MONASH MOTORSPORT

FINAL YEAR THESIS COLLECTION

Implementation of a Driving Simulator within a Formula Student Team

Tom Behrendt - 2017

IMPLEMENTATION OF A DRIVING SIMULATOR WITHIN A FORMULA STUDENT TEAM

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ABSTRACT

A driving simulator has been developed for use by Monash Motorsport with the overall objective to improve the performance of a Formula Student (FSAE) team.

NOMENCLATURE

g – Acceleration due to gravity in $m./sec^2$
a – Acceleration in $m./sec^2$
t – Time in seconds
μ_y – Lateral coefficient of friction
A_X – Longitudinal acceleration (g) = a_x/g
A_y – Lateral acceleration (g) = a_y/g
C.G – Centre of Gravity
ACTI – Assetto Corsa Telemetry Interface

INTRODUCTION

Formula Student (FSAE) is an international engineering competition in which universities design, manufacture and race open wheel style cars. The competition contains two disciplines; dynamic and static events. Dynamic events include Acceleration, Skid-pad, Autocross and Endurance competitions that test the performance of a car on track. Static events are comprised of Cost, Business Presentation and Design, which require students to justify their designs to a panel of judges and justify their business case and vehicle cost.

The purpose of this project is to identify how a driving simulator can be used to improve the performance of an FSAE team. The format of the competition requires that all drivers are students and more than often engineers from within the team. As a result, drivers must be trained and prepared for the competition. In the absence of a physical car and representative competition track for training, alternative methods must be explored.

The objectives of developing this driving simulation were to:

Create a resource that will assist in driver preparation for undriven tracks at both testing and competition. This includes both vehicle characteristics as well as track memorization.

Provide an alternative, driver behavior based perspective during the design of a vehicle. Will a higher performance, larger, aerodynamic package disrupt driver visibility? This view in design is commonly dismissed in favor of raw performance values.

Deliver a hands-on experience representing Monash University at external events. This is to aid in improving overall public relations, with the aim to attract the public and invite discussions regarding the team and project.

Literature Review

The following studies describe previous work undertaken to correlate simulators with real vehicles, particularly with respect to behavioral patterns seen when driving on highways.

In 1982, the Institute for Perception TNO [1], investigated the comparisons between a simulator and instrumented car. Both the behavior of the human operator, as well as dynamic characteristics were investigated. 24 experienced drivers and 24 very inexperienced drivers were required to complete various tasks whilst driving on a straight section of a four-lane highway in both a simulation and instrumented car. The study concluded that there was very strong correlation for longitudinal control in both contexts. Lateral control performance produced moderate correlation, with absolute validity not achieved due to the absence of kinesthetic feedback.

In 1998, a study was conducted at the Monash University Accident Research Centre [2], where a set of young drivers ranging from learner drivers to probationary were exposed to a simulator to enhance attentional control skills. Participants were trained to complete two tasks concurrently whilst driving. Firstly, maintain a set distance behind a vehicle moving at a variable speed, and secondly perform a numerical calculation task. When compared the control group, participants exposed to training performed higher. Concluding that variable priority training enhanced the ability to detect, perceive and respond to potential traffic hazards.

Regarding reaction time studies, Joshua D. Hoffman et-al [3], conducted an experiment at the General Motors Milford Proving Ground. Drivers following a modified vehicle in an instrumented car, and were required to respond to hard braking conditions at target speeds. The experimental procedure was then closely mimicked at the IDS simulation facility. An agreement between results was indicated, however a difference in braking strategy was found. It was noted that the sensory cues between the IDS and CAMP studies varied, with the resolution of the simulator impairing the subject's ability in detecting relative motion.

This project will understand the previous studies regarding behavioral driving patterns, and focus on correlating the vehicle characteristics of a simulator.

Methodology

The simulator was constructed from the Monash Motorsport 2013 chassis, with consideration to best represent the ergonomics of an FSAE vehicle. Electronics including a fully custom steering wheel and pedals were designed and installed in place of the pre-existing physical components.

Figure 1: Demonstration of the completed simulator during the Lotus Club Tour of Monash Motorsport's facilities in 2017

From this a foundation was formed to develop a simulation of the 2017 Monash Motorsport vehicle. Tracks of physical testing locations as well the competition were modelled and imported AC. Utilizing data acquired from physical testing at these locations, it would then be possible to calibrate a vehicle model in the simulator. Finally, a correlation could be made between driver ability in both the simulator, and a real-life vehicle.

