Self-Drive Annual Competition

Competition Dates: June 1-4, 2018

Oakland University

Rochester, Michigan

October 29, 2017 Version

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I. COMPETITION INFORMATION

I.1 TEAM ENTRIES

Teams may be comprised of undergraduate and graduate students, and must be supervised by at least one faculty advisor. Interdisciplinary (Electrical, computer, mechanical, systems engineering, etc.) teams are encouraged. Students must staff each team. Only the student component of each team will be eligible for the awards. Faculty supervisor will certify that all team members are bonafide students on application form and will also provide contact information (telephone number and e-mail address) for him and the student team leader on the form. Business/Non-Engineering students are encouraged to join teams to promote marketing, sponsorships, and other program management functions. For a student to be eligible to compete as a team member, they are required to have attended at least one semester of school as a registered student between June 2017 and June 2018.

Team sponsors are encouraged. Sponsors' participation will be limited to vehicle donation, sensor(s), hardware donation and/or funding support. Sponsors logos may be placed on the vehicle and may be displayed inside of the team maintenance area. Teams should encourage sponsor attendance at the Self-Drive.
Schools are encouraged to have more than one entry; but are limited to a maximum of three per school, and each vehicle must have a separate team of students and a design report in a defined format. See design rules for format. Each entry must be based on a different software and must be documented by a separate application form and design report, submitted in accordance with all deadlines. All entries must have a team name and each application form must be TYPED and accompanied with a $300.00 non-refundable registration fee made payable to Oakland University. Intention to compete must be received no later than February 28, 2018, by mailing your application form to:

Prof Ka C Cheok
446 EC SECS-ECE Dept.
Oakland University
Rochester, MI 48309-4478
Also PDF version of the registration must be e-mailed along with any questions to
IGVCquestions@yahoo.com.

International Teams Note
International (non-United States Teams) requiring Visa invitation letters must limit team participation to a maximum of twelve students and two faculty. Changes and additions to original submission entry are not permitted after March 30th, 2018.

I.2 VEHICLE CONFIGURATION

1.2.1 The Self-Drive competition is designed for FMVSS-500/EU Quadricycle type electrical vehicles (EV) equipped with automotive drive-by-wire systems. The primary Side by Side 2-Person EV vehicles are John Deere, Cub Cadet, Honda, Kawasaki, Arctic Cat, Polaris, Yamaha, Kubota.

Figure 1: FMVSS-500 Vehicle Example - Polaris GEM e2

Teams may build their own drive-by-wire kits or use off the shelf drive-by-wire solutions sold by various companies such as TORC Robotics, Dataspeed, AutonomousStuff and Clearpath Robotics.

1.2.2 Design Specifications. Entries must conform to the following specifications :

- Design: Side by Side 2-person four-wheel ground vehicle
- Type of Vehicle: Electrical, no gas
- Maximum Length: 115 in (as reference, Polaris Gem e2 is 103 in, Renault Twizy is 91 in)
- Maximum Width: 60 in (as reference, Polaris Gem e2 is 55.5 in, Renault Twizy is 47 in)
- Maximum Height: 75 in (as reference, Polaris Gem e2 is 73 in, Renault Twizy is 57 in)
- Maximum Weight: 1500 lbs
- Maximum Speed: Speed is limited to 5 mph in 2018 as safety features of Self-Drive course are developed.
- Mechanical E-stop Location: The E-Stop button must be a push to stop, red in color and a minimum of one inch in diameter. It must be easily identifiable and activate safely, even if the vehicle is moving. It must be located inside the cabin, as well as outside on sides and rear of vehicle. Vehicle E-Stops must be hardware based and not controlled through software. Activating the E-Stop must bring the vehicle to a quick and complete stop.
- Wireless E-Stop: The wireless E-Stop must be effective for a minimum of 100 feet. Vehicle E-stops must be hardware based and not controlled through software. Activating the E-Stop must bring the vehicle to a quick and complete stop. During the competition performance events the wireless E-stop will be held by the Judges.
- Safety Light: the vehicle must have easily identified brake lights red in color and reverse lights yellow in color. A strobe light must be mounted on roof and activated when the vehicle is under robotic control.

I.3 QUALIFICATION

On the first day of competition all vehicles must pass Qualification to receive standard award money in the Self-Drive Design Competition and compete in Self-Drive performance events. During the Qualification the vehicle must be put in autonomous mode to verify the mechanical and wireless E-Stops and to verify minimum speed, lane following, obstacle avoidance and waypoint navigation. The vehicle software cannot be reconfigured for waypoint navigation qualification, and must be integrated into the

original autonomous software. For the maximum speed run, the vehicle may be in autonomous mode or joystick/remote controlled. Judges will not qualify vehicles that fail to meet these requirements.

Teams may fine tune their vehicles and resubmit for Qualification. There is no penalty for not qualifying the first time. Vehicles that are judged to be unsafe will not be allowed to compete. In the event of any conflict, the judges' decision will be final.

To complete Qualification the vehicle must pass or perform all of the following criteria:

- **Length**: The vehicle will be measured to ensure that length does not exceed specifications.
- **Width**: The vehicle will be measured to ensure that width does not exceed specifications.
- **Height**: The vehicle will be measured to ensure that height does not exceed specifications.
- Weight: The vehicle weight shall not exceed 1500 lb.
- **Mechanical E-stop**: The mechanical E-stop will be checked for locations:
    - inside the vehicle at the instrument panel.
    - outside the vehicle located on two sides and rear.
- **Wireless E-Stop**: The wireless E-Stop will be checked to ensure that it is effective for a minimum of 100 feet.
- **Passenger(s) Safety:** seat belts and helmets are required.
- **Safety Light**:
    - The Safety Light should be located on the roof of the vehicle.
    - The Safety Light is on and solid when vehicle is powered up or comes out from autonomous mode.
    - The Safety Light is flashing when vehicle is running in autonomous mode.
- **Speed**:
    - minimum speed 1 mile per hour.
    - maximum speed 5 miles per hour.
- **Lane Following**: The vehicle must demonstrate that it can detect and follow lanes.
- **Obstacle Avoidance**: The vehicle must demonstrate that it can detect and avoid obstacles.
- **Waypoint Navigation**: Vehicle must prove it can find a path to a single two meter navigation waypoint by navigating around an obstacle.

During the Qualification the vehicle must be put in autonomous mode to verify the mechanical and wireless E -stops and to verify minimum speed, lane following, obstacle avoidance and waypoint navigation. The vehicle software cannot be reconfigured for waypoint navigation qualification. It must be integrated into the original autonomous software. For the max speed run the vehicle may be in autonomous mode or joystick/remote controlled. Judges will not qualify vehicles that fail to meet these requirements. Teams may fine tune their vehicles and resubmit for Qualification. There is no penalty for not qualifying the first time. Vehicles that are judged to be unsafe will not be allowed to compete. In the event of any conflict, the judges' decision will be final.

Please see section VI.1. Appendix A: Qualification Testing for further information.

I.4 INDEMNIFICATION AND INSURANCE

Teams will be required to submit an Application Form prior to February 28, 2017. The Application Form can be downloaded from www.igvc.org.

