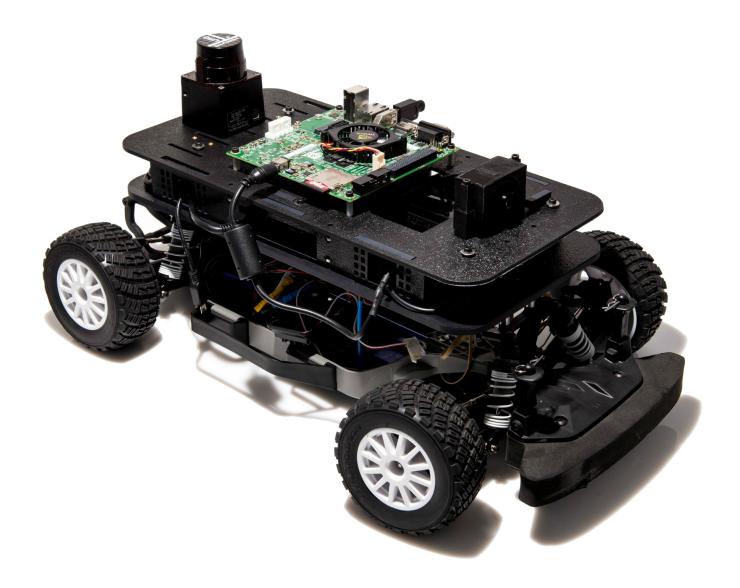
The Rules Version 1.0





Copyright

Copyright (c) <2016> <copyright holders>

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EX-PRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGE-MENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LI-ABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN AC-TION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

Contributors

Houssam Abbas Madhur Behl Matthew Brady Phil Hu Timothy Hu Paril Jain Paritosh Kelkar Nischal K N Rahul Mangharam Liz W. P. Ng Matthew O'Kelly Carter Sharer

The Simple Version

This entire document can be summarized in three concise statements:

- 1. Build from the *F1/10 starter kit*: your car will meet the vehicle specification.
- 2. Achieve the simple race objectives: *don't crash* and *minimize laptime*.
- 3. Adhere to the *honor code*: "no member of the F1/10 community shall take unfair advantage of any other member of the F1/10 community"

In order to minimize *what if's* and promote an *organized* competition we have provided significant detail explaining the ins and outs of the preceding statements within this document. Thanks and have fun!

The F1/10 Team

Contents

1	Copyright	2
2	Contributors	2
3	The Simple Version	3
4	Introduction4.1Scope and Precedence4.2Vision4.3Overview4.4Objectives	5 5 6 6
5	Awards 5.1 Award Terms	6 6
6	Eligibility6.1Eligibility6.2Team Registration and Qualification	7 7 7
7	Vehicle Requirements7.1Safety Requirements7.2Autonomy and Communication7.3Physical Characteristics7.4Hardware	8 8 8 9
8	Sporting Regulations and Honor Code8.1Sporting Regulations8.2Honor Code8.3Collisions and penalties8.4Referees	10 10 10 11 11
9	Overview9.1Scenario9.2Data Recording9.3Wireless Network	12 12 12 12
10	Organization of the Competition10.1 Competition Overview10.2 Starting10.3 Qualifying Lap10.4 Schedule10.5 Competition Schedule	13 13 13 13 14 14

Introduction

This document provides a preliminary overview of the proposed rules for the 1st F1/10 competition. We acknowledge borrowing liberally from the experience of the DARPA Urban Challenge regulations and Formula One Sporting Regulations. We welcome feedback so please drop us an email.

4.1 Scope and Precedence

The rules apply to *all participants* in the F1/10 competition. The F1/10 organizing committee will release the following additional physical artifacts, documents and data which carry the full authority of the rules in this document:

- Modular starter chassis kit
- Assembly and startup instructions
- Master schedule
- ROSBAG data set and Route Network Definition File (RNDF)
- Guidance regarding racing surface, including surface type and elevation changes.
- Printable race-day tag sample
- Video demonstration criteria (as necessary)
- Approved sensor list
- Vehicle chassis specification (weight and size)
- E-Stop and safety guidelines
- Racing rules
- Final event procedures

Interpretation of the rules will be adjudicated by the organizing committee and decisions will be final. We reserve the right to disqualify teams which exhibit non-competitive behavior deemed to be in violation of the honor code, not necessarily covered within the scope of the rules.

4.2 Vision

The *intellectual merit* of the F1/10 encompasses the development of computationally efficient and effective, planning and perception algorithms which enable *safe* autonomy. The *broader impacts* of the F1/10 competition include hands on learning and development of practical tools for the analysis of cyberphysical-systems.

