# EML4551 - Senior Design
# Team #303:1/10 F1 Autonomous Car
# Concept Generation

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## I. Concept Generation:

The concept generation process benefits from free and creative thinking, and considering all possible solutions to the problem at hand. This projects mission is to design and build an autonomous 1/10th scale vehicle. There are numerous methods of accomplishing this task, and no shortage of efficient configurations. However, per the project scope implemented, the design and components of this particular project must abide by the rules and guidelines presented in the F 1/10 Autonomous Racing Competition Rule Book. WIth that being said, the first step in concept selection is to categorize different concepts by whether or not they do, in fact, abide.

Selection 1: F1/10 Rules and Guidelines Compliance

| | Yes | No | | Yes | No |
|---|---|---|---|---|---|
| **Locomotion** | | | **Sensors** | | |
| Tracks | | X | Stereoscopic Camera | X | |
| Propellers | | X | LIDAR | X | |
| Wheels | X | | IR Sensor | | X |
| Legs | | X | Webcam | X | |
| Castors | | X | Front/Back camera | X | |
| **Motor** | | | **Chassis** | | |
| Titan® 12-Turn 550 motor | X | | Traxxas Rally 1/10 Race Car | X | |
| Traxxas Velineon 1/10 brushless | X | | 3D Printed ABS Plastic | X | |
| Castle Creations 1/10 X SCT | X | | 3D Printed Carbon Fiber | X | |
| Steam Engine | X | | Aluminum Frame - Water Jet | X | |
| Air Turbine | X | | **Steering** | | |
| **Tires** | | | Linear actuator | X | |
| Rubber (Traxxas Stock) | X | | Rack and Pinion | X | |
| Plastic | | X | Stepper Motor | X | |
| Air Filled | X | | Skid Steering | X | |
| Solid | | X | Baja Steering | X | |

| | | | | | |
|---|---|---|---|---|---|
| Omnidirectional | | X | Mecanum Steering | X | |
| Big Rear/ Small Front | X | | **Body** | | |
| Same Size | X | | Winnebago | X | |
| Duratrax Bandito Buggy Tire | X | | No Body | X | |
| 1/10 Tamiya F1 Tire | X | | F1 Car Body | X | |

| | Yes | No | | Yes | No |
|---|---|---|---|---|---|
| **Microprocessor** | | | **Battery** | | |
| Teensy 3.2 or 3.1 | X | | LiPO | X | |
| Mbed | X | | AA | X | |
| Raspberry Pi | | X | NiMH | X | |
| Arduino | | X | Li-ion | X | |
| Ti MSP | | X | AAA | X | |
| **External Controller** | | | **Braking** | | |
| Xbox Controller | X | | Motor Braking | X | |
| PS4 Controller | X | | Brake Pads | X | |
| IPhone | X | | Air Jet | | X |
| Standard RC Car Controller | X | | Bike Brakes | X | |
| **Weight Distribution** | | | **IMU** | | |
| Front Axle | X | | SparkFun 9DoF Razor IMU M0 | X | |
| Rear Axle | X | | 3DM-GX3® - 25 | X | |
| Center | X | | | | |
| **Motor Controller** | | | **Power Distribution** | | |
| FOC box speed controller | X | | Designed | X | |
| Traxxas VXL3m ESC | X | | Teensy 3.1 | X | |

| **Wheel Base** | | | Teensy 3.2 | X | |
|---|---|---|---|---|---|
| 10.0 Inches (256mm) | X | | | | |
| 11.0 Inches (281mm) | X | | | | |
| 13.0 Inches (303mm) | X | | | | |
| 15.0 Inches (381mm) | | X | | | |

## II. Possible Configurations

**Concept 1:**

One design we generated utilizes skid steering for our steering system in combination with traxxas rubber wheels and motor braking. The pros to this system are that it makes turning 90 degree corners very easy, reduces the effect of weight distribution on our system and could eliminate the need to spend money on more complex steering and braking systems. The cons however, outweigh the pros to this design. This system makes it more difficult to keep track of where our system is autonomously and could reduce the speed at which our system is able to complete the course. Autonomous navigation accuracy and speed of completion are the two cornerstones of the Formula 1/10th competition and for that reason we believe we should not use this concept combination and focus on finding a better combination for navigation and speed.

**Concept 2:**

This design utilizes a rack and pinion steering system in combination with a stepper motor, Traxxas rubber wheels and motor braking. This system is a suitable design because it allows us to navigate the course quickly, reduces the need to buy and program a more complex braking system and makes it relatively easy to keep track of where our system is autonomously. In, addition, all components used in this concept abide by the F1/10th rulebook. The cons to this system are that it is required to purchase and program another motor (of a different type) in order to utilize our steering system. Furthermore, our steering system is capable of making too harsh of corrections when trying to find the center of the lane while navigating autonomously, which could cause extreme oscillation of our vehicle in the lane. However, this issue could be solved by programming a suitable PID controller, which could make the over corrected error go to zero over time. For these reasons, we believe this concept is one of our top choices for our F1/10 autonomous vehicle design.

