The 28th Annual Intelligent Ground Vehicle Competition (IGVC) & Self-Drive

June 5th – 8th, 2020
Oakland University
Rochester, Michigan

New for 2020
Two Ramps in AutoNav
AutoNav Chicane moved to mid-course
Self Drive updates

22 Oct 2019 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 2019 and June 2020.

Team sponsors are encouraged. Sponsors' participation will be limited to 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 IGVC.

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 chassis and 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 $500.00 non-refundable registration fee made payable to *Oakland University*. Intention to compete must be received no later than **February 28, 2020**, 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.

For 2020 IGVC will include Self-Drive Challenge employing street legal FMVSS-500 vehicle with automotive quality driving sensors See Section V for Demonstration event details.

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, 2020.

I.2 VEHICLE CONFIGURATION

The competition is designed for a small semi-rugged outdoor vehicle. Vehicle chassis can be fabricated from scratch or commercially bought. Entries must conform to the following specifications:

- **Design**: Must be a ground vehicle (propelled by direct mechanical contact to the ground such as wheels, tracks, pods, etc. or hovercraft.
- **Length**: Minimum length three feet, maximum length seven feet.
- **Width**: Minimum width two feet, maximum width four feet.
- **Height**: Not to exceed 6 six feet (excluding emergency stop antenna).
- **Propulsion**: Vehicle power must be generated onboard. Fuel storage or running of internal combustion engines and fuel cells are not permitted in the team maintenance area

(tent/building).

- **Average Speed:** Speed will be checked at the end of a challenge run to make sure the average speed of the competing vehicle is above one (1) mph over the course completed. Vehicle slower than the minimum average speed will be disqualified for the run.
- **Minimum Speed:** There will be a stretch of about 44 ft. long at the beginning of a run where the contending vehicle must consistently travel above 1 mph. A vehicle slower than this speed is considered to "hold-up traffic" and will be disqualified.
- **Maximum Speed:** A maximum vehicle speed of five miles per hour (5 mph) will be enforced. All vehicles must be hardware governed not to exceed this maximum speed. No changes to maximum speed control hardware are allowed after the vehicle passes Qualification.
- **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 easy to identify and activate safely, even if the vehicle is moving. It must be located in the center rear of vehicle at least two feet from ground, not to exceed four feet above ground. 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 (Autonomous Challenge and Navigation Challenge) the wireless E-stop will be held by the Judges.
- **Safety Light:** The vehicle must have an easily viewed solid indicator light which is turned on whenever the vehicle power is turned on. The light must go from solid to flashing whenever the vehicle is in autonomous mode. As soon as the vehicle comes out of autonomous mode the light must go back to solid.
- **Payload**: Each vehicle will be required to carry a 20-pound payload. The shape and size is approximately that of an 18" x 8" x 8" cinder block. Refer to section I.3 Payload.

I.3 PAYLOAD

The payload must be securely mounted on the vehicle. If the payload falls off the vehicle during a run, the run will be terminated. The payload specifications are as follows: 18 inches long, 8 inches wide, 8 inches high and a weight of 20 pounds.

I.4 QUALIFICATION

All vehicles must pass Qualification to receive standard award money in the Design Competition and compete in the Auto Nav performance events. To complete Qualification the vehicle must pass/perform all of the following criteria.

- **Length**: The vehicle will be measured to ensure that it is over the minimum of three feet long and under the maximum of seven feet long.
- **Width**: The vehicle will be measured to ensure that it is over the minimum of two feet wide and under the maximum of four feet wide.
- **Height**: The vehicle will be measured to ensure that it does not to exceed six feet high; this excludes emergency stop antennas.
- **Mechanical E-stop**: The mechanical E-stop will be checked for location to ensure it is located on the center rear of vehicle a minimum of two feet high and a maximum of four feet high and for functionality.
- **Wireless E-Stop:** The wireless E-Stop will be checked to ensure that it is effective for a minimum of 100 feet. During the performance events the wireless E-stop will be held by the Judges.
- **Safety Light:** The safety light will be checked to ensure that when the vehicle is powered up the light is on and solid. When the vehicle is running in autonomous mode, the light goes from solid

to flashing, then from flashing to solid when the vehicle comes out of autonomous mode.

- **Speed:** The vehicle will have to drive over a prescribed distance where its minimum and maximum speeds will be determined. The vehicle must not drop below the minimum of one mile per hour and not exceed the maximum speed of five miles per hour. Minimum speed of one mph will be assessed in the fully autonomous mode and verified over a 44 foot distance between the lanes and avoiding obstacles. No change to maximum speed control hardware is allowed after qualification. If the vehicle completes a performance event at a speed faster than the one it passed Qualification at, that run will not be counted.
- **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.

I.5 INDEMNIFICATION AND INSURANCE

Teams will be required to submit an Application Form prior to **February 28, 2020**. 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 IGVC events.

NOTE: The IGVC 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 AUTO-NAV CHALLENGE COMPETITION

All teams must pass Qualification to participate in this event.

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 Auto-Nav COURSE

The Auto-Nav Challenge is laid out on a grassy area. The Course will be approximately 600 feet long in an area 100ft wide and 200 feet deep. This distance is identified so teams can set their maximum speed to complete the course pending no prior violations resulting in run termination. Track width will vary from ten to twenty feet wide with a turning radius not less than five feet.

Outer boundaries will be designated by continuous or dashed white lines approximately three inches wide, painted on the grass. Track width will be approximately ten feet wide. Alternating side-to-side dashes will be 15-20 feet long, with 10- 15 feet separation. A minimum speed will be required of one mph and will be a requirement of Qualification and verified in each run of the Auto-Nav Challenge. If the vehicle does not average one mph for the first 44 feet (30 seconds) from the starting line, the vehicle run will be ended. The vehicle will then need to average over one mph for the entire run.

Competitors should expect natural or artificial inclines (ramps) with gradients not to exceed 15% and randomly placed obstacles along the course. The course will become more difficult to navigate autonomously as vehicle progresses. Obstacles on the course will consist of various colors (white, orange, brown, green, black, etc.) of construction barrels/drums that are used on roadways and highways. Natural obstacles such as trees or shrubs and manmade obstacles such as light posts or street signs could also appear on the course. The placement of the obstacles may be randomized from left, right, and center placements prior to every run. Simulated potholes of 2 foot diameter solid white circles may be inserted. These simulated pot must be avoided or an end of run will occur.

There will be a minimum of five feet clearance, minimum passage width, between the line and the obstacles; i.e., if the obstacle is in the middle of the course then on either side of the obstacle will be five feet of driving space. Or if the obstacle is closer to one side of the lane then the other side of the obstacle must have at least five feet of driving space for the vehicles.

The Course will be primarily sinusoidal curves with series of repetitive barrel obstacles. Two waypoint pairs for the course will be provided prior to competition. One waypoint pair will be the entrance and exit of the course in No Man's Land. There will be two additional waypoints in No-Man's Land.

Six (6) minutes will be allowed for course negotiation.

Example Auto-Nav Course with Ramps

180ft

140ft

Ramp

Ramp

Min
Speed
Check

Min
Speed
Check

Start

Start: Path 1

Start: Path 2

= Barrel/obstacle

= GPS waypoint

= Painted lines

Ramps
Sponsored by
Continental
Automotive
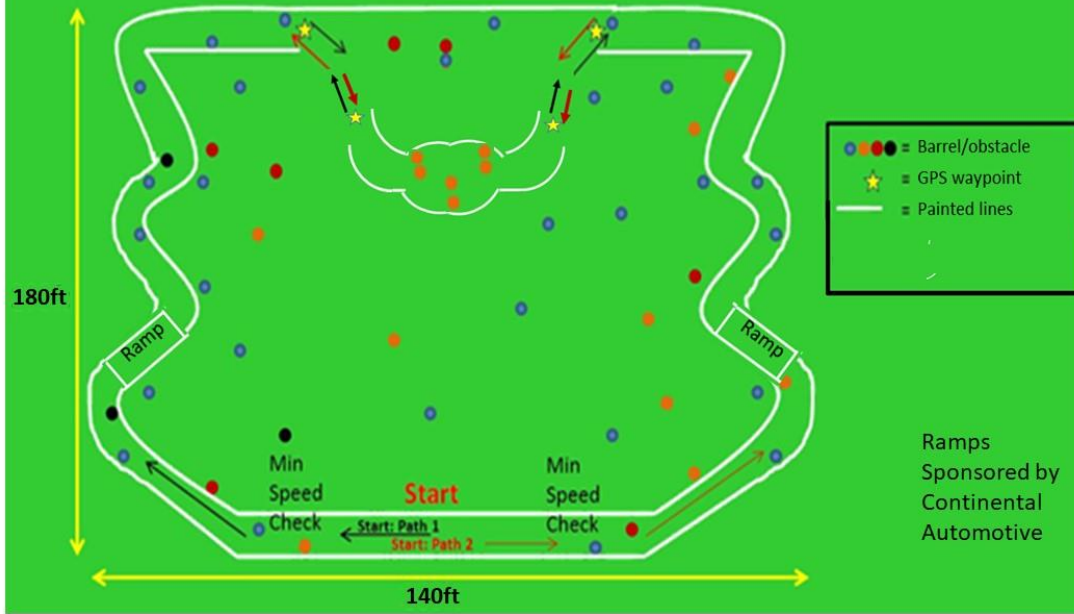
II.4 COMPETITION RULES & PROCEDURES

- 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 in the starting point to prep 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 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 Auto-Nav 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.

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	Loss of Payload	0 Feet	Yes	Yes
10	Too slow, did not average 1 mph	Disqualified	No	No

- **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.
- **Loss of Payload**: If the payload falls of the vehicle the run will be ended.
- **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.
- For standard award money consideration, entry must exhibit sufficient degree of autonomous mobility by completing the Auto-Nav course. If a tie is declared between entries, the award money will be split between them.
- If your vehicle is overtaken by a faster vehicle you will be commanded to stop and your time will be recorded and allowed to be restarted with remaining time after the faster vehicle passes. Total distance will be assessed at the 5 minute mark of runtime.

II.7 GROUNDS FOR DISQUALIFICATION

- Judges will disqualify any vehicle which appears to be a safety hazard, degrades the course 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.

III. DESIGN COMPETITION

All teams must participate in the Design Competition and submit design report in mandatory format.

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 IGVC report (15 page maximum) shall follow a modified version of the American Astronautical Society (AAS) paper format that is used by the Association for Unmanned Vehicle Systems International (AUVSI). The report must follow the outlined format provided in section III.6 **(DESIGN REPORT FORMAT – MANDATORY)** located at the end of this Written Report section. Each vehicle must have a complete report in defined format below of its own (a report cannot cover more than one vehicle). All reports, both for new vehicles and for earlier vehicles with design changes, 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, 2020.** 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:

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

Design of the lane following and obstacle detection/avoidance systems must be specifically described. Along with how the vehicle uses mapping techniques to perceive and navigate through its environment. Describe how the system uses GPS for waypoint navigation and localization.

Components acquired ready-made must be identified, but their internal components need not be described in detail. The steps followed during the design process should be described along with any use of Computer-Aided Design (CAD). How considerations of safety, reliability, and durability were addressed in the design process should be specifically described, as well as problems encountered in the design process and how they were overcome. Identification of Failure Points and Modes of hardware is required. Furthermore, description of how failure points are addressed and resolved if they should occour during the days of the competition. The analysis leading to the predicted performance of the vehicle should be documented, specifically:

- Speed
- Ramp climbing ability
- Reaction times
- Battery life
- Distance at which obstacles are detected
- How the vehicle deals with complex obstacles including switchbacks and center islands dead ends, traps, and potholes)
- How the team identifies and addresses vehicle failure points and modes (Not an FMEA)
- Accuracy of arrival at navigation waypoints
- Comparison of these predictions with actual trial data is desirable.

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.

Vehicles that have been entered in IGVC in earlier years and have not had significant changes in design are ineligible in either the design or performance events. Vehicles that have been changed significantly in design (hardware or software) from an earlier year are eligible, but will require a completely new design report treating both the old and new features, thus describing the complete vehicle as if it were all new.

Judges will score the written reports as follows:	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**

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 will be as follows:

Judges will score the oral presentations as follows:	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**

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 the audience may participate by assisting the oral presenters, but at no time is the faculty advisor to participate in this part of the design competition.

III.4 EXAMINATION OF THE VEHICLE

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

Judges will score the vehicle examinations as follows:	Maximum Points
1. Packaging neatness, efficient use of space	20
2. Serviceability	20
3. Ruggedness	20
4. Safety	20
5. Degree of original content in the vehicle (as opposed to ready-made)	50
6. Style (overall appearance)	20
Total	**150**

III.5 FINAL SCORING

The number of points awarded by the individual judges will be averaged for each of the 23 judging areas above, and these results will be offered to each participating team for their edification. The total of the average scores over all 23 areas (max 1300) 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 Finals Oral presentation scoring will have maximum points as below:

Judges will score the final presentations as follows:	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**

The vehicle examination scoring will be the same as in the preliminary judging, as shown above.

III.6 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
- Decision on frame structure, housing, structure design
- 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. INTEROPERABILITY PROFILES CHALLENGE

Participation in the IOP Challenge is recommended. IOP participation must be with the IGVC robot vehicle.

IV.1 TECHNICAL OVERVIEW

The Interoperability Profiles (IOPs) have been developed by the Robotic Systems Joint Project Office (RSJPO) to help facilitate interoperability between controller, robotic platforms, and payloads. There are four IOPs defined that help facilitate this interoperability – the Overarching IOP, the Communications IOP, the Payloads IOP, and the Controls IOP. These IOPs cover overarching platform requirements, communications requirements, payloads requirements, and controller (i.e. Operator Control Unit) requirements, respectively. These documents are formed using something called IOP attributes, which defines a specific way that a certain function needs to be achieved, usually in terms of interfaces. For example, Overarching Profile defines a Mobility attribute that specifies different types of mobility like Teleoperation or waypoint following, and those attributes specify the requirements for interfacing with those capabilities. The four IOPs listed above are supported by two additional IOP documents – the JAUS Profiling Rules IOP, and a Custom Services, Messages, and Transports document. These two additional documents profile the SAE Joint Architecture for Unmanned Systems (JAUS) and define how JAUS services, messages, and transports are used to implement IOP compliant interfaces.

This challenge focuses on successful implementation of a number of IOP attributes, primarily from the JAUS Profiling Rules document. Each entry will interface with the Judges Testing Client (JTC) as specified in the sections that follow. The JTC will be running testing software called the Conformance Verification Tool (CVT), which evaluates JAUS services interfaces, and will also be running Common Operating Picture (COP) software that will display information coming from the entrant's platform while it is executing the tasks defined by the Interoperability Profiles Challenge. There will be two parts to this challenge – a test of JAUS interfaces using the CVT, and a local waypoint navigation challenge that will be monitored by the COP.