Manufacturing

The chassis required rust removal and cleaning due to direct exposure to the elements. The steering mounts were removed, with mounting hardware to accommodate a Logitech G27 wheelbase designed and welded into the existing chassis. Ergonomics were taken from the original design, with the steering wheel oriented in the same fixed position as driven by the car in its active state. Electronic pedals were modified and mounted to replicate the adjustability of the original pedalbox.

Textile feel was identified as a key factor in improving overall fidelity. With the Logitech system having an oversized steering wheel and light feedback paddle shifters, it was decided to replicate the custom steering wheel assembly in the current motorsport vehicle. Due to low weight, high-performance requirements, a Krontec quick release (QR) was chosen for the competition vehicle. The sim did not have to satisfy these design requirements and a cheaper QR could be compromised to reduce manufacturing cost. This created some packaging issues due to its larger size, and thus a redesign was required. A 3.2" Nextion TFT display was added to accommodate future design avenues. With the team implementing two MoTeC D153 displays in future vehicles it will assist in early concept validation as to whether it resides on the wheel or dash. Force feedback (FF) in the steering wheel was iterated through driver response, with the final configuration showing a significant improvement over the stock feedback settings. A conservatively lower feedback resistivity was chosen to prevent clipping issues seen in stronger FF tested.

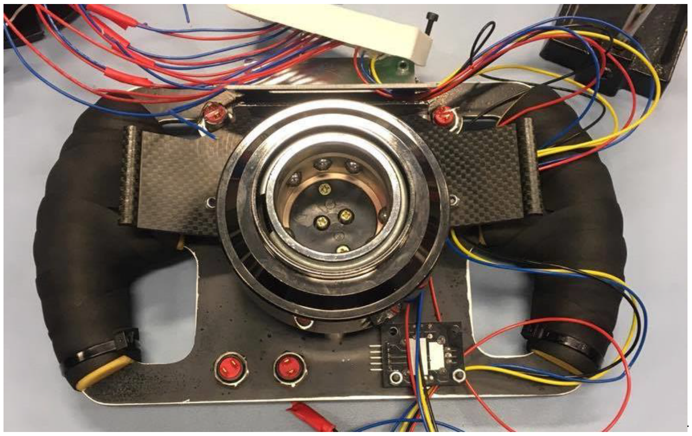


Figure 2: Wiring of the touch screen display and button inputs for the fully customized steering wheel.

Track Modelling

Track modelling was conducted with modelling software *Race Track Builder* (RTB) and rendering software *3dsMax*. RTB is an intuitive program designed for recreating real-world locations. Utilizing topology and satellite imaging data from google, it is possible to overlay game environments on top, thus creating dimensioned tracks. Track surfacing within the software often created strange impurities and bumps, particularly in tight radius corners where the curve approximation failed. These uncertainties were post-processed in raw rendering software. Using 3dsMax it is possible to edit the whole environment at a polygon level. By reconstructing the mesh for various objects, it was possible to modify surfaces and improve the fidelity of a track surface. The following tracks were constructed based on topology data, with cone configurations dimensioned:

Oakleigh Go-Kart Club
Gloria Pyke Netball Courts
OC1 Synchrotron Parking Lot
Calder Park Raceway (FSAE-A 2016 Endurance track)