Each Team's sponsoring institution will also be required to submit a Certificate of Insurance at the time the Application Form is submitted. The certificate is to show commercial general liability coverage in an amount not less than $1 million. In addition, each individual participating at the competition will be

required to sign a Waiver of Claims when they arrive at site and before they can participate in the Self-Drive events.

NOTE: The Self-Drive Committee and Officials will try to adhere to the above official competition details, rules and format as much as possible. However, it reserves the right to change or modify the competition where deemed necessary for preserving fairness of the competition. Modifications, if any, will be announced prior to the competition as early as possible.

II SELF-DRIVE CHALLENGE COMPETITION

II.1 OBJECTIVE

A fully autonomous unmanned ground robotic vehicle must negotiate around an outdoor obstacle course under a prescribed time while maintaining a minimum of speed of one mph over a section and a maximum speed limit of five mph, remaining within the lane, and avoiding the obstacles on the course. Judges will rank the entries that complete the course based on shortest adjusted time taken. In the event that a vehicle does not finish the course, the judges will rank the entry based on longest adjusted distance traveled. Adjusted time and distance are the net scores given by judges after taking penalties, incurred from obstacle collisions and boundary crossings, into consideration.

II.2 VEHICLE CONTROL

Vehicles must be unmanned and autonomous. They must compete based on their ability to perceive the course environment and avoid obstacles. Vehicles cannot be remotely controlled by a human operator during competition. All computational power, sensing and control equipment must be carried on board the vehicle. No base stations allowed for positioning accuracy is allowed. Teams are encouraged to map the course and use that information to improve their performance on the course.

II.3 SELF-DRIVE COURSE

Figure 2: Self-Drive Course Location, Oakland University

https://www.openstreetmap.org/search?query=42.6738805%2C%20-83.198877#map=19/42.67388/-83.19888

II.4 SELF-DRIVE COMPETITION RULES AND PROCEDURES

• The competition will take place in the event of light rain or drizzle but not in heavy rain or lightning.

• Each qualified team will have up to two runs (time permitting) in each of three heats.

• Starting order will be based on order of qualification. Teams will setup on-deck in that order. Failure to be on-deck will place you at the end of the order for the run and may forfeit you final (second) run in a heat based on heat time completion.

• No team participant is allowed on the course before the team's first run, and only one student team member is allowed on the course during a run. This shall in no case be the faculty advisor.

• At the designated on-deck time, the competing team will be asked to prepare their vehicle for an attempt. On-deck teams start in the order they arrive in the starting area unless they give way to another team.

• A Starting Official will call teams to the starting line. The Starting Official's direction is final. The Starting Officials may alter the order to enhance the competition flow of entries; e.g. slower vehicles may be grouped together to allow successive running of two vehicles on the course simultaneously.

• A team will have one minute to prepare the vehicle at the starting line and point out to the Competition Judges the buttons to start and stop the vehicle.

• The Competition Judge will start the vehicle by a one touch motion; i.e. pushing a remote control button, hitting the enter key of a keyboard, a left mouse click, lifting the e-stop up, flipping a toggle switch, etc. The Competition Judge will also carry the wireless E-Stop.

• An attempt will be declared valid when the Competition Judge initiates the start signal at the designated competing time.

An attempt will continue until one of the following occurs:

- The vehicle finishes the course.
- The vehicle was E-Stopped by a judge's call.
- The team E-Stops the vehicle.
- Six minutes have passed after the vehicle run has started for the Self-Drive Course.
- The vehicle has not started after one minute after moving to the start line or at the judges' discretion.

• Time for each heat will be strictly observed.

• Tactile sensors will not be allowed.

• Based on the above allowable run times, if the vehicle has not completed the course in the 10 minute time period, the attempt will be ended by a judge's choice E-stop, with no additional penalty for that run.

• Each vehicle must navigate the course by remaining inside the course boundaries and navigating around course obstacles. Crossing internal lines is not allowed and will be judged an E-Stop end of run with penalty.

• For the following Traffic Violations, the appropriate ticket will be issued and deducted from the overall distance or time score. Refer to section II.5 Traffic Violation Laws.

• Hands should be visible and off the vehicle's steering wheel at all times during run time.

II.5 TRAFFIC VIOLATION LAWS

	Traffic Violations	Ticket Value	E-Stop	Measurement
1	Hold-up Traffic	End of Run	Yes	>60 secs. to 88 ft
2	Leave the Course/Scene	- 10 Feet	Yes	Yes
3	Crash/Obstacle Displacement	- 10 Feet	Yes	Yes
4	Careless Driving	- 5 Feet	No	No
5	Sideswipe/Obstacle Touch	- 5 Feet	No	No
6	Student's Choice E-Stop	- 10 Feet	Yes	Yes
7	Judge's Choice E-Stop	- 0 Feet	Yes	Yes
8	Blocking Traffic	- 5 Feet	Yes	Yes
9	Too slow, did not average 1 mph	Disqualified	No	No

Table 1: Traffic Violation Laws

• **Hold-up traffic**: Must maintain 1 mph, there will be a speed check at 44/88 foot mark of the course, will result in end of run with time recorded
• **Leave the scene\course**: All portions of the vehicle cross the boundary. The overall distance will be measured from the starting line to the furthest point where the final part of the vehicle crossed the boundary edge.
• **Crash**: The overall distance will be measured from the starting line to the collision point with the obstacle.

• **Careless Driving**: Crossing the boundary while at least some part of the vehicle remains in bounds.
• **Student E-Stop**: Student e-stop is used if the team feels that there may be damaged caused to their vehicle or they know that it is stuck and want to end their time.
• **Judge E-Stop**: The overall distance will be measured from the starting line to the front of the vehicle or where the final/furthest remaining part of vehicle if stopped, crossed the boundary outside edge.
• **Obstacle Displacement**: Defined as displacing permanently the obstacle from its original position. Slightly rocking/Tilting an obstacle with no permanent displacement is not considered obstacle displacement. An obstacle that rocks or tilts significantly but with no displacement will still be considered a end of run. Judges calls are final.
• **Blocking Traffic**: Vehicles stopping on course for over one minute will be E-Stopped and measured.
• **Too Slow**: If the vehicle does not maintain 1 mph minimum average speed limit throughout the course this run is disqualified.

II.6 HOW COMPETITION WILL BE JUDGED

• A team of judges and officials will determine compliance with all rules.

• Designated competition judges will determine the official times, distances and ticket deductions of each entry. At the end of the competition, those vehicles crossing the finish line will be scored on the time taken to complete the course minus any ticket deductions. Ticket values will be assessed in seconds (one foot = one second) if the vehicle completes the course within the run time.

• The team with the adjusted shortest time will be declared the winner.

• In the event that no vehicle completes the course, the score will be based on the distance traveled by the vehicle minus the ticket deductions. The team with the adjusted longest distance will be declared the winner.

• The scoring criteria is based on the weighted combination of the three challenges: Self-Drive Design Review (20% weight), Functions Testing (30 % weight) and completed Self-Drive course (50 % weight). Please see "Table 8: Self-Drive Cumulative Scoring System Example" for further details.

II.7 GROUNDS FOR DISQUALIFICATION

• Judges will disqualify any vehicle which appears to be a safety hazard or violate the safety requirements during the competition.

• Intentional interference with another competitor's vehicle and/or data link will result in disqualification of the offending contestant's entry.

