in the hierarchy of controls for managing risks within a Safe System Approach [21] in the workplace. Control should include engineering approaches, e.g. increasing rollover resistance and enhancing rollover crashworthiness design, while still maintaining the operational capabilities of the vehicles. Nevertheless, the authors also support administrative controls, but as a complimentary component of a larger holistic Safe System Approach based on the Swedish 'Vision Zero' criteria (i.e., no deaths in the workplace). Even higher-level controls in work situations would be to (a) ban quad bikes and/or (b) substitute SSVs for Quad bikes.

Administrative controls are generally accepted as the lesser effective form of control in a Vision Zero (no deaths) Safe System Approach, in the hierarchy of safety controls. Nevertheless, the Industry (FCAI) have advised the Authors that:

*“In the USA, where since 1991 the only increases in control have been in administrative controls (i.e., increasing passage of state laws regarding Quad bike usage, increasing to 47 out of 50 states as of 2013), during 1999 – 2006 Quad bike fatality rates (per 10,000 vehicles in use) decreased by 29%, and during 2001-2010, Quad bike emergency department rates (per 10,000 vehicles in use) decreased by 56% (Garland (2011, Tables 4 and 7) [22], demonstrating the effectiveness of administrative controls.”*

However, this statement fails to recognise the significant limitations that the CPSC note in all their reports regarding collection of fatality and injury data and the number of vehicles in use. Whilst the authors agree with the Quad bike Industry (FCAI) regarding their call for further in-depth research of injury and vehicle data relating the characteristics of Quad bike and SSV rollover crashes in general and also in relation to vehicle stability, handling and crashworthiness design would be of benefit, the authors disagree that vehicle design safety advances cannot proceed until such data is fully obtained and analysed. This argument should not be used to hinder safety design advancement for Quad bikes and SSVs. The authors consider that until such data can be obtained, the principles established over the past 50 years in mobility safety for all vehicle types can be usefully and appropriately applied to Quad bike and SSV safety design.

For this reason, Australian users of Quad bikes, farm safety stakeholder groups, government occupational health and safety regulators, and safety researchers, see from the history of safety advances in road vehicle transport that design countermeasures are possible, practical and effective, and that fitment of OPDs to Quad bikes is seen as a means of harm minimisation. In contrast, the Quad bike Industry (FCAI) continues to negate promotion of any design solutions concerning fitment of OPDs. The Quad bike Industry’s resistance to fitment of OPDs (in their view) is that there is no scientifically valid ‘in service’ research data indicating that fitment of OPDs would be effective, not harmful and not compromising the capabilities of the vehicle. Hence, there exists a decades-long impasse on advancing Quad bike rollover crashworthiness safety and the need for a new approach, as a way ahead to reduce Quad bike trauma until such data is collected [8].

What is clear is that rollover is a major contributor to fatal and serious injury outcomes involving Quad bikes and SSVs, and therefore measures aimed at reducing both the incidence and severity of rollover are obvious injury prevention countermeasures that should be strongly advanced. The authors do not agree with Industry (FCAI) that Quad bikes and SSVs are exempt from such fundamental safety principles which apply to all mobile vehicles that transport people (e.g., cars, trucks, trains, trams, buses, motorcycles, bicycles, etc.). A pro-active approach should be taken rather than waiting another decade until such in-depth data may become available, with many additional casualties occurring as a consequence of such delays. We are reminded here of the wise aphorism “Do not let the *best* be the enemy of the *good*”, with regard to progressing Quad bike and SSV safety.

On this basis, in order to assist consumers and workplace plant managers to address their current technical and political challenges to improving the design of Quad bikes and SSVs in regards to rollover safety, particularly in the farm environment, the Australian Terrain Vehicle Assessment Program (ATVAP) Star Rating System for Quad bikes and SSVs was developed. While clearly the authors make no claim that a ‘newly-born’ ATVAP can draw on a long and well validated history, as can the NCAP (worldwide New Car Assessment Programs), with its now 36 years history of development, innovation and robust validation (NCAP, started in the USA in 1978), it is apparent that such testing based star rating system for consumer information has been a major catalyst for and helped promote large technological safety advances in automobile safety [23].

