The logo for the Intelligent Ground Vehicle Competition (IGVC) is a circular emblem. It features a blue background with a white outline. The words "Intelligent Ground Vehicle Competition" are written in a circular path around the perimeter. In the center, the letters "IGVC" are prominently displayed in a large, white, sans-serif font.

**The 18<sup>TH</sup> Annual Intelligent  
Ground Vehicle Competition  
(IGVC)**

**June 4<sup>TH</sup> - 7<sup>TH</sup>, 2010  
Oakland University  
Rochester, Michigan**

*In memory of Paul Lescoe*

---

***Student Teams are Invited to Display Their Vehicles at The Association for  
Unmanned Vehicle Systems International's Unmanned Systems North America  
2010 Symposium & Exhibition Held at Colorado Convention Center  
in Denver, Colorado on August 24<sup>TH</sup> – 27<sup>TH</sup>, 2010***

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**October 17, 2009 Version**

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# I. COMPETITION INFORMATION

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## I.1 TEAM ENTRIES

Teams may be comprised of undergraduate and graduate students, and must be supervised by at least one faculty advisor. Interdisciplinary teams are encouraged (EE, ME, CS, etc.). 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 himself 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 2009 and June 2010.

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 distinct design report. 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 \$250.00 non-refundable registration fee made payable to *Oakland University*. Intention to compete must be received no later than **February 28, 2010**, by mailing your application form to:

**Gerald C. Lane  
C/O Dr. Ka C. Cheok  
102G SEB  
SECS-ESE Dept.  
Oakland University  
Rochester, MI 48309-4478**

If you have any questions, please contact Bernard Theisen by telephone at (586) 574-8750, fax: (586) 574-8684 or e-mail: [bernard.theisen@us.army.mil](mailto:bernard.theisen@us.army.mil).

## 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 five feet.
- **Height:** Not to exceed 6 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).
- **Speed:** For safety, 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 50 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.
- **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.
- **A priori Data:** The intent is to compete without a priori or memorized data. Course position data should not be mapped/stored. This is difficult to enforce, each team is expected to comply with the intent. Both the Autonomous Challenge and Navigation Challenge courses will be changed after each heat and between runs to negate any memorization or course familiarization techniques.

### 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 performance events (Autonomous Challenge and Navigation Challenge). To complete Qualification the vehicle must pass/perform the following eight 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 five 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 50 feet. During the performance events the wireless E-stop will be held by the Judges.
- **Max Speed:** The vehicle will have to drive at full speed over a prescribed distance where its speed will be determined. The vehicle must not exceed the maximum speed of five miles per hour. 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 2 meter navigation waypoint.

During the Qualification the vehicle must be put in autonomous mode to verify the mechanical and wireless E-stops and to verify lane following and obstacle avoidance. The vehicle software can be reconfigured for waypoint navigation qualification. 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 sign an application form prior to **February 28, 2010**. Along with the application form, there will be a Waivers of Claims that will need to be signed by each individual who will be participating at the competition.

Additionally, the Team's sponsoring institution will also be required to supply AUVSI with 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.

NOTE: The IGVC Committee and Officials will adhere to the above official competition details, rules and format as much as possible. However, they 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.

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## II AUTONOMOUS CHALLENGE COMPETITION

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***All teams must pass Qualification to participate in this event.***

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### II.1 OBJECTIVE

A fully autonomous unmanned ground robotic vehicle must negotiate around an outdoor obstacle course under a prescribed time while staying within the 5 mph speed limit, and avoiding the obstacles on the track.

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, pothole hits, 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.

### II.3 OBSTACLE COURSE

The course will be laid out on grass, pavement, simulated pavement, or any combination, over an area of approximately 60 to 120 yards long, by 40 to 60 yards wide and be 700 to 800 feet in length. This distance is identified so teams can set their maximum speed to complete the course pending no prior violations resulting in run termination. The course boundaries will be designated by continuous or dashed white and/or yellow lane markers (lines) approximately three inches wide, painted on the ground. Track width will be approximately ten feet wide with a turning radius not less than five feet. Alternating side-to-side dashes will be 15-20 feet long, with 10-15 feet separation.