IV.2 CONFORMANCE VERIFICATION TOOL

The Conformance Verification Tool (CVT) is a piece of software that runs on the Judges Test Client (JTC). The purpose of the CVT is to test the JAUS interfaces provided by the entrant's system. The CVT will execute tests based on IOP attribute definitions, and will primarily send messages from the input message set of the required JAUS services and will look for appropriate responses or changes in state. The CVT is the primary tool used to evaluate an entrant's system, and will be supported through the review of Wireshark logs.

IV.3 COMMON OPERATING PICTURE

The Common Operating Picture (COP) will provide a high level view of the systems in operation that successfully implement the JAUS protocol as profiled by the IOPs. This software is a simple reporting and recording tool for the Judges to use while the entrant's system performs the tasks required for this challenge. It will provided information such as the reported pose, location, and speed of the entrant's system.

IV.4 COMMUNICATIONS PROTOCOLS

The teams will implement a wireless 802.11 b/g or hardwired Ethernet data link. The interface can be implemented at any point in the student team's system including the control station or mobility platform.

The Internet Protocol (IP) address to be used will be provided at competition. For planning purposes, this address will be in range of 192.168.1.100 to 192.168.1.200. The JTC will have both hard-wire and 802.11 b/g capabilities The IP address of the JTC will nominally be 192.168.1.42, but can be changed in case of IP address conflicts.   . All teams will be provided an IP address to be used during the competition. The last

octet of the IP address is significant, as it will also be used as the subsystem identifier in the team's JAUS ID. The JTC and the team's robot will be on the same flat network (i.e. there shall be no router. The port number for all JAUS traffic shall be 3794.

IV.5 REQUIREMENTS – IOP ATTRIBUTTES

1.5.1 Overarching Requirements

Overarching requirements define the high level requirements for the entrant system. These requirements will not directly be scored, but reference attributes within the other IOP documents.

IOP Attribute	Value	Description	Comments / Parameters
Platform Databus	None	No platform databus is mandated.	There will be bonus points awarded for providing an Ethernet connector.
Transport	UDP	The entrant's shall use JAUS communications over the UDP protocol.	All UDP traffic shall be on the JAUS port, 3794.
Mobility	Basic Navigation	This attribute value specifies that the entrant's system shall provide an interface for doing waypoint navigation.	Local waypoint navigation shall be used.
Mobility	Teleoperation	This attribute value specifies that the entrant's system shall provide an interface for remote control of the system.	

1.5.2 Payloads Requirements

There are currently no payloads requirements.

1.5.3 Communications Requirements

There are currently no communications requirements.

1.5.4 JAUS Profiling Rules Requirements

The attributes required from the SAE JAUS Profiling Rules IOP will in most cases define JAUS services that must be implemented by the entrant's system. JAUS services define a message interface and a state protocol that must be followed.

1.5.4.1 Core Interoperability Attributes

These attributes are from the Core Interoperability Attribute group.

IOP Attribute	Value	Description
Core Requirements	Default	Specifies core services that must always be implemented for any JAUS component. Mandated JAUS Interoperability Attribute Options are Core::Core Services, Core::Access Control, and Core::Liveness. The following parameter values will be used: Access Control Timeout = 0 (no timeout)
Subsystem ID Assignment	Static	Specifies a static JAUS subsystem ID will be assigned.
Node ID Assignment	Static	Specifies that a static JAUS node ID will be assigned.
Transport	JUDP	Specifies that the JAUS over UDP transport protocol will be used, as specified in AS5669A.

1.5.4.2 Platform Management Attributes

These attribute are from the Platform Interoperability Attribute Group.

IOP Attribute	Value	Description
Platform Management***	Basic	Defines platform management services such as Discovery, Liveness, PlatformMode, HealthMonitor, and

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| | PlatformState. | |

*** The HealthMonitor, PlatformMode, and PlatformState services will not be tested and are not required to be implemented for this challenge.

1.5.4.3 Entrant Navigation and Reporting Capabilities

This capability attribute and added options describes the navigation and reporting capabilities that the entrant must provide.

IOP Attribute	Value	Description
Global::Capability ("Navigation and Reporting")	Defaul	The Interoperability Options in the rows below are added to this Capability attribute.
IOP Attribute Option	Value	Description
Autonomy and Behaviors :: Basic Navigation	Local	Requires the use of the Local Waypoint Driver and Local Waypoint List Driver services that provide an interface for setting up and commanding local waypoint navigation.
Global :: Local Position and Attitude	Defaul	Requires the use of the Local Pose Sensor service that provides an interface for querying the Local Position of the platform, in reference to a local coordinate frame. The default rate of 1 Hz for reporting local pose applies.
Global :: Velocity State Sensor	Defaul	Requires the use of the Velocity State Sensor service that provides an interface for reporting the velocity (rotational and translational) of the platform. A 10 Hz reporting rate shall be supported.
Remote Control	Default	The Remote Control Interoperability Attribute provides the capability to control a platform via line of sight remote control.

1.5.5 Competition Setup

All teams will be assigned a JAUS Subsystem ID based on their assigned IP address. The JAUS Subsystem ID is part of the JAUS ID which consists of three elements: a Subsystem ID, a Node ID, and a Component ID. The Subsystem ID uniquely identifies a major element that is an unmanned system, an unmanned system controller, or some other entity on a network with unmanned systems. A Node ID is unique within a subsystem and identifies a processing element on which JAUS Components can be found. A Component ID is unique within a Node and represents an end point to and from which JAUS messages are sent and received. The last octet of the assigned IP address will be used as the team's JAUS Subsystem ID. For example, the team assigned the IP address of 192.168.1.155 will use the JAUS Subsystem ID of 155. A team will provide two JAUS Components - a Navigation and Reporting JAUS Component that contains all the services defined by the Navigation and Reporting capability, and platform management JAUS Component specified by the Platform Management attribute basic value. A team may use any valid JAUS Node ID and JAUS Component ID for their Navigation and Reporting Component, and shall use a JAUS Node ID of 1 and a JAUS Component ID of 1 for their platform management component. As an example, the team with JAUS Subsystem ID 155 would use the full Subsystem-Node-Component ID of 155-1-1 for their Platform Management Component (see figure below).
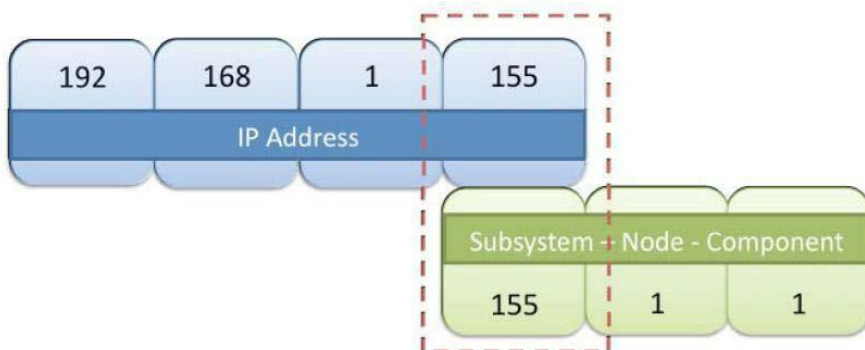
Figure 1-1: IP and JAUS ID Assignment Example

The team's subsystem and the JTC will run on the same communications network as described in the Communications Protocol section. The JTC will be running software tools that will present at least three separate JAUS components. The most important element running on the JTC will be the Conformance Verification Tool (CVT). The CVT will be used to test the IOP interfaces required for this JAUS challenge. It will run a series of automated tests that send a message to a team's subsystem and look for expected responses. The CVT presents one primary JAUS Component, and creates a second JAUS Component for certain access control tests. The CVT may be at any valid JAUS Node ID and JAUS Component IDs on the JTC Subsystem.

The JTC will also be running the Common Operational Picture (COP) process. This process is a monitoring process that will be used to evaluate the performance requirements of the IOP Challenge. The COP will run in a separate component from the CVT and will send query messages to the team's Navigation and Reporting Component, as well as create certain periodic events to monitor information from the team's platform. The COP will display information on platform velocity, position, liveness, and status to the judges, and will be used for evaluation of these elements.
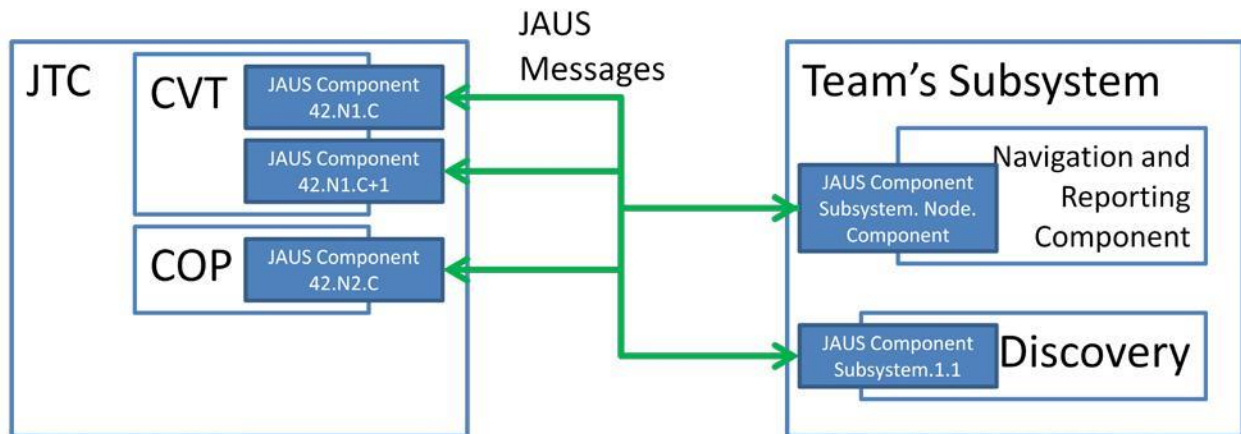
Figure 1-2: JAUS Challenge Setup

In summary, each team will be assigned an IP address by the judges. The last octet of that IOP address will be the team's subsystem identifier. The Judges Testing Computer (JTC) will be a subsystem as will each team's entry into the competition. The JTC will run the CVT and the COP. The Team's Subsystem will run a single Navigation and Reporting JAUS Component and a Platform Management Component (these may be combined into a single component). The JAUS port 3794 shall be used for all JAUS communications.

IV.6 COMPETITION TASK

1.6 Competition Task Description

Messages passed between the JTC and the team entries will include data as described in the task descriptions below. The JTC will initiate all requests subsequent to the discovery process described as Task 1. A single Navigation and Reporting Component is required of all teams. This interface will implement all of the messages for the services defined in the Requirements – IOP Attributes sections, and expanded upon below. All messages from all services implemented will be tested.

The judges will evaluate each team's ability to meet the IOP Challenge for the tasks described below in accordance with the scoring chart. Note that the tasks specified with "Tie-Breaker" points are only used to break ties.

Task	Maximum Points
Qualification (Network Setup and Transport Discovery)	N/A – Must qualify before proceeding with other tasks.
IOP Interfaces Tasks	
Capabilities Discovery	5
Core Services	5
Events	5
Platform Management	5
Navigation and Reporting	5
IOP Interfaces Tasks SUB-TOTAL:	25
Performance Tasks	
Safe Operation	5
Remote Control	10
Waypoint Navigation	10
Position and Orientation Report	5
Velocity State Report	5
Performance Tasks SUB-TOTAL:	35
All Tasks TOTAL:	**75**
Tie-Breaker Tasks	
Waypoint Navigation Course Total Run-Time	(6 – rank)* Tie-Breaker Points
Maximum Tie-Breaker Points Possible:	10

* Ranking is determined by completing all waypoints in the shortest amount of time. The team that finishes in the shortest amount of time gets a rank of 1, and therefore would get (6 – 1) = 5 Tie-Breaker points. Tie-Breaker points for total run time only apply to teams who successfully achieve all waypoints on the course. If more than 5 teams achieve all waypoints, the teams with rank lower than 5 will be awarded 0 tie- breaker points. If after the tie-breaker points are evaluated, there are still teams tied, shortest run-time will be used as the final tie-breaker.

1.6.1   Qualification (Network Setup and Transport Discovery)

For any two elements in the system to communicate meaningful data, there must first proper network and communications configuration and a handshake to ensure that both sides use the same protocol and are able to communicate with one another.

The first part of this qualification task is to ensure that the JTC and the team's subsystem can communicate with each other over a flat network. There are up three possible options a team may choose for communications: wired network, judge hosted wireless network, and team hosted wireless network. A team must qualify for every network type that it will use during the IOP Challenge. For example, if a team plans to do only its IOP interfaces tasks on its first run using a wired network, and then plans to do its performance tasks in its next run using a judge hosted wireless network, then it must qualify for both networks.

1.6.1.1 Wired Network

For the Wired Network, the judges will provide a Gigabit Ethernet switch that a team may plug their subsystem into using a standard RJ-45 Ethernet connector. Both the team's subsystem and the JTC will be plugged into the Ethernet switch and assigned their respective static IP addresses.

1.6.1.2 Judge Hosted Wireless Network

For the Judge Hosted Wireless Network, the judges will a 2.4 GHz b/g wireless router that the JTC will be connected into through a wired connection. The team's subsystem shall connect to the Judge Hosted Wireless Network using information provide to each team. In order to help facilitate secure communications and prevent accidental presence of other teams on the wireless network, the SSID of the wireless network will be unique for each team in the form of "JAUSXXX", where XXX is the three-digit Subsystem ID assigned to the team. Each team will also be given a randomly generated passphrase to use with commercial standard wireless encryption of the network.

1.6.1.3 Team Hosted Wireless Network

For the Team Hosted Wireless Network, the judges will connect the JTC to a team's wireless network using information provided by the team. The default wireless capabilities of the JTC computer will be used, and possibly augmented by an external antenna solution to improve communications. If choosing this option, it is the responsibility of the team to ensure that the judges are properly able to connect the JTC to the team's network, so use of commercial standard wireless network practices is highly encouraged.

