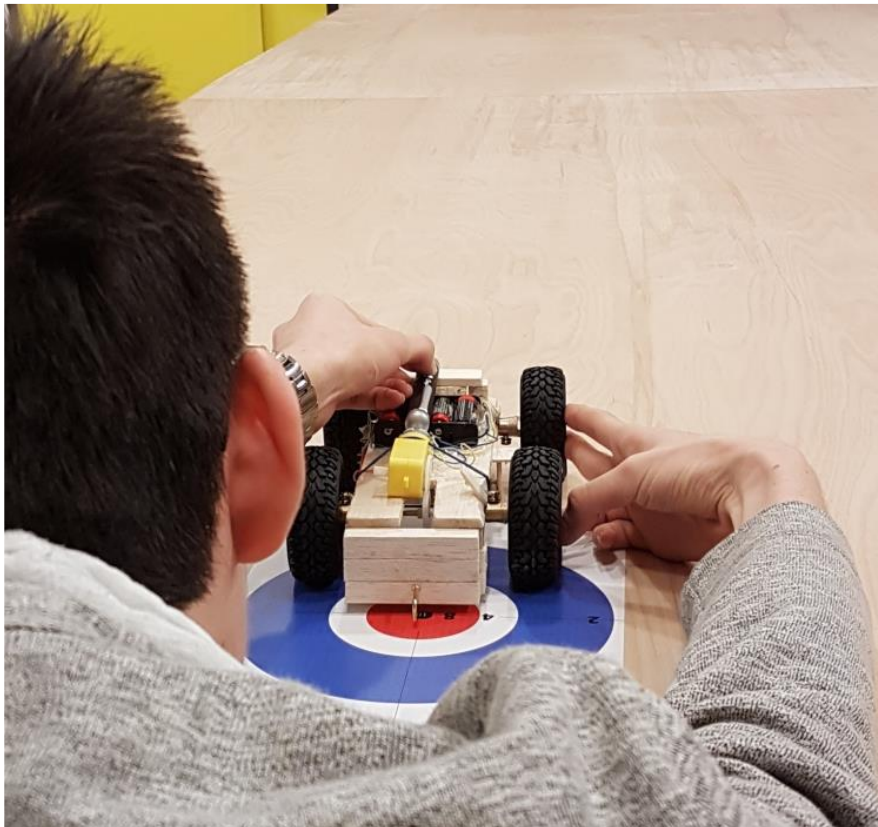


DESIGN CHALLENGE PROJECT SPECIFICATION AND RULES 2024

Institution of
**MECHANICAL
ENGINEERS**

IMechE DESIGN CHALLENGE

REPEATABLE VEHICLE



Project Specification and Rules for the 2024 Repeatable vehicle Design Challenge

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Note: this specification must be read in conjunction with the respective document

“IMechE Design Challenge - General Specification 2024”
available on the IMechE Design Challenge website.

Please check the IMechE Design Challenge website for updates.

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List of Amendments:

Version	Page	Details	Date
1.0	-	(Document Released)	

List of Major Changes Since 2023

- Integration of all the categories in a single document. See relevant sections for applicability
- Removal of duplicated section if already covered in the associated general specification "IMEchE Design Challenge - General Specification 2024".

Please report any errors to Emma.Pateman@imeche.org so that corrections can be made.

1. Introduction

The Design Challenge, organised by the Institution of Mechanical Engineers, is an annual competition for students from university technical colleges (UTCs) and students on an undergraduate engineering degree programme. The Design Challenge comprises five parts, all of which are detailed in the General Specification.



Figure 1 Example of self driving vehicle (Volvo, docks autonomous truck)

This year the challenge is to design, build and test a device to simulate an autonomous vehicle, such as driverless truck used in confined areas like docks, ports or mines, automated trolleys for warehouses or any other similar device.

The competing device should be capable of doing a repeatable task in straight line, on a track laid horizontally. The device can be of any construction and propulsion method, limited only by cost, and size, within the specification detailed in this document and the associated "IMechE Design Challenge - General Specification 2024". The device can be based on any moving technology with contact with the horizontal surface, such as wheeled, walking, sliding, jumping, rolling.