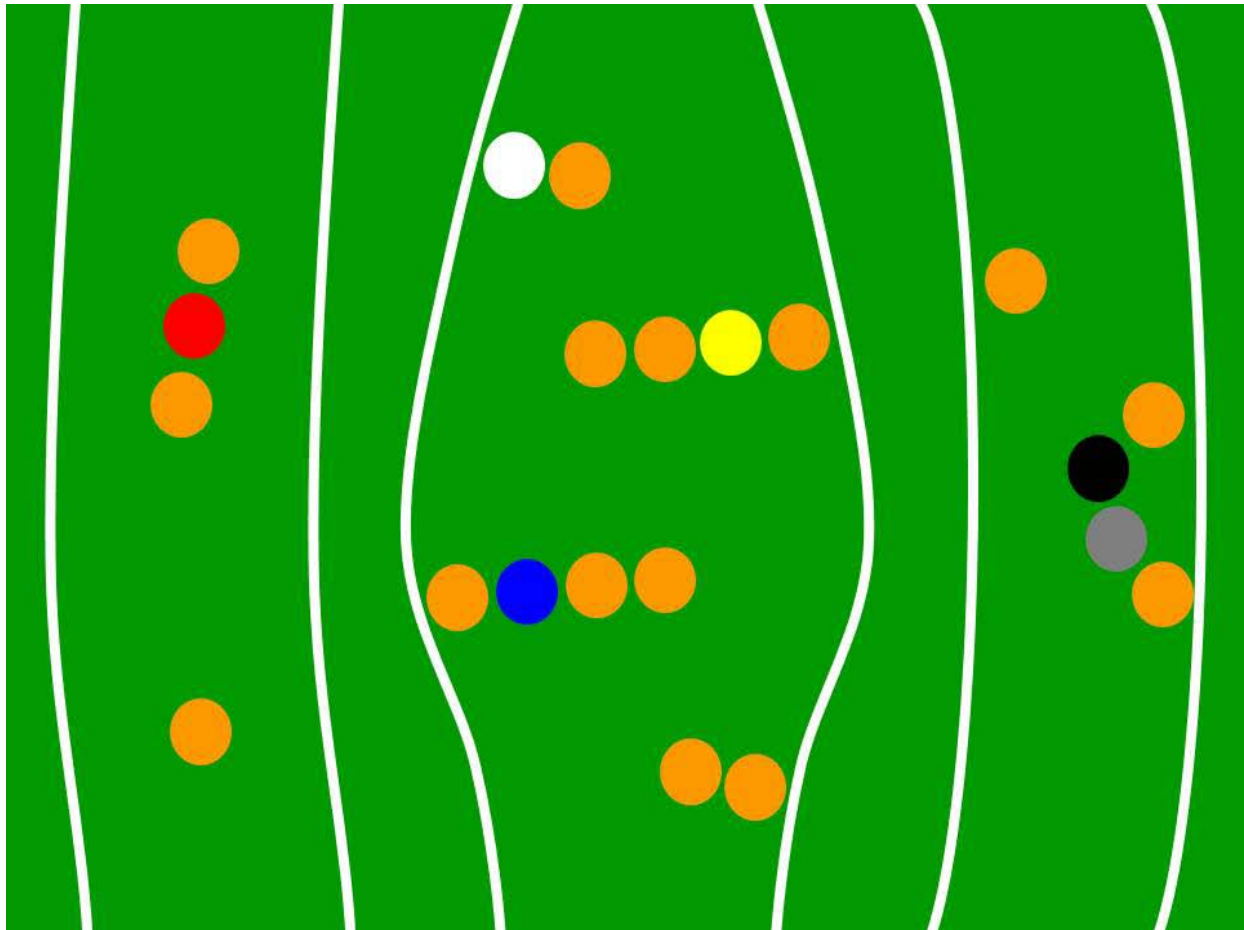
Expect natural or artificial inclines with gradients not to exceed 15%, sand pit (sand depth 2 - 3 inches) and randomly placed obstacles along the course. The course will become more difficult to navigate autonomously as vehicle progresses. The sand pit may be simulated with a light beige canvas tarp covering the entire width of the track for ten feet.

Obstacles on the course will consist of various colors (white, orange, brown, green, black, etc.) 5-gallon pails, construction drums, cones, pedestals and barricades that are used on roadways and highways. Natural obstacles such as trees or shrubs and manmade obstacles such as light post 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.

Potholes will be two feet in diameter and two inches in depth will be placed on the course. Simulated potholes are two feet diameter white circles, and may also be used on the course (Course width will be adjusted here to insure minimum passage width).

There will be a minimum of six 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 six 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 six feet of driving space for the vehicles.

Also in the event will be complex barrel arrangements with switchbacks and center islands. These will be adjusted for location between runs. Direction of the obstacle course may also be changed between heats.



**Examples of Obstacle Configurations on the Autonomous Course**

## **II.4 COMPETITION PROCEDURES**

- The competition will take place in the event of medium rain but not in heavy rain or lightning.
- Each qualified team will have the up to two runs (time permitting) in each of three heats.
- Judges/officials will assign a designated starting order. 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 team member is allowed on the course during a run.
- 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.
- The Starting Official will call teams to the starting line. The Starting Officials' direction is final; the Starting Official may alter the order to enhance the competition flow of entries (e.g. slower vehicles may be grouped together to allow the running of two vehicles on the course simultaneously).
- A team will have one minute in the starting point to prep the vehicle for the judge to start the vehicle.
- The judge will start the vehicle by a one touch motion; i.e. hitting the enter key of a keyboard, a left mouse click, lifting the e-stop up, flipping a toggle switch, etc.

- An attempt will be declared valid when a designated judge gives 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.
  - Five minutes have passed after the vehicle run has started.
  - The vehicle has not started after one minute after moving to the start line or at the judges' discretion.
  - Teams will ready the vehicle for start and advise the IGVC Judge to push one button to start the vehicle, the vehicle must be ready for a judges start command in one minute.
  - An official will carry the E-Stop.
- Time for each heat will be strictly observed.
- Tactile sensors will not be allowed.
- Actual potholes (two feet in diameter and two inches deep) or simulated potholes (two feet diameter top soil circle) will introduced on the course.
- Each vehicle will be given 5 minutes per attempt to complete the course, if the vehicle has not completed the course in the 5 minute time period, it will ended by a judge's choice E-stop, with no penalty assigned for that run.
- Each vehicle must navigate the course by remaining inside the course boundaries and navigating around course obstacles. 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 Practice Course

All teams that have Qualified will be given six tokens. Each token represent one opportunity to use the Autonomous Challenge Practice Course. The course will be open daily for use from the time a team Qualifies till the start of the third heat of the Autonomous Challenge. The course will be run like the Autonomous Challenge with the same rules and similar obstacles. One token allows a maximum of six minutes (one minute at the start point and five minutes for the run) on the Autonomous Challenge Practice Course. In that time you must position your vehicle at the start, prep the vehicle for the judge to start, and can continue to run as long as you do not break any of the rules of the Autonomous Challenge. If so, your run and remaining time will be ended. All teams will still have unlimited access to the regular practice fields.

