SPEEDWAY 20X4

ROBORACE: Greed for Speed

St. Lucia Grand Prix

Description, Rules and Regulations v0.5 201405019

Task Description

The objective is to build a small autonomous race car that automatically negotiates a racetrack in the fastest time possible, while avoiding hazards and other cars. This document lays out the rules of the challenge, describes key concepts, and lists permitted materials and specific prohibitions.

Definitions

Raceway:	The area consisting of all tiles mounted on the testing arena.
Track:	The shaded driving surface that delineates the path of the race.
Car:	A vehicle for driving on the track, either built by a team or provided as a pace car
Team:	Any and all students in a group working on the project
Judge:	The course coordinator or duly-appointed adjudicating staff member.
Race:	The competitive match involving multiple team cars; not for marks
Time-trial:	Car performance demonstration, assessed as part of marking

Time Trials

The race car must complete a series of time-trials on increasingly difficult courses, with marks being given for demonstrated functionality. Functionality will be scored by a point system, with advanced behaviour gaining more points. Teams are given 5 minutes of set up time, and then 15 minutes to complete at least one lap of no more than 5 minutes. Although timed, points are not specifically awarded for achieving any given lap-time. Instead, the fastest lap-time will determine starting grid position for the exhibition race. Cars that false-start during a time-trial will be restarted with a cumulative 5-second time penalty.

Grand Prix

An exhibition race session will be held in the last week of semester. No marks are awarded for the exhibition race, but the top teams will be awarded a trophy. To qualify for the race, a team's car must demonstrate all basic and intermediate functionality levels, and complete a lap autonomously. Depending on the number of qualifying teams, the race may be divided into heats. The number of laps to be driven in each race will be no less than 6 and no more than 15. During each race, each car will be required to complete at least one pit-stop, as instructed by the judge; all teams will complete the same number of pit-stops. Cars will be required to adhere to the safe-driving guidelines.

If no cars are capable of completing the race after 15 minutes, the non-disqualified cars will be placed in order of number of laps and total progress towards the goal.

Track and Handling Procedures

Teams and cars must adhere to a set of procedures that stipulate the set up and handling of cars during the time trials and race.

1. At the instruction of the judge, teams must place their vehicle on the track starting grid according to starting order. After placing the car on the track, the students may not touch or interfere with the car in any way, except for during a pit-stop or as directed by the judge. Students standing around the testing arena must not act in any way that may interfere with the function of cameras or vision processing algorithms.
2. Students must not directly trigger any commands to the car except for a "start" signal to begin the race, the command to make a pit-stop, and the command to exit the pit-lane. All other communications sent to the car must be autonomous.
3. A race or time-trial is started by a GO light being automatically lit by a count-down timer. Three lights will be lit in sequence – first one red light, then an orange light, and then the green GO light. Cars that move before the green light is lit are false started. Cars that do not move on the green light may be moved to the pit lane by the judge to avoid obstruction to other cars.
4. During a pit-stop, the car must come to a complete stop, fully inside the pit lane, before being handled by a student. Students must not touch or interfere with any other cars in the pit-lane. When replacing the car, it must be set down at the finish-line end of the pit lane, behind any cars preparing to exit.
5. In the case of an accident, the judge may remove damaged cars from the track and place them in the pit lane; undamaged cars will be moved clear of any debris, returned to their prior positions and allowed to continue. Debris will be cleared by the judge.
6. If a car snags on an object or leaves the raceway, the judge may move the car to the point where it left the track. A car proceeding around the track in the wrong direction will be turned around by the judge. A car that short-cuts will be returned to the place where it left the track.
7. Cars must complete all loops of the contiguous raceway track, and pass between the marker flags of checkpoint gates.

Cars that violate the race rules may be given one or more infraction notices, at the judge's discretion. Cars that accrue three or more infraction notices during a race will be disqualified. Infractions and penalties include:

Infraction	**Notice penalty**
Colliding with obstacles	0-1
False start	1
Leaving the raceway	1
Unsafe driving	1-2
Short-cutting (not completing whole loops)	2
Failure to pit when instructed	2
Interfering with cars	2
Cheating	3
Other infractions as determined by the judge	1-3

<u>The judge shall be the final arbiter of what infraction notices are issued.</u>

Time-Trial Scoring criterion

Points are awarded for demonstrating specific functionality related to driving around the raceway. The judge shall be the final arbiter of whether functionality requirements are satisfied. Scoring will take the form a time-trial in which the car has up to 15 minutes to complete a lap, during which points and penalties may be awarded. If the car is not capable of completing a lap autonomously, individual functional behaviours may be demonstrated by manually moving the car around the raceway. Functionality is divided into three tiers; to be eligible for points for the higher tiers, all the functionality of the previous tier must first be demonstrated. If the car must be freed by the judge during a trial, a 1 point penalty will be levied per instance.