• Damaging the course or deliberate movement of the obstacles or running over the obstacles may result in disqualification.

• Actions designed to damage or destroy an opponent's vehicle are not in the spirit of the competition and will result in disqualification of the offending contestant's entry.

II.8 SELF-DRIVE SCENARIOS

All tests shall be conducted on the paved test track with an open sky environment. The course will be two lanes wide and each lane will have a width of eight ft. No other vehicles or unauthorized personal shall be present when the tests are active. The test judge shall be seated at the driver seat and the team's representative shall be seated as a passenger. The judge shall hold the remote e-stop in his/her hands.

After passing Qualification Testing (Appendix A), the team is ready for Self-Drive Functions Testing (Appendix B) and Main Course (Appendix C).

The following signs and obstacles may be present on the track during Functions Testing and Main Course.

Sign / Obstacle	Dimensions
"Road Closed"	24" H x 30" W minimum height from ground is 5 feet
"One Way"	12" H x 36" W minimum height from ground is 5 feet
"Stop"	24" H x 24" H minimum height from ground is 5 feet
“No Turns"	24" H x 24" H minimum height from ground is 5 feet
Mannequin	71.7" height, 18.1" width shoulder to shoulder, 37.4" chest, 29.9" waist, 37.8" hips
Barrel(s)	39.7"H x 23.5"W Weight: 8 lbs
Pothole	2' diameter solid white circle or plastic mirror

Table 2: Traffic Signs and Obstacles specifications

The evaluation will be completed with three judges who will track the vehicle through each test. Evaluation points and comments will be marked in the Self-Drive Evaluation Worksheet. After the test completion, the test score will be reviewed with a team representative. The Judge(s) and a team representative will initial the evaluation sheet upon finished discussion.

III. DESIGN COMPETITION

III.1 OBJECTIVE

Although the ability of the vehicles to negotiate the competition courses is the ultimate measure of product quality, the officials are also interested in the design strategy and process that engineering teams follow to produce their vehicles. Design judging will be by a panel of expert judges and will be conducted separate from and without regard to vehicle performance on the test course. Judging will be based on a written report, an oral presentation and examination of the vehicle.
Design innovation is a primary objective of this competition and will be given special attention by the judges. Innovation is considered to be a technology (hardware or software) that has not ever been used by this or any other vehicle in this competition. The innovation needs to be documented, as an innovation, clearly in the written report and emphasized in the oral presentation.

III.2 WRITTEN REPORT

The Self-Drive report (15 page maximum) shall follow an IGVC format. IGVC format is adopted and modified version of the American Astronautical Society (AAS) paper format that is used by the

Association for Unmanned Vehicle Systems International (AUVSI). The word template can be downloaded from www.igvc.org. Each vehicle must have a complete report in defined format below of its own (a report cannot cover more than one vehicle). All reports must include a statement signed by the faculty advisor certifying that the design and engineering of the vehicle (original or changes) by the current student team has been significant and equivalent to what might be awarded credit in a senior design course.
Participants are required to submit an electronic copy in PDF format along with a scanned copy of the statement in PDF format by May 15, 2018. Everything must be e-mailed along with any questions to IGVCquestions@yahoo.com. Reports arriving after that date will lose 10 points in scoring for each day late, statements arriving after that date will lose 5 points in scoring for each day late. Teams are encouraged to submit reports even several weeks early to avoid the last minute rush of preparing vehicles for the competition, and there will be no penalty for last minute changes in the vehicle from the design reported. The electronic copy of the report will be posted on the competition's web site in PDF format after the completion of the competition.
The paper should present the conceptual design of the vehicle and its components. Especially important to highlight are any unique innovative aspects of the design and the intelligence aspects of the vehicle. Also included must be descriptions of:

Components	Description
electronics	design planning process
electrical system	signal processing
actuators	plan for path following (both solid & dashed lines)
software strategy	failure point & mode
sensors	plan for control decisions
computers	system integration plan
mapping	high speed operations

Table 3: Description of conceptual design of the vehicle and its components

The following items should be specifically described:
• Design of the lane following, obstacle detection/avoidance systems
• How vehicle deals with complex obstacles
• Distance at which obstacles are detected
• How the vehicle uses mapping techniques to perceive and navigate through its environment
• Speed
• Ramp climbing ability
• Reaction times
• How the system uses GPS for waypoint navigation and localization
• Accuracy of arrival at navigation waypoints
• Comparison of these predictions with actual trial data is desirable
• Using charts with statistical analysis of data is highly encouraged
• Ready-made components must be identified
• Any use of Computer-Aided Design (CAD)
• Battery life
• How considerations of safety, reliability, and durability were addressed
• Problems encountered in the design process and how they were resolved
• Identification of Failure Points and Modes (not an FMEA)
• How failure points were addressed and resolved if they should occur during the days of the competition.

Although cost itself is not a factor in judging (these are considered research vehicles), the report should include a cost estimate (not counting student labor) for the final product if it were to be duplicated. A breakdown of the cost by component is helpful.

The team organization and the names of all members of the design team, with academic department and class, should be included along with an estimate of the project's total number of person-hours expended.

	Scoring Criteria	Maximum Points
1	Conduct of the design process and team organization (including decision-making & software development)	50
2	Failure points identification and resolution methods to be used if this failure occurs. (Not an FMEA)	100
3	Quality of documentation (English, grammar, completeness, and style)	50
4	Effective innovation represented in the design (as described above)	150
5	Description of mapping technique	100
6	Description of mechanical design	100
7	Description of electronic design	100
8	Description of software strategy	150
9	Description of systems integration Descriptions to include: lane following, obstacle detection/ avoidance, and waypoint navigation (GPS or other)	150
10	Efficient use of power and materials	50
11	Attention given to safety, reliability, and durability and failure modes	50
	Total	1050

Table 4: Scoring Sheet for Written Report

III.3 ORAL PRESENTATION

The technical talk should relate the highlights of the written report described above and include any updates of the design since the written report. Audio or video tape presentations of the text are not allowed, but graphic aids may be presented by video, slide projection, computer projection, overhead transparencies, or easel charts. The presentation must be made by one or more student members of the team to the judges and other interested members of the audience and should last not more than 10 minutes. A penalty of 5 points will be assessed for each minute or fraction thereof over 11 minutes. After the presentation, judges only may ask questions for up to 5 minutes. The audience should be considered as a senior management group of generally knowledgeable engineers upon whom the project is dependent for funding and the team is dependent for their employment.

	Scoring Criteria	Maximum Points
1	Clear, well planned and understandable explanation of the innovations	50
2	Logical organization and subject knowledge of the talk	50
3	Effective use of graphic aids	30
4	Articulation and eye contact during presentation	40
5	Demonstrated simulation of vehicle control in performance events	10
6	Response to questions	10
7	Salesmanship	10

	Total	200

Table 5: Oral Presentation Scoring Sheet

Effective use of graphic aids includes not blocking the view of the screen by the presenter and simple enough graphics that are large enough to read (block diagrams rather than detailed circuit diagrams). Articulation refers to the clarity and loudness of speaking. Eye contact refers to speaking to the audience and judges (not reading notes or screen or looking above audience heads). Response to questions means short answers that address only the question. Salesmanship refers to the enthusiasm and pride exhibited (why this vehicle is the best). Participants are responsible for providing their own visual aids and related equipment (the vehicle itself may be displayed). A computer-connected projector will be made available. Projectors may also be supplied by the participants. During the oral presentation, the following question period and the examination of the vehicle, team members sitting in the audience may participate by assisting their team members.