The device must be totally self-contained and the method of starting it must be attached to, and travel with, the device at all times. Points will be awarded for the accuracy of the device performing the mission.

The competing device should:

- complete the specified mission of repeated movements
- be started manually and perform the mission autonomously, without any other external support or control of any sort
- be capable of performing on a real installation where errors in horizontality and track flatness may be present and on a commercial substrate where real manufacturing tolerances are present, without requiring any post treatment or adjustment of the track surface or the vehicle
- vehicle accuracy and repeatability will be evaluated according to the precision relative to the target scheme provided, see Appendix 1 - Target Area

Sections applicable or not applicable to a specific category of competing devices will be noted and identified in this document where relevant; see "IMechE Design Challenge - General Specification 2024" - section 4 for further guidance.

2. Main competition general description

The vehicles will run on a 1m wide lane over a range of distance from 1.4m – 4.0m, to reach a vertical wall of 0.3m \pm 10% height. The lane will be horizontal and the wall vertical, made with commercial materials. These wood-based materials should be considered equivalent: plywood, OSB, MDF. No surface treatment shall be required; the vehicle(s) shall be capable of dealing with different surface friction, flatness and overall geometrical conditions.

The lanes' width shall be defined with suitable marking.

Commercial building boards may have a standardized width and length of 1.22 x 2.44m approx. The junction between two boards may not be flat: error in edge joint level up to 3mm and gap up to 2 mm will be considered acceptable. Screws could be used to join the board to a support located underneath, providing the screws do not protrude from the surface and do not sit below the surface by more than 3mm. No longitudinal joint or junction shall be present within a single lane.

As substitution for board-based lane construction, the use of existing hard floor surfaces could be considered acceptable, after consultation with the IMechE and the DC Steering committee. In this case, the starting point shall be maintained constant, and the vertical limit (barrier) shall be movable, capable of being secured to the floor to withstand the contact with the vehicles without resulting in its displacement. The starting point cannot be changed to always use a fixed wall as vertical reference.

The competing area shall be structured so that multiple lanes of the same composition are available. Multiple lanes adjacent shall have a minimum distance between them of 1.0m, to allow for access. The lanes width shall be defined with suitable marking. Vertical movable barriers shall be installed to simulate different distances for the different missions.

The competing lanes could be located on a floor or on raised supports such as tables, trestles, sawhorses or similar, for accessibility and visibility reasons.

Track flatness and barrier verticality will be within normal building tolerances; example of level error 8mm over 1.5m horizontal and example of plumb error 8mm over 3m vertical.

On the same competition, all the lanes and barriers shall be provided with the same set of materials.

The distance to the vertical barrier will be varied over three ranges for the competition heats and finals, and teams will make attempts at each of the short, medium and long-range distances.

For each range, a target distance will be chosen by the organisers on the day of competition between the min. and max. limits, at intervals of 0.05m (50mm). Distance ranges for the three levels will be provided but the vehicle shall be capable of dealing with any distance within the given range. In other words, the position of the vertical barrier for each distance is not fixed and will vary between the ranges specified below, to further assess the capability of the vehicle.

The distance to the vertical barrier will be varied over three ranges for the competition heats and finals, and teams will make attempts at each of the short, medium, and long-range distances.

The range distances (minimum to maximum) and are as follows:

- Short range 1.4m – 2.4m
- Medium range 2.4m – 3.2m
- Long range 3.2m – 4.0m

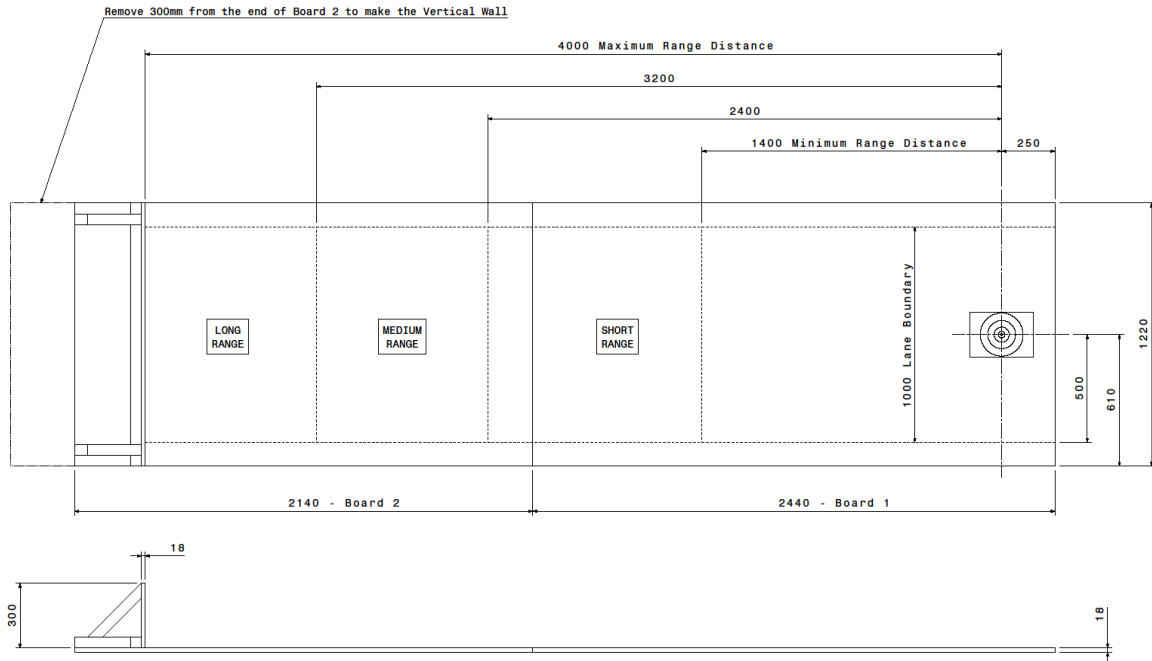


Figure 2 Typical lane set-up with the wall set at the maximum range distance; dimensions for the areas; example of using commercial boards

All the necessary dimensions will be verified with a single commercially available tape measure; distances will be considered equivalent with $\pm 1\text{cm}$ of uncertainty of the measurement reading. The calibration of the tape measure will not be assessed - required. A single operator will be selected to carry out all the measurements.

The vehicle attempt will be considered null if any portion of the vehicle exits the lanes as defined.

The vehicle should be left independently to operate in each attempt and no operator shall touch the vehicle at any point, including in case of fall from a raised support. If any operator touches the vehicle before all the teams are allowed to do so, that attempt will be considered null.

3. Main competition conditions

Referring to "IMechE Design Challenge - General Specification 2024":

- the vehicles in category *Concept Challenge* shall be designed to perform as per 0
- the vehicles in category *Foundation Challenge* shall be designed and built to perform as per 0
- the vehicles in category *Advanced Challenge* shall be designed and built to perform as per 0

At the competition, the tracks will be cleaned as per a normal industrial installation (wiped with paper or vacuum cleaned)

The team competing will not be allowed to select a specific track: all the tracks shall be verified by the judging panel and considered equivalent

3.1 Vehicle datum pointer

Each device shall be equipped in the rear area (the area opposite to the movement forward to the wall) with a datum pointer. The standard pointer can be procured from RS Components, with part number 397-4954. It shall be included in the BoM, all the characteristics listed to fulfil the BoM requirements.



Figure 3 Datum pointer

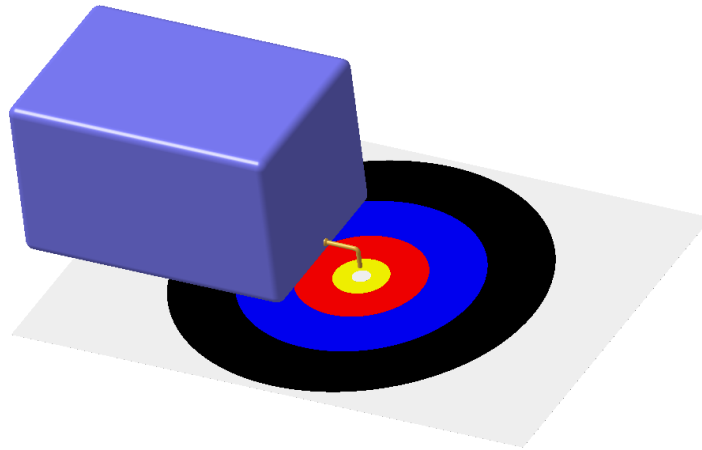


Figure 4 Example of relative position of the device, the datum pointer and the target