Once the networking portion of qualification is completed, the transport discovery qualification task begins. The discovery process, show in the figure below, will occur at the application layer. The process begins with the JTC broadcasting a QueryIdentification message using the default multicast address 239.255.0.1. This multicast address shall be used by both the JTC and the team's Subsystem to implement all JAUS logical broadcast semantics. The JTC will send a QueryIdentification message every 5 seconds until it receives a response from the Team's Platform Management Component. Once a response is received showing an appropriate subsystem name, the JTC will send a Query Identification directly to the address of the Discovery service to ensure proper direct communications. Once this has happened, the system is qualified on the network type or types chosen and may proceed with the rest of the IOP challenge. **Note: Other messages may be multicast using 239.255.0.1 – do not assume QueryIdentification is the only message that might be multicast!**
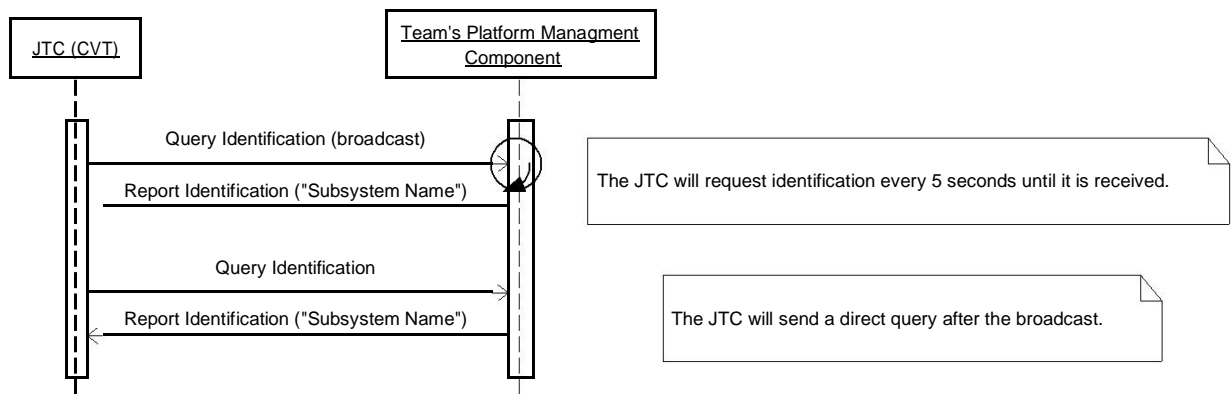
Figure 1-3: Transport Discovery Process

1.6.2   IOP Interface Tasks

IOP interface tasks involve implementing JAUS services and messages as defined in the SAE JAUS Profiling Rules IOP document. IOP Interface tasks are scored using the Conformance Verification Tool (CVT), which exercises the interfaces of each JAUS service defined for an attribute. The CVT will send out a sequence of messages to the team's Subsystem, and will look for expected responses within a given amount of time. In general, the messages sent out by the CVT are queries, but there will also be messages sent that cause a change in the state of the platform (note: during interface testing, no messages that should cause movement of a platform will be sent). The results of most CVT tests will be a simple pass/fail based on if an expected message response was received in response to a specific query, but there are some responses where the presence of certain fields or the values of fields will also be evaluated.

One test that will be performed over for multiple tasks is a presence vector test. A presence vector in JAUS is a field (usually 1-4 bytes) that indicates whether a specific field within a message is present (or when sending a query with a presence vector, what fields are requested). For example, with a one-byte presence vector, a value of "1" in the Nth bit indicates the field N of the message is present or

requested. The CVT will be used to test proper use of the presence vector for messages that are required to report certain fields – at least these fields must be supported when requested. Other fields may be supported. When a presence vector is included in a query, the returned fields is determined by a bit-wise or of the requested presence vector and the required presence vector (i.e. the fields that the JAUS component / service must actually report). A team may support fields in addition to the ones required and should report those fields if requested. Some examples using the Query Velocity State and Report Velocity State messages are shown below:

Table 1-1: Fields in Presence Vector

Field Number	Field Name
0	Velocity X
1	Velocity Y
2	Velocity Z
3	Velocity RMS
4	Roll Rate
5	Pitch Rate
6	Yaw Rate
7	Rate RMS
8	Time Stamp

Table 1-2: Correct Response - All fields requested and only the required fields are returned.

	Presence Vector (unsigned short integer)																Value (Hex)
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Required Fields	X						X		X								0x0141
Requested Fields	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0xFFFF
Reported Fields	X						X		X								0x0141

Table 1-3: Incorrect Response – Did not return the timestamp field when requested.

	Presence Vector (unsigned short integer)																Value (Hex)
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Required Fields	X						X		X								0x0141
Requested Fields	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0xFFFF
Reported Fields	X						X										0x0041

Table 1-4: Correct Response – Returned the required field that was requested.

		Presence Vector (unsigned short integer)															Value (Hex)
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Required Fields	X						X		X								0x0141
Requested Fields	X	X	X	X													0x000F
Reported Fields	X																0x0001

Table 1-5: Incorrect Response – Returned the Yaw Rate and Timestamp fields when they were not requested.

		Presence Vector (unsigned short integer)															Value (Hex)
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Required Fields	X					X			X								0x0141
Requested Fields	X	X	X	X													0x000F
Reported Fields	X					X			X								0x0141

The sections that follow describe the individual IOP interface tasks and how they will be tested, including how the task points are assigned.

1.6.2.1 Capabilities Discovery Task

For the Capabilities Discovery Task, the CVT will find the team's Discovery Service in the same way done in the Qualification Task and will then send a Query Services message to the team's Discovery Service. This is actually a test that must be performed before any CVT test since the location of services must be known in order to test them. If service discovery is not completed, other tests can still be performed by specifying the location of the other services. The service discovery sequence is done as shown below:
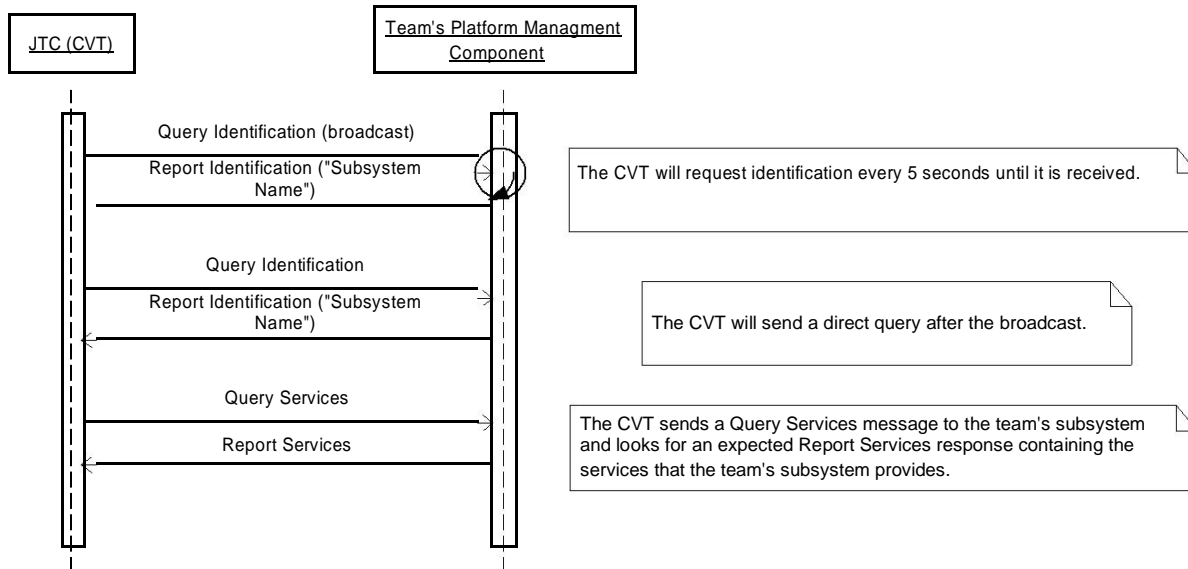
Figure 1-4: Capabilities Discovery Procedure
Note: The CVT may broadcast (using the multicast address 239.255.0.1) the QueryServices message instead of doing discovery using Query Identification.

The two tables below show the fully qualified service names, including service version, that the CVT will be expecting to find for each JAUS Component provided by the team's subsystem.

Table 1-6: Platform Management Component Required Services

Platform Management Component		
Service Name	**Fully Qualified Service Name**	**Service Version**
Transport	urn:jaus:jss:core:Transport	1.0
Events	urn:jaus:jss:core:Events	1.0
Access Control	urn:jaus:jss:core:Access Control	1.0
Liveness	urn:jaus:jss:core:Liveness	1.0
Discovery	urn:jaus:jss:core:Discovery	1.0

Table 1-7: Navigation and Reporting Component Required Services

Navigation and Reporting Component		
Service Name	**Fully Qualified Service Name**	**Service Version**
Transport	urn:jaus:jss:core:Transport	1.0
Events	urn:jaus:jss:core:Events	1.0
Access Control	urn:jaus:jss:core:AccessControl	1.0
Management	urn:jaus:jss:core:Management	1.0
Liveness	urn:jaus:jss:core:Liveness	1.0
Waypoint Driver	urn:jaus:jss:mobility:LocalWaypointDriver	1.0
Waypoint List Driver	urn:jaus:jss:mobility:LocalWaypointListDriver	1.0
Velocity State Sensor	urn:jaus:jss:mobility:VelocityStateSensor	1.0
Local Pose Sensor	urn:jaus:jss:mobility:LocalPoseSensor	1.0
Primitive Driver	urn:jaus:jss:mobility:PrimitiveDriver	1.0

Scoring for this task is performed by deducting points from the maximum task score based on missing services or incorrect services versions.

Scoring Starting Points = 5	
Deduction	**Points Deducted**
Missing Service (includes misspelling)	-1 per missing service
Incorrect Service Versions	-1
No response to Query Services message	-10

1.6.2.2 Core Services Task

For this task, the team's subsystem must demonstrate proper implementation of the services defined by the Core Requirements Interoperability Attributes. These services are Transport, Events, Access Control, Management, and Liveness. All five services are required for the Navigation and Reporting JAUS Component, and all but Management are required for the Platform Management Component.

The following messages input-output pairs must be supported:

Service	Input Message	Expected Response	Required Fields (Presence Vector)
Events	Query Events	Report Events	N/A
	Create Event	Confirm Event Request	N/A
		Reject Event Request	N/A
	Update Event	Confirm Event Request	N/A
		Reject Event Request	N/A
	Cancel Event	Confirm Event Request	N/A
		Reject Event Request	N/A
	[Event Triggered]	Event	N/A
Access Control	Request Control	Confirm Control	N/A
	Release Control	Reject Control	N/A
	Query Control	Report Control	N/A
	Query Authority	Report Authority	N/A
	Query Timeout	Report Timeout	N/A
	Set Authority	[set authority internal event]	N/A
Management	Shutdown		N/A
	Standby		N/A
	Resume		N/A
	Reset		N/A
	Set Emergency		N/A
	Clear Emergency		N/A
	Query Status	Report Status	N/A
Liveness	Query Heartbeat Pulse	Report Heartbeat Pulse	N/A

The following is an example test pattern the CVT may perform – final test plan may vary and will be released prior to the competition.

Table 1-8: Core Services Test Patterns

Service	Message Sent	Expected Response	Fields or Values Expected
Events	Query Events	Report Events	If team uses events there may be existing events in here.
	Create Event (for supported event)	Confirm Event Request	
	Query Events	Report Events	Created event is found with proper parameters.
	Update Event (for supported event)	Confirm Event Request	
	Query Events	Report Events	Created event has been properly updated.
	Cancel Event (for supported event)	Confirm Event Request	
	Query Events	Report Events	Created Event is not present.

	Create Event (unsupported parameters or message)	Reject Event Request	
Access Control	Query Control	Report Control	JAUS ID = 0.0.0
	Request Control (default authority greater)	Confirm Control	ResponseCode = insufficient authority.
	Query Control	Report Control	JAUS ID = 0.0.0
	Request Control (default authority NOT greater, control available)	Confirm Control	ResponseCode = control accepted.
	Query Control	Report Control	JAUS ID = CVT first component ID
	Set Authority (valid authority)		
	Query Authority	Report Authority	Authority = set authority
	Query Timeout	Report Timeout	Timeout = 0
	Request Control (different source component, authority less than or equal to current controller)	Confirm Control	ResponseCode = Insufficient Authority
	Query Control	Report Control	JAUS ID = CVT first component ID
	Request Control (different source component, authority greater than current controller)	Reject Control (to first component) Confirm Control (to second component)	ResponseCode = Control Accepted for second component
	Query Control	Report Control	JAUS ID = CVT second component ID
	Release Control	Reject Control	ReponseCode = Control Released
Management	Set Emergency (Emergency Code = STOP)		
	Query Status	Report Status	Status = Emergency
	Request Control (authority valid)	Confirm Control	Response Code = Not Available
	Clear Emergency (Emergency Code = STOP)		
	Request Control (authority valid)	Confirm Control	Response Code = Control Accepted
	Query Status	Report Status	Status = Standby
	Set Status (status = Resume)		
	Query Status	Report Status	Status = Resume
	Set Status (status = Reset)		
	Query Status	Report Status	Status = Init or Standby
	Set Emergency (Emergency Code = STOP)		
	Query Status	Report Status	Status = Emergency
	Request Control (from	Confirm Control	Response Code = Not

			Available
	Release Control	Reject Control	Response Code = Not Available
	Clear Emergency (Emergency Code = STOP)		
	Query Status	Report Status	Status = Standby
Liveness	Query Heartbeat Pulse	Report Heartbeat Pulse	

Points for this task will be awarded based on successfully passing each service test for each of the two components. Points will be deducted for presence vector test (can't go below 0 points).

Scoring Maximum Points = 5	
Test	**Points**
Events Service	2
Access Control Service	1
Liveness Service	1
Management Service	1
Incorrect Presence Vector Use	-2 (deduction)

1.6.2.3 Events Task

The team's subsystem is required to support periodic events for reporting certain information. These events will be tested with a special tool within the CVT defined to create and test events. The required periodic events are:

Event (Report Message)	Service	Component(s)	Required Rate
Report Heartbeat Pulse	Liveness	Platform Management Navigation and Reporting	1 Hz
Report Velocity State	Velocity State Sensor	Navigation and Reporting	1 Hz
Report Local Pose	Local Pose Sensor	Navigation and Reporting	1 Hz
Report Status	Management	Navigation and Reporting	1 Hz
Report Control	Access Control	Platform Management Navigation and Reporting	1 Hz

The following procedure will be used to test successful implementation of each event:
1. The CVT sends a Create Event message, specifying the report message, the required rate, and the type of event (periodic).
2. The team's event service (on the receiving component) handles the Create Event message and creates an event.
3. The team's event service send back a Confirm Event response to the CVT indicating successful creation of the periodic event at the requested rate.
4. The team's event service sends periodic events to the CVT, at the required rate (a +/- 20% variation is acceptable).
5. The CVT monitors the events to check for proper rate.
6. The CVT sends a Cancel Event message with the proper event ID when it is done with its test.
   Scoring will be based on properly implementing the full sequence above for each event specified. A maximum of 10 points may be awarded.