III.4 EXAMINATION OF THE VEHICLE

The vehicle must be present and will be examined by the judges after the oral presentation or at another convenient time during the competition. Software is not included in this judging.

Judging will be as follows:

Scoring Criteria		**Presented**	**Passed**	**Penalty Points**
Vehicle	4 wheels, front and rear bumpers, fire extinguisher			
	manual E-stop			
	1 actuator easily accessible and labeled			
	no design elements harmful to surroundings			
Navigation System	GPS			
	IMU			
	Etc.			
Integrated Sensor Fusion System	camera(s)			
	lidar(s)			
	radar(s)			
	ultrasonic			
	infrared			
Safety	audible and visible warning devices in RUN mode			
	rear brake lights work in autonomous mode			
Safety E-stop	wireless E-stop system with stop/restart of the vehicle			
	E-stop actuation is smooth and controlled (no swerving, skidding, excessive delay)			

Delay before start (Safety?)	5-10 seconds pause after entering into RUN mode and before moving			

Table 6: Vehicle Examination Scoring Sheet

III.5 FINAL SCORING

The number of points awarded by the individual judges will be averaged for each of the judging areas above, and these results will be offered to each participating team for their edification. The total of the average scores over all areas (max 1200) will be used to determine the ranking.

When two (or three) teams of judges are used (due to a large number of entries) each judging team will determine the top three (or two) winners in their group, and the resulting six contestants will participate in a runoff of oral presentations and vehicle examinations judged by all judges to determine an overall Design Winner. The six teams will be judged in random order.

For the Finals competition four criteria from the written report judging will be added to the normal oral presentation scoring shown above for preliminary judging. Thus, the Final Oral presentation scoring will have maximum points as below:

	Scoring Criteria	Maximum Points
1	Clear explanation of the innovations	50
2	Description of mapping technique	30
3	Description of Electronic Design	30
4	Description of Software Strategy	30
5	Description of System Integration	30
6	Logical organization of the talk	50
7	Effective use of graphic aids	25
8	Articulation	25
9	Demonstrated Simulation of Vehicle Control	10
10	Response to questions	10
11	Salesmanship	10
	Total	300

Table 7: Final Oral Presentation Scoring Sheet

III.6 SELF-DRIVE DESIGN REPORT FORMAT - MANDATORY

1. Title Page
   - University/College Name
   - Vehicle/Team Name
   - Vehicle Photo/Sketch/Symbol
   - Date Submitted
   - Team Captain's Name and E-Mail
   - Team Members Names and E-Mails
   - Faculty Advisors Name and Statement of Integrity
2. Conduct of design process, team identification and team organization
   - Introduction
   - Organization
   - Design assumptions and design process
3. Effective innovations in your vehicle design
   - Innovative concept(s) from other vehicles designed into your vehicle
   - Innovative technology applied to your vehicle
4. Description of mechanical design
   - Overview

- Description of drive-by-wire kit
- Suspension
- Weather proofing

5. Description of electronic and power design
   - Overview
   - Power distribution system (capacity, max. run time, recharge rate, additional innovative concepts)
   - Electronics suite description including CPU and sensors system integration/feedback concepts
   - Safety devices and their integration into your system
6. Description of software strategy and mapping techniques

Overview

- Obstacle detection and avoidance
- Software strategy and path planning
- Map generation
- Goal selection and path generation
- Additional creative concepts

7. Description of failure modes, failure points and resolutions
   - Vehicle failure modes (software, mapping, etc) and resolutions
   - Vehicle failure points (electronic, electrical, mechanical, structural, etc) and resolutions
   - All failure prevention strategy
   - Testing (mechanical, electronic, simulations, in lab, real world, etc.)
   - Vehicle safety design concepts
8. Simulations employed
   - Simulations in virtual environment
   - Theoretical concepts in simulations
9. Performance Testing to Date
   - Component testing, system and subsystem testing, etc.
10. Initial Performance Assessments
    - How is your vehicle performing to date

IV. AWARDS AND RECOGNITION

All schools are only eligible to win award money once per Self-Drive; if more than one team from the same school places in the event, only the highest placing team will be placed in a standing and receive money for Self-Drive.

The scoring criteria is based on the weighted combination of the three challenges: Self-Drive Design Review (20% weight), Functions Testing (30 % weight) and completed Self-Drive course (50 % weight).

Please see the example below:

	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6
Design Review Place	1	2	5	3	4	6
Design Review Weighed (20%)	1.2	2.4	6.0	3.6	4.8	7.2
Functions Testing Place	3	4	2	1	6	5
Function Testing Weighted (30%)	3.9	5.2	2.6	1.3	7.8	6.5
Self-Drive Course Place	4	3	1	2	5	6
Self-Drive Course Weighted (50%)	6.0	4.5	1.5	3.0	7.5	9.0
Final Score Weighed	11.1	12.1	10.1	7.9	20.1	22.7
Final Place	**3**	**4**	**2**	**1**	**5**	**6**

Table 8: Self-Drive Cumulative Scoring System Example

Award Money

(Based on top cumulative point score)

For award $ vehicles must perform all functions and course autonomous to be eligible for standard $.

Place	Amount ($)
1st	$3,000.00
2nd	$2,000.00
3rd	$1,500.00
4th	$1,000.00
5th	$750.00
6th	$500.00

Table 9: Self-Drive Award Money

Nominal $ table below is for vehicles not performing all functions autonomously.

Place	Amount ($)
1st	$1,000.00
2nd	$800.00
3rd	$600.00
4th	$500.00
5th	$400.00
6th	$300.00

Table 10: Self-Drive Nominal Award Mone

V. PUBLICATION AND RECOGNITION

Internal recognition of all participating teams through Self-Drive publications.
Videos of the competition event will be distributed to sponsors, media and the public. All design reports, articles, videos and pictures will be posted on the IGVC website www.igvc.org

Name	Editor(s)
Jerry Lane, Jane Tarakhovsky, Andrew Kosinski	2017

Table 11: Self-Drive Rules Editors

All questions and concerns should be e-mailed to IGVCquestions@yahoo.com

VI. APPENDIXES

VI.1 APPENDIX A. QUALIFICATION TESTING

Name:							
Test Type	**Test ID**	**Name**	**# of Runs**	**Time**	**Comments**	**Judge's Initials**	**Team's Initials**
Qualification	Q1	E-Stop test					
Qualification	Q2	Lane Keeping (Go Straight)					
Qualification	Q3	Left Turn					
Qualification	Q4	Right Turn					
Qualification	Q5	Stop Sign detection					

Table 12: Qualification Test Data Sheet

Qualification Test Descriptions

Test Q1. E-Stop test

1. Test Goal

This test is intended to evaluate safety features - E-Stop (manual and/or wireless)

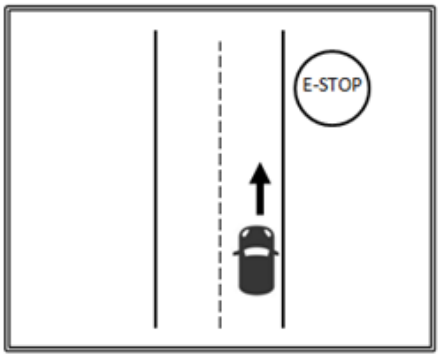

Figure 3: Qualification Testing. E-Stop

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Judge manually pushes E-Stop
6. Vehicle reaches full stop within XX seconds
7. End test run

4. Evaluation

Pass / Fail Criteria - vehicle is able to stop within XX seconds

Test Q2. Lane Keeping (Go Straight)

1. Test Goal

This test is intended to evaluate if the vehicle is able to stay within lane boundaries, without wheels crossing the line or driving on the line while driving XX feet road drive.