The datum pointer end shall be directed vertically towards the surface the vehicle is sitting on, not touch it and allow a gap to the target, not to interfere with it while in movement. The maximum distance from the surface shall be of 6mm.

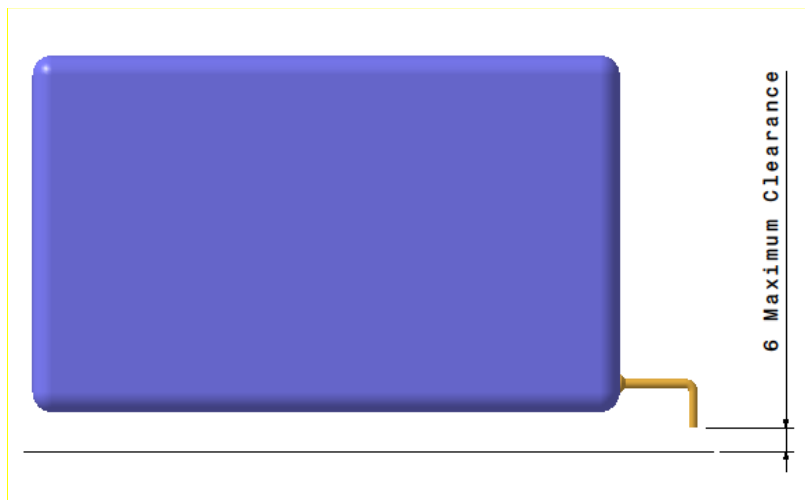


Figure 5 The Datum Pointer must be no more than 6mm above the lane surface

3.2 Target and scoring zones

The target is made of a series of circles, of different sizes, with dimensions as show in Appendix 1 - Target Area. Each band between the circles represents a score; the highest score being the target centre; the points will then become progressively fewer as the circles increase in diameter.

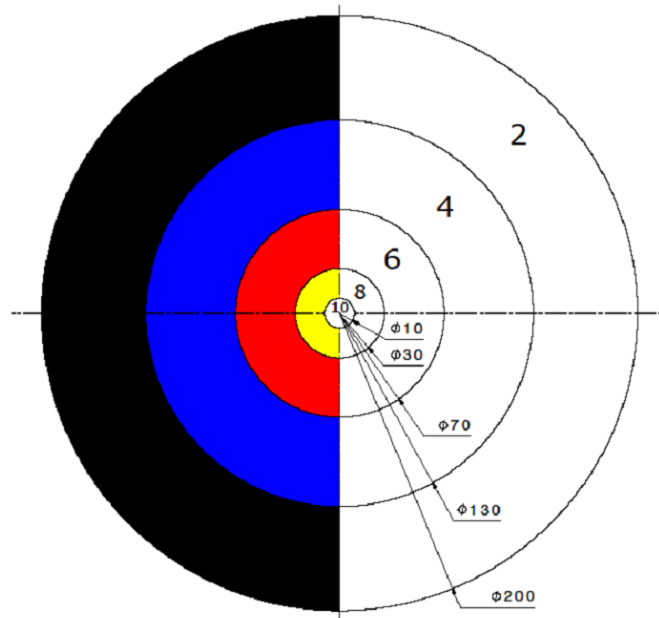


Figure 6 Target Area and Scoring Zones (not full size). The bullseye is worth 10 points

The Target Area must be printed on a white gloss background on a single A4 sheet as a peelable sticker. The RGB colour codes are, from outer to inner: Black 0,0,0; Blue 0,0,255; Red 255,0,0; Yellow 255,255,0; White 255,255,255.