Scoring Maximum Points = 5	
Test	**Points**
Report Heartbeat Pulse Event	1
Report Velocity State Event	1
Report Local Pose Event	1
Report Status Event	1
Report Control Event	1

1.6.2.4 Platform Management Task

For this task, the team's subsystem must demonstrate proper implementation of the services defined by the Platform Management Interoperability Attribute's Basic Value, with the exception of Platform State, Platform Mode, and Health Monitor. The required services are Discovery and Liveness. Liveness is tested as part of the Core Services task, so it will not be tested separately as part of this task.

The following messages input-output pairs must be supported:

Service	Input Message	Expected Response	Required Fields (Presence Vector)
Discovery	Register Services	[Services specified are registered and will show up in subsequent Report Services messages]	N/A
	Query Identification	Report Identification	N/A
	Query Configuration	Report Configuration	N/A
	Query Subsystem List	Report Subsystem List	N/A
	Query Services	Report Services	N/A
Liveness	Query Heartbeat Pulse	Report Heartbeat Pulse	N/A

The first part of the test for this task is identical to that in the Capabilities Discovery Task – a query identification message will be broadcast and used to find the Discover Service, and a Query Services message will be used to get a Report Services message. The other query messages will also be sent and the expected report messages looked for by the CVT. For this test, the content of the report messages will not be inspected.

The second part of testing for this task is proving proper handling of the Register Services message. The CVT will perform this test by sending a Register Services message that contains a set of unique service names to the team's Discovery Service, and then using Query Services to find out if those services were properly registered. The CVT will try two more times to successfully register its services if the first time fails.

Scoring for this task is based on successful responses for each of the queries, and successfully handling the Register Services message.

Scoring Maximum Points = 5	
Test	**Points**
Query Identification	1
Query Configuration	1
Query Subsystem List	1
Query Services	1
Register Services	1 points will be awarded if all services are verified to have been properly registered

1.6.2.5 Navigation and Reporting Task

The navigation and reporting task tests the services that are found on the Navigation and Reporting Component, other than those already tested in the Core Services Task. The services tested are Velocity State Sensor, Local Pose Sensor, Local Waypoint Driver, and Local Waypoint List Driver. The following input / output message pairs are required to be implemented:

Service	Input Message	Expected Response	Required Fields (Presence Vector)
Velocity State Sensor	Query Velocity State	Report Velocity State	Velocity X, Yaw Rate, and Timestamp (0141h)
Local Pose Sensor	Query Local Pose	Report Local Pose	X, Y, Yaw, Timestamp (0143h)
Local Waypoint Driver	Set Travel Speed	[Team sets its travel speed to that specified]	N/A

	Set Local Waypoint	[Team sets its current waypoint to that specified]	X, Y (0003h)
	Query Travel Speed	Report Travel Speed	N/A
	Query Local Waypoint	Report Local Waypoint	X, Y (0000h)
Local Waypoint List Driver	Set Element	Confirm Element Request	N/A
	Query Element List	Report Element List	N/A
	Query Element Count	Report Element Count	N/A
	Execute List	[Team's platform starts executing waypoint list if in proper state]	Speed (01h)
	Query Active Element	Report Active Element	N/A
	Query Travel Speed	Report Travel Speed	N/A
	Query Local Waypoint	Report Local Waypoint	X, Y (0003h)

The Execute List message will not be sent during the IOP Interfaces portion of the tasks – it will not be sent until the performance tasks are started.

Scoring for this task is based on successfully passing the test for each service, and is a maximum of 10 points. Points will be deducted for improper use of presence vectors.

Scoring Maximum Points = 5	
Test	**Points**
Velocity State Sensor Service	1
Local Pose Sensor Service	1
Local Waypoint Driver Service	1
Local Waypoint List Driver Service	2
Incorrect Presence Vector Use	-2 (deduction)

1.6.3   Performance Tasks

Performance tasks demonstrate the ability of a team's platform to properly use the IOP interfaces that have been implemented in a practical situation. The Performance Tasks portion of this challenge will test the ability of the team's platform to properly report information and execute on commands, using IOP interfaces. **All tasks in the Performance Tasks portion of the IOP Challenge will be initiated by the judges – students may not interact with the platform after the Performance Tasks begin other than to emergency stop the platform if needed or to manually drive the platform to a starting point as instructed by a judge.**

IOP Performance Tasks MUST be done with an actual robot – no simulations may be used for this portion of the IOP challenge.

Performance tasks will be performed on the IOP Challenge course. The IOP challenge course consists of two areas – a "Safety" area and a "Navigation" area. The "Safety" area is where the Safe Operation Task is performed – it is a simple straightaway stretch alongside the "Navigation" area. The "Navigation" area will contain between 4 and 10 local (X, Y coordinate frame) waypoints, where each waypoint is defined by a center (X, Y) location and a waypoint tolerance of 1 meter (radius). The Navigation area is where the Waypoint Navigation, Velocity State Report, and Pose and Orientation Report tasks will be performed. The figure below shows a notional concept of what the IOP Challenge course will look like.
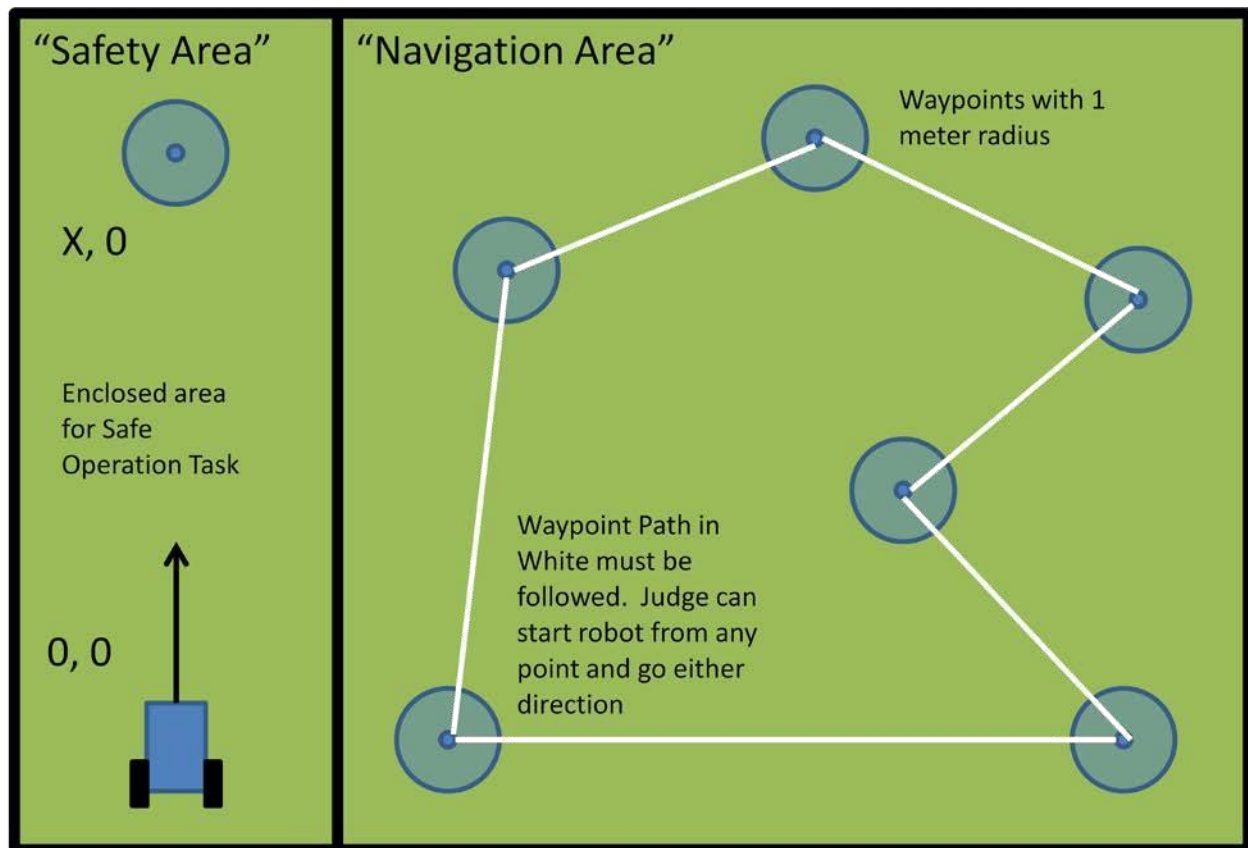
Figure 1-5: Notional Concept of IOP Challenge Course

1.6.3.1 Safe Operation Task

Note: The use of the Set Emergency JAUS message is NOT a substitute for an independent, wireless E-Stop. All teams must have an independent wireless E-Stop.

The Safe Operation Task will be used to demonstrate a team's platform's ability to properly respond to a Set Emergency command during operation. The Safe Operation Task is run in the "Safety" area of the IOP challenge course. The JTC will take control of the robot and command it to go at low speed to a waypoint in the direction that it is pointing. At some point during the Safe Operation task, the judge will send a Set Emergency message to the robot – when this happens, the robot should stop executing its current waypoint and safely stop. The judge then confirm that the reported travel speed (Report Travel Speed message) is 0 and that attempts to set a travel speed other than 0 while in the emergency state do not succeed. After verification that the robot has successfully handled the Set Emergency message, the judge will clear the emergency and set a new travel speed, at which point the robot should resume heading towards its waypoint. Finally, the judge will tell the team to initiate their wireless E-stop to demonstrate that it is capable of stopping the robot. The figure below shows the exact sequence diagram for this test.
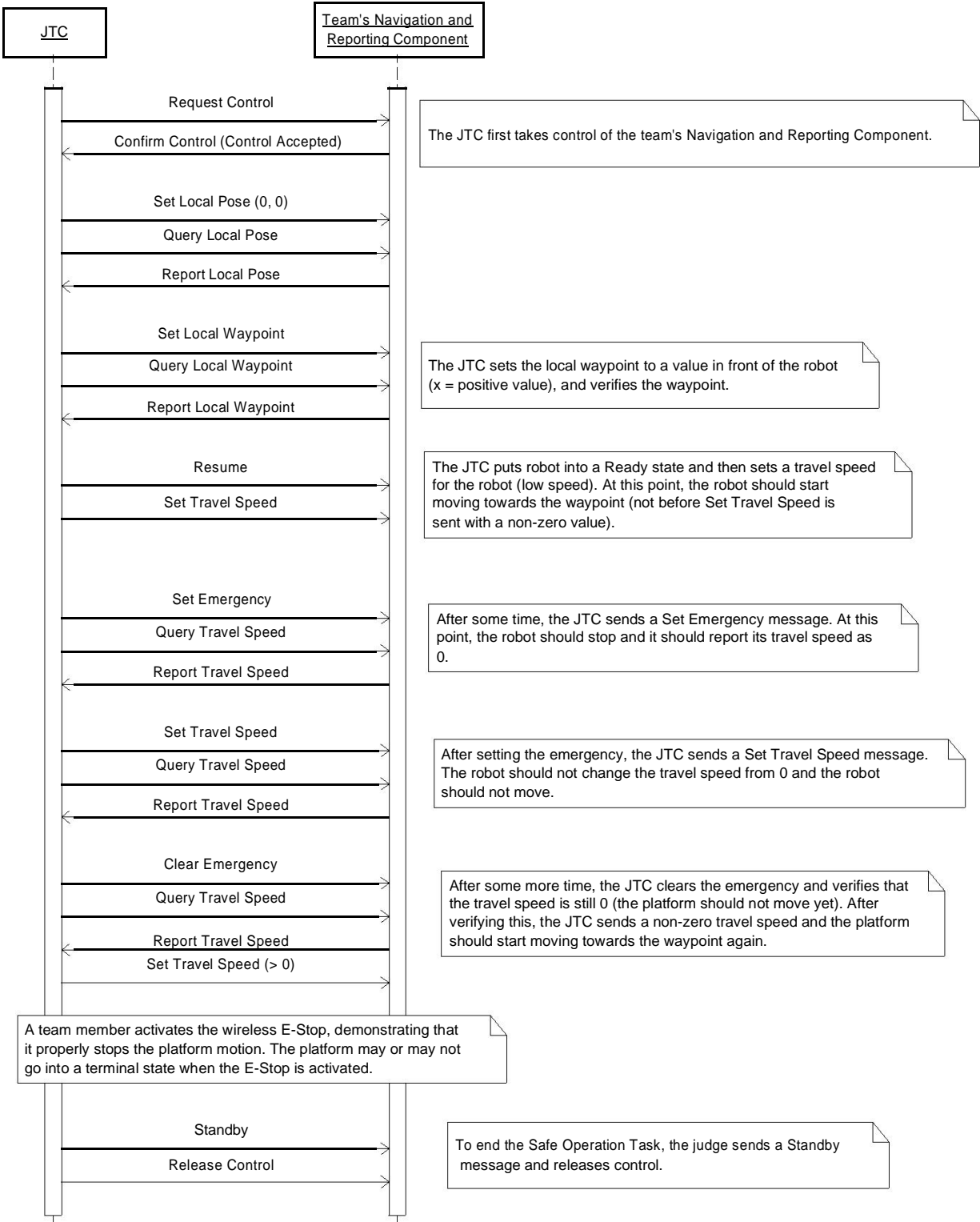
JTC

Team's Navigation and Reporting Component

Request Control

Confirm Control (Control Accepted)

The JTC first takes control of the team's Navigation and Reporting Component.

Set Local Pose (0, 0)

Query Local Pose

Report Local Pose

Set Local Waypoint

Query Local Waypoint

The JTC sets the local waypoint to a value in front of the robot (x = positive value), and verifies the waypoint.

Report Local Waypoint

Resume

The JTC puts robot into a Ready state and then sets a travel speed for the robot (low speed). At this point, the robot should start moving towards the waypoint (not before Set Travel Speed is sent with a non-zero value).

Set Travel Speed

Set Emergency

Query Travel Speed

After some time, the JTC sends a Set Emergency message. At this point, the robot should stop and it should report its travel speed as 0.

Report Travel Speed

Set Travel Speed

Query Travel Speed

After setting the emergency, the JTC sends a Set Travel Speed message. The robot should not change the travel speed from 0 and the robot should not move.

Report Travel Speed

Clear Emergency

Query Travel Speed

After some more time, the JTC clears the emergency and verifies that the travel speed is still 0 (the platform should not move yet). After verifying this, the JTC sends a non-zero travel speed and the platform should start moving towards the waypoint again.

Report Travel Speed

Set Travel Speed (> 0)

A team member activates the wireless E-Stop, demonstrating that it properly stops the platform motion. The platform may or may not go into a terminal state when the E-Stop is activated.

Standby

To end the Safe Operation Task, the judge sends a Standby message and releases control.