## II.6 TRAFFIC VIOLATION LAWS

	Traffic Violations	Ticket Value	E-Stop	Measurement
1	Leave the Course/Scene	- 10 Feet	Yes	Yes
2	Crash/Obstacle Displacement	- 10 Feet	Yes	Yes
3	Careless Driving	- 5 Feet	No	No
4	Sideswipe/Obstacle Touch	- 5 Feet	No	No
5	Student's Choice E-Stop	- 5 Feet	Yes	Yes
6	Judge's Choice E-Stop	0 Feet	Yes	Yes
7	Potholes	- 5 Feet	No	No
8	Blocking Traffic	- 5 Feet	Yes	Yes
9	Loss of Payload	0 Feet	Yes	Yes

- **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 outside 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.
- **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. Rocking/Tilting an obstacle with no permanent displacement is not considered obstacle displacement. Rocking/Tilting is a – 5 feet ticket value.
- **Actual and Simulated Potholes:** Hitting or crossing potholes will result in – 5 feet ticket value for each pothole hit or crossed and render run ineligible for standard prize money.
- **Blocking Traffic:** Vehicles stopping on course for over one minute will be stopped and measured.

## II.7 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 five minute 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 passing the money barrel. The money barrel location is determined by the judges during the final/actual course layout. If a tie is declared between entries, the award money will be split between them.

## II.8 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.
-

### III. DESIGN COMPETITION

---

**All teams must participate in the Design Competition.**

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#### 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 report should not exceed 15 letter-sized pages, including graphic material and all appendices, but not including the title page. Line spacing must be at least 1.5, with at least a 10 point font (12 is preferred). Each vehicle must have a distinct and complete report of its own (a report cannot cover more than one vehicle). Participants are required to submit four hard copies of the report and an electronic copy on a CD; failure to submit either of these will result in **disqualification**. 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. The certification should also include a brief description of the areas in which changes have been made to a vehicle from a previous year. Everything must be mailed so as to arrive by **May 17, 2010**, addressed to:

**Bernard Theisen  
21281 Curie Avenue  
Warren, MI 48091-4316**

**Written reports arriving after that date will lose 10 points in scoring for each business day late, electronic copies arriving after that date will lose 5 points in scoring for each business 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  
electrical system  
actuators  
software strategy  
sensors  
computers

design planning process  
signal processing  
plan for path following  
(both solid & dashed lines)  
plan for control decisions  
system integration plan

Design of the lane following and obstacle detection/avoidance systems must be specifically described. Also, the system used for waypoint navigation should be detailed.

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. 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. 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
- 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 (15 pages or less) treating both the old and new features, thus describing the complete vehicle as if it were all new.

<b>Judges will score the written reports as follows:</b>	<b>Maximum Points</b>
1. Conduct of the design process and team organization (including decision-making & software development)	50
2. Completeness of the documentation	50
3. Quality of documentation (English, grammar, and style)	50
4. Effective innovation represented in the design (as described above)	150
5. Description of electronic design*	100
6. Description of software strategy*	150
7. Description of systems integration*	150
*Descriptions to include: lane following, obstacle detection/ avoidance, and waypoint navigation (GPS or other)	
8. Efficient use of power and materials	50
9. Attention given to safety, reliability, and durability	50
<b>Total</b>	<b>800</b>

### 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:

<b>Judges will score the oral presentations as follows:</b>	<b>Maximum Points</b>
1. Clear and understandable explanation of the innovations	50
2. Logical organization of the talk	25
3. Effective use of graphic aids	25
4. Articulation	20
5. Demonstrated simulation of vehicle control in performance events	10
6. Response to questions	10
7. Salesmanship	10
<b>Total</b>	<b>150</b>

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. 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.

### **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 during the competition. Software is not included in this judging. Judging will be as follows:

<b>Judges will score the vehicle examinations as follows:</b>	<b>Maximum Points</b>
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
<b>Total</b>	<b>150</b>

### **III.5 FINAL SCORING**

The number of points awarded by the individual judges will be averaged for each of the 22 judging areas above, and these results will be offered to each participating team for their edification. The total of the average scores over all 22 areas (max 1100) will be used to determine the award winners.

When two teams of judges are used (due to a large number of entries) each judging team will determine the top three winners in their group, and the resulting six contestants will participate in a runoff of oral presentations and vehicle examinations judged by all judges. Those results will be combined with the original written report scores to determine the final winner.

## IV. NAVIGATION CHALLENGE

---

***All teams must pass Qualification to participate in this event.***

---

### IV.1 OBJECTIVE

Navigation is a practice that is thousands of years old. It is used on land by hikers and soldiers, on the sea by sailors, and in the air by pilots. Procedures have continuously improved from line-of-sight to moss on trees to dead reckoning to celestial observation to use of the Global Positioning System (GPS). The challenge in this event is for a vehicle to autonomously travel from a starting point to a number of target destinations (waypoints or landmarks) and return to home base, given only the GPS coordinates of the targets in latitude and longitude.

### IV.2 ON-BOARD SENSORS

It is expected that most contestants will use Differential GPS, but non-differential GPS is allowed as well as dead reckoning with compasses, gyros, and wheel odometers. Vision systems and/or sonar and laser rangefinders may be used for obstacle detection. There are a number of handheld GPS systems that connect to laptop computers available on the market for under \$200. Garmin, SkyMap/GPS, and Magellan are some; Earthmate even has one for Macintosh. These may not be convenient to integrate in vehicle control programs. However, differential GPS units are available from Hemisphere GPS, Trimble, Thales, Magellan, Garmin, NovAtel, and Starlink (and possibly others). Differential correction signals are available in the Southeast Michigan area from the U.S. Coast Guard. WAAS or any of the commercial suppliers of corrections are also allowed. The use of a base station to supplement the on board GPS unit is not permitted.