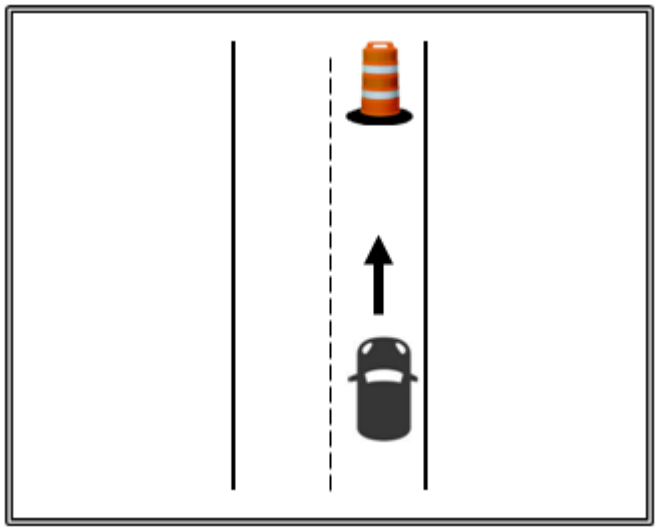

Figure 4: Qualification Testing. Lane Keeping. Go Straight

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle reaches full stop within XX from the obstacle (barrel)
6. End test run

4. Evaluation

Pass / Fail Criteria - vehicle is able to stop without hitting the barrel or moving away from the lane's boundaries

Test Q3. Left Turn

1. Test Goal

This test is intended to evaluate if a vehicle is able to make a left turn across the traffic, merge into expected lane and drive within this lane until an obstacle is detected.

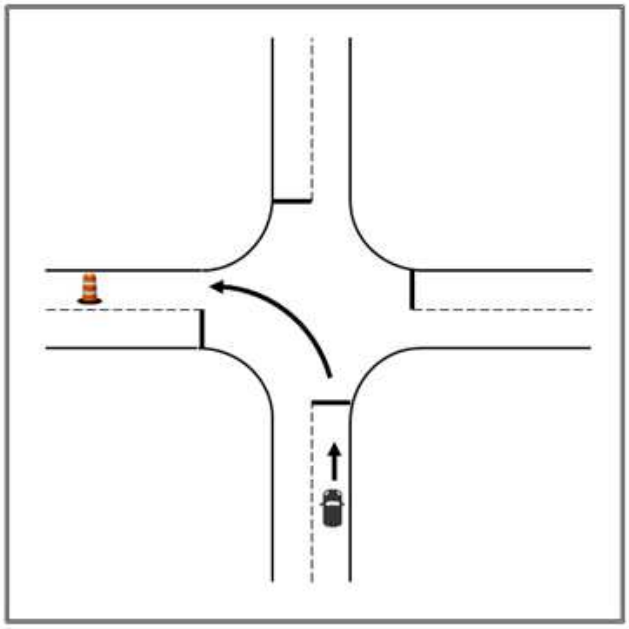

Figure 5: Qualification Testing. Left Turn

2. Test setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle turns left across the traffic and merges into correct lane
6. Vehicle maintains the target speed
7. Vehicle reaches full stop within XX from the obstacle (barrel)
8. End test run

4. Evaluation

Pass / Fail Criteria - vehicle is able to turn left, merge into correct lane and stop without hitting the barrel or moving away from the lane's boundaries

Test Q4. Right Turn

1. Test Goal

This test is intended to evaluate if the vehicle is able to make a right turn, merge into the lane and drive within a lane until an obstacle is detected.

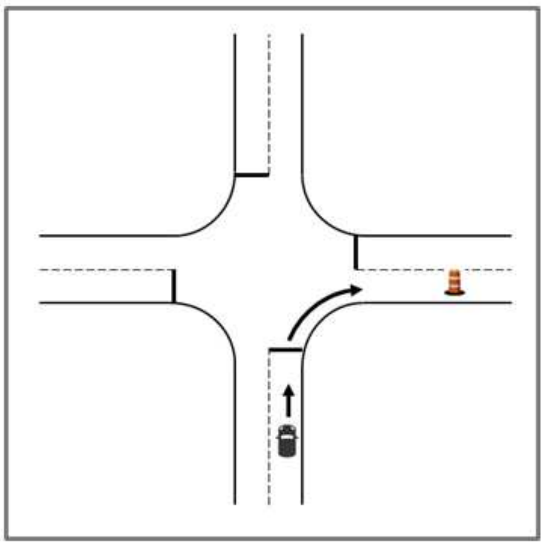

Figure 6: Qualification Testing. Right Turn

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle makes right turn and merges into correct lane
6. Vehicle maintains the target speed
7. Vehicle reaches full stop within XX from the obstacle (barrel)
8. End test run

4. Evaluation

Pass / Fail Criteria - vehicle is able to turn right, merge into correct lane and stop without hitting the barrel or moving away from the lane's boundaries

Test Q5. Stop Sign detection

1. Test Goal

This test is intended to evaluate if the vehicle is able to stop at the "Stop" sign.

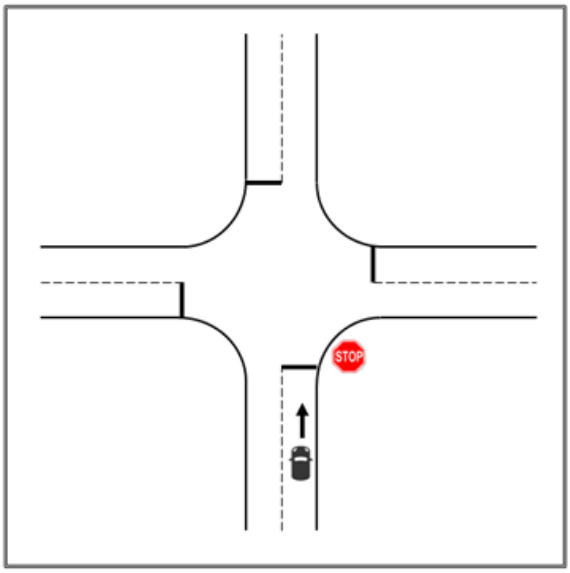

Figure 7: Qualification Testing. Stop Sign Detection

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Stop Sign** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle reaches full stop within XX from perpendicular white line next to the "Stop" sign
6. End test run

4. Evaluation

Pass / Fail Criteria - vehicle is able to stop before touching or crossing perpendicular white line on the road next to the "Stop" sign.