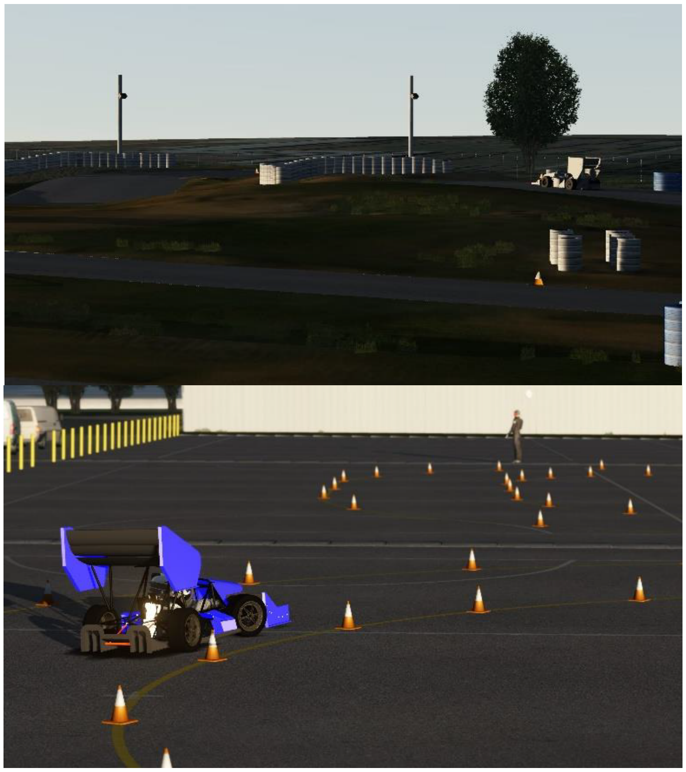


Figure 3: Oakleigh Go-Kart track and Gloria Pyke Netball Courts in Assetto Corsa

A generic 'carpark' environment with a sample of track configurations have been distributed to the FSAE community to assist in the development of simulators within other universities. These include the constant radius sweeps, acceleration, skid pad and short autocross tracks. To date, this resource has been downloaded over 750 times by teams and enthusiasts.

Car Modelling

By taking the MMS vehicle CAD model, it was possible to convert it to a mesh model that could be imported in the game. CAD software contains the internal features and mathematical accuracy required for low tolerance part design. Rendering software uses an approximate method, only modelling surfaces and external features. The result is a much lower file size, with a reduced number of faces and vertices. This is essential for Assetto Corsa; the game does not allow an imported object to contain more than 65,000 vertices, thus the objective was to convert the CAD to an approximate model. Using the open source processing system Meshlab, clustering decimation was used to iteratively re-construct the mesh whilst converging vertices. The result is a significantly lower file size. Figure 4 represents the 2012 engine CAD, before and after simplification.

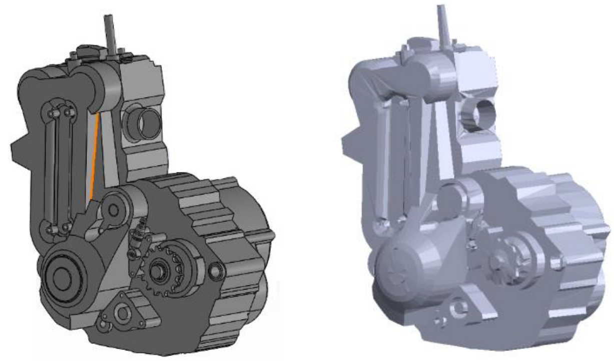


Figure 4 Left: 18,930 vertices (1797kb). Right: 2,675 vertices (273kb)

All small and internal components were removed from the model including fasteners, rodends and electrical routing lines. The remaining objects were exported and optimized separately, before being re-assembled in 3dsMax. The result is a model, in the case of the 2017 vehicle, reduced from 518mb down to 24mb. A secondary requirement of Assetto Corsa to the 65,000 vertices limit is a total file size of 44mb inclusive of textures. A full model well below this limit allowed for detail to be re-introduced, as well as a larger range of textures applied.

Figure 5: Cockpit footage of the Monash Motorsport 2017 vehicle in Assetto Corsa

Calibration

The on-track data acquired for this comparison was derived from existing testing sessions of steady state cornering sweeps. The goal of the physical testing was to achieve small but important incremental gains, and thus the change in performance was minimal when comparing to a relative model in the simulator.

The vehicle's dynamic driving characteristics were recreated virtually through consultations with current team members and alumni, along with comparisons drawn to physical testing both on-track and via dynamometer engine tuning.

In Milliken Milliken's 'Race Car Dynamics' it is remarked that a tire is simply too complex to evaluate as whole. μ_y is the ratio of the lateral force a tire can generate relative to the load applied to it [5]. In the simulator model, μ_y was isolated and moderated until a reasonable lateral acceleration (A_y) vs time plot was satisfied. To create a simple model, surface temperature was fixed to 34˚C with an ambient temperature of 26˚C. Tire pressure maintained 12psi regardless of conditions. No further investigation was taken regarding other tire parameters such as a camber dependency and friction limit angle, with fidelity determined by driver feedback and telemetry comparison only.