Release Control

Figure 1-6: Safe Operation Task Sequence Diagram

A team's robot must pass all aspects of the test for this task in order to receive the full 5 points. Failure of this task for any reason results in 0 points. **Also, if a team's robot is unable to pass this test, it may not perform the Waypoint Navigation Task and must be remotely controlled for the Velocity State Report and Position and Orientation Report tasks. If the reason for failure is a non-working wireless E-Stop, no further performance tasks may be performed.** Reasons why this test may be failed include:

- The team's robot does not give the JTC control
- The team's robot does not correctly set a 0, 0 local pose
- The team's robot does not correctly set the local waypoint
- The team's robot starts moving while in a non-ready state
- The team's robot does not start moving while in a ready state and commanded a non-zero travel speed (travel speed will be approximately 0.5 meters/second)
- The team's robot does not stop after the Set Emergency message is sent (approximately 1 second will be given for the robot to stop)
- The team's robot does not move after the emergency has been cleared and a travel speed sent
- The team's robot does not stop after the wireless E-Stop has been activated

1.6.3.2 Remote Control Task
A team may only do the Remote Control Task if it successfully completes the Safe Operation Task.

The Remote Control Task is run in the "Navigation" area of the IOP challenge course. The Remote Control Task is performed as follows:
1.   The team places their robot at a location within the Navigation area specified by the judges.
2.   The JTC will send a series of SetWrenchEffort messages to the team's robot (after taking control and commanding it to the Ready state). These SetWrenchEffort messages will command translational motion in the X direction (forward and back) and / or rotational motion in the Z direction (clockwise / counter-clockwise).
3.   The judges will observe the motion of the platform and evaluate its proper response to the SetWrenchEffort messages.

Scoring for this task is based on proper response to the SetWrenchEffort message – the maximum score for this task is 10 points. 5 points will be removed if the platform turns or drives in the wrong direction. Another 5 points will be removed if the platform does not move consistent with the commanded effort percentage, as determined by the judges. No points are awarded if the platform does not move.

1.6.3.3 Waypoint Navigation Task

A team may only do the Waypoint Navigation Task if it successfully completes the Safe Operation Task.

The Waypoint Navigation Task is run in the "Navigation" area of the IOP Challenge course. The Waypoint Navigation Task is performed as follows:
1.   The team places their robot at a starting point designated by the judges. The judges may specify any waypoint in the "Navigation" area of the IOP Challenge course as the starting point, and may instruct the team to face its platform towards either of two adjacent waypoints.
2.   The JTC will send a Set Local Pose message with the X, Y value for the waypoint that the team's robot starts at. Note that this position is not necessarily the origin of the local coordinate system.
3.   The JTC will take control of the team's robot and send it a list of local waypoints, with the starting point being the head of the list. The list of waypoints will be setup such that each team will travel to all waypoints along a path that is the same distance, regardless of the starting position and orientation.
4.   The JTC will send Resume command to the robot to take it to a Ready state, and will then send an Execute List message to start execution of the local waypoint list.
5.   The robot will continue to run until it either reaches the final waypoint, the team calls an end to the

run, the judges call an end to the run for safety reasons, or the allotted run time runs out.

The number of waypoints that a team's robot successfully achieves will be recorded. A waypoint is successfully achieved if approximately one-half or more of the team's robot, subject to the judge's judgment, crosses into the 1 meter waypoint radius. **Waypoints must be achieved in order - the run stops if the robot reaches another waypoint before reaching the next one in its list.** For teams that successfully achieve all waypoints, a time will be recorded to be used as final tie-breaker in case all other tie-breakers are insufficient.

Scoring for this task will be based on the number of waypoints achieved – the maximum score is 10 points. Since the number of waypoints may vary, the score per waypoint will be 10 / N, where N = number of waypoints on the course.

1.6.3.4 Position and Orientation Report Task

If a team does not successfully complete the Safe Operation Task, they may still perform this task by remotely controlling their robot around the waypoint course so long as their wireless E-Stop was demonstrated to function properly.

The Position and Orientation Report Task requires the team's robot to report its position and orientation as it travels around the course, using the Report Local Pose message. The team must report its local X, Y position, yaw (heading), and timestamp. The COP on the JTC is responsible for establishing the message flow need to get local pose information from the team's Navigation and Reporting Component. The COP will either try to create a periodic, 1 Hz event, or send Query Local Pose messages at 1 Hz.

Five (5) total points are available for this task. Points will be awarded for accurately reporting the position and orientation around the course. Half points will be awarded if only pose or only orientation is reported. The accuracy of the timestamp sent back will not be evaluated for this task.

1.6.3.5 Velocity State Report Task

If a team does not successfully complete the Safe Operation Task, they may still perform this task by remotely controlling their robot around the waypoint course so long as their wireless E-Stop was demonstrated to function properly.

The Velocity State Report Task requires the team's robot to report its translational (X direction) and rotational (yaw rate) velocity as it travels around the course, using the Report Local Pose message. The team must report its X direction velocity, yaw rate velocity, and timestamp. The COP on the JTC is responsible for establishing the message flow need to get velocity state information from the team's Navigation and Reporting Component. The COP will either try to create a periodic, 1 Hz event, or send Query Velocity State messages at 1 Hz.

Five (5) total points are available for this task. Points will be awarded for accurately reporting velocity state around the course. Half points will be awarded if only yaw rate or only X velocity is reported accurately.

1.6.4   Tie-Breaker Tasks

Tie-Breaker tasks only apply in the case of ties. They provide tie-breaker points that are used for the sole purpose of breaking ties. There is currently only one tie-breaker task.

1.6.4.1 IOP Compliant Payload Connector

The team shall provide one Connector Type A connector as specified in the Payloads IOP. This connector shall be provided at a location that is easily accessible to the judges. At some point in the future of this competition, this connector may be used to add a judges' or team payload to the platform. For the purposes of this IOP Challenge, they team does not need to provide Gigabit Ethernet at this connector – Fast Ethernet is acceptable. The team shall NOT connect power to this connector at this time – only the data lines shall be populated

1.6.5   General IOP Challenge Rules and Information

1.6.5.1 Qualification

A team must qualify be completing the Qualification Task for each network option it plans to use during its runs. A team will not be allowed to begin a run until it has qualified. Teams may attempt to qualify at any time. Time limits will only be applied to qualification if other teams are waiting.

1.6.5.2 Runs

There are two types of official runs that a team may do after qualifying: an IOP Interface run and a Performance run.

An IOP Interface run only tests a team's IOP interface software and does not test the physical performance of their robot system. During an IOP interface run, the team does not need to use their actual robot system – they can bring a computer, a simulation, or any other device that is running their IOP interface software. The team's IOP software device will be put on the same network as the JTC, which will run a series of mostly automated tests against the team's IOP software interfaces. IOP interface runs have a time limit of 5 minutes, and a team may do up to 5 IOP interface runs per day.

A Performance run tests a team's robot performance in addition to its successful implementation of its IOP requirements. During a performance run, a team must use its actual robot – no simulations are allowed. A performance run begins with the same tasks as in an IOP interface run, and then proceeds to do the Performance tasks. The Performance tasks start with a Safety Operation Task – if this task is successfully completed, the team is allowed to do the Waypoint Navigation Task, during which the Position and Orientation Report and Velocity State Report tasks take place simultaneously. If the team's robot does not pass the Safe Operation task, it may still be remotely controlled to perform the Position and Orientation Report and Velocity State Report tasks, so long as its wireless E-Stop is working correctly, but will not be allowed to do the Waypoint Navigation Task. Since we cannot assess the safety impacts of changes that teams make between runs, the Safe Operation Task must be performed during each run. Also, since we cannot guarantee that the version of software a team ran during a IOP Interface test is the same as during a Performance test, the results of IOP interface tasks from IOP Interface tests cannot be combined with the results of Performance test results from a different run. For example, if a team scored 50 points on the IOP interface tasks during its first IOP Interface run, then got 40 points on the IOP interface tasks during a full Performance run, it does not get the original 50 points added to its performance results – each run is scored individually, and the team keeps the highest score it has achieved on any individual run. **Performance runs are limited to 15 minutes and 3 per day. A team may do no more than a total of 5 runs of any type in a day.**

1.6.5.3 Schedule Considerations

If there are a lot of teams waiting to make a run or time is running short, judges may, at their discretion, take action to help ensure greater fairness and faster flow of the IOP Challenge. Actions taken may include, but are not limited to:

• Reducing allowed run times.
• Reducing number of total allowed runs on a given day.
• Prioritize teams waiting who have done less runs.
• Prioritize one type of run over another type
• Specify strict rigid time slots when teams can make a run

There will likely be three total days of runs. The days will likely be organized as follows:
• Day 1: Limited amount of time, judges setup testing equipment and course. May be limited to just qualification and IOP interface tests. Qualification and IOP interface tests may take priority over Performance tests.
• Day 2: Full day, likely no special restrictions on schedule
• Day 3: Full or extended day, later in day may see schedule restriction, time slots, prioritization, etc.

1.6.5.4 Scoring Considerations

The judges will utilize the testing tools specified in this document to score all entries. In addition, Wireshark packet capture logs will be taken during each run. The judges reserve the right to make scoring corrections based on review of these packet capture logs.

V. Self Drive Challenge

V.A1 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 2019 and June 2020**.

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 $500.00 non-refundable registration fee made payable to Oakland University. Intention to compete must be received no later than February 28, 2020, 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, 2020**.

V.A2 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 2020 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. During an autonomous mode the light must be blinking and otherwise be turned off.

V.A3 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:
    o   inside the vehicle at the instrument panel.
    o   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**:
    o   The Safety Light should be located on the roof of the vehicle.
    o   The Safety Light is on and solid when vehicle is powered up or comes out from autonomous mode.
    o   The Safety Light is flashing when vehicle is running in autonomous mode.
- **Speed**:
    o   minimum speed 1 mile per hour.
    o   maximum speed 5 miles per hour.
    o   Maximum speed in reverse is 2 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.

V.A4 INDEMNIFICATION AND INSURANCE

Teams will be required to submit an Application Form prior to February 28, 2020. 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.

V.B1 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.

V.B2 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.

V.B3 SAFETY REQUIREMENTS AND UNIT TESTS

1. Overview

The Self Drive Safety Requirements had been derived from "Automated Driving Systems 2.0: A vision for safety", published by U.S. Department of Transportation [1]. The safety guidelines are aimed at guiding Self-Drive teams to analyze, identify, and resolve safety considerations prior to deployment at the Self-Drive Proving Ground.

2. Scope and Purpose

This compliance is mandatory and required for teams to participate.

3. Safety Elements

3.1 System Safety

The design and validation processes include a hazard analysis and safety risk assessment for vehicle overall design. Design decisions shall address risks that could impact safety-critical system functionality.

Design safety considerations should include:

- Design architecture
- Sensors
- Actuators
- Communication Failure
- Potential software errors
- Reliability
- Potential inadequate control
- Undesirable control actions
- Potential collisions with environmental objects and other road users
- Potential collisions that could be caused by vehicle's actions
- Leaving the roadway
- Loss of traction or stability
- Violation of traffic laws
- Deviations from normal (expected) driving practices

All design decisions shall be tested, validated, and verified as individual subsystems and as part of the entire vehicle architecture. It is suggested to document all changes, design choices, analysis, associated testing and etc.

3.2 Operational Design Domain (ODD)

Roadway Type: local road with 2 lanes – 8 ft per lane, 20 ft minimum turning radius

Geographic Area: Self-Drive proving ground, flat paved area with some slopes at Oakland University

Speed Range:

- Speed limit – 5 mph
- Speed in Reverse - 2 mph

Environmental Conditions:

- Weather: sunny, cloudy, rainy
- Daytime

3.3 Object and Event Detection and Response (OEDR)

The vehicle is expected to operate in normal and pre-crash scenarios.

Normal Driving relates to:

- Keeping the vehicle in lane
- Obeying traffic laws (as outlined in the Self-Drive manual)
- Responding to barrels and mannequins (stopping and/or avoiding)

Hazardous Driving relates to:

- Vehicle's control loss
- Crossing-path crashes
- Lane change/merge
- Road departure
- Backing up
- Parking maneuvers

3.4 Fallback (Minimal Risk Condition)

Self-Drive teams are encouraged to have a documented process for transitioning to a minimal risk condition or safe state when a problem is encountered, or a vehicle cannot operate safely. Detections may include the following features: vehicle has malfunctioned, operating in a degraded state or operating outside of ODD.

3.5 Tester and Judge Safety

- All judges must wear orange reflective vests
- Observing judges must maintain safety distance from the Vehicle Under Test
- No standing forward or behind the vehicle on the test track. Minimum side distance observation is 20 ft.
- Vehicle Testing Procedure: trained team member shall be seated at the driver's seat and be proficient at vehicle shutdown during malfunction. The judge shall be seated at the passenger's seat. The second judge, holding the remote E-stop, will observe vehicle from the test ground. Either judge must activate E-stop (manual or remote) if vehicle starts to perform outside of the scope of the function or route, or if the vehicle exhibits danger for environment.
- Judges will practice shutdown before vehicle tests begin

3.6 Human Machine Interface

The vehicle shall be capable of informing the human operator or occupant through various indicators, such as warning displays, blinking lights or sounds, that the system is:

- Functioning properly
- Currently engaged in Autonomous Mode
- Currently "unavailable" for use
- Experiencing a malfunction; and/or

- Requesting control transition from the vehicle to the operator

3.7 Crashworthiness

1.Occupant Protection

- Occupants must wear helmets
- Seat belts should be buckled up during the test
- Doors or side vehicle webbing will protect students and judges from extending outside of the vehicle envelope. Doors or webbing must be easily opened, released for occupant exit.

2. Surroundings at the test track

- Vehicle must apply safe-following behavior when approaching other vehicles behind in a traffic lane, and maintain safe-following distance
- Vehicle must apply safe check-and-go behavior when pulling around a stopped vehicle, pulling out of parking spot, moving through intersections, and in situations where collisions are possible

3.8 Post-Incident Vehicle Behavior

- Turn off the system (disengage electrical power)
- Move vehicle off the test track to the safe location

3.9 Data Recording

During the run, the log file must be recorded. The recorded data must be immediately available upon judges' request.

The minimum logged data must include:

- Timestamps
- Vehicle Speed
- Braking
- Steering angle or yaw rate
- Detected Object (relative to your system)
- Maneuver related input (relative to your system)

4. Mandatory Safety Unit Tests

For each test, provide time plot documenting vehicle movement.

4.1 Requirements
1. Test in autonomous mode
2. All vehicle speeds are in m/s
3. Stopping time is in mps (meters per second)
4. All other time is in seconds

4.2. Unit Tests

Unit test 1: Emergency stop

Provide plot of speed vs time

Unit test 2: Emergency stop remote

Provide plot of speed vs time

Unit test 3: Speed limit test

Provide plot of speed vs time. **Accelerate until speed limit of 5 mph is reached.** Plot should continue at least for 20 seconds after the speed limit had been reached. Test your system with the following speeds:

1) Speed is 3 mph (1.34 mps)
2) Speed is 5.2 mph (2.28 mps)
3) Speed is 6.0 mph (2.68 mps)

Unit test 4: Right Lane boundary is crossed. Apply brakes if line had been crossed.