No other numbers, marking or scheme shall be printed on the bands or on the white background area. No black line shall be printed between different colour bands.

An example of the printable target is shown in Appendix 1 - Target Area. Each university shall produce their own target according to the rules, and verify it complies with sizes and shape as detailed in this document.

3.3 Main competition conditions – single target

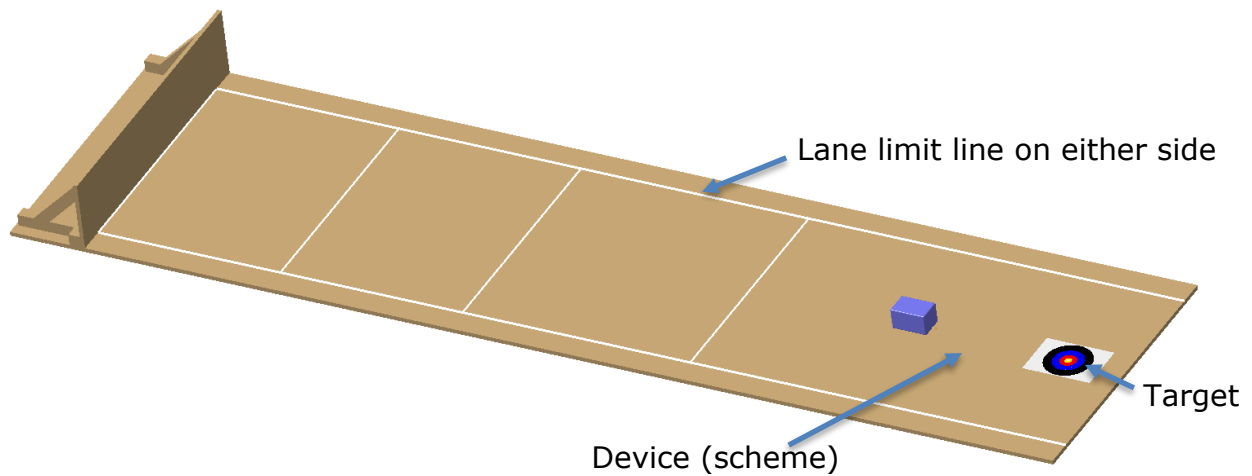


Figure 7 Typical lane set-up with the wall set at the maximum range distance

The aim of this competition is to design a vehicle that could start with the reference datum on the centre of the target, travel towards the wall and return with the same datum as close as possible to the starting point and stop. The mission shall be performed without human intervention, except for the start switching operation.

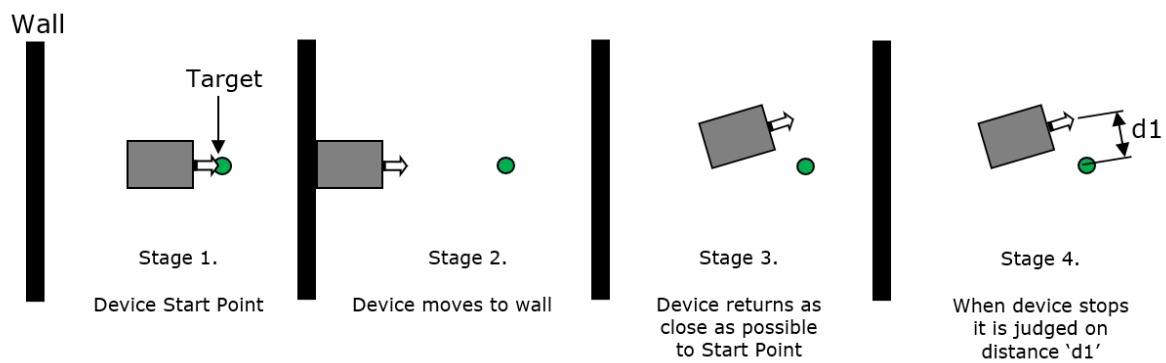


Figure 8 Schematic of the competition in four stages (not to