**Concept 3:**

One design utilizes a front and back camera design, using stereoscopic cameras in order to detect the depth of the surroundings. The pros for this design are that it allows the

vehicle to collect more information from its surroundings as well as eliminating the need to purchase other components. With a camera in the front and the back, the vehicle would be capable of moving in reverse safely as well as being able to tell how fast the vehicle is moving based on the rate of distance change. This would eliminate the need for the purchase of an IMU as well as the need for a LIDAR sensor since the vehicle would now have more complete information about its environment. Since the LIDAR sensor is the most costly potential item in the budget, using this design would greatly relieve the budget and allow room for unexpected expenses. The cons to this design are that this concept would still not provide as accurate results as the LIDAR, which has a 360° field of view and accuracy within millimeters. The front and back camera concept would also be more difficult to integrate in ROS whereas the LIDAR has many packages already made to assist with integration. The wheel base will be set at 10in to allow for better cornering efficiency. The pros of having a shorter wheelbase transfers to higher cornering speeds. For motor and steering communication a embed microcontroller will be used. The embed micro controller will be controlled using two options: user control from an xbox controller via bluetooth module and the Nvidia Jetson tx2 for autonomous control. The entire Traxxas rally car will be the base for our autonomous vehicle. This will allow more time to be used developing the coding algorithms used to drive the car autonomously . Since most of the development needs to be in those areas for this project design.

**Concept 4:**

This concept utilizes the Traxxas brushless motor with a 10in wheel base and a custom designed 3D printed carbon fiber chassis. The main idea of the design is based of the assumption that the project will not be going to the competition this year, but will be taken up by future students as a continuation project and taken to competition. With the most expensive potential component being the LIDAR sensor, if the LIDAR is taken out of the build there is a large portion of the budget unallocated. Instead of purchasing an inferior LIDAR in order for it to fit in the budget, the unallocated funds can be used in order to purchase higher quality components for the other aspects of the vehicle, leaving the only component that needs to be purchased by the continuation team the LIDAR itself, making the project affordable and giving it a real shot to perform well in competition. The 10in wheel base would allow for the vehicle to take sharper turns allowing it to conserve speed and complete the course faster. The brushless motor provides more than enough power for the vehicle to surpass its targets, allowing for the possibility for superior performance. The custom carbon fiber chassis gives the vehicle its most aerodynamic build while allowing the team to custom build the chassis around the components that will be used, providing a better weight distribution and use of the weight on the vehicle. The downfall of this concept is that it makes the initial autonomy of the vehicle harder to achieve and less accurate without the LIDAR and with all the top of the line components, if the project is not continued, the vehicle would be over-engineered for its purpose and be an overall waste of the funds allocated.

**Concept 5:**

For this concept high performance would be driving factor for the autonomous f1 car as well as pleasing our Space Ball fan customer base. To give our vehicle a performance edge the use of the Castle creations 1/10 XST motor would give the vehicle acceleration faster than almost any other motor of this scale. The motor would be mounted with the FOC box speed

controller. The chassis used would be the Traxxas 1/10 rally car chassis because of its durability and light plastic design. For wheels the Tamiya's high grip pro 1/10 scale F1 tires give us that efficiency in off the line acceleration , motion transference and high cornering speed abilities. The wheel base would be set at 11 inches apart front to back . This will give less brake dive on entering a corner while maintaining a short wheel base for greater cornering agility .For the steering as single servo with rack and pinion would be used for simple and efficient steering inputs. To make sure our vehicle has the accurate detection of its environment a front mounted LIDAR would be installed accompanied by a ZEDD camera for optical detection of corners and tracklines to give a diversity of detection type abilities. The sensors data will all be processed through our onboard computer : Jetson TX2 with its high processing ability it will be able to make the decisions needed for our Autonomous vehicle to track corner distances speed and turning pitch for entering and leaving corners. From the Jetson our motor controls will be sent into a 36 Bit Teensy 3.6 micro controller. The 36 bit allows for greater resolution of output data from the jetson to the microcontroller in order to relay those instructions to the motor and servo . A PID controller will be installed to get accurate steering a pitch data to reduce steering confusion and over aching input loops causing which can cause a crash. For the weight distribution the batter will be mid mounted and low in the chassis for better center of gravity. The boards will be rear axle biased by 60% to give better grip to the rear tires for higher acceleration possibilities. The batter will be a 7.2v high density Li-ion poly-cell with a discharge rate of 6 amps at 1 C to give at least 15 mins of run time and enough energy density to hit over 40 miles an hour . To top off the vehicle a removable 1/10 replica Spaceballs winnebago will be mounted over the chassis. It would be made from abs plastic and give aesthetic appeal to the autonomous vehicle. The body will also give added crash protection. For user control a bluetooth module with a playstation controller would be installed into the microcontroller to switch control from the Jetson to the user. This option would be well with in the 2000$ budget given for this project and solid platform for further innovation.