Provide the following plots:

1) Plot speed vs time
2) Plot lateral velocity vs time

Unit test 5: Left Lane boundary is crossed. Apply brakes if line had been crossed.

Provide the following plots:

1) Plot speed vs time
2) Plot lateral velocity vs time

Unit test 6: Object detection

Apply brakes if the object is at the certain distance.

Provide the following plots:

1) Plot speed vs time
2) Plot speed vs distance to object, brake active

Unit test 7: Backing up operation. Speed in reverse should never exceed 2 mph (0.89 mps).

Please test the system with the following speeds:

1) Speed limit is 1 mph
2) Speed limit is 3 mph

Provide the following plot:

1) Plot speed in reverse vs time

V.B4 SELF-DRIVE COURSE

[TBD]

Figure 2: Self-Drive Course Location, Oakland University

V.B5 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.
• The full vehicle crossed over the lane.
• The barrel was displaced during the run.

• 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 6 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 allowed with penalty of 25 points.

• For the following Traffic Violations, the appropriate ticket will be issued and deducted from the overall distance or time score. Refer to V.B6 Traffic Violation Laws.

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

V.B6 TRAFFIC VIOLATION LAWS

	Traffic Violations	Ticket Value Points	E-Stop	Measurement
1	Hold-up Traffic	End of Run	Yes	>60 secs. to 88 ft
2	Lane Excursion	- 25	Yes	Yes
3	Crash/Obstacle Displacement	End of Run	Yes	Yes
4	Sideswipe/Obstacle Touch	- 25	No	No
5	Student's Choice E-Stop	- 10	Yes	Yes
6	Judge's Choice E-Stop	- 0	Yes	Yes
7	Blocking Traffic	- 5	Yes	Yes
8	Too slow, did not average 1 mph	Disqualified	No	No

Table 1: Traffic Violation Laws

• **Hold-up traffic**:   An attempt to fix the issue on the spot, withholding an opportunity for other teams to run
• **Lane Excursion**: A portion of the vehicle crosses a lane. The penalty is applied only once per segment of the course. The number of excursions per segment is recorded.
• **Crash/Obstacle Displacement**: The barrel or another obstacle was fully displaced from its original position.
• **Sideswipe/Obstacle Touch:** The barrel was touched without being displaced.

• **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.
• **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.

V.B7   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.

• In the event that two or more teams had completed the course, the team with the better time score 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.

V.B8   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.

V.B9 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 team's representative shall be seated at the driver seat and the test judge 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.

V.C1 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.

V.C2 WRITTEN REPORT

The Self-Drive report (17 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, 2020. 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

V.C3 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.

V.C4 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	5-10 seconds pause after entering into RUN mode and before moving			

Table 6: Vehicle Examination Scoring Sheet

V.C5 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

V.C6 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
11. Mandatory Unit Tests up to date (see V.B3 section 4)
   - **Unit test 1: Emergency stop**

- **Unit test 2: Emergency stop remote**

- **Unit test 3: Speed limit test**

- **Unit test 4: Right Lane boundary is crossed.**

- **Unit test 5: Left Lane boundary is crossed.**

- **Unit test 6: Object detection**

- **Unit test 7: Backing up operation. Speed in reverse should never exceed 2 mph (0.89 mps).**

V.D 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 Money

V.E 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

V.F1 APPENDIX A. QUALIFICATION TESTING

Name:							
Test Type	**Test ID**	**Name**	**# of Runs**	**Time**	**Comments**	**Judge's Initials**	**Team's Initials**
Qualification	Q1a	E-Stop Manual					
Qualification	Q1b	E-Stop Wireless					

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 Q1a. E-Stop Manual

1. Test Goal

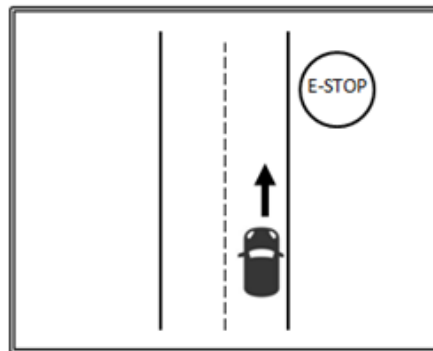This test is intended to evaluate safety features of Manual E-Stop.

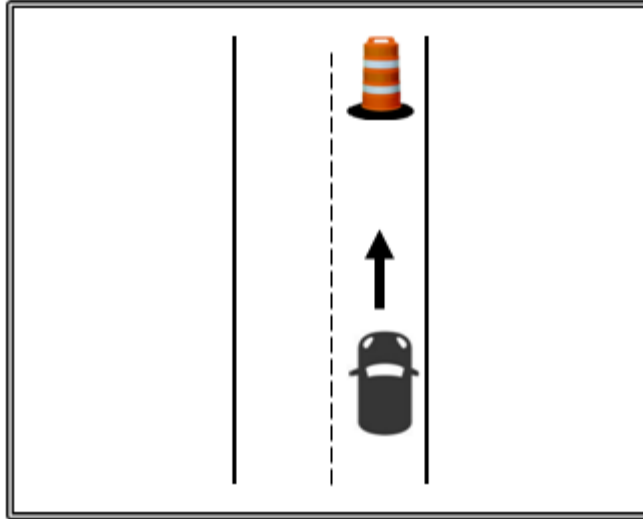**Figure 3: Qualification Testing. E-Stop Manual**

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o **Flag 2** to indicate the position where E-Stop button is pressed
- o **Flag 3** to indicate the maxim distance for the vehicle to come to the complete stop

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 at **Flag 2**
6. Vehicle comes to full stop before reaching **Flag 3**
7. End test run

4. Evaluation

Pass / Fail Criteria - vehicle is able to stop before reaching **Flag 3**

Test Q1b. E-Stop Wireless

1. Test Goal

This test is intended to evaluate safety features of Wireless E-Stop
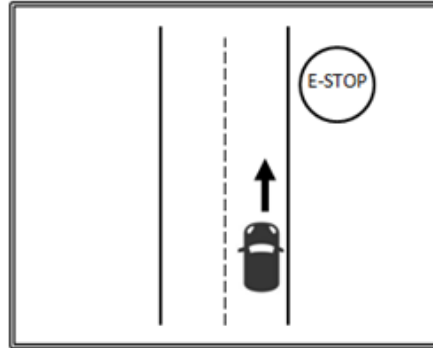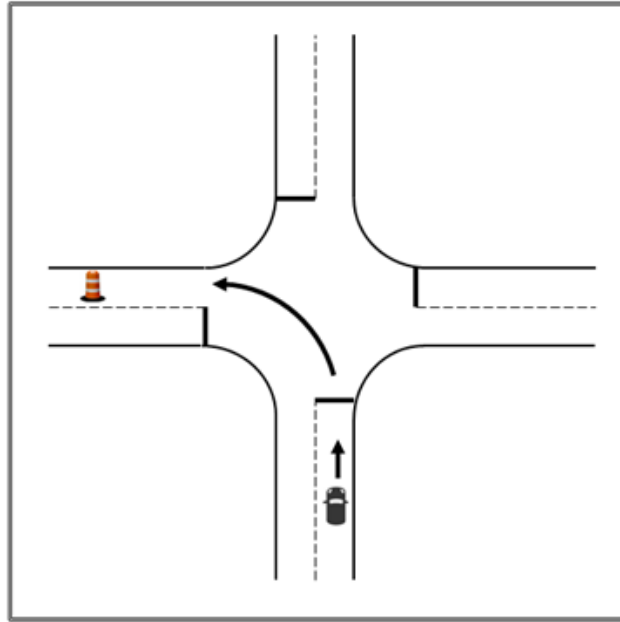

Figure 4: Qualification Testing. E-Stop Wireless

2. Test Setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary
- **Flag 2** to indicate the position where E-Stop button is pressed
- **Flag 3** to indicate the maxim distance for the vehicle to come to the complete stop

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 (between 4 – 5 mph)
5. Judge manually pushes E-Stop at **Flag 2**
6. Vehicle reaches full stop before reaching **Flag 3**
7. End test run

4. Evaluation

Pass / Fail Criteria - vehicle is able to stop before reaching **Flag 3**

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.

Figure 5: 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** about 50 ft away 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 (between 4 – 5 mph)
5. Vehicle reaches full stop within 3 ft from the obstacle (barrel)
6. End test run

4. Evaluation

Pass / Fail Criteria - vehicle stays within lane boundaries without wheels crossing the lines. Vehicle reaches full stop within 3 ft of barrel.

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.
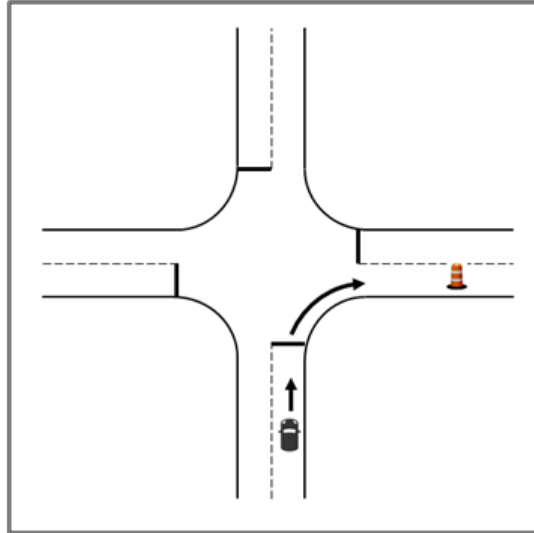
Figure 6: Qualification Testing. Left Turn

2. Test setup

The following items shall be placed on the road:

- **Flag 1** to indicate starting point at which vehicle is stationary. The flag could be placed near the stop bar or several feet away from the stop bar per judges' decision.
- **Barrel** to indicate ending point. The barrel is placed about 30 ft away from the stop bar in the right lane

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 (between 4 – 5 mph)
5. Vehicle turns left across the traffic and merges into correct lane
6. Vehicle maintains the target speed (between 4 – 5 mph)
7. Vehicle reaches full stop within 3 ft 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 crossing 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 7: 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. The flag could be placed near the stop bar or several feet away from the stop bar per judges' decision.
- **Barrel** to indicate ending point. The barrel is placed about 30 ft away from the stop bar in the right lane

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 (between 4 – 5 mph)

5. Vehicle makes right turn and merges into correct lane

6. Vehicle maintains the target speed (between 4 – 5 mph)

7. Vehicle reaches full stop within 3 ft 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 crossing boundaries

Test Q5. Stop Sign detection

1. Test Goal

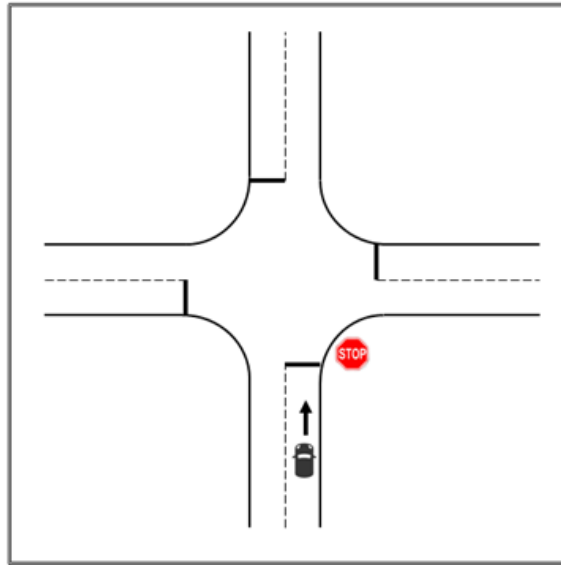This test is intended to evaluate if the vehicle is able to stop at the "Stop" sign.

Figure 8: Qualification Testing. Stop Sign Detection

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary. The flag is placed about 30 ft away from the stop sign.
- o **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 (between 4 – 5 mph)
5. Vehicle reaches full stop within 2 ft 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.

V.F2   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 pedestrian detection						
Function	F8	Unobstructed pedestrian detection						
Function	F9	Pedestrian detection. Lane Changing						
Function	F10	Obstacle detection. Lane Changing						
Function	F11	Merging						
Function	F12	Curved Road evaluation. Lane Keeping						
Function	F13	Curved Road evaluation. Lane Changing						
Function	F14	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.
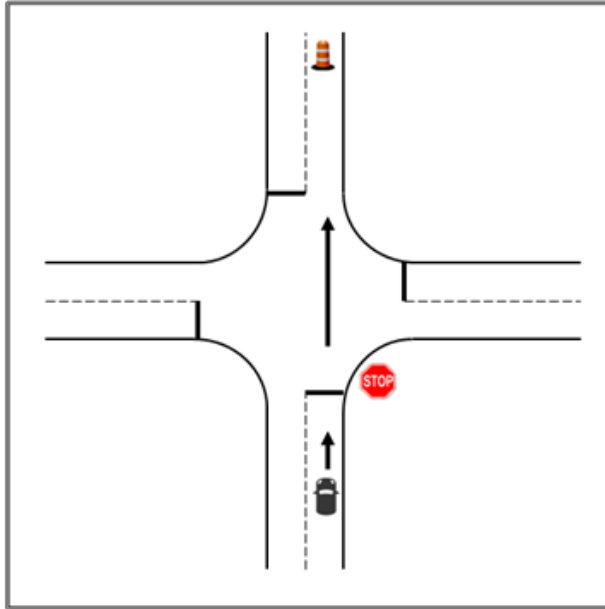
Figure 9: Functions Testing. Lane Keeping

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o **'Stop'** sign
- o **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 (between 4 – 5 mph)

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 (between 4 – 5 mph)

5. Vehicle reaches full stop within 3 ft 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.
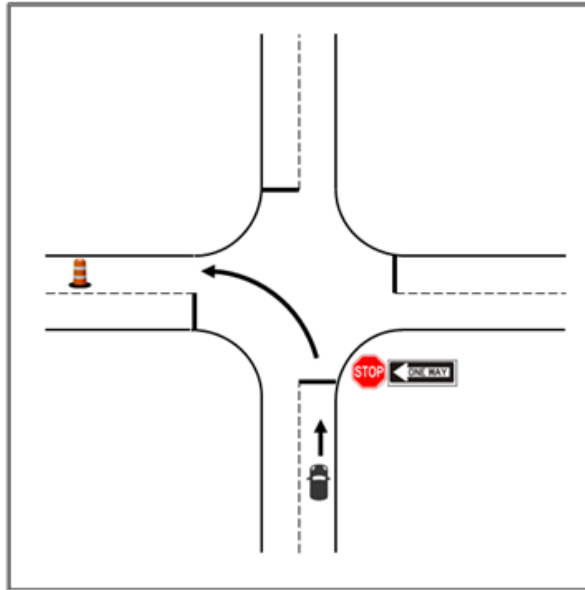