Basic Functionality	**30/30 Points**
Car moves upon activation	3
Car drives in a straight line	4
Car executes turns	5
System detects raceway	8
Car follows track over two whole tiles	10

Intermediate Functionality	**40/40 Points**
Car starts automatically on GO signal	3
Detects obstacles	6
Car avoids an obstacle	6
Car never leaves track	7
Car enters and exits pit-lane autonomously	8
Car completes whole lap	10

Advanced Functionality	**40/30 Points**
Car never contacts obstacles	6
Car completes pit-stop inside 15 seconds	7
Car drives behind occlusions, through tunnels	8
Detects and overtakes pace car	8
No offboard processing	10

Pit stops

During time trials and the exhibition races, each car must perform at least one pit-stop as dictated by the judge. Teams may elect to stop at the pit at their own discretion (to change batteries, equipment etc), but must still complete all judge-mandated stops.

During a pit-stop, the team may remove the car from the raceway and make any alterations or changes they see fit, provided the car always meets the design guidelines. Upon placing the car back on the raceway, students must not touch or interfere with the car until it returns to the pit again.

During a judge-mandated stop, the team must remove and replace one of several specified components, as dictated by the judge:

- Main electronics board(s)
- Drive motor(s)
- All wheels/tires
- Main battery(s)

The replacement items may be the same piece(s) of hardware as removed from the car. If an item removed from the car during the stop is to be replaced, it must first be placed on the ground prior to being reinstalled. It is permissible to remove connectors, fasteners and support structure along with the component, so long as the additional removed material does not constitute a substantial fraction of the vehicle. For example, removing a spur gear along with a motor is ok, but not the whole rear of the car containing the motor.

During time-trials, the car must make a pit-stop prior to completing the lap; the judge will randomly determine what component must be removed. During a race, the judge will notify each team on which lap(s) their car must make a pit-stop, and what component(s) must be removed.

<u>The following definitions apply:</u>
Electronics: Any circuit board or soldered assembly with integrated circuits, excluding circuit boards or soldered assemblies which are predominantly populated by sensors or radio, or solely consist of conductive traces.

Drive motors: The motor (or motors) that propel the vehicle. Where more than one motor drives the vehicle, only one such motor must be replaced.

Wheels/tires: The wheels/tires are the parts of the car that touch the ground and propel the vehicle forward. This includes conventional rubber tires, rubber wheels, raceways, feet and paddles. It excludes passive wheels and skids or sliders that do not rotate.

Batteries: Batteries are any energy storage device used to propel the vehicle, including (but not limited to) chemical cells, fuel-cells, super-capacitors, elastic members or pressure vessels. If more than one battery is used to power the motor, all must be replaced. Batteries which do not power the motors in any way do not need to be removed.

<u>In all cases, the judge will dictate what parts must be replaced.</u>

The Raceways

Speedway 20X4 features a modular race track, built out of painted plywood tiles. The track can be rearranged as desired to test various features and configurations. Towards the end of semester, it will be arranged into particular designs of increasing difficulty for incremental testing.

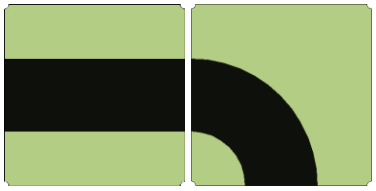
The track tiles all feature a road surface 200 mm wide, with 150 mm of clearance on each side. The road surface will be black, aside from starting grid positions and chequered finish line, which are white. The area surrounding the track will be painted lime green, and may be flocked with miniature grass or dirt, and fitted with scale objects such as trees, crash barriers, edging, pylons, grandstands, flyovers and other obstructions.