Initially a skid pad layout was used for a base comparison to investigate vehicle parameters under steady state performance. Figure 6 represents $A_y\ vs\ t$ and $A_y\ vs\ A_x$ plots for a μ_y of 1.75. There is a clear similarity between the two, with the simulated vehicle cornering with a slightly lower A_y. Data acquisition rate was (50hz) for the MoTeC ADL1 in the physical testing, and (20hz) for ACTI in the simulation.

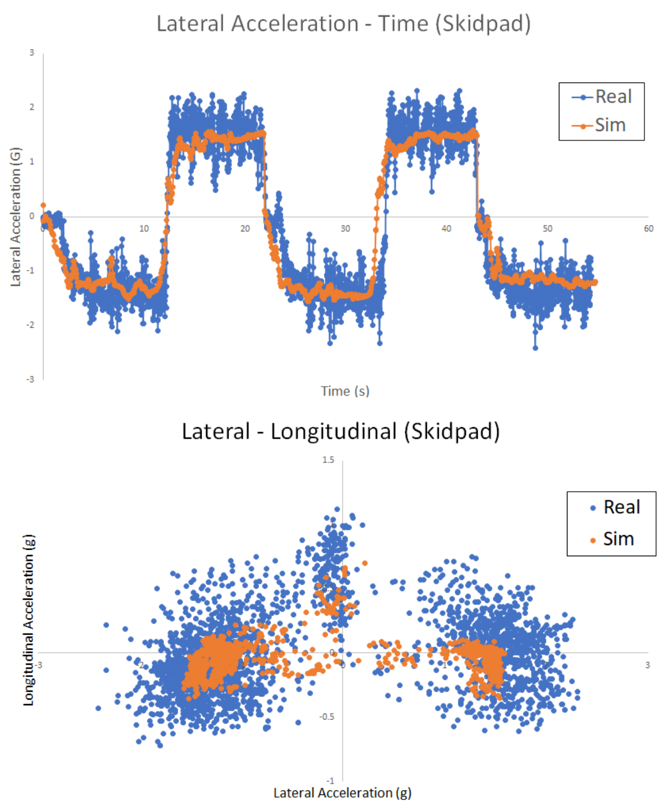


Figure 6 Plots $A_y\ vs\ t$ (top) and $A_y\ vs\ A_x$ (bottom).

The model was applied to transient motion to investigate gear position accuracy. A commonly driven track at physical testing was chosen, with a length of ~400m and several turns including a slalom. The following graphs show a representation of the calibration. RPM vs Speed indicated a strong linearity to physical testing, with 2nd and 3rd gears showing strong similarity. The 4th gear momentarily driven in physical testing was not seen in the simulator. Gear ratios can be adjusted as a well as final drive ratio to correct this result. Torque curve was taken from dynamometer testing of a 5L plenum with measurements incrementally taken for RPM values at 100% throttle.

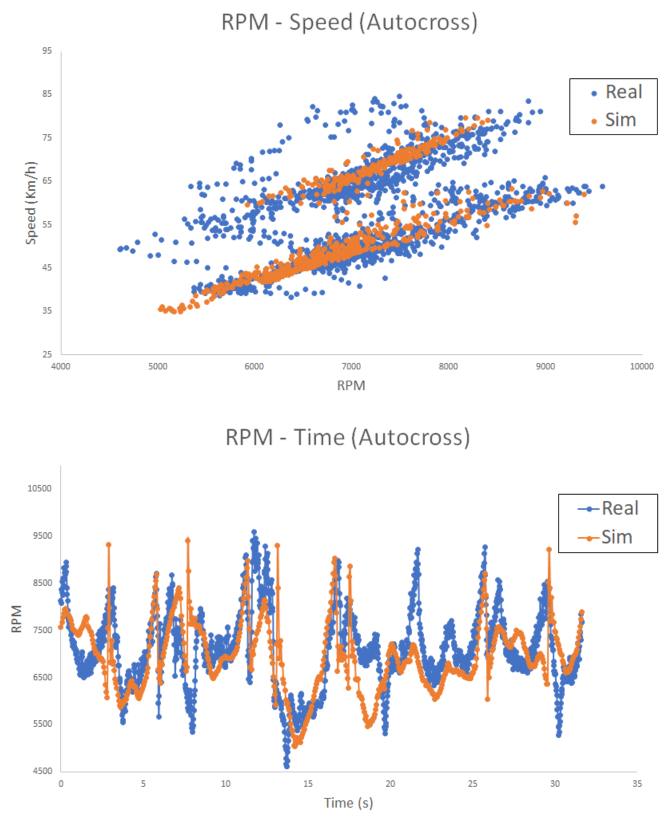


Figure 7 Plots of RPM vs speed (km/h) and RPM vs time (s) for autocross track FSG1