4.3 Overview

The F1/10 competition is an education, research, and development program with the goal creating autonomy that goes beyond simple safety (*ie conserva-tive algorithms*). As autonomous vehicles leave research labs and drive onto our roads, we need new solutions which are *better than human drivers*– exhibiting lightning quick reflexes, expert tactics, and scenario understanding. The F1/10 competition offers researchers an opportunity to test such concepts in a cost effective and safe manner by competing against other state-of-the-art driving algorithms using small, cost-effective, unmanned vehicles.

4.4 Objectives

Each competitor will:

- Construct a 1/10th scale autonomous vehicle within the constraints described herein
- Provide a robust and safe mechanism for bringing an errant vehicle to a stop as described in this document
- Demonstrate teleoperation of the vehicle in order to verify basic functionality
- Persistently complete a mission defined by the safe traversal of ordered series of checkpoints with the objective of minimizing completion time.
- Interpret static obstacles within the environment in order to maintain collision free progress
- Exhibit context dependent speed and angular velocity control in a static environment.
- Interpret dynamic obstacles within the race environment in order to enable predictive controls and planning, such as is necessary to ensure collision free progress.
- Exhibit context dependent speed and angular velocity control in a dynamic environment
- Navigate in areas where sensors may not provide map-based localization (*ie LiDAR range is insufficient*)
- Accomplish these goals using a low power embedded processor specified by the organizers

Awards

5.1 Award Terms

The organizing committee will provide a modest cash prize and development hardware to winning teams. We are considering that such awards will be predicated on the following criteria:

- In order to collect a monetary award the winning team must present their approach and release their source code under the GPL license.
- In order to collect a hardware award the winning team must present their approach, but may withhold their source code.
- A winning team may withhold their approach and source code if they forgo monetary and hardware awards. *This outcome is discouraged*.

Eligibility

6.1 Eligibility

In order for a team to be eligible the following criterion must be met:

- The team must have at least 5 students
- At least one unique member from each team must be present
- Each team must have a unique vehicle *ie a research lab may not field six teams with one car*
- Students may be a member of multiple teams
- Universities fielding multiple teams will be placed in the same bracket during the qualification round in order to discourage conceptually similar approaches to the competition

6.2 Team Registration and Qualification

To Qualify for the competition, a team must:

- Respond to our request for interest so we have a rough count of the number of competitors.
- Register for the competition at f1tenth.org As soon as a team registers, the organizers will send out the assembly kit to the team in question. The registering team should be confident of its participation in the competition as a fair amount of resources will be spent in assembling and delivering the assembly kit.
- Every team is required to present a video by 8/10/2016 demonstrating basic *keyboard control* of the car. Failure to present this video to the organizers will lead to disqualification from the race. These requirements are minimal and ensure that all teams have an opportunity to get the meat of the work, *innovative algorithms*, or seek assistance

Vehicle Requirements

7.1 Safety Requirements

In order to ensure the safety of competitors and minimize incidental hardware damage:

- Each car must have an emergency disconnect switch (*affectionately: the big red button*) that removes all power from the main power system (i.e. the batteries that supply power to the drive motor) at a point in the circuit as close as practical to the power supply. This switch must be rated for a breaking current of at least 50 percent greater than the power limiting fuse rating.
- Each car must have the ability to switch to *Manual Mode* directly from *Autonomous Mode* at any time using only the Traxxas Remote.

7.2 Autonomy and Communication

The F1/10 competition is for *fully autonomous*, *self-contained* vehicles, as such:

- No transmitters or communication beacons (other than WiFi and race infrastructure related communication) of any kind are allowed. Everything necessary for the vehicle's navigation/processing/sensing must be attached and part of the vehicle itself.
- Cooperation amongst vehicles is strictly prohibited. Two teams cannot collude to manipulate race outcomes or share computational resources.
- Competitors may not modify the course in any way. Including but not limited to covering of reflective surfaces or the addition of markers/beacons.

7.3 Physical Characteristics

As in Formula-based racing the physical dimensions and appearance of vehicles is restricted:

- The vehicle shall fit a standardized rear profile. The organizers will provide a *race license plate* (RCL) for each competitor following successful inspection. The RCL will include infrastructure for lap timing and an April-Tag for vehicle identification. Sample tags will be available to download from the race organizers, and *their use for dynamic obstacle state estimation is encouraged.*
- The space indicated for the AprilTag must be reserved for the AprilTag only. The non-Traxxas part of the car's chassis could be anything that the team desires as long as the car, from the back.
- A chassis cannot include any part/mechanism that can be solely responsible for inflicting damage or deceiving another car.