Figure 10: Functions Testing. Intersection Testing. Left Turn

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 (between 4-5 mph)
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 (between 4 – 5 mph)
9. Vehicle reaches full stop within 3 ft 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.
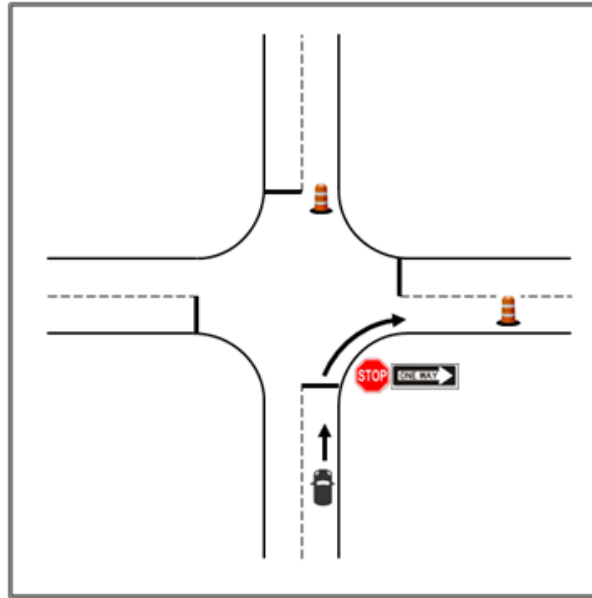

Figure 11: Functions Testing. Intersection Testing. Right Turn

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o '**Stop'** sign
- o **'One Way'** sign
- o **Barrel** to indicate blocked road
- o **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 (between 4 – 5 mph)
5. Vehicle reaches full stop within 30 cm 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 (between 4 – 5 mph)
9. Vehicle reaches full stop within 3 ft 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.
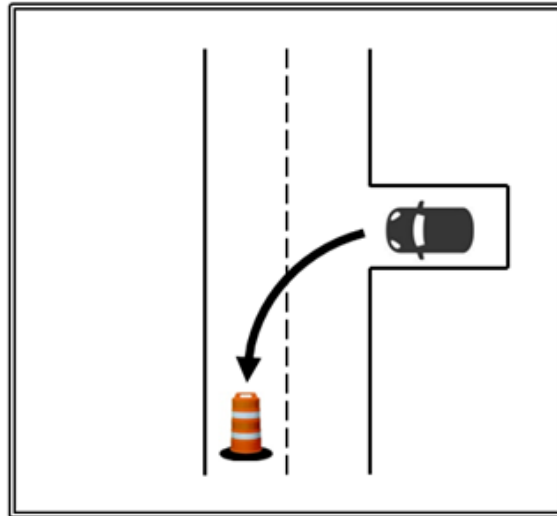

Figure 12: Functions Testing. Parking. Pull Out

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o **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 3 ft from the obstacle (**Barrel**)
6. End test run

Test F5. Parking. Pull In

1. Test Goal

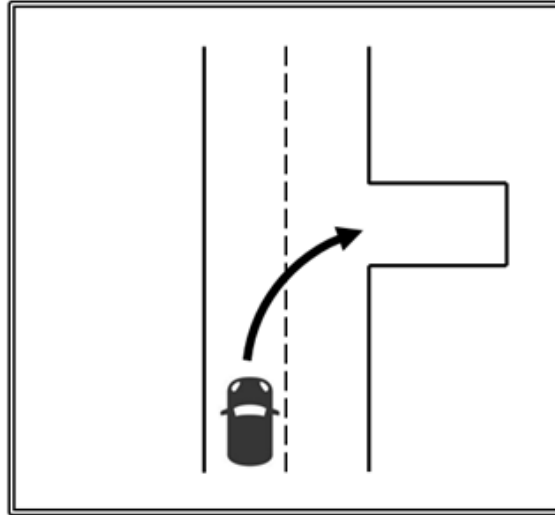This test is intended to evaluate if a vehicle is able to pull into a representative parking space.

Figure 13: Functions Testing. Parking. Pull In

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o **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. It should be fully in the box without crossing any lines.
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.
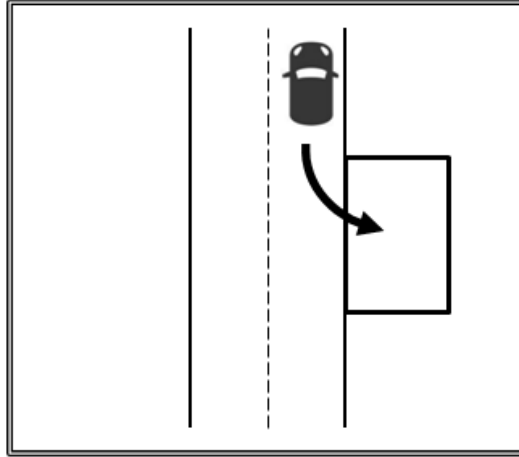

Figure 14: Functions Testing. Parking. Parallel

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o **Barrel 1** to indicate 1st obstacle in front of the parking spot
- o **Barrel 2** to indicate 2nd obstacle behind the parking spot

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. It should be fully in the box without crossing any lines.
6. End test run

Test F7. Obstructed pedestrian detection

1. Test Goal

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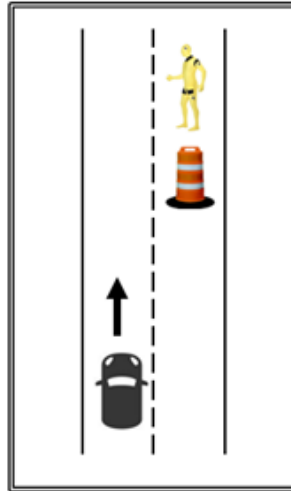

Figure 15: Functions Testing. Obstructed Pedestrian Detection

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o **Barrel** to indicate ending point
- o **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 (between 4 – 5 mph)
5. Vehicle reaches full stop within 5 ft from the obstacle (**Mannequin**)

6. End test run

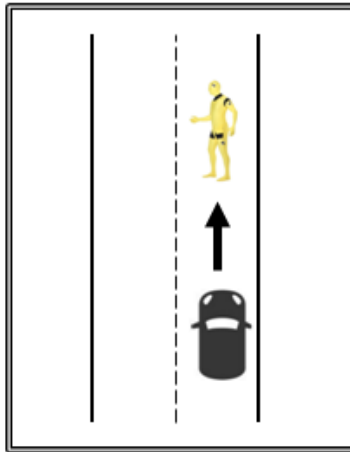# Test F8. Unobstructed pedestrian detection

Figure 16: Functions Testing. Unobstructed Pedestrian Detection

2. Test Setup

The following items shall be placed on the road:

- o **Flag 1** to indicate starting point at which vehicle is stationary
- o **Barrel** to indicate ending point
- o **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 (between 4 – 5 mph)
5. Vehicle reaches full stop within 5 ft from the obstacle (**Mannequin**)

6. End test run

Test F9. Pedestrian 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)
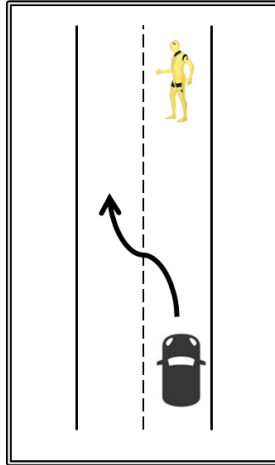
Figure 17: Functions Testing. Pedestrian Detection. Lane Changing

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:
   o **Flag 1** to indicate starting point at which vehicle is stationary
   o **Mannequin** to indicate obstacle
   o **Barrel 1** 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 (between 4-5 mph)
   5. Vehicle detects **Mannequin**
   6. Vehicle performs safely transition into the next lane 10 ft away from the Mannequin
   7. Vehicle maintains the target speed in the new lane (between 4-5 mph)
   8. Vehicle reaches full stop within 3 ft from the obstacle (**Barrel 1**)
   9. End test run

Test F10. 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 object on the road.
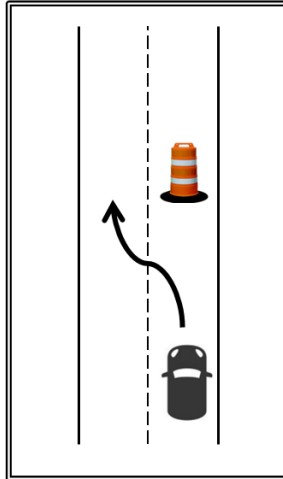
Figure 18: Functions Testing. Obstacle Detection. Lane Changing

2. Test Setup

There will be a distance of approximately 85 ft between the barrel and the vehicle.
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

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 (between 4 – 5 mph)
5. Vehicle detects obstacle (**Barrel 1)** and safely moves into the next lane
6. Vehicle maintains the target speed in the new lane (between 4 – 5 mph)
7. Vehicle reaches full stop within 3 ft from the obstacle (**Barrel 2**)
8. End test run

Test F11. Merging

1. Test Goal

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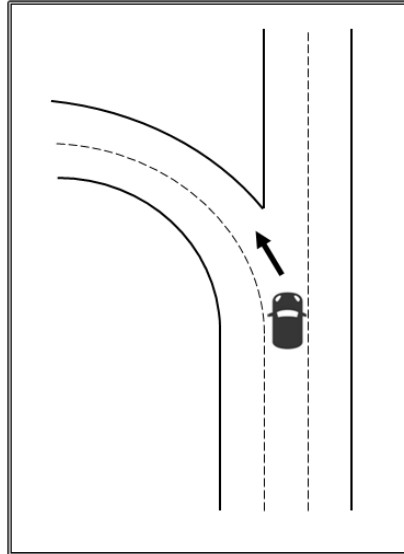

Figure 19: Functions Testing. Merging

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 (between 4 – 5 mph)
5. Vehicle merges into the next lane (**2 GPS Waypoints**)
6. Vehicle maintains the target speed (between 4 – 5 mph)
7. Vehicle reaches full stop within 3 ft from the obstacle (**Barrel**)
8. End test run

Test F12. 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 20: 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 (between 3 – 5 mph)
5. Vehicle reaches full stop within 3 ft from the obstacle (barrel)
6. End test run

Test F13. 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.
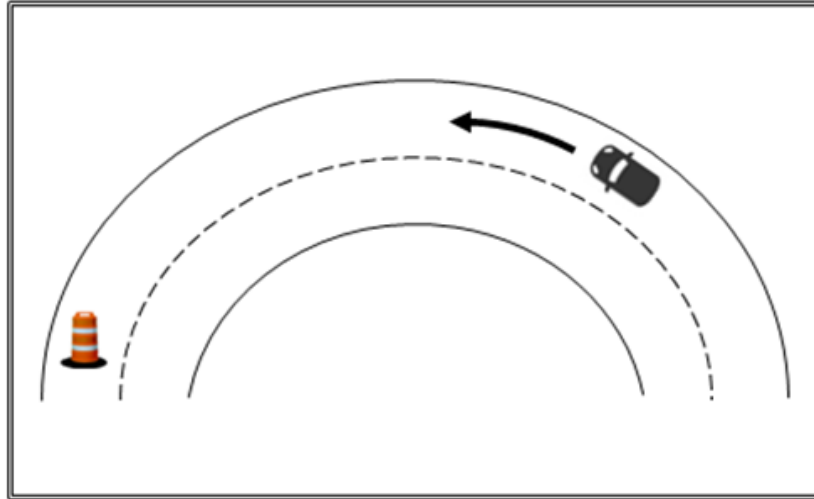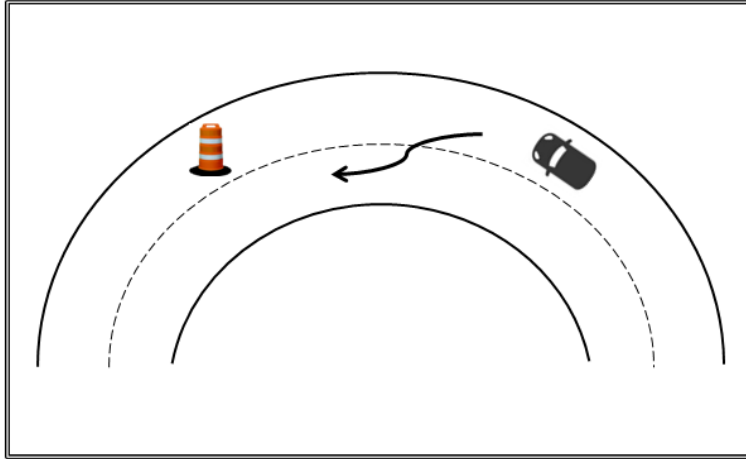
Figure 21: Functions Testing. Curved Road Evaluation. Lane Changing

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 (between 3 – 5 mph)
5. Vehicle detects obstacle (**Barrel 1)** and safely moves into the next lane
6. Vehicle maintains the target speed in the new lane (between 3 – 5 mph)
7. Vehicle detects obstacle (**Barrel 2)** and safely moves into the next lane
8. Vehicle maintains the target speed in the new lane (between 3 – 5 mph)
9. Vehicle reaches full stop within 3 ft from the obstacle (**Barrel 3**)
10. End test run

Test F14. Pothole Detection

1. Test Goal

This test is intended to evaluate if a vehicle is able to detect a pothole and safely change lane.
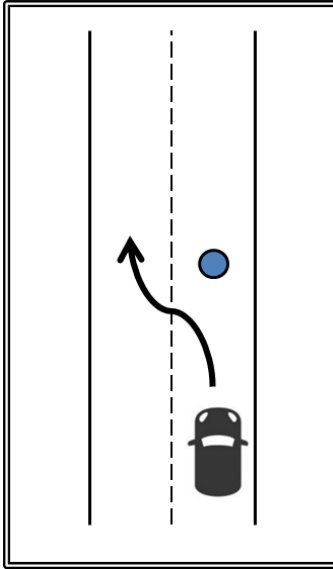
Figure 22: Functions Testing. Pothole Detection

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 (between 4 – 5 mph)
5. Vehicle detects pothole and safely moves into the next lane
6. Vehicle maintains the target speed in the new lane (between 4 – 5 mph)
7. End test run

V.F3   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.