The objective is to introduce a robust, test based rating system, in order to provide workplace and consumer based incentives for informed, safer and appropriate vehicle purchase (highlighting ‘Fit For Purpose’ criteria), and at the same time generate corresponding incentives and competition amongst the Quad bike Industry for improved designs and models for the workplace environment. The premise is that Quad bikes and SSVs with a higher resistance to rollover and improved rollover crashworthiness will result in reduced rollover related fatalities and serious injuries. It is proposed that those vehicles receiving high stability and crashworthiness overall rating index values, will in fact be found to have lower fatality and serious injury rates as has occurred with other vehicle types [24, 25]. This opinion takes its basis from the NCIS Coronial data [6], which indicates overwhelmingly that rollover, pinned entrapment and asphyxiation are the major casual factors involved in farm place deaths related to Quad bikes. It is hoped that ATVAP will be implemented in Australia (and internationally) to provide design safety gains for Quad bikes, SSVs and similar type vehicles for farm, workplace and indeed eventually in recreation use, over the years as it matures and accumulates further real world data to provide appropriate development, validation and refinement.

The following sections provide an overview of the components of the ATVAP rating system.

## ATVAP METHOD

The Australian national Heads of Workplace Safety Authorities (HWSA) committee identified in 2011 Quad bike safety to be a major issue on farms in Australia and New Zealand. As a result the ATVAP Star Rating method was developed within a major program of tests, namely the Quad bike Performance Project (QBPP), managed and carried out at the TARS unit at the University of New South Wales (NSW), Australia [26]. The QBPP was funded by the New South Wales Workcover Authority with a contribution from the Australian Competition and Consumer Commission (ACCC). The series of tests were carried out on a selection of 16 production vehicles consisting of 8 Quad bikes, 3 recreational Quad bikes and 5 SSVs. Testing was carried out at the NSW state government's Roads and Maritime Services Crashlab crash testing facility. The test program essentially consisted of three Parts, namely, Part 1: Static tests, Part 2: Dynamic handling tests and Part 3: Rollover crashworthiness tests.

While initially, the project was limited to testing Quad bikes only, it became apparent early in the test program that it would have been far too limiting in scope to simply restrict testing to only Quad-bikes, and that Side by Side vehicles (SSVs) should also be included as they were increasingly being used on farms and as possible safer alternatives to Quad bikes. This was a fundamental (yet still controversial to some) decision made early in the program to expand the mix of 'workplace' and 'recreational' Quad bikes and SSVs. This was also the first time that such a comparison of vehicle stability, handling and crashworthiness has been made across such a diverse range of terrain vehicle types. This decision has proven to be valid and invaluable. It has enabled the focus of the testing to broaden from just considering what improvements to Quad bikes could be made by manufacturers. What has resulted is a much more fundamental approach to risk reduction/management options involving, in principle, appropriate vehicle selection and 'fitness for purpose' criteria, and provision of previously unavailable comparison of Star Rating information for Quad bikes and SSVs for consumers. Hence, the ATVAP rating should be of both Quad bikes and SSVs compared together.