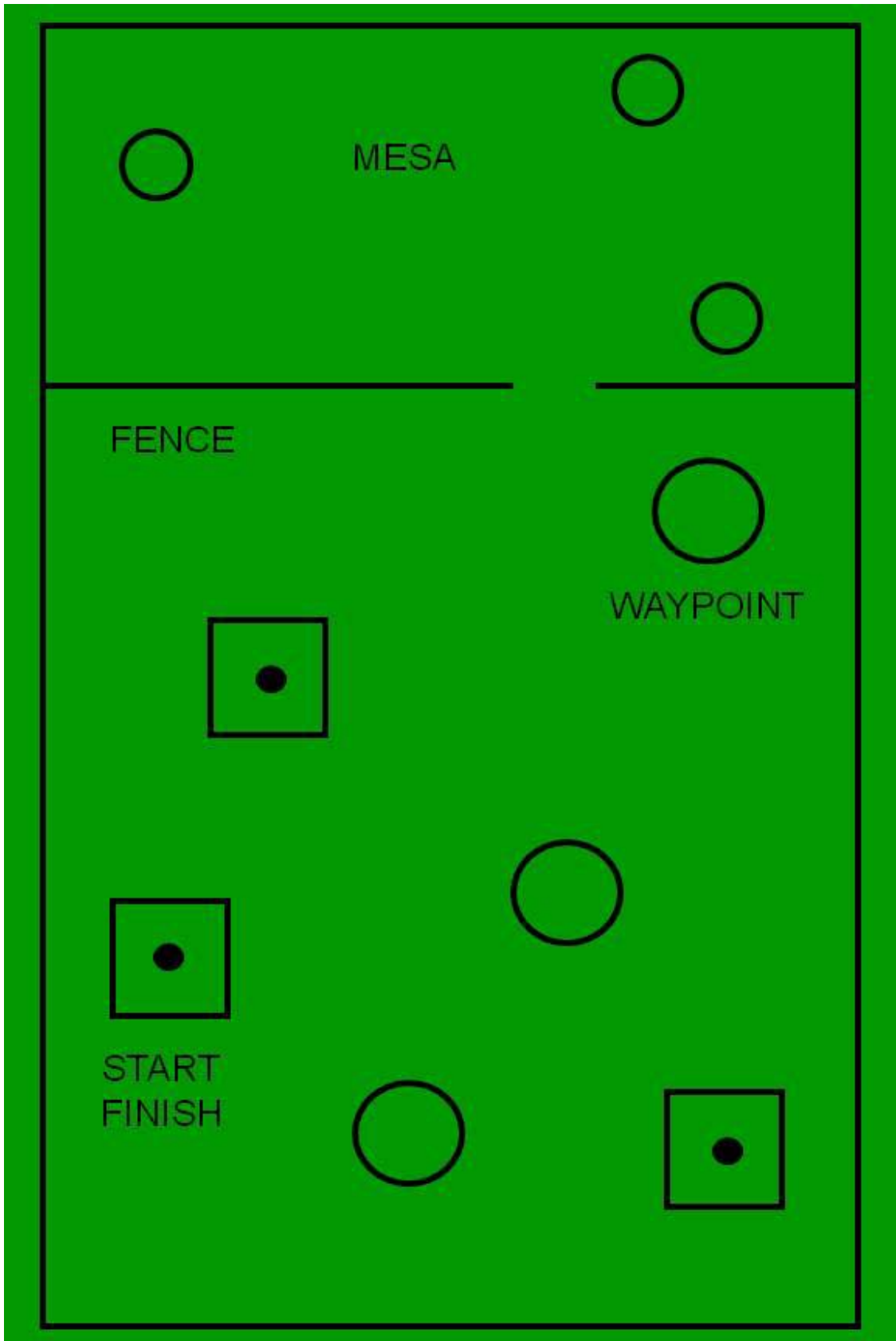
### IV.3 GPS COURSE

The map in the figure below shows a typical course for the Navigation Challenge. This is a practice map for use by teams during development of their vehicle. Coordinates for the actual navigation course waypoints will be given to the contestants on **June 5, 2010** in degrees latitude and longitude, but no XY coordinates will be provided. There will be three starting boxes (one for each heat) that serve also as waypoints. (To locate the course perimeter, the southwestern corner of the course will be 10 meters west and 30 meters south of the westernmost starting box. The course is oriented to true north.)

The competition course will be run on grass and will be approximately 55 by 65 meters (roughly 0.1 acre), and the total travel distance on the course will be on the order of 220 meters depending on the route chosen for the vehicles. The exact waypoint locations will be marked on the grass for use by the judges, but there will be no standup markers to indicate those positions. Construction barrels, barricades, fences, and certain other obstacles will be located on the course in such positions that they must be circumvented to reach the waypoints. These may be randomly moved between runs.

The course will be divided into two areas by a fence with a 2 meter wide opening located somewhere along it (no coordinates are provided). The opening will be randomly relocated along the fence at the start of each run. Waypoints south of the fence (the Valley) will have 4 meter diameter circles or squares around them (visible only to the judges) and waypoints north of the fence (the Mesa) will have 2 meter circles around them.

No team participant is allowed on the course before the team's first run, and only one team member is allowed on the course during a run.