Key Features

Finish Line

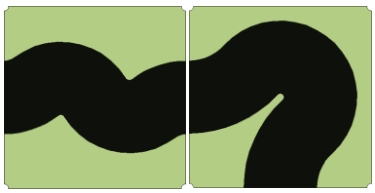
The only double-tile in the set, the Finish Line also includes the pit lane and starting grid. All races and time trials start at the starting grid and end across the finish line. The Finish Line is always placed close to the edge of the raceway, so that students can get easy access to cars during setup and pit stops.

Straights and Curves



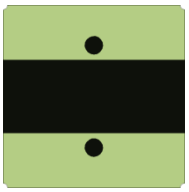
Straights and 90 degree curves are the basic building block segments of the track. There are numerous straights and curves in every layout.

Chicane and Hair pin turn



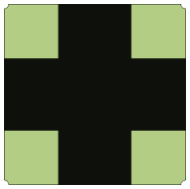
Chicane and hair-pin turn are more difficult versions of the straight and curved sections. They occur more rarely in track layouts.

Checkpoint

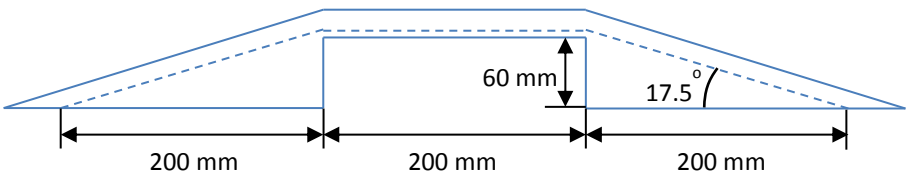


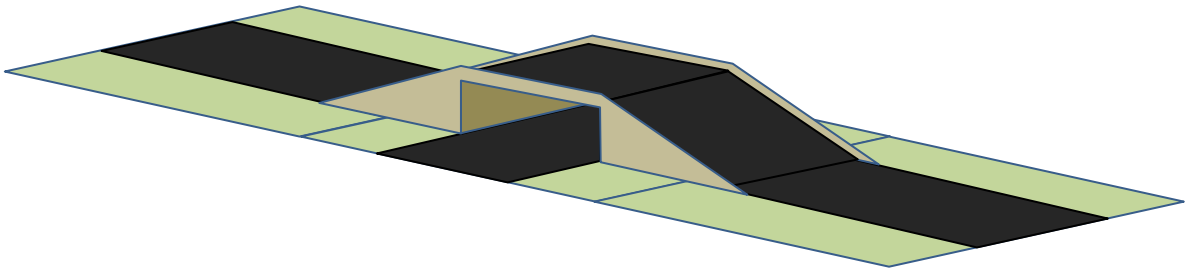
The checkpoint is a straight tile with a gate marker. This tile is always placed at the opposite side of the track from the finish line. A car must pass through the gate markers to successfully complete a lap. There is only one checkpoint per track.

Cross-over and fly-over



Cross-over and flyover tiles are points where the track intersects or overlaps itself. Flyovers are constructed from straight tiles, using a small bridge. There is at most one cross-over or flyover in a track. Cars must proceed straight through a cross-over, and give way to cars approaching from the right. Flyover geometry is given below:





Tunnel and Mountain

Not tiles *per se*, some tracks may include sections where obstacles occlude the view from one or all cameras. These will take the form of a large mountain or a covered over tunnel. Tunnels will always be linear straight through, with no turns or blind-ends inside. The tunnel will be 400 mm long, with 200 mm width and 60 mm height.