### Part 1 - Static Stability Tests.

Static Stability tests provide the first arm of the assessment and rating of Quad bikes and SSVs for rollover propensity (Figure 1). This test series should be comprised of tilt table tests for rollover resistance in lateral roll,



*Figure 1: Photographs from the tilt table tests, showing Quad bike with ATD for a lateral roll tests, and SSV for lateral roll, rear and forward pitch tests.*

forward and rearward pitch. The tests use a 95<sup>th</sup> percentile Hybrid III Anthropomorphic Crash Test Dummy (ATD) as a surrogate rider with a test mass of 103kg. The test matrix should include the vehicle on its own and then with a rider, and with combinations of maximum cargo loads on the front and rear. The Tilt Table Ratio (TTR), which is approximately the Tan of the angle of the tilt table shown in Figure 1, from the project tests for the Quad bikes, ranged from as low as 0.41 to at most 0.6 in the lateral roll direction with the ATD seated on the vehicle. The TTR for the SSVs were notably higher than for the Quad bikes, on the other hand, and ranged from 0.64 to 0.96 in the same (lateral) roll direction also with the same ATD. It was also found that OPDs had little effect on static stability measures.

It is important to highlight that a relative index which compares one vehicle with another should be developed. As such no one vehicle is then being disadvantaged against another as the same criteria and weighting is applied to all vehicles. Preliminary parametric analyses of the effect of any weighting variations from the test program [27] indicate that the relative static stability index of one vehicle compared with another is relatively insensitive to such variations. The stability indices are firstly based on the TTR values for each of three tilt test directions, by summing and then averaging the TTR values for each loading combination within those test directions:

1. Lateral Roll
2. Forward Pitch
3. Rear Pitch

The final Static Stability Overall Rating Index for each vehicle is then derived from weighted average TTR values for each of the three test directions.

In order to show a perspective regarding the stability of Quad bikes and SSVs in the lateral roll direction, Figure 2 provides a comparison of the author's postulated rollover crash rate versus Static Stability Factor (SSF) for Quad Bikes and SSVs compared to NHTSA's Mengert (1989) rollover crash rates for cars and SUVs [24], and New Zealand's (DIER, 2006) rollover crash rates for heavy articulated and rigid trucks [25]. Figure 2 is essentially a composite with the addition of the author's postulated curve, showing the relationship between the TTRs measured for Quad bikes and SSVs [26, 27] versus relative rollover crash rate. Furthermore, Figure 2 shows that the stability of Quad bike's TTR (SSF and TTR are similar measures) is in the lower range and not dissimilar to trucks; whereas the TTR (SSF) for higher stability SSVs overlaps with a four wheel drive/ Sports Utility Vehicles (SUVs). The authors postulate that the likely rollover risk for lower stability Quad bikes could be as much as four times (or higher) as the highest stability SSVs. Better data collection is required for Quad bike and SSV crashes to determine the actual rollover risk curve for these vehicles, as has been done for the other motor vehicle types.