2010 Practice Map for the Navigation Course

## **IV.4 RUN PROCEDURE AND SCORING**

There will be three heats during the day with start and stop times the same as those in the Autonomous Challenge. It is intended that each team will be allowed up to two runs on the course during each of the three heats. The trial with the best performance will be used for scoring. Starting times will be first-come-first-served within each heat, except that teams up for their first trial will have priority over those wanting a second trial. It is unlikely that there will be time in the day for all registered teams to get six tries.

Vehicles will park in the starting box selected by the judges for each heat and have 5 minutes for final adjustments before starting. Vehicles may seek the waypoints in any order, and the vehicle actually reaching the most waypoints (counting also the Start/Finish boxes) in the allotted six minute run time will be the winner. The vehicle must finish in the same box in which it started. If two or more vehicles reach the same number of waypoints, the vehicle doing so in the least time will be declared the leader. If two or more vehicles reach the same number of waypoints while stopped by the six-minute rule, they will be declared tied and will share any awards.

If a vehicle fails to come within two meters of a target in the southern area of the course or one meter in the northern area, it will not be judged to have reached that target. In order to qualify for standard award money a vehicle must reach at least six waypoints (not counting the start/finish box).

## **IV.5 RUN TERMINATION**

All runs will be terminated by an E-stop (by the students or the judges) signaled by a judge's whistle or bell, either:

- When the vehicle arrives back at the original starting point or enters that starting box any time after first leaving it.
  - If any part of the vehicle leaves the perimeter of the field
  - If the vehicle strikes any obstacle.
  - If six minutes have elapsed since the start of the run (220 meters in six minutes is 1.4 miles per hour).
  - In all cases the judges' call will be final.
-

## V. JAUS CHALLENGE

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*Participation in the JAUS Challenge is recommended.*

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### V.1 TECHNICAL OVERVIEW

Each entry will interface with the Judge's COP providing information as specified below. The general approach to the JAUS interface will be to respond to a periodic status and position requests from the COP. This requires the support of the JAUS Transport Specification (AS5669A) and the JAUS Core Service Set (AS5710). The JAUS Transport Specification supports several communication protocols, the competition will use only the Ethernet based JUDP. The Core services required for the competition include the discovery, access control, and management services. The JAUS Mobility Service Set (AS6009) or JSS-Mobility defines the messaging to be used for position communications and waypoint based navigation.

### V.2 COMMON OPERATING PICTURE

The COP will provide a high level view of the systems in operation that successfully implement the JAUS protocol as described above. This software is a simple validation, reporting and recording tool for the Judges to use while verifying student implementations of the JAUS standard. It provides a graphical display of the operational area in relative coordinates. Primitive graphics are loaded in the display of the COP to add perspective. Each reported status is displayed on the COP user interface and recorded for future reference. For competitions and systems reporting positional data, a 2-D map on the COP display is annotated with the updated position as well as track marks showing the previous position of the system for the current task.

### V.3 COMMUNICATIONS PROTOCOLS

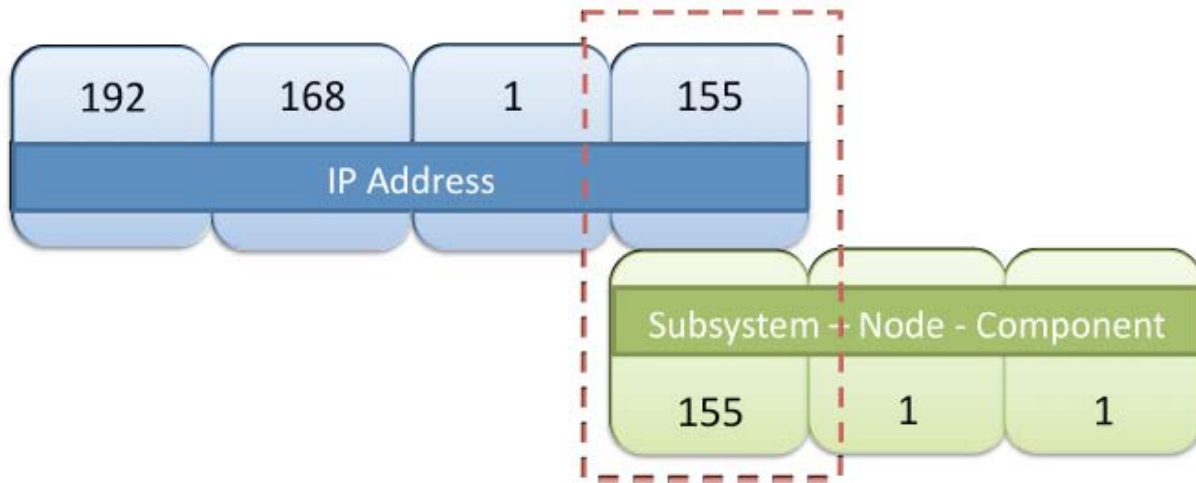
The teams will implement a wireless 802.11b/g or hardwired Ethernet (RJ-45) data link. The interface can be implemented at any point in the student team's system including the control station or mobility platform.

The Internet Protocol (IP) address to be used will be provided at the competition. For planning purposes, this address will be in the range of 192.168.1.100 to 192.168.1.200. The Judge's COP will have both hard-wire and 802.11b/g capabilities where the IP address of the COP will be 192.168.1.42. 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 port number for all JAUS traffic shall be 3794.