Relative validity was achieved in the $A_y\ vs\ t$ plot for FSG1, with an offset at the 15-25sec mark created by misalignment of the slalom cone configuration between the real and sim tracks. Due to the acquisition rate of ACTI a smaller cluster is seen in the $A_y\ vs\ A_x$ plots, with density showing a similar distribution to the physical testing.

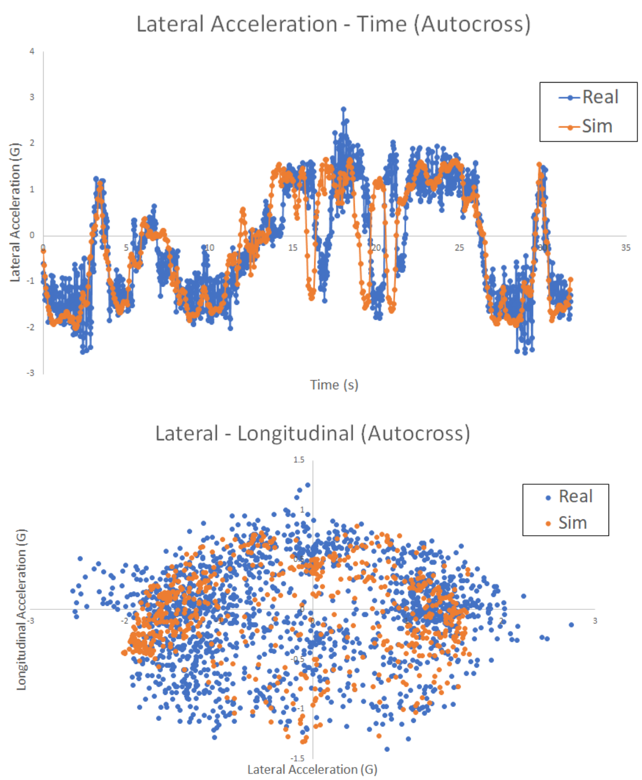


Figure 8 Comparative plot of RPM (horizontal) and speed (km/h) (vertical) for FSG1

Correlation

Members of the team participated in a social karting event during the year. Each driver completed a 15-minute race, recording ~18 laps each. A comparison was drawn to simulated event, with drivers completing 18 laps of a different track.

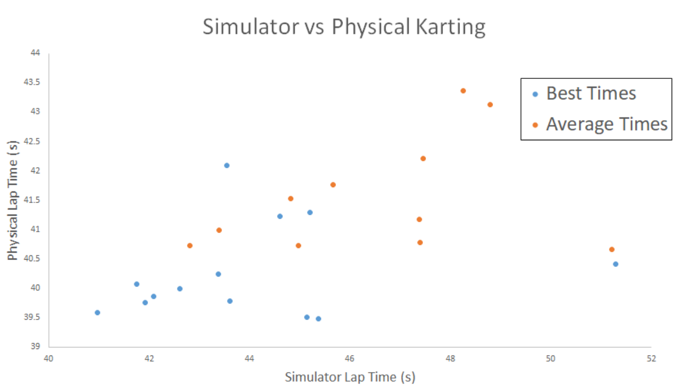


Figure 9: Best lap time for the karting event (horizontal) compared to the average lap time for the simulated event (vertical) of each driver.

A similar comparison was drawn to research taken by Travis Leenarts [5], with the following a comparison to a physical karting session and simulation in ‘Live for Speed’.