- Every car chassis has to be designed to simply support the sensor suite in the desired configuration.
- A chassis (or any other part of the vehicle) cannot be designed to deceive other vehicle's sensor systems. For example one cannot add lights or paint in order to affect the operation of LiDAR and camera systems. Such modifications will be reviewed at the discretion of the advisory committee. Please refer to the *Honor Code* if you are unsure of a particular approach.

In order to check basic requirements are met the organizing team will test each competitors vehicle during registration via two procedures:

- The vehicle must fit completely inside a bounding box with inner dimensions HxWxL
- The vehicle must weigh at least x lbs and at most y lbs

7.4 Hardware

- Sensor Configuration: Each team must choose a sensor configuration *only* from this subset of sensors. Alternate sensors will not be considered, the purpose of this competition is the development of driving algorithms. Please see the bill of materials for part numbers and ordering information.
 - Camera (*at most 2*): ZED, Structure Sensor, Pointgrey, Minoru, Webcam
 - LIDAR (at most 1): Hokuyo 10LX, RP Lidar, Hokuyo 04LX
 - IMU (at most 1):Memsic IMU440CA-200, Razor
 - WIFI (*exactly 1*): Ubiquiti Picostation M2
- · Computing: Each car must use only:
 - Planning and Perception (exactly 1): NVIDIA Jetson TK1
 - Control (*exactly 1*): MBed or Teensy
- Chassis and Vehicle:
 - Vehicle (*exactly 1*): Traxxas Rally 1/10
 - Suspension (*swappable*): Any
 - Axle Conversion (*swappable*): Stock, ST Racing Concepts ST3654-17S CNC Machined Aluminum 17mm Hex Conversion
 - Tires (*swappable*): Stock, Duratrax Bandito Buggy Tire C2 Mounted White (1/8 Scale)

Sporting Regulations and Honor Code

8.1 Sporting Regulations

There are strict rules governing on-track behavior the organizing committee will have the power to impose various penalties on a driver committing an offense during a race or practice session. Offenses include:

- Jumping the start of the race
- Causing an avoidable accident
- Unfairly blocking another driver
- Impeding another driver while being lapped
- Driving in the opposite direction to the race (with intent) unless this is absolutely necessary in order to move the car from a dangerous position.
- Driving unnecessarily slowly, erratically or in a manner which could be deemed potentially dangerous to other drivers or any other person
- Drivers must make every reasonable effort to use the track at all times and may not deliberately leave the track without a justifiable reason.
- More than one change of direction to defend a position is not permitted. If a driver has moved off the racing line while defending their position, they may move back but must ensure there is at least one car's width between their own car and the edge of the track.
- Any driver defending his position on a straight, and before any braking area, may use the full width of the track during his first move, provided no significant portion of the car attempting to pass is alongside his. Whilst defending in this way the driver may not leave the track without justifiable reason.
- Maneuvers liable to hinder other drivers, such as deliberate crowding of a car beyond the edge of the track or any other abnormal change of direction, are not permitted.
- If blame is not immediately clear, or if an incident involves multiple drivers, it will normally be investigated after the session or race
- The most common penalties stewards issue are a drive-through penalty, a five-second time penalty and a ten-second time penalty
- In extreme cases stewards may choose to enforce tougher penalties. They can drop a driver any number of grid positions at the next Grand Prix; impose time penalties; reprimand a driver; exclude a driver from the results; or suspend a driver from the next race

8.2 Honor Code

In homage to other successful honor codes we offer the following simple guideline: *No member of the F1/10 community shall take unfair advantage of any other member of the F1/10 community*. Examples of unfair behavior include: teleoperation, exploitation of the rules *ie skirting mission requirements via a loophole*, or purposely disabling another robot. First and foremost, the competition is an opportunity for learning, research, and fun. This code should be self-evident.

8.3 Collisions and penalties

- Collisions between the vehicles may occur during race. A robot will be considered *at fault* in a collision if it hits another robot from behind, or it appears to have lost control and hits another vehicle. The judges will decide if the vehicle at fault will be allowed to continue. If the vehicle is deemed unfit to continue, the team will be counted as not finishing (DNF). If the vehicle is allowed to finish time will be recorded and penalties will be applied.
- A team purposely accruing time penalties *is in violation of the Honor Code*.
- Collisions will be heavily penalized in order to avoid the scenario where *the team with the worst collision avoidance won*. This is a race which is designed to test the *intelligence* of the vehicle.
- In the event that the 2 cars simultaneously collide with each other during a race, and the collision is deemed a *no-fault* collision by the referees, the race will be restarted. Such a procedure will take place no more than 3 times to determine a clear winner. If a clear winner cannot still be determined, the cars will be pitted against remaining cars in the group/shuffled into groups. If however, these cars display a similar pattern in other races, they will be disqualified.
- All restarts will occur from a common restart point and the signal sent from the organizers will indicate the node on the RNDF from which the restart occurs.
- All vehicles will be required to stop safely via the Traxxas controller at the end of the the race at the end of each race.
- In the event of a car not starting in the race; the car will be kept on standby until all the races in its group are completed. Cars that fail to start again will be declared unfit to race.
- Cars which fail to start in head to head rounds will be given 2 further opportunities.