### V.4 JAUS SPECIFIC DATA

The JAUS ID mentioned above is a critical piece of data used by a JAUS node to route messages to the correct process or attached device. As indicated above each team will be provided an IP address in which the last octet will be used in their respective JAUS ID. A JAUS ID 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 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. So for the team assigned the IP address of 192.168.1.155, the completed JAUS ID of the position-reporting component might be 155-1-1 where the node and component are both assigned the IDs of 1. This is shown in the IP and JAUS ID Assignment Figure below. The Node ID and Component ID are discussed further in the JAUS Service Interface

Definition Language standard (AS5684). The COP software will be programmed with the assumption that all services required by the specific competition are implemented on a single component.



**IP and JAUS ID Assignment**

In summary, each team will be assigned an IP address by the judges. The last octet of that IP address will be the team's subsystem identifier. The COP will be a subsystem as will each team's entry in the competition. The COP will have a JAUS ID of 42:1:1 and an IP address of 192.168.1.42. The port number shall be 3794.

## V.5 COMPETITION TASK DESCRIPTION

Messages passed between the COP and the team entries will include data as described in the task descriptions below. The COP will initiate all requests subsequent to the discovery process described as Task 1. A system management component is required of all teams. This interface will implement several of the messages defined by the Management Service defined in the JSS-Core. This service inherits the Access Control, Events and Transport services also defined by the JSS-Core document. The implementation of the Access Control interfaces will be necessary to meet the JAUS Challenge requirements; however no messages from the Events service will be exercised. The sequence diagram in Discovery and System Management Figure shows the required transactions for discovery including the access control setup and system control protocol. This interaction is required for every task.

The judges will evaluate each team's ability to meet the Interoperability Challenge for the tasks described below in accordance with the scoring chart.

Judges will score the task as follows:	Maximum Points
1. Transport Discovery	10
2. Capabilities Discovery	10
3. System Management	10
4. Velocity State Report	10
5. Position and Orientation Report	10
6. Waypoint Navigation	10
<b>Total</b>	<b>60</b>

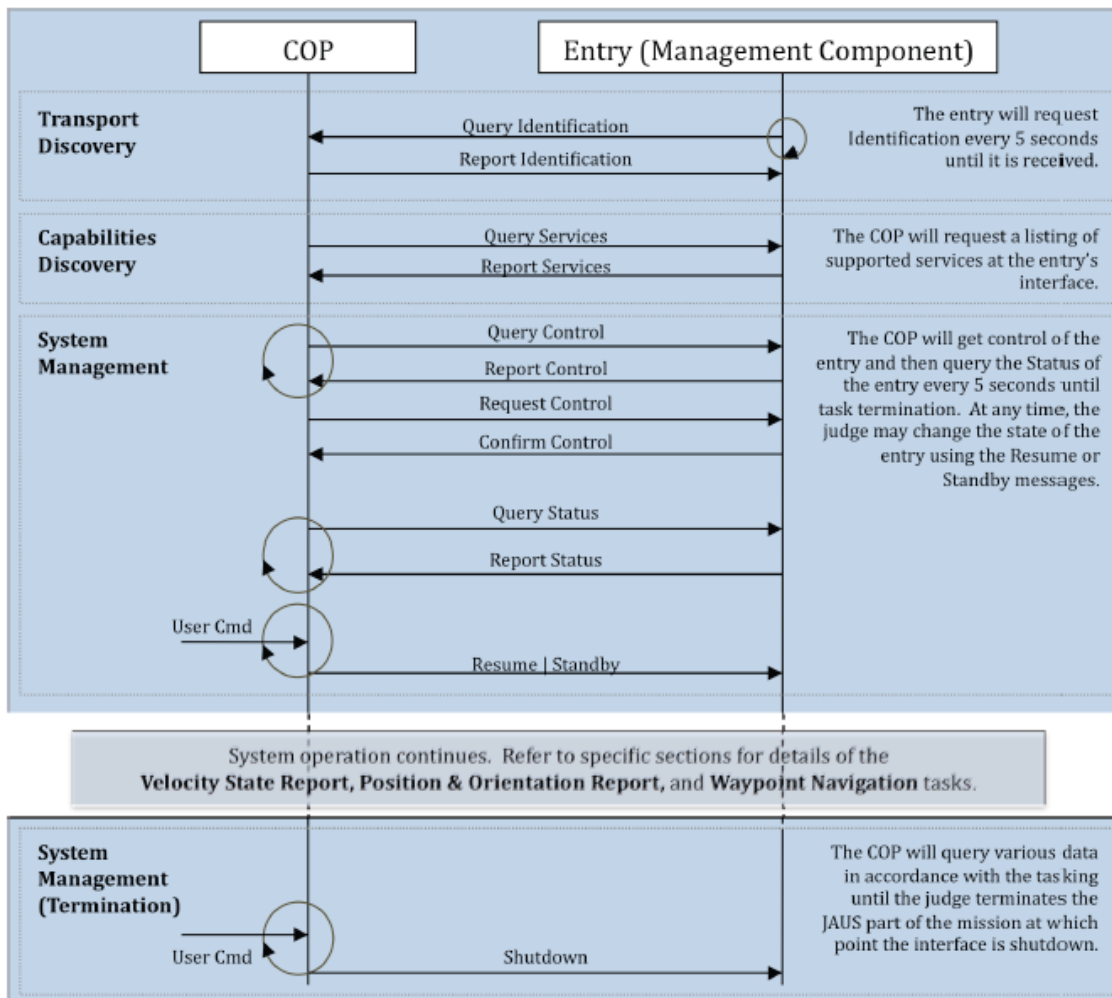
## V.6 TRANSPORT DISCOVERY

For any two elements in the system to communicate meaningful data there must first be a handshake to ensure both sides use the same protocols and are willing participants in the interaction. For the sake of simplicity, the team's entry shall initiate the discovery protocol with the Judge's COP, and the IP address and JAUS ID of the COP shall be fixed. The IP address and JAUS ID of the Judge's COP are defined as:

COP IP ADDRESS: 192.168.1.42:3794  
 COP JAUS ID: 42-1-1 (Subsystem-Node-Component)

The discovery process, in Discovery and System Management Figure, will occur at the application layer. The student team's JAUS element will send a request for identification to the COP once every 5 seconds. The COP will respond with the appropriate informative message and request identification in return from the team's JAUS interface. After the identification report from the COP, the team entry will stop repeating the request. This transaction will serve as the basic discovery between the two elements.