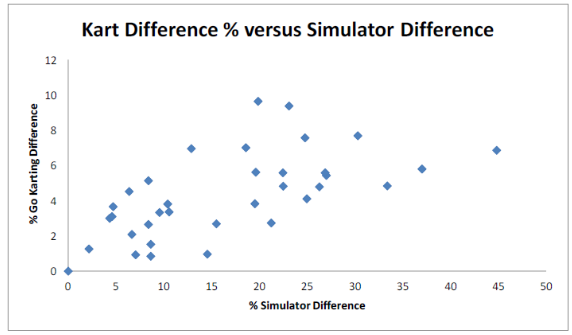
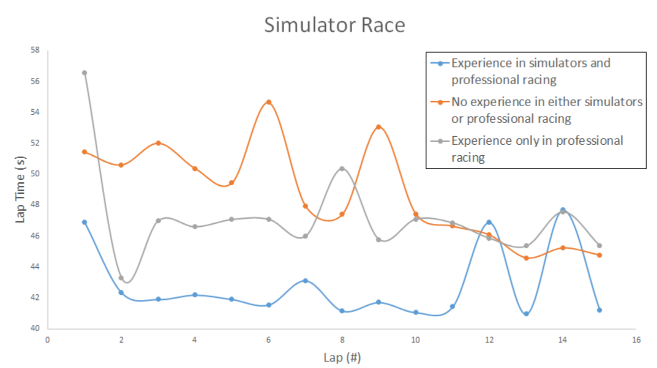


Figure 10: Comparative lap times compared as a percentage of the fastest for both karting (vertical) and simulation (horizontal) for each driver. [5]

There is better linearity with the newly developed simulation, however due to a small number of participants for the simulation it is inconclusive if there is a strong relationship. The design of the survey did not investigate the physical outcome of training a driver on the sim, with the graphs below showing the deviation in times for three case drivers; Experienced in both simulators and professional racing (A), experience neither simulators/racing (B) and experienced only in professional racing (C). list in graph



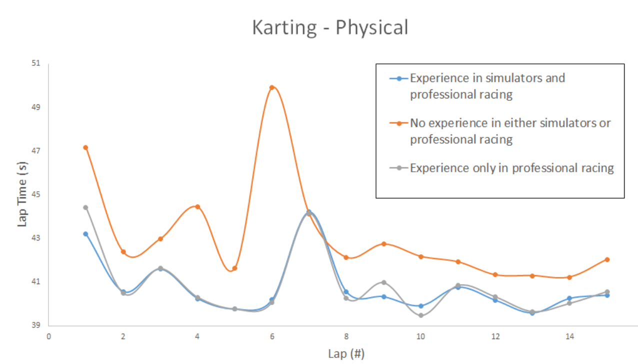


Figure 11 Lap time comparison between three drivers of varying experience levels for both the simulated (top) and physical karting (bottom) sessions.

Marketing / Engagement

The simulator has been used as an engagement tool for various events and activities. These range from the Australian Grand Prix to team fundraisers. Previously the team would display a Monash built car, with the public able to interact with team members and discuss the Formula Student project. With the addition of the simulator, it has allowed the public to experience the cars design hand-on and develop an understanding of the vehicles dynamic characteristics. An Oculus CV1 virtual reality headset was acquired to allow for greater immersion, and was displayed with the simulator at the 2017 Technology and Gadget Expo in June.

CONCLUSIONS

The Monash driving simulator is the result of significant input and development with both engineers and drivers of the Monash Motorsport team. It is a product that can be used to develop key vehicle dynamic characteristics in a car for an undriven track. It also opens an alternative avenue for concept design, aiding in visualizing the driver's perspective in a simulated environment.

The driving simulator provides an approximate indication for both gear position, lateral acceleration and lap time for a given track configuration. A simple method was used to calculate a tire model, with a lateral coefficient of friction determined to be 1.75. This was determined through comparisons to physical testing and telemetry in the driver simulator. Powertrain properties including the gear ratio, final drive ratio and torque curve were compared through both the physical on-track testing as well as dynamometer testing. The result is a simulator that can provide relative validity in both RPM vs speed, and lateral acceleration vs time plots for a given track. This fundamental data is the basis on which future validation can be built on, as well as use in concept design for future physical cars.

ACKNOWLEDGEMENTS

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FSAE Teams listed below for providing CAD models / Assetto Corsa models of their vehicles to assist in future comparative analysis:

Revolve NTNU, NOR
RMIT Electric Racing, AUS
University of Cantebury Motorsport, NZ
Western Michigan University, USA,
Coopers Motorsport, USA,

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