[TBD]

Figure 23: Main Course Testing Location, Oakland University

2. Test Setup

The following items shall be placed on the road:

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

3. Test Script

TBD

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

V.G REFERENCES

[1]. "Automated Driving Systems 2.0: A vision for safety". U.S. Department of Transportation, NHTSA, September 2017

https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf

VI. CYBER CHALLENGE

VI.1 OBJECTIVE

The overall goal of the IGVC Cyber Challenge is to promote knowledge of vehicle security best practices in an educational context. Understanding of the NIST RMF process is a primary objective of this competition and will be given special attention by the judges. Understanding of the NIST RMF process will be demonstrated by a written report describing the process in general, followed by a specific case study using either a provided or novel threat concept applied to a specific vehicle. An oral presentation will be delivered during the IGVC competition and will demonstrate team understanding of the NIST RMF process as well as how it was applied to the choice, design, and implementation of cyber controls for team robots specific to chosen threat scenario. Cyber controls as outlined in the report and implemented on the team vehicle will be audited by judges after oral presentation. The audit will rely on the professional experience of the judges and will rely on teams describing ahead of time how they intend to prove efficacy of implemented controls ahead of the competition in the written report.

VI.2 WRITTEN REPORT

The IGVC Cyber Challenge report shall follow a modified version of the American Astronautical Society (AAS) paper format that is used by the Association for Unmanned Vehicle Systems International (AUVSI). The report must follow the outlined format provided in section III.6 **(DESIGN REPORT FORMAT – MANDATORY)** located at the end of this Written Report section. Each vehicle must have a complete report in defined format below of its own (a report cannot cover more than one vehicle). All reports, both for new vehicles and for earlier vehicles with design changes, 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 17, 2020.** Report and statement 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. The electronic copy of the report will be posted on the competition's web site in PDF format after the completion of the competition.

VI.3 ORAL PRESENTATION

The technical presentation should relate the highlights of the written report described above and include any updates of the design since the written report. Audio or video 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.

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 the audience may participate by assisting the oral presenters, but at no time is the faculty advisor to participate in this part of the design competition.

VI.4 Cyber Controls Audit

The vehicle must be present and will be examined by the judges immediately after the oral presentation and will last no more than 40 minutes. The burden of proof for the efficacy of the implemented controls lies with the student groups and should be fully explained in the written report and oral presentation. Proof of working controls should not rely solely complex software tools which would themselves require independent audit.

Demonstrations of controls should favor those which rely on common sense interpretation per below. Any controls which require engineering interpretation will be judged effective at the sole discretion of the auditing official(s).

Examples of Controls Requiring Common Sense Auditor Interpretation

Team implements access control to program/alter robot software. Access control has login screen which will accept correct password (as given to official to enter), but forbids access when incorrect code is entered.

Example of Control Requiring Partial Engineering Interpretation

Team implements wireless access encryption which they claim adheres to some industry standard. Demonstrated by means of remote laptop with correct access credentials which both works and doesn't with correct and incorrect credentials.

Whether claimed encryption adheres to the standard the student team claims would require extensive independent testing and thus in terms of the scope of the competition will rely solely on the subjective judgement of the auditing official.

In this example the remote login demonstrated would constitute a common sense demonstration, but the claim of encryption graded xyz is not easily verified. Because the common sense portion constitutes a fully implemented control independent of the encryption, full points would be awarded.

Example of Control Requiring Only Engineering Interpretation

Team implements complex intrusion avoidance algorithm which is claimed to ignore unauthorized robotic actuation commands.

While a very impressive feat indeed, because extensive third-party penetration testing would be required to verify the claim, this control would likely not receive any points toward the audit.

Efficacy being at the sole discretion of the auditing official, it's possible that such a case could result in full points if and only if the means of demonstration were as novel as the control, leaving no doubt as to the controls efficacy.

VI.5 DESIGN REPORT FORMAT - MANDATORY

First Section: Team Intro and Overview

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

Conduct of design process, team identification and team organization

- Introduction
- Organization

Second Section: Demonstrate Understanding of NIST RMF Process

Overview of NIST RMF process

- Categorize
- Select
- Implement
- Assess
- Authorize
- Monitor

Identified threat concept

- Pick from provided list

Thorough threat modelling

a. Security category vs security impact level
b. Info needed to categorize an information system
c. Information system boundaries

       d.   Types of information process by information systems

Identification and mapping of cyber controls to counter identified threats

       e.   Defense-in-depth
       f.   Technology based controls
       g.   Management and operational controls
       h.   Security policies
       i.   Holistic approach to information security

Third Section: NIST RMF Process Applied to Competition Robot

Description of implemented cyber controls

- Relation of Chosen Controls to Mitigated Risk
- Design and Implementation Details of Controls
- Description of Appropriate but Unimplemented Controls

Description of cyber controls demonstration strategy

- Describe in detail how controls will be demonstrated
- Demonstration/control must be provable by simple audit (no special tools that would require further audit)

VI.6 EXAMPLE THREAT CONCEPTS

Scenario 1: Military Robotic Patrol

       Your robot is part of a mission to protect a forward operating base (FOB) in Southwest Asia. It is a hot, empty desert environment surround by various sized sand dunes. The FOB is considered to be basic and temporary, and therefore consists of an arrangement of tents that serve various functions (including a hospital, a machine shop, and sleeping quarters) and a large open space to park ground vehicles and other similar systems. The FOB is under constant threat of attack by enemy forces, and is therefore protected by a ring of barbed wire with a fortified entry control point, and sentries (mounted and dismounted) in key tactical locations. Your robot is part of a team of robots tasked with autonomously patrolling the FOB perimeter to detect intrusions. Your robots are not weaponized and only serve to provide early warning to the sentries of an imminent attack. Your robots may also patrol areas around the perimeter that are out of the sentry line-of-sight, during daytime and nighttime, and be out of communication range for brief periods of time.

Scenario 2: Robotic Warehouse Inventory Management

       Your robot is part of a large wholesale distribution company that manages a very large inventory of items. The inventory is housed among multiple warehouse buildings in a distribution center the size of square mile. Your robot is tasked with transporting listed items between the various warehouse buildings and the mailing center, and therefore will operate in both indoor and outdoor environments. The robots also communicate and synchronize their jobs via a local campus-wide wireless network. The distribution center campus is shared among approximately 2000 other company employees or contractors, and new deliveries (via trucks) are arriving every 15 minutes around the clock.

Scenario 3: Make-Up-Your-Own

Create a scenario for your robot to operate in and consider the various cyber threats that it can be exposed to. Get as creative as you like! Consider ideas like: robotic assisted living, planetary exploration, subterranean or mining applications, autonomous pizza delivery, amusement park entertainment, etc. Make it hard, make it real, make it secure!

VI.7   Cyber Controls

- Data ports turned off (could be on a sliding scale for judging. For example not even powered for full compliance, partial compliance if powered but doesn't appear in OS device manager when attached, minimal compliance if doesn't auto-load/mount devices and appears as unrecognized device)
- Something like a token that is required for operation which expires, a keypad to enable robotic operation, a wireless tether with a render useless capability, geo-fencing.
- Wireless encryption/login

Examples from NIST include (https://nvd.nist.gov/800-53/Rev4/impact/moderate):

AC-1 Access Control Policy and Procedures
AC-2 Account Management
AC-3 Access Enforcement
AC-4 Information Flow Enforcement
AC-8 System Use Notification
AC-14 Permitted Actions without Identification and Authentication
AC-17 Remote Access
AC-18 Wireless Access
AC-19 Access Control for Mobile Devices
AC-20 Use of External Information Systems
AU-2 Audit Events
AU-5 Response to Audit Processing Failures
CA-1 Security Assessment and Authorization Policy and Procedures
CA-2 Security Assessments
CA-3 System Interconnections
CA-7 Continuous Monitoring
CA-9 Internal System Connections
CM-2 Baseline Configuration
CM-4 Security Impact Analysis
CM-6 Configuration Settings
CM-8 Information System Component Inventory
CM-11 User Installed Software
IA-3 Device Identification and Authentication
IA-5 Authenticator Management
IR-4 Incident Handling
MA-1 System Maintenance Policy and Procedures
PE-5 Access Control for Output Devices
PL-2 System Security Plan
PL-8 Information Security Architecture

RA-3 Risk Assessment

RA-4 Vulnerability Scanning

SA-5 Information System Documentation

SA-8 Security Engineering Principles

SA-9 External Information System Services

SA-11 Developer Security Testing and Evaluation

SC-2 Application Partitioning

SC-7 Boundary Protection

SC-13 Cryptographic Protection (If Applicable)

SC-15 Collaborative Computing Devices

SC-18 Mobile Code

SC-39 Process Isolation

SI-3 Malicious Code Protection

SI-4 Information System Monitoring

SI-7 Software, Firmware, and Information Integrity

VI.8 CYBER CHALLENGE SCORING

Written Report

Judges will score the oral presentations as follows:	Maximum Points
1. Quality of Documentation (English, grammar, completeness, and style)	50
2. Overview of NIST RMF Process	50
3. Identified threat concept	50
4. Thorough threat modelling	50
5. Identification and mapping of cyber controls	50
6. Description of implemented cyber controls	100
7. Description of cyber controls demonstration strategy	100
Total	450

Oral Presentation

Judges will score the oral presentations as follows:	Maximum Points
1. Clear, well planned and understandable explanation of NIST RMF Process	100
2. Logical organization and subject knowledge of the talk	50
3. Effective use of graphic aids	50
4. Articulation and eye contact during presentation	50
5. Response to questions	50
Total	300

Cyber Audit

Judges will score the vehicle examinations as follows:	Maximum Points
1. Cyber controls are appropriate for identified threats	150

2. Cyber controls are able to be demonstrated	150
3. Cyber controls implemented operate successfully	100
4. Cyber controls are effective in mitigating related threat	50
Total	450

Aggregate Score

Judges will score the vehicle examinations as follows:	Maximum Points
1. Written Report	450
2. Oral Presentation	150
3. Cyber Audit	600
Total	1200

VII. AWARDS AND RECOGNITION

All schools are only eligible to win award money once per event (Auto-Nav Challenge, Design Competition and IOP Challenge); if more than one team from the same school places in the same event, only the highest placing team will be placed in a standing and receive money for that event.

VII.1 AUTO-NAV CHALLENGE COMPETITION

Award Money
(Vehicle must complete course)

1ST Place	$ 3,000
2ND Place	$ 2,000
3RD Place	$ 1,500
4TH Place	$ 1,000
5TH Place	$ 750
6TH Place	$ 500

Nominal Award Money
(Vehicle must attain one waypoint in No Man;s Land)

1ST Place	$ 1,000
2ND Place	$ 800
3RD Place	$ 600
4TH Place	$ 500
5TH Place	$ 400
6TH Place	$ 300

VII.2   VEHICLE DESIGN COMPETITION

Design Competition Standard Awards
Dr. William G. Agnew Awards

1ST Place	$ 3,000
2ND Place	$ 2,000
3RD Place	$ 1,000
4TH Place	$ 750
5TH Place	$ 500
6TH Place	$ 250

Nominal Award Money
(Vehicle did not pass Qualification)

1ST Place	$ 600
2ND Place	$ 500
3RD Place	$ 400
4TH Place	$ 300
5TH Place	$ 200
6TH Place	$ 100

VII.3   IOP CHALLENGE

IOP Competition Standard Awards
Robot Vehicle must perform IOP challenge and qualify for eligibility of Standard IOP Award

1ST Place	$ 1,500
2ND Place	$ 1,000
3RD Place	$ 500
4TH Place	$ 350
5TH Place	$ 250
6TH Place	$ 150

Nominal Award Money
(Robot Vehicle must perform IOP challenge & Vehicle did not pass Qualification)

1ST Place	$ 600
2ND Place	$ 500
3RD Place	$ 400
4TH Place	$ 300
5TH Place	$ 200
6TH Place	$ 100

VII.4   Self Drive formerly SPEC 2 Awards are listed in a separate volume

VII.5   CYBER CHALLENGE AWARDS

1st ----------$1,500
2nd----------$1,100
3rd------------$900
4th------------$700
5th------------$500

6th------------$300

VII.6 ROOKIE-OF-THE-YEAR AWARD

The Rookie-of-the-Year Award will be given out to a team from a new school competing for the first time ever or a school that has not participated in the last five competitions (for this year the team would be eligible if they haven't competed since the 2012 IGVC). To win the Rookie-of-the-Year Award the team must be the best of the eligible teams competing and perform to the minimum standards of the following events. In the Design Competition you must pass Qualification, in the AutoNav Challenge you must pass the Rookie Barrel and in the IOP Challenge you must be compliant. The winner of the Rookie-of-the-Year Award will receive $1,000 in award money; in the case the minimum requirements are not met the best of the eligible teams competing will receive $500.

VII.7 GRAND AWARD

The Grand Award trophies will be, presented to the top three teams that perform the best overall (combined scores per below), in all three challenges. For each Challenge, points will be awarded to each team, below is a breakdown of the points:

Standard Grand Award Points*

Challenge	First	Second	Third	Fourth	Fifth	Sixth
Auto-Nav	24	20	16	12	8	4
Design	24	20	16	12	8	4
IOP	24	20	16	12	8	4

Nominal Grand Award Points**

Challenge	First	Second	Third	Fourth	Fifth	Sixth
Auto-Nav	12	10	8	6	4	2
Design	12	10	8	6	4	2
IOP	12	10	8	6	4	2

* For Standard Grand Award Points, the team must complete the Auto-Nav course and qualify in Auto Nav for the Design Competition points and fully participate in all IOP Challenge aspects for IOP points.

** For Nominal Grand Award Points in each Challenge, The team must qualify to be eligible in the Auto-Nav Challenge and have their vehicle present for the Design Competition and IOP Challenge.

VIII PUBLICATION AND RECOGNITION

International recognition of all participating teams through AUVSI publications.

Videos of the competition event will be distributed to sponsors, media and the public. All design reports, articles, videos and pictures will be post on the IGVC website www.igvc.org.

Name	Years as Editor
Jerry Lane & Andrew Kosinski	2014-2019
Bernard Theisen	2013-2014
Jerry Lane	2011-2013
Bernard Theisen	2006-2010
Greg Gill	2005-2006
Bernard Theisen	2004-2005
Dan Maslach	2003-2004
Bernard Theisen	2001-2003
Stephen W. Roberts	2000-2001
Scot Wheelock	1999-2000
Geoff Clark	1998-1999
G. Edzko Smid	1997-1998
Candy McLellan and G. Edzko Smid	1996-1997
Jerry Lane, Paul Lescoe and Ka C. Cheok	1992-1996

IGVC Rules Editors

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

IX "IGVC In Memory Of"

Paul Lescoe	TARDEC Robotics Engineer	IGVC Co-Founder & Co-Chair
James Overholt	TARDEC Chief Roboticist	IGVC Judge & Official
Nattu Natajaran	UMD Professor	IGVC Faculty
Wayne Wheelock	Former TARDEC Director	IGVC Design Judge

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