Cameras

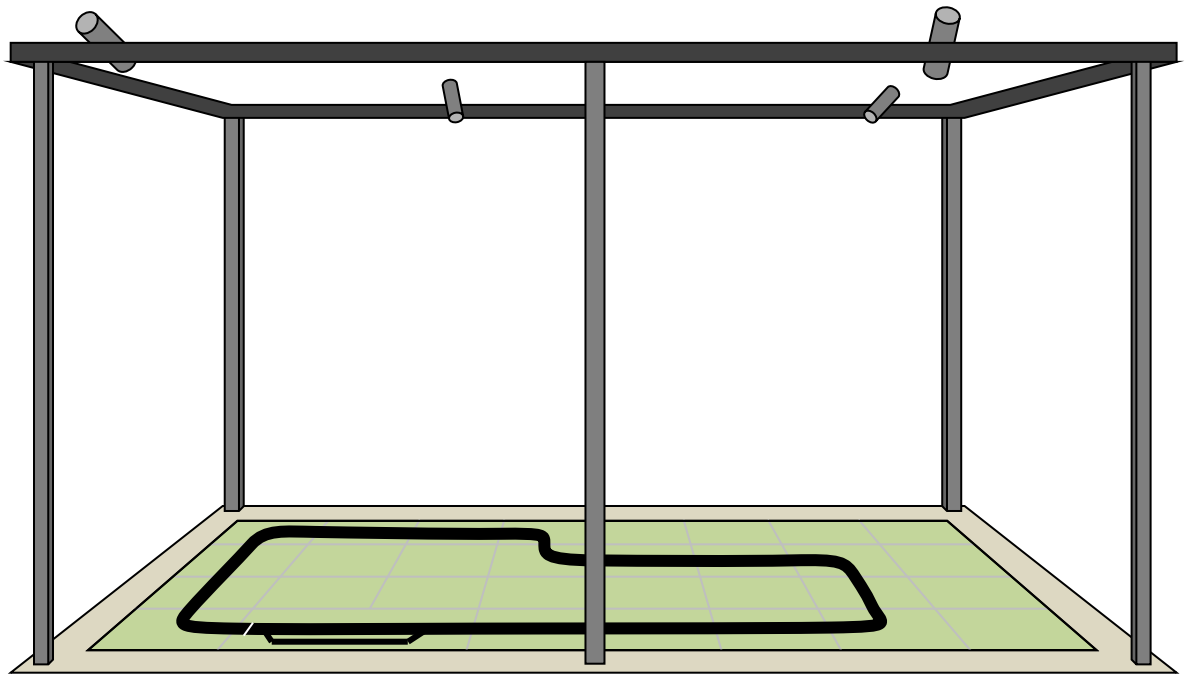
Four MS Lifecam Studio cameras will be arranged around the track, connected to a PC server which will make video streams available to all teams on the track via a gigabit Ethernet switch. Teams may choose which camera(s) to draw a feed from dynamically during the race or time-trials. During time-trials it is permissible for a team to directly connect to the cameras via USB, rather than the server. The placement of the cameras is at the discretion of the judge, and will change from race to race and between time-trials. Cameras may be mounted anywhere on the rail along the edges of the testing arena. Spotlights may also be mounted along with the cameras.

Starting lights

Three starting lights will be located on a black box at the starting line, and will light in sequence to indicate the start of the race. The lights will be coloured green, orange/yellow and red (from left to right) and will be fitted inside standard 40mm ping-pong balls. The balls will not be touching, and will be set against a black background as viewed from above and from the front. At commencement of the race, the lights will illuminate in sequence, separated by one second.

Testing arena

The testing arena consists of a 4 m by 2 m open space surrounded by a framework for holding tiles in place. Six vertical supports hold up a rail around the periphery of the testing arena, on to which cameras and light sources are mounted. The rail is approximately 1.5 m above the track surface. The testing arena will use blue sail cloths to reduce ambient light, but the amount and colour of incident light will vary throughout the day.



Safe Driving Guidelines

All cars must adhere to safe driving guidelines to regulate behaviour on the raceway. Cars that drive unsafely will be issued with infraction notices; repeat offenders will be disqualified.

Raceway Following

Cars must follow the raceway, and avoid leaving the marked track. Cars must always proceed around the raceway in the direction specified by the starting grid (clockwise on the main loops).

Contact and Minimum Clearance

Contact between cars is discouraged. Cars must maintain safe distance from other cars whenever possible. Each car is responsible for maintaining a minimum clearance of 50 mm in front and 10 mm to either side. While incidental contact is accepted as inevitable, cars that make intentional, repeated or dangerous contact will be issued infractions.

Passing

Advancing cars must wait until it is safe before overtaking a slower leading car. The overtaking car is responsible for maintaining safe separation between itself and the lead car at all times. After passing, the car must establish rear clearance of 100 mm before crossing back in front of the overtaken car.