8.4 Referees

The races will be referred by members of the race organization committee. Their word/judgment regarding events in the races they oversee is final.

9.1 Scenario

Please refer to appendix to see the layout of the final race track.

- The race track will be located at Carnegie Mellon University in Pittsburgh. Although the final layout has not yet been selected, teams may expect that racing will occur in hallways roughly 2-5 meters wide. Furthermore, teams may expect multiple turns (in both directions!), uneven walls, varying lighting conditions, and in later rounds another autonomous competitor.
- Maximum and minimum width of the course: 4 meters. Minimum centerline radius turn on the course: 3 meters details will be provided in the RNDF and ROSBAG data.
- A ROSBAG containing sensor data collected by the organizers F1/10 car of a superset of the course will be provided by 8/10/2016
- We note that such data will be a superset of possible course layouts in order to discourage *railroad-like* approaches where the majority of planning is done offline (rewarding teams with better access to the facilities and more expensive ancillary equipment).

9.2 Data Recording

- We emphasize that we will provide all teams with detailed course data provided at by 8/10/2016 with a README that describes the various data.
- However, each team is free to visit the venue any number of times after it is open to the public, for any sort of data collection or calibration that they might think is necessary. *In the spirit of innovation we encourage teams to share data and simulation platforms which they might develop*.

9.3 Wireless Network

• During the actual race itself, every team will be required to connect to a common wireless network provided by the organizers.

Organization of the Competition

10.1 Competition Overview

- The race will comprise of time trials and the car with the fastest time wins.
- Participating teams will be split into pools according to their lap times in the qualifying lap.
- Cars in each pool will compete against every other car in that pool and the top X cars will qualify for the next rounds
- The final round will feature head to head racing between the top cars from the different pools
- The winning car will be the car with most wins
- This iteration of the competition will not support in any race, more than 2 cars. However, the participants of the competition are more than welcome to race amongst themselves on the race track.

10.2 Starting

- The participants will be expected to connect to a common wireless network. It is the responsibility of the team to make sure they have been assigned unique IPs and test the connection to the wireless network
- The organizers will send a trigger signal that is meant to start the race. To ensure that all cars receive the signal at the same time, it is required for all cars to 'subscribe' to the topic 'ReadySetGo' that will be 'published' on the common wireless network.
- As soon as a boolean 'True' is received on this topic, the competing cars are expected to begin the race. the dataType that is expected on the the 'ReadySetGo' topic is Boolean. Teams should verify that their starting protocol works as expected in their run of the Qualifying lap.

10.3 Qualifying Lap

- Every team must perform at least one qualification lap on the race track before it actually takes part in any race. The lap timing of the car in this qualifying lap will decide the pool which it is assigned.
- On the qualifying laps, it is each team's responsibility to ensure that the following modules are inspected:
 - Starting Protocol
 - Kill switch
 - Size limit
- Upon successful tech inspection teams will be issued a transponder. The IR transponder is used to record each vehicle's lap time. The team is responsible to ensure that the transponder is working

10.4 Schedule

10.5 Competition Schedule

The competition will be split over 2 days. The first day will involve:

- Technical Inspection: This will be conducted on a first come, first serve basis.
- Qualifying Lap: The teams that are cleared by the technical inspection team are expected to proceed to complete their qualifying laps. Details regarding the importance of the qualifying lap are mentioned in the 'Race Organization' section.
- All qualifying laps and technical inspection of cars are expected to be completed on the day before the competition.
- The cars will be segregated into pools(sizes of which will depend on number of entrants) according to their qualifying lap times. These groups will be announced by the end of the day

The second day of the competition will be the race day.

- No new teams will be allowed to register on this day.
- Each car will be pitted against every other car in its own pool. The top cars will move on to the next round. Higher the number of wins, better ranked is the car.
- The winner will be expected to talk about the algorithms used in their car in order to collect prizes. If the team has created videos, scenarios that showcase the result of their algorithm against other generic algorithms, they are expected to show/demonstrate this material after the award ceremony.
- All teams are more than welcome to race more than 2 cars on the tracks after the events of the day have been completed. This of course will be outside the F1/10 Competition 2016 and the race organizers will have no jurisdiction/responsibility for the races held after the conclusion of the competition.