The COP software will be programmed with the assumption that all services required by the specific competition are provided at the single JAUS ID. Furthermore, as per the AS5669A Specification, the team's entry shall receive JUDP traffic at the same IP address and port number that initiated the discovery protocol. Teams should note that this is different from common UDP programming approaches in which the outbound port for sent messages is not bound.



**Discovery and System Management**

The following table shows the messages sent from the COP to the team's entry, along with the expected response and minimal required fields to be set using the presence vector (PV) if applicable, required to complete this portion of the challenge:

Input Messages	Expected Response	Required Fields (PV)
Query Identification	Report Identification	N/A

## V.7 CAPABILITIES DISCOVERY

Following the completion of the Transport Discovery handshake the COP will query the entry for its capabilities. The Query Services message and Report Services message are defined in the AS5710 document and require the inheritance of the Transport service. The COP will send a Query Services message to a student team entry. Upon receipt of the message the student team entry shall respond with a properly formed Report Services message.

The following table shows the messages sent from the COP to the team's entry, along with the expected response and minimal required fields to be set using the presence vector (PV) if applicable, required to complete this portion of the challenge:

Input Messages	Expected Response	Required Fields (PV)
Query Identification	Report Identification	N/A

## V.8 SYSTEM MANAGEMENT

The implementation of the status report is required. This interoperability task, like the discovery tasks above, is also a prerequisite for all other tasks. The task begins with the discovery handshake as described above and continues for an indeterminate period of time. The protocol is given in Discovery and System Management Figure. The following table shows the messages sent from the COP to the team's entry, along with the expected response and minimal required fields to be set using the presence vector (PV) if applicable, required to complete this portion of the challenge:

Input Messages	Expected Response	Required Fields (PV)
Query Control	Report Control	N/A
Request Control	Confirm Control	N/A
Query Status	Report Status	N/A
Resume	<none>	N/A
Standby	<none>	N/A
Shutdown	<none>	N/A

## V.9 VELOCITY STATE REPORT

In the Velocity State Report task the COP will query the entry for its current velocity state. The COP will send a Query Velocity State message to a student team entry. Upon receipt of the message the student team entry shall respond with a properly formed Report Velocity State message.

The following table shows the messages sent from the COP to the team's entry, along with the expected response and minimal required fields to be set using the presence vector (PV) if applicable, required to complete this portion of the challenge:

Input Messages	Expected Response	Required Fields (PV)
Query Velocity State	Report Velocity State	Velocity X, Yaw Rate & Time Stamp [320 Decimal, 0140h]

## V.10 POSITION AND ORIENTATION REPORT

For performing the task Position and Orientation Report, the discovery and status protocols described above are also required. In addition to the COP queries for status, the vehicle systems will also be required to respond correctly to local position queries. The reports will be validated for relative position and with respect to a relative time offset to ensure the time contained within each position report is valid with respect to some timer within the entry's system. In other words, the position reports must show that the travel occurred at a reasonable speed and not instantaneously. Additional variation in the position reporting using the available presence vectors is allowed. Minimally, all entries must report X, Y and Time Stamp.

The following table shows the messages sent from the COP to the team's entry, along with the expected response and minimal required fields to be set using the presence vector (PV) if applicable, required to complete this portion of the challenge:

Input Messages	Expected Response	Required Fields (PV)
Set Local Pose	<none>	X, Y & Yaw [67 Decimal, 0043h]
Query Local Pose	Report Local Pose	X, Y & Time Stamp [259 Decimal, 0103h]

## V.11 WAYPOINT NAVIGATION

The team entry shall implement the Local Waypoint List Driver service from the JAUS Mobility Service Set (AS6009). From a starting point in the JAUS challenge test area the student entry will be commanded to traverse, in order, a series of 4 waypoints. Time will be kept and will start at the moment that the student entry exits the designated start box. Upon leaving the start box the student entry will proceed to the first waypoint in the list. Upon satisfactorily achieving each waypoint the team will be credited with 2.5 points. **Time** is kept for each waypoint achieved. The shortest overall time taken to achieve this task will determine the winner in the event of a tie.

The following table shows the messages sent from the COP to the team's entry, along with the expected response and minimal required fields to be set using the presence vector (PV) if applicable, required to complete this portion of the challenge:

Input Messages	Expected Response	Required Fields (PV)
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	<none>	N/Speed (value of 1)
Query Active Element	Report Active Element	N/A
Query Travel	Report Travel Speed	N/A
Query Local Waypoint	Report Local Waypoint	X & Y (value of 3)

## VI. AWARDS AND RECOGNITION

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*All schools are only eligible to win award money once per event (Autonomous Challenge, Design Competition, Navigation Challenge and JAUS 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.*

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### VI.1 AUTONOMOUS CHALLENGE COMPETITION

#### Autonomous Competition Standard Awards

1 <sup>ST</sup> Place	\$5,000
2 <sup>ND</sup> Place	\$4,000
3 <sup>RD</sup> Place	\$3,000
4 <sup>TH</sup> Place	\$2,000
5 <sup>TH</sup> Place	\$1,000
6 <sup>TH</sup> Place	\$ 750