Adversarial Driving

Cars may not intentionally impinge on the clearance around other cars. Cars may not apply sudden braking, except to avoid an accident. Cars may not cut-off overtaken cars, nor prevent cars passing from overtaking. Cars may not stop, slow-down, swerve or zig-zag across the road as an obstruction to other cars. If such driving behaviour is construed to be intentional (or reasonably foreseeable and preventable by programming), the offending team will be issued an infraction.

Crossings

Where a raceway layout includes the crossroads tile, crossing cars must give way to their right, and only proceed when there is sufficient clearance to cross without causing other cars to brake. Cars must always proceed straight through crossroads. No turning is permitted.

Pit-Lane

Cars entering the pit-lane should not slow down so much as to create an obstruction for other cars. Cars exiting the pit-lane must wait until sufficient clearance is available to enter the raceway without causing other cars to brake. Cars waiting to exit the pit-lane must do so as soon as possible, so as to allow other cars in the pit-lane to advance.

Miscellaneous

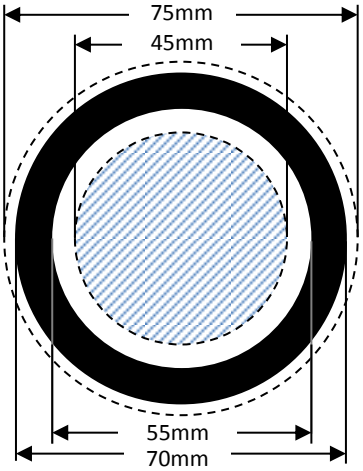
After completing a race, a finished car will compete one victory lap, whereupon it must retire to the pit-lane to exit the raceway.

Race Car Design Guidelines

Each team constructs one race car with a spare set of replacement components, using a limited budget. The judge shall be the final arbiter of whether a car is legal, and what parts of it constitute each replaceable component.

Dimensions

The dimensions of the car and any attached parts must be less than 150 mm long by 75 mm wide by 50 mm high. There is no minimum ground clearance, but 5 mm is recommended. The car must have a flat, level top surface area suitable for mounting a 70 mm tracking marker on. Technical drawings of the tracking marker geometry are published on the course website.



The markers contain a clear centre area that may be filled by a custom identifying marker of the team's choosing (so long as it does not impede other team's ability to use the marker). Teams may add additional tracking markers as desired, provided they do not obstruct the standard marker.

Construction

The car may be constructed from any material, but <u>at least one component must be machined from metal</u>, using milling, lathing, water-jet cutting or any combination thereof. Drill press or band saw alone are insufficient. No pre-built structural parts (eg. from a hobby kit) may be used, including wheels, chassis or suspension. Gearboxes or gearmotors that come preassembled may be used as-is; kit gearboxes must have fabricated housings.

The following components may be bought prefabricated:

- Bearings, tubes, shafts and rods
- Springs, magnets, hinges, latches
- Screws, zip-ties and assorted fasteners
- Gears, sprockets and chain/links, preassembled gearboxes
- Discrete electronic components, ICs, connectors, wire, solder
- Motors, gearmotors and servos
- Batteries
- Electronics modules: sensors, processor boards, radios, etc.
- Other items by permission of the judge

<u>At least one printed circuit board must be custom built and assembled.</u> This PCB must perform a non-trivial electrical function, and must include at least four electrical or electronic components. Protoboard or veroboard assemblies will not be counted towards this requirement.

<u>Onboard Li-poly batteries may total no more than 15 kJ maximum energy capacity.</u>

The car may be equipped with any item not explicitly prohibited, up to the budget limit. The car may include communication links to off-board computational facilities to allow remote processing and control.

Budget

The total cost of materials, parts and components incorporated in the product shall be no more than $150. Regardless of actual cost to construct, the team must demonstrate that the product produced *could* be constructed from $150 of parts. Up to $150 will be provided for purchase orders through ETSG. **Reimbursements will *not* be permitted.**

Cost of parts shall be calculated on a per-item basis; parts that are purchased in multiple units may be costed per unit – e.g. a bag of 10 nails for $10 may be charged at $1 per nail used. Bulk unit discounts from suppliers may be applied, provided the quantity of items used in the product is sufficient to earn the discount. Items sourced for free (i.e. not paid for) may be costed at half the as-new purchase price. While it is not necessary to have circuit boards manufactured at ETSG, any boards produced by outside fabricators must be purchased via ETSG's order system in order to be paid out of budget.