VI.2 APPENDIX B. FUNCTIONS TESTING

Functions Testing consists of the following independent tests:

Name:								
Test Type	**Test ID**	**Name**	**# of Runs**	**Time**	**Penalty Points**	**Comments**	**Judge's Initials**	**Team's Initials**
Function	F1	Intersection Testing. Lane Keeping						
Function	F2	Intersection Testing. Left Turn						
Function	F3	Intersection Testing. Right Turn						
Function	F4	Parking. Pull Out						
Function	F5	Parking. Pull In						
Function	F6	Parking. Parallel						
Function	F7	Obstructed/ Unobstructed pedestrian detection						
Function	F8	Pedestrian & Obstacle detection. Lane Changing						
Function	F9	Merging						
Function	F10	Curved Road evaluation. Lane Keeping						
Function	F11	Curved Road evaluation. Lane Changing						
Function	F12	Pothole detection						

Table 13: Function Testing Scoring Sheet

Test F1. Lane Keeping

1. Test Goal

This test is intended to evaluate if the vehicle is able maneuver within lane boundaries, without wheels crossing the line or driving on the line while driving XX road drive.

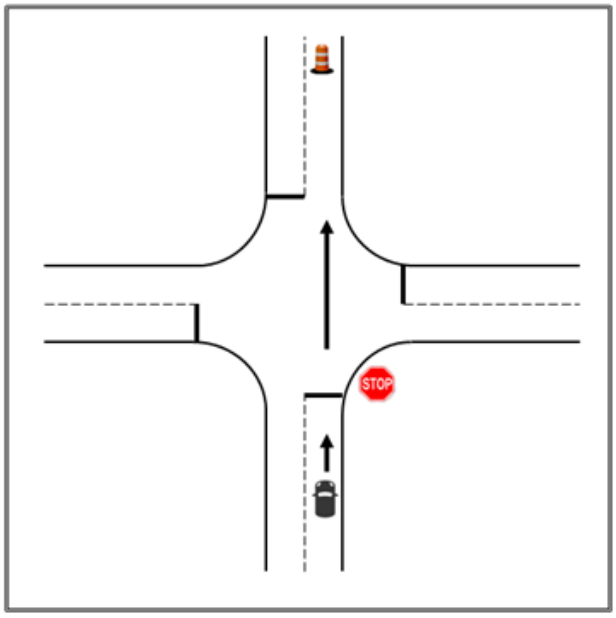

Figure 8: Functions Testing. Lane Keeping

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **'Stop'** sign
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle reaches full stop within 30 cm from perpendicular white line next to the "Stop" sign
6. Vehicle takes off from full stop
7. Vehicle maintains the target speed
5. Vehicle reaches full stop within XX from the obstacle (barrel)
6. End test run

Test F2. Intersection Testing. Left Turn

1. Test Goal

This test is intended to evaluate if a vehicle is able to stop at the 'Stop' traffic sign, make a left turn across the traffic, merge into expected lane and drive within this lane until an obstacle is detected.

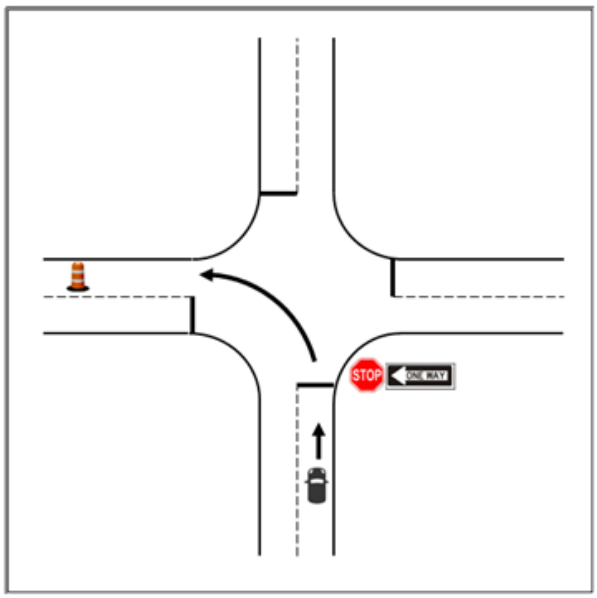

Figure 9: Functions Testing. Intersection Testing. Left Turn

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **'Stop'** sign
- **'One Way'** sign
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle reaches full stop within 30 cm from perpendicular white line next to the "**Stop**" sign
6. Vehicle takes off from full stop
7. Vehicle turns left across the traffic and merges into correct lane
8. Vehicle maintains the target speed
9. Vehicle reaches full stop within XX from the obstacle (**Barrel**)
10. End test run

Test F3. Intersection Testing. Right Turn

1. Test Goal

This test is intended to evaluate if a vehicle is able to stop at the 'Stop' traffic sign, make a right turn, merge into the lane and drive within a lane until an obstacle is detected.

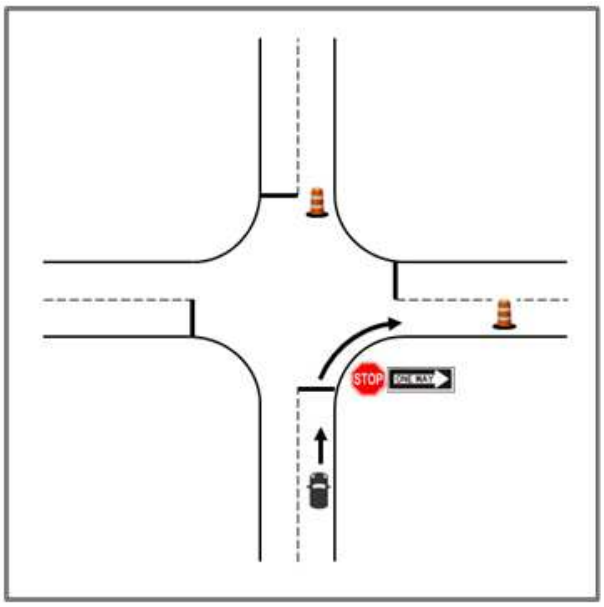

Figure 10: Functions Testing. Intersection Testing. Right Turn

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **'Stop'** sign
- **'One Way'** sign
- **Barrel** to indicate blocked road
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle reaches full stop within XX from perpendicular white line next to the "**Stop**" sign
6. Vehicle takes off from full stop
7. Vehicle turns right and merges into correct lane
8. Vehicle maintains the target speed
9. Vehicle reaches full stop within XX from the obstacle (**Barrel**)
10. End test run

Test F4. Parking. Pull Out

1. Test Goal

This test is intended to evaluate if a vehicle is able to reverse out (or pull out) of the representative parking space.

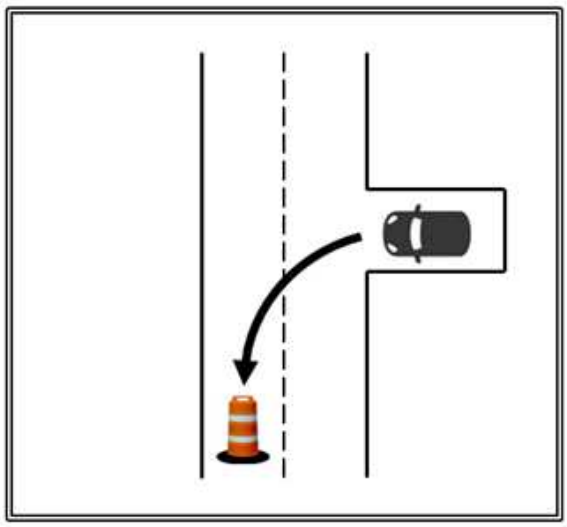

Figure 11: Functions Testing. Parking. Pull Out

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle slowly pulls out from the parking spot
5. Vehicle reaches full stop within XX from the obstacle (**Barrel**)
6. End test run

Test F5. Parking. Pull In

1. Test Goal

This test is intended to evaluate if a vehicle is able to pull into a representative parking space.