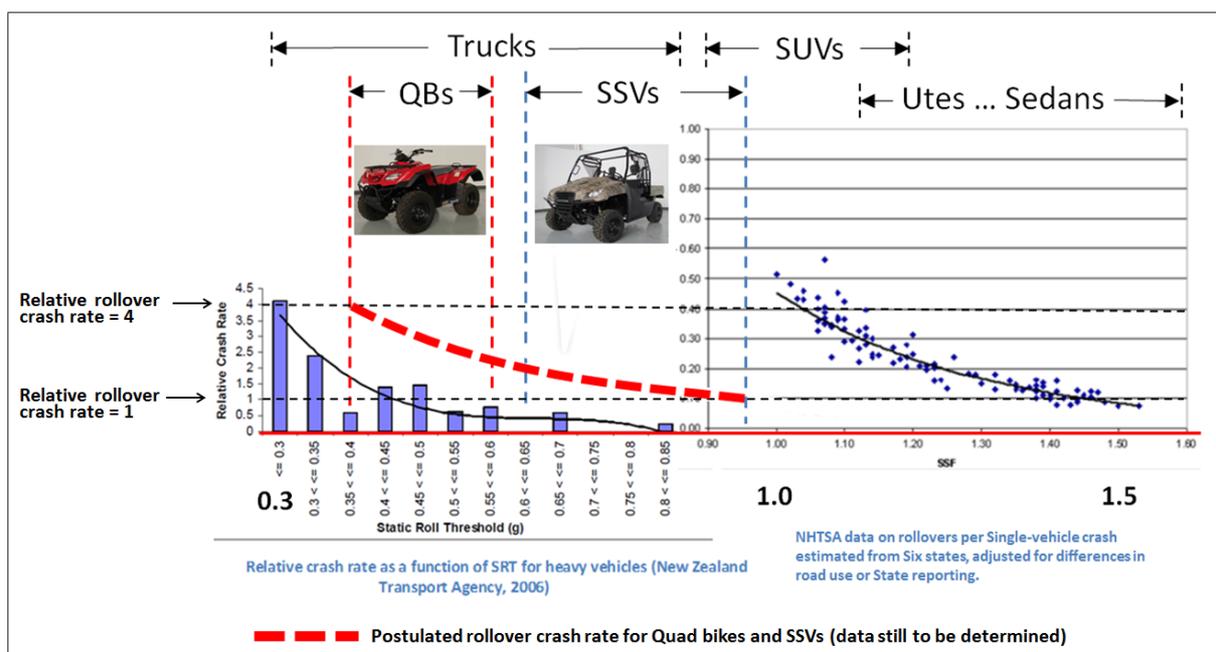


Figure 2: The Author's postulated crash rate versus Static Roll Threshold (SSF  $\approx$  TTR) for Quad Bikes and SSVs with rider/driver (with 95<sup>th</sup> ATD) compared to NHTSA's Mengert chart for relative rollover crash risk for cars and SUVs [24] and to New Zealand Transport Agency's Relative Rollover crash rate for trucks [25].

Hence, the authors are of the opinion that history has clearly demonstrated that advances in safety for all types of land mobile vehicles are correlated with improvements in stability, handling and crashworthiness. There is no reason why Quad bikes and SSVs should be any different and not obey the same laws of physics and vehicle dynamics.

### **Part 2 - Dynamic Handling Tests.**

This Part was comprised of dynamic handling tests [Figure 3] which included the ISO 4138: 2012 Passenger Cars - Steady State Circular Driving test method and the ISO 7401: 2011 Road Vehicles - Lateral Transient Response – open loop test method [28]. Both these test methods were modified for a Quad bike and a SSV. An obstacle perturbation bump test (simulating riding one side over a rock like object) was also included and is presented in a companion ESV paper [29]. Components of these dynamic handling tests complemented the static stability evaluation.

The proposed Dynamic Handling Overall Rating Index is based on the summation of the Index values from the following four dynamic test results with rider/ driver for each vehicle:

1. **Steady-state circular driving behaviour dynamic tests** - the limit of lateral acceleration,  $A_y$  (g)
2. **Steady-state circular driving behaviour dynamic tests** - scores either the understeer or oversteer characteristic. The point of transition between understeer and oversteer is also rated.
3. **Lateral transient response dynamic tests** - the steering response time.
4. **Bump obstacle perturbation tests** - the measured acceleration of the ATD pelvis.

Figure 3 shows the test setup for both the Quad-bikes and the SSVs. The circular tests provide information on the vehicle's limit of lateral acceleration and whether it has an understeer, oversteer or neutral steering characteristic, and the point of transition between them, if it transitioned from one characteristic to another. The step steer response tests provide information on the vehicle's lateral transient response time. The perturbation bump test provided information on pitch and yaw response and how much the perturbation disturbs and displaces the rider from their riding position. Details of the tests and results and how the vehicles were rated are presented in [28].

The focus of the dynamic handling rating index is to encourage those dynamic characteristics that provide predictable and forgiving handling characteristics while remaining responsive and highly mobile in a farming and workplace environment. Moreover, in order to provide predictable and forgiving handling characteristics while remaining responsive and highly mobile, in the author's opinion a vehicle should be designed to provide a light understeer response of between 1 to 2 degrees per g lateral acceleration. In light off-road vehicles, this understeer characteristic should continue to at least 0.5g lateral acceleration. Those vehicles that demonstrated this characteristic are provided with a higher rating Index value.