Each team will be provided with 500g of 3D printer filament in a unique colour. Once this material has been exhausted, no further filament will be provided. You may not use other 3D printer filament than that provided.

Specific Prohibitions

- **No human input**
  Remote control, tele-operation or other input devices must be removed or disabled prior to the start of a race or time trial. The judge may elect to have the disabled or removed state of any input device demonstrated prior to starting. The judge shall be the final arbiter of whether the steps taken to disable a device are adequate.

- **No additional off-board sensing**
  Only the provided camera array and sensors mounted on the car may be used to determine the state of the car, raceway and other competitors. Sensors on off-board computers, such as webcams, must be disabled. The judge may elect to have the disabled status of any sensor demonstrated prior to the start of a race or time trial. The judge shall be the final arbiter of whether a sensor is adequately disabled.

- **No markers or alterations**
  No signs, structures, markers, radio beacons or other equipment may be employed beyond those provided by the raceway and camera array. No alterations may be made to the raceway, its contents or the camera. Cars that cause damage to the raceway may be disqualified.

- **No internet connection**
  The car may not be connected to the internet, nor may any off-board processing facility be connected to the Internet. Where wifi or similar wireless protocols are used to connect between the car and another computer, it must be demonstrated that no computer on its network is connected to the Internet. The judge may elect to have the connection status of any input device demonstrated prior to a race or time trial. The judge shall be the final arbiter of whether a connection constitutes connection to the Internet.

- **No foul play**
  No item or system that interferes with other cars, the raceway, cameras or communications may be used. This includes (but is not limited to) mounted weapons, released objects, electronic jamming, optical jamming (eg. bright lights or reflective films), sprays, coatings, slicks, smoke screens or other nefarious devices that could appear in a Bond film or episode of Wacky Races. Teams that use any device that the judge deems to be unsporting will be disqualified.

The Aim of the Project and the Spirit of the Rules

Without a doubt, engineering students are extremely creative and talented at finding clever solutions to difficult problems. This project aims to teach you about the practical trade-offs encountered by real engineers when facing a multi-faceted challenge with broad scope and many possible solutions. It is recognised that no set of rules could cover every possible edge case without becoming cumbersome fodder for ‘rules lawyers’.

Thus, the two cardinal rules are:

1. Judge’s discretion is final.
2. Stay within the spirit of the problem.

If you think what you are attempting might not be in accordance with the spirit of the rules… it probably isn't. However, there is no harm in asking! The judge will determine whether a particular approach is permissible. It is best to ask these sorts of questions early in the semester!

Other Miscellanea

By-laws, clarifications and addenda go here. This used to be a short section, but previous years' students have shown that it is *depressingly* necessary to spell-out exactly what you should not be doing. But you're going to be smarter and better dressed than them, *right*?

1. All OH&S inductions and procedures *must* be adhered to. You **WILL** be ejected from the lab if you are unsafe or in violation of footwear requirements. Repeat offenders will be barred from the teaching labs for the remainder of the semester.

2. It is the responsibility of all students to keep the teaching labs in clean, functioning condition. Lab cleanliness will be arbitrated by a warning system, as posted on the class blackboard site and class website.
    a. The lab status starts at GREEN.
    b. If the condition of the labs deteriorates and becomes too messy, status will change to YELLOW, indicating that clean-up is needed.
    c. If conditions do not improve or deteriorate further, the status will be changed to RED and the labs will be set to fixed-hours, with after-hours access prohibited.
    d. If conditions do not improve or deteriorate further, the status will be changed to BLACK and the labs will be locked to students until the next practical session, whereupon the labs must be completely cleaned before any work may resume.

3. The follow are specifically prohibited:
    a. Eating in the lab
    b. Sleeping in the lab
    c. Leaving the lab door open (all students have access cards)
    d. Giving non-enrolled students/non-students access to the lab
    e. Non-work related activities (eg. computer games)

    Students found to be violating these rules will have lab access revoked.

4. 'Vegas rules' are in effect: what happens in c404 *stays* in c404. Under no circumstances may project infrastructure, test equipment, tools, supplies, furniture, etc. be removed from the teaching labs. Transgressors will be barred from the teaching labs for the remainder of semester.

5. No grade will be awarded until all assigned tools and equipment are returned and accounted for.