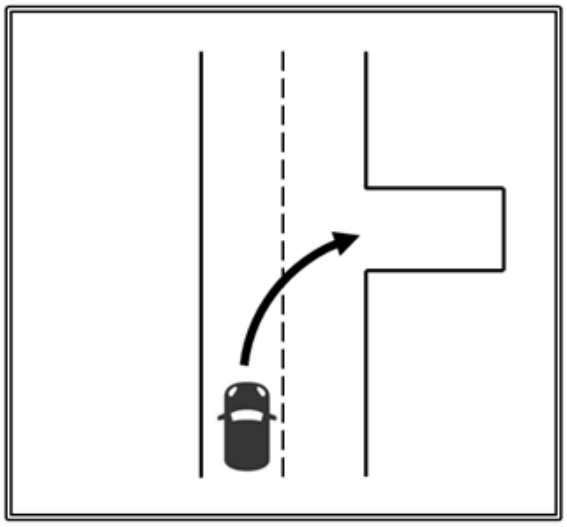

Figure 12: Functions Testing. Parking. Pull In

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Flag2** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle slowly pulls into the parking spot
5. Vehicle reaches full stop
6. End test run

Test F6. Parking. Parallel

1. Test Goal

This test is intended to evaluate if a vehicle is able to parallel park into the representative parking space.

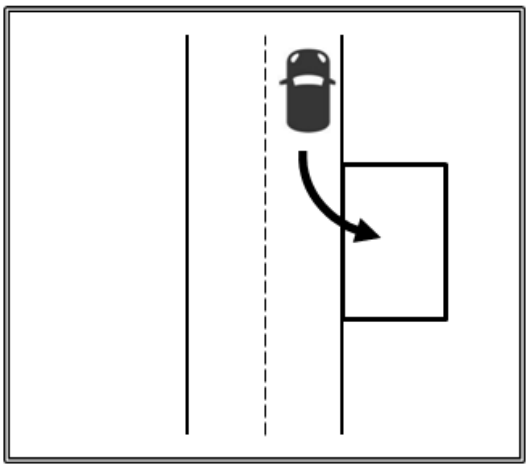

Figure 13: Functions Testing. Parking. Parallel

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel 1** to indicate 1st obstacle
- **Barrel 2** to indicate 2nd obstacle

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle backs off from full stop at **Flag 1**
4. Vehicle slowly pulls into the parking spot
5. Vehicle reaches full stop between **Barrel 1** and **Barrel 2**
6. End test run

Test F7. Obstructed/ Unobstructed pedestrian detection

1. Test Goal

This test is intended to evaluate if a vehicle is able to stop if it detects obstructed/unobstructed pedestrian (mannequin) crossing the road.

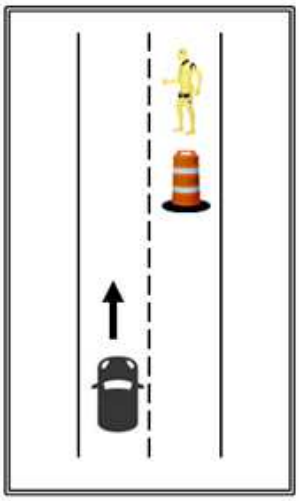

Figure 14: Functions Testing. Obstructed Pedestrian Detection

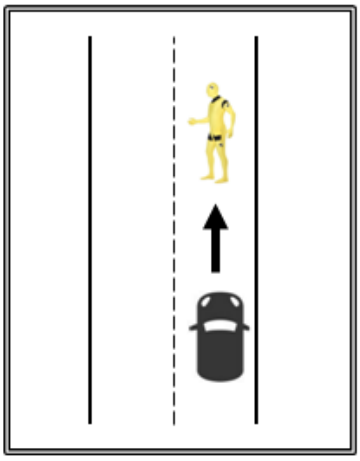

Figure 15: Functions Testing. Unobstructed Pedestrian Detection

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel** to indicate ending point
- **Mannequin**

3. Test Script

1. Begin test run

2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle reaches full stop within XX from the obstacle (**Mannequin**)
6. End test run

Test F8. Pedestrian & Obstacle detection. Lane Changing

1. Test Goal

This test is intended to evaluate if a vehicle is able to safely change lane if it detects stationary pedestrian (mannequin) or barrel.

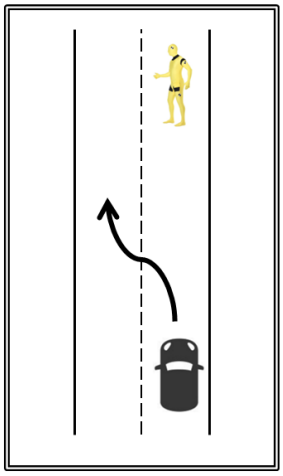

Figure 16: Functions Testing. Pedestrian Detection. Lane Changing

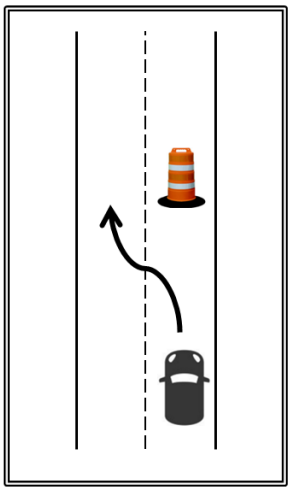

Figure 17: Functions Testing. Obstacle Detection. Lane Changing

2. Test Setup

There will be a distance of approximately 85 ft between the mannequin/barrel when mannequin will start crossing the road.

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary

- **Barrel 1** to indicate obstacle
- **Barrel 2** to indicate ending point
- **Mannequin**

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle detects obstacle (**Barrel 1** or **Mannequin)** and safely moves into the next lane
6. Vehicle maintains the target speed in the new lane
7. Vehicle reaches full stop within XX from the obstacle (**Barrel 2**)
8. End test run

Test F9. Merging

1. Test Goal

This test is intended to evaluate if a vehicle is able to perform a merge onto a representative highway.

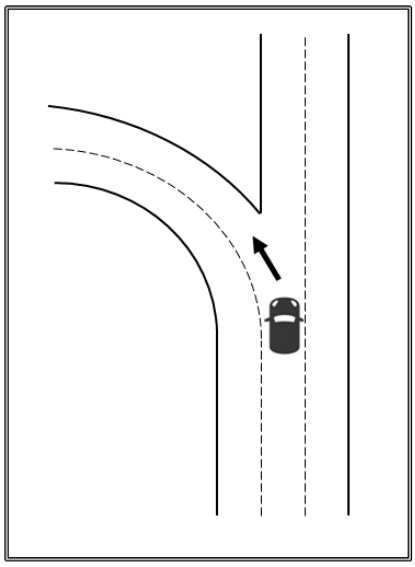

Figure 18: Functions Testing. Merging

2. Test Setup

Merging location could be indicated to vehicle through GPS waypoints.
The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **2 GPS Waypoints**
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**

4. Vehicle maintains the target speed
5. Vehicle merges into the next lane (**2 GPS Waypoints**)
6. Vehicle maintains the target speed
7. Vehicle reaches full stop within XX from the obstacle (**Barrel**)
8. End test run

Test F10. Curved Road Evaluation. Lane Keeping

The minimum inside curve radius is 10 meters (32.8084 feet).