Most Quad bikes had a fixed rear differential, which meant that the rear wheels rotated in unison, even when on a curve. Most SSVs that had an open differential (or the option to switch from an open to fixed differential and vice versa), all exhibited light understeer handling characteristics. When the rear differential was locked, the vehicle demonstrated oversteer characteristics. For those that had an open differential did not tip but either simply broke traction on the rear inside wheel and reduced speed or slid out, under the test conditions.

### **Part 3 - Rollover Crashworthiness Tests.**

This Part of the proposed ATVAP was comprised of tests that focused mainly on rollover crashworthiness. Some exploratory testing and procedures were carried out for the purposes of developing a rollover crashworthiness rating (see: Figures 4 and 5). A Motorcycle 50<sup>th</sup> % ATD (MATD) was used as the rider/driver in the exploratory rollover crashworthiness tests that were undertaken for the purposes of developing the rollover crashworthiness rating Index. The MATD is based on the HIII ATD but with enhanced features.

The tests carried out were:

1. Measurements of static ground contact force for a Quad bike with and without an OPD on its left and right side and when inverted (Figure 4: top left frame). The mass difference between different model Quad bikes was not sufficient to provide significant discrimination in terms of asphyxia potential [6, 26], as in most cases the 50 kg asphyxia load criterion would be exceeded.
2. Inspection and measurements of Side by Side Vehicle (SSV) occupant retention (Figure 4: top right frame) in accordance with the United States (US) American National Standard for Recreational Off-



**Figure 3: Steady state circle testing on asphalt and on grass. Top left: Rider on Quad bike following circle. Top right: Rider on Quad bike following grass circle at point of tilt. 2nd row: Grass circle test site 3rd row: Typical Quad bike circular driving behaviour test where both wheels lifted. Bottom: An SSV that was tested with outrigger wheels fitted.**



**Figure 4: Examples of: 1. (top left) Quad bike contact force tests using load scales; 2. (top right) Side-by-Side Vehicle occupant retention; 3. (bottom left) SSV Roll-Over Protective Structure (ROPS) lateral pull test; and 4. (bottom right) Rollover test with occupant and Lifeguard OPD.**

Highway Vehicles ANSI/ROHVA 1-2011 with additional constraint requirements applied [30], i.e. points are deducted if there is extension of any part of the ATD outside the plane of the vehicle width when the vehicle is tilted over on the tilt table; and the seat belts in all seats are not a 3 point seat belt or harness (4 or 5 point). Bonus points are awarded if there is a seat belt warning light which switches off when the seat belt is locked in, for a seat belt audible alarm that is maintained for at least 5 minutes when a person is seated in the vehicle and turns off when the seat belt is locked in, and for a seat belt interlock system that is ignition or speed interlock based.

3. SSV ROPS structure load tests consisting of applying a lateral load (Figure 4: bottom left frame) followed by a vertical load then a longitudinal load to the vehicle ROPS whilst recording the deflection and noting the structural integrity, in accordance with the ISO (2008) test option [31] for the US ANSI/ROHVA 1-2011 requirements [30].
4. Vehicle and rider/driver dynamic rollover tests consisting of positioning a MATD in the operator's position of a Quad bike or Side by Side Vehicle, tilting the vehicle to an angle at which rollover would occur, and releasing the vehicle from an initial static position to rollover to observe 'survival space' and functionality of the OPD (Figure 5), and in the case of the SSVs the ROPS and restraints (Figure 4: top right frame). Lateral roll (Figure 5), forward pitch (Figure 4: bottom right frame) and rearward pitch was carried out for the Quad bike. Two SSVs were also tested in lateral roll.