#### Nominal Award Money

(Short of money barrel)

1 <sup>ST</sup> Place	\$1,000
2 <sup>ND</sup> Place	\$ 800
3 <sup>RD</sup> Place	\$ 600
4 <sup>TH</sup> Place	\$ 400
5 <sup>TH</sup> Place	\$ 200
6 <sup>TH</sup> Place	\$ 100

### VI.2 VEHICLE DESIGN COMPETITION

#### Design Competition Standard Awards

1 <sup>ST</sup> Place	\$3,000
2 <sup>ND</sup> Place	\$2,000
3 <sup>RD</sup> Place	\$1,000
4 <sup>TH</sup> Place	\$ 750
5 <sup>TH</sup> Place	\$ 500
6 <sup>TH</sup> Place	\$ 250

#### Nominal Award Money

(Vehicle did not pass Qualification)

1 <sup>ST</sup> Place	\$ 600
2 <sup>ND</sup> Place	\$ 500
3 <sup>RD</sup> Place	\$ 400
4 <sup>TH</sup> Place	\$ 300
5 <sup>TH</sup> Place	\$ 200
6 <sup>TH</sup> Place	\$ 100

### VI.3 NAVIGATION CHALLENGE COMPETITION

#### Navigation Competition Standard Awards

1 <sup>ST</sup> Place	\$4,000
2 <sup>ND</sup> Place	\$3,000
3 <sup>RD</sup> Place	\$2,000
4 <sup>TH</sup> Place	\$1,000
5 <sup>TH</sup> Place	\$ 750
6 <sup>TH</sup> Place	\$ 500

#### Nominal Award Money

(Did not make 7 waypoints)

1 <sup>ST</sup> Place	\$ 800
2 <sup>ND</sup> Place	\$ 600
3 <sup>RD</sup> Place	\$ 400
4 <sup>TH</sup> Place	\$ 300
5 <sup>TH</sup> Place	\$ 200
6 <sup>TH</sup> Place	\$ 100

### VI.5 JAUS CHALLENGE

#### JAUS Competition Standard Awards

1 <sup>ST</sup> Place	\$3,000
2 <sup>ND</sup> Place	\$2,000
3 <sup>RD</sup> Place	\$1,000
4 <sup>TH</sup> Place	\$ 750
5 <sup>TH</sup> Place	\$ 500
6 <sup>TH</sup> Place	\$ 250

#### Nominal Award Money

(Vehicle did not pass Qualification)

1 <sup>ST</sup> Place	\$ 600
2 <sup>ND</sup> Place	\$ 500
3 <sup>RD</sup> Place	\$ 400
4 <sup>TH</sup> Place	\$ 300
5 <sup>TH</sup> Place	\$ 200
6 <sup>TH</sup> Place	\$ 100

### VI.5 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 ninth IGVC in 2004). 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 Autonomous Challenge you must pass the Rookie Barrel and in the Navigation Challenge you must make three waypoints. 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.

## VI.6 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 competitions. For each competition, points will be awarded to each team, below is a breakdown of the points:

Autonomous Challenge	Passed Money Barrel	Short of Money Barrel
First Place	48	24
Second Place	40	20
Third Place	32	16
Fourth Place	24	12
Fifth Place	16	8
Sixth Place	8	4

Design Competition	Vehicle Qualified	Vehicle Failed to Qualify
First Place	24	12
Second Place	20	10
Third Place	16	8
Fourth Place	12	6
Fifth Place	8	4
Sixth Place	4	2

Navigation Challenge	Completed 7 Waypoints	Short of 7 Waypoints
First Place	36	18
Second Place	30	15
Third Place	24	12
Fourth Place	18	9
Fifth Place	12	6
Sixth Place	6	3

J AUS Competition	Vehicle Qualified	Vehicle Failed to Qualify
First Place	24	12
Second Place	20	10
Third Place	16	8
Fourth Place	12	6
Fifth Place	8	4
Sixth Place	4	2

## VI.7 PUBLICATION AND RECOGNITION

International recognition of all participating teams through AUVSI and SAE publications.

Special recognition for the vehicles will be held at the Association for Unmanned Vehicle Systems International's Unmanned Systems North America 2010 Symposium & Exhibition Held at Colorado Convention Center in Denver, Colorado on August 24<sup>TH</sup> – 27<sup>TH</sup>, 2010

All teams are invited to display the winning vehicles in the AUVSI exhibit halls.

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](http://www.igvc.org).

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***If you have any questions, please feel free to contact any of the following IGVC Officials:***

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<b><u>Name</u></b>	<b><u>Years as Editor</u></b>
<b>Bernard Theisen</b>	<b>2006-2010</b>
<b>Greg Gill</b>	<b>2005-2006</b>
<b>Bernard Theisen</b>	<b>2004-2005</b>
<b>Dan Maslach</b>	<b>2003-2004</b>
<b>Bernard Theisen</b>	<b>2001-2003</b>
<b>Stephen W. Roberts</b>	<b>2000-2001</b>
<b>Scot Wheelock</b>	<b>1999-2000</b>
<b>Geoff Clark</b>	<b>1998-1999</b>
<b>G. Edzko Smid</b>	<b>1997-1998</b>
<b>Candy McLellan and G. Edzko Smid</b>	<b>1996-1997</b>
<b>Jerry Lane, Paul Lescoe and Ka C. Cheok</b>	<b>1992-1996</b>

**IGVC Rules Editors**

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**October 17, 2009 Version**