1. Test Goal

This test is intended to evaluate if a vehicle is able to detect a curved road and stay in the lane.

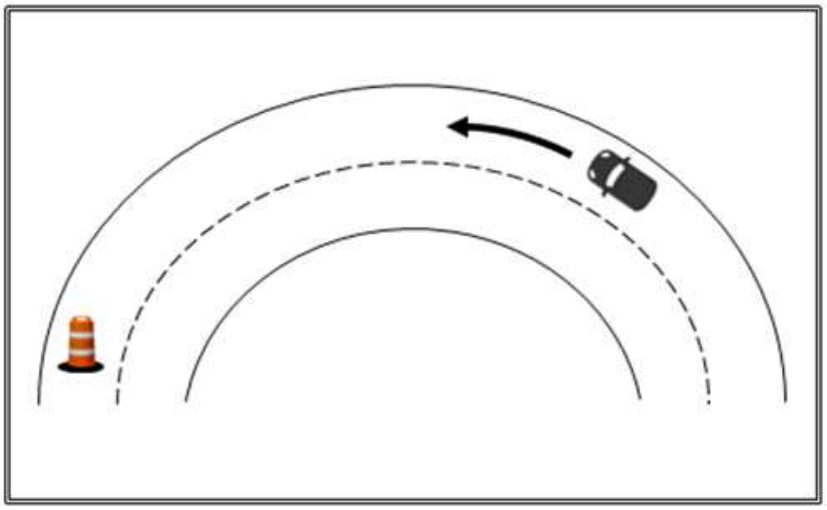

Figure 19: Functions Testing. Curved Road Evaluation. Lane Keeping

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle reaches full stop within XX from the obstacle (barrel)
6. End test run

Test F11. Curved Road Evaluation. Lane Changing

1. Test Goal

This test is intended to evaluate if a vehicle is able to perform a lane change on the curved road if obstacles are detected.

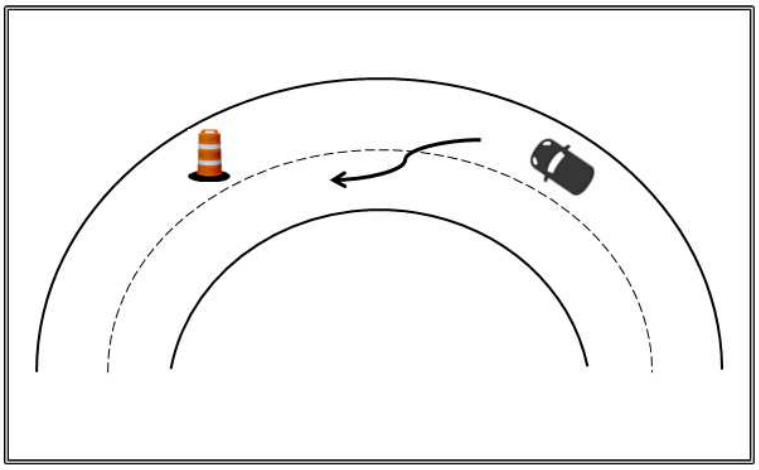

Figure 20: Functions Testing. Curved Road Evaluation. Lane Changing

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrel 1** to indicate 1st obstacle
- **Barrel 2** to indicate 2nd obstacle
- **Barrel 3** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle detects obstacle (**Barrel 1)** and safely moves into the next lane
6. Vehicle maintains the target speed in the new lane
7. Vehicle detects obstacle (**Barrel 2)** and safely moves into the next lane
8. Vehicle maintains the target speed in the new lane
9. Vehicle reaches full stop within XX from the obstacle (**Barrel 3**)
10. End test run

Test F12. Pothole Detection

1. Test Goal

This test is intended to evaluate if a vehicle is able to detect a pothole and safely change lane.

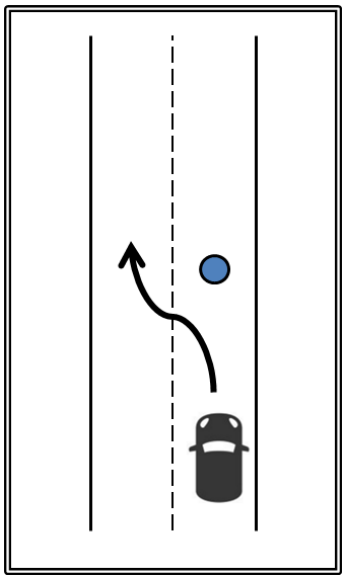

Figure 21: Functions Testing. Pothole Detection

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Pothole** (2 foot diameter solid white circle or plastic mirror)
- **Barrel** to indicate ending point

3. Test Script

1. Begin test run
2. Judge pushes 'start' button
3. Vehicle takes off from full stop at **Flag 1**
4. Vehicle maintains the target speed
5. Vehicle detects pothole and safely moves into the next lane
6. Vehicle maintains the target speed in the new lane
7. End test run

VI.3 APPENDIX C. MAIN COURSE TESTING

Main Test Description

1. Test Goal

This test is intended to evaluate if a vehicle is able to follow lane, change lane, detect and avoid obstacles, detect signs, merge into loop and park at the specified locations.

At least two waypoints will be present on the course.

Figure 22: Main Course Testing Location, Oakland University

https://www.openstreetmap.org/search?query=42.6738805%2C%20-83.198877#map=19/42.67388/-83.19888

The red container represents the area reserved for Self-Drive competition. The white line within red container corresponds to existing paved road. Please note that the starting point is on the downward slope. Parking lot has a painted single lane (marked as black line in Figure 22). The lane width is 8 ft.

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Barrels**
- **Mannequin**
- **Signs**

3. Test Script

tdb

4. Evaluation

Name:					
Item	**Functions**		**Attempted**	**Passed**	**Penalty Points**
1	**Speed within limits**				
2	**Lane Keeping**	wheels completely within marked boundaries of travel lane			
3	**Lane Changing**	moves completely to next lane			
		keeps safe distance from obstacle during the change			
4	**Pedestrian Detection**	static pedestrian			
		unobstructed pedestrian			
		obstructed pedestrian			
5	**Obstacle/Vehicle Detection**	stationary vehicle			
		moving ahead vehicle			
		crossing vehicle			
6	**Merging**	5-10 seconds delay before merging			
		passed 2 or more GPS waypoints			
7	**Left Turn**	10 sec delay			
8	**Right Turn**				
9	**Intersection detection/logic**				
10	**Autonomous Parking**	forward			
		backwards			
		parallel			
11	**Stop sign/cross lines detection**				
12	**Pothole detection**				

Table 14: Overall Test Performance Scoring Sheet