It became apparent that it was unrealistic currently to be able to discriminate the rollover crashworthiness between different Quad bike models [32]. However, discrimination between vehicle types, e.g. Quad bikes and SSVs, was realistic. Further, it was also evident from preliminary rollover, forward pitch and rearward pitch testing, that due to the stochastic ('hit and miss') nature of severe injury risk to a rider and the large range of possible relevant rollover test permutations, it was unrealistic to continue with such tests for rating Quad bikes. Indeed it was deemed by the authors that the term "Crashworthy Quad bike" was essentially a contradiction in terms. For this reason for the Quad bike type, all were assumed to be rated equally for rollover crashworthiness, and all were assigned the same arbitrarily low minimum value points rating when assessing rollover

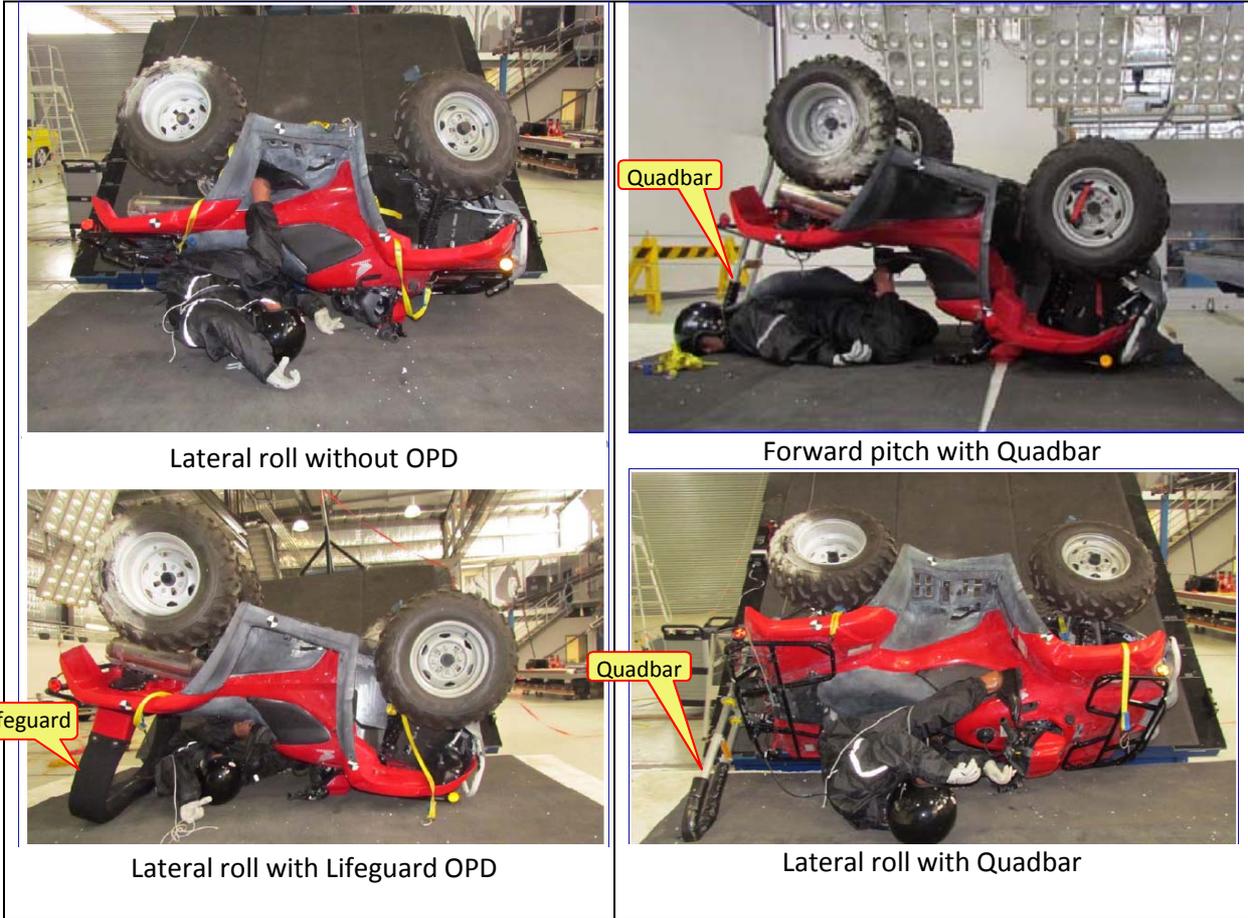


Figure 5: Examples of Quad bike lateral rollover and forward pitch tests with and without OPDs [32]. For more details see 'Part 3: Rollover Crashworthiness Test Results' report.

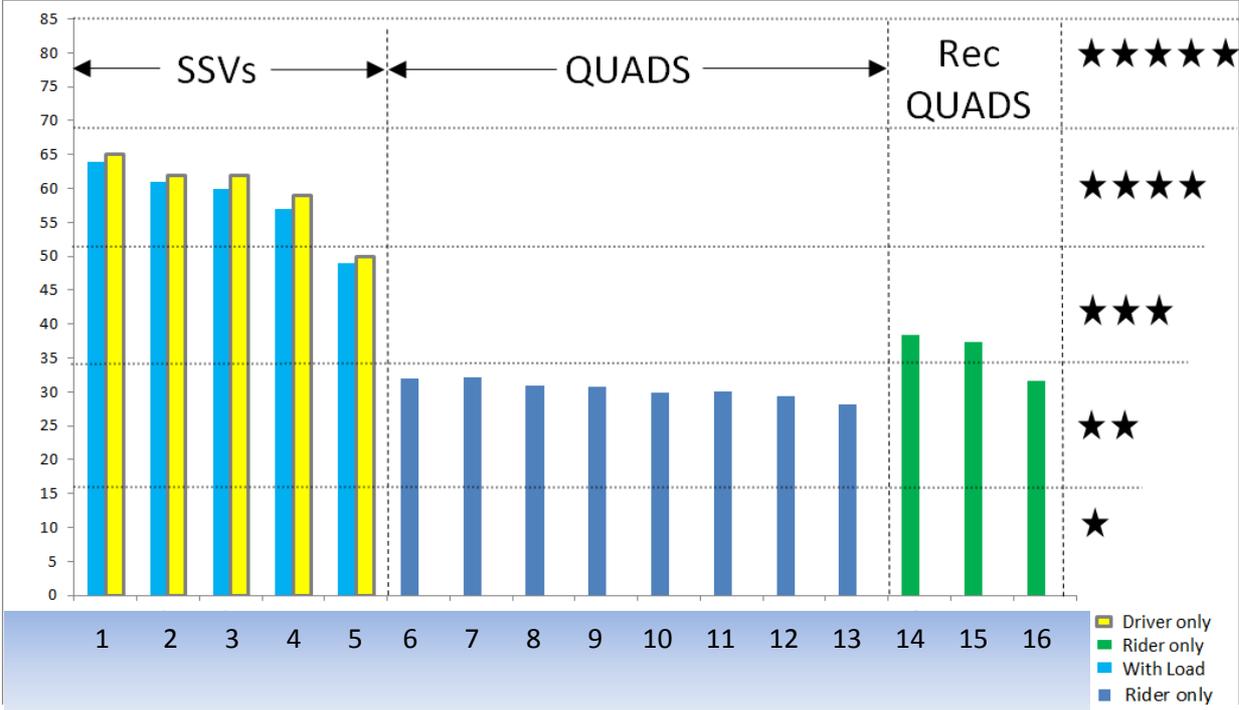
crashworthiness protection. Fundamentally Quad bikes do not and cannot satisfy fully the well-known principles of occupant protection in rollover crashes even with an OPD attached, i.e. good containment and crush prevention. If the straddle position is maintained with respect to the vehicle’s design and ‘separation’ is the crashworthiness criterion adopted by the Industry (FCAI) then it is unlikely the Quad bikes would not achieve any points higher than the lowest range (approximately 1/5<sup>th</sup> of maximum score). The main reason the Quad bikes can be allocated some points even though they were at the lowest range of values, is that riders have survived when a Quad bike has rolled and indeed when the vehicle has rolled over the rider.

In contrast to Quad bikes, the SSVs do adhere in general to rollover crashworthiness principles, in that they are typically fitted with ROPS, seatbelts and various degrees of containment measures which combine to keep the occupants within a protected space. As the effectiveness of such designs in terms of severe injury prevention can vary widely, it is possible to discriminate and rate SSVs. Hence, the rollover crashworthiness of SSVs tested were evaluated against the ANSI/ROHVA standard [30] and fundamental crashworthiness principles of rider/occupant protection in rollovers. In contrast to the Quad bikes, well designed SSVs offer superior rollover crash protection in a typical farming environment. This is provided that three point (or harness) seatbelts and helmets are worn and other occupant lateral restraints are fitted and are in place, e.g. doors, side meshing, etc. The results from the rollover crashworthiness tests provide sufficient discrimination in the range of vehicles tested (Quad bikes and SSVs) to use as a basis for the rollover safety rating system.

**The ATVAP Star Rating System**

The Star Rating is the sum of the points for the three tests (Parts 1 to 3), with equal points allocated to each test performance requirement, i.e. Static stability, Dynamic Handling and Rollover Crashworthiness. Additional bonus points (approximately 10% to 15%) can be provided for vehicles that have an open rear differential, both a seat belt warning light and audible sound which turns off when the seat belt is locked in, and a seat belt interlock which either prevents vehicle startup or restricts the maximum speed of the vehicle to around 5 to 10 km/h.

Figure 6 shows the final graph of the 16 production vehicles tested in the Quad Bike Performance Project albeit the particular models have been masked at this point in time. The graph shows that the SSVs outperformed the Quad bikes significantly. The star rating shows that the SSVs demonstrated superior static stability (see Figure 2), superior dynamic handling reflecting a slight understeer characteristic, minimal disturbance of steering in the bump test [29], and superior rollover crashworthiness, when compared to the Quad bikes. The Recreational Quad bikes have no physical provision (e.g. load rack, etc.) to carry loads. Two of these vehicles (3 star) demonstrated superior static stability and dynamic handling characteristics indicating these design features can be improved for Quad bikes. For SSVs, it is however vital to recognize, that as with passenger vehicles, the significant variation in the Star rating between different SSVs.



**Figure 6: Final Points and Star Rating of the 16 production Quad bikes and SSVs tested.**

## CONCLUSIONS

The aims of the project were to also introduce a robust, test based Star Rating system, similar to other product rating systems, in order to provide consumer based incentives (and assist workplace plant managers) for informed, safer and appropriate vehicle purchase (highlighting 'Fit For Purpose' criteria) that reduced the risk of being injured in a rollover in a workplace setting, and at the same time generate corresponding incentives and competition amongst the Quad bike and SSV Industry for improved designs and models. Those aims were met. It was possible to develop a Star Rating system, that was capable of providing sufficient discrimination in the range of vehicles tested and commonly used, (Quad bikes and SSVs) as a basis for consumers to be able to choose a vehicle that provides a lower risk of rollover, and lower risk of injury if the vehicle does roll.

There are no standards or compliance requirements in Australia for Quad bikes or SSVs. The proposed Australian Terrain Vehicle Assessment Program (ATVAP) consumer Star Rating system presented provides a rapid means of applying a performance benchmark testing protocol that can lead to significantly reduce rollover injury risk. Using the Star Rating system, manufacturers would be encouraged to compete with each other in order to make their products attractive to potential consumers and workplace plant managers wanting to purchase a safer workplace/farming vehicle and comply with workplace regulations.

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