**Concept 6:**

Another viable combination would be to use Buggy Tires with the standard Traxxas Rally Car chassis, motor, and motor controller. The power used to drive the motor would come from an 6000mAh Li-PO pack with a current limiter at 7.2 volts . A linear Actuator would be connected to the motor controller as well to control the right and left motion of the front tires. This would give it more precise steering capability than a rack and pinion and better turning response than skid steering. In order to keep with the wishes of our sponsor, a winnebago themed body would be installed. It is possible to use IR sensors on the front and back to determine distance and velocity, while using a LIDAR to map surroundings in order to avoid obstacles. Small disc brakes could control braking very accurately and would allow for simultaneous acceleration and braking through cornering. A playstation or xbox controller to use when in user control mode would be able to control steering, braking, and acceleration at the same time, which would benefit this configuration.

## III. Other Concepts:

This section contains concepts that do not meet the F1/10 rules and regulations but still have functional benefits in achieving the project goals.

**Concept 1:**

For this design the vehicle would have skid steering and tracks with steam engine to power the locomotion. The advantage of having skid steering on a vehicle is it gives it the ability to turn within its own length. Having tracks would eliminate the need for a steering component freeing up some of the weight on the vehicle. A track is very long piece of high friction material usually made out of rubber and would give a greater contact patch for our vehicle then tires would. This could allow it to corner faster. For the propulsion unit a steam engine would be used to power the tracks. A steam engine has many advantages. It can run for as long as it has water in it boiler and fuel gel in its tray. This gives the possibilities for many runs through the day vs a battery which needs to be charged. Steam engines are cheap due to there uncomplex design which can reduce the cost of our vehicle. As for the sensors on the vehicle a front mounted IR sensor an emitter would be mounted to the front along with a zedd camera . The board would be the Jetson TX2 for processing and decision making. For the controls of the treads the tx2 will be linked to a Tinsy microcontroller. The Tinsy that would controll 2 friction clamps on the boilers output shafts which would be differential. For the wireless a dongle would be attached to the Jetson and an xbox controller would be used for user control.

**Concept 2:**

One intriguing possibility for an autonomous vehicle is to use a combination of a wind turbine engine attached to a stepper motor on a vehicle with omni-directional vehicles. In addition to this it would use a stereoscopic camera and LIDAR to sense its surroundings. In order for this to work efficiently it would have to have its weight centered. This vehicle would be able to incredibly rapid and accurate changes in direction due to omnidirectional wheels. However, this design also has its limitations. Once moving, it would be hard to decelerate or stop unless a second turbine in the opposite direction were used to control speed. This configuration would also need to utilize a custom designed chassis in order to mount the necessary equipment. With a turbine the power requirements are going to be high, thus multiple batteries would be needed. Also, the control system for this system would need to be very accurate as the vector changes would be almost instantaneous. This option is most likely well out of the budget, and incredibly complex, but would be very unique and interesting.

**Concept 3:**

Concept 3 will introduce castors for wheels having a wheel almost like a office chair wheel that can free spin is an option we considered with using a motor to turn the wheels a certain angle to navigate turns quicker along with a path. While the castor wheels might not be the best to pair a motor for forward movement, due to the actual structure of the wheels not having a point to connect to be driven by a motor; an air turbine will be connected to it and will give forward thrust to the device and all four wheels will turn in accordance to each other. The

vehicle will be using lidar and a  Zed stereoscopic camera to navigate around the track and be able to gather outside inputs to and give the data to the Nvidia and from there the nvidia will give directions to the air turbine and the wheel motors to give an angle to all the wheels to tell it to continue to go straight or to turn all wheels a certain degree to navigate a turn. The turbine steering driver will be outputted from a Raspberry PI which is a high function mini computer that can perform the same functions as any ARM or AVR microcontroller. But due to the F1/10 autonomous vehicle rule book it is a banned controller.  Before we go on with more details on chassis build and integration of other parts. Decisions were made to scratch this idea for it does not fit into the regulations of the F1/10 constraints of the rule book but also to have an autonomous car that will not send direct power to the wheels to provide movement to the car, is not a route we want to take for it will add extra layers to this build that are useless and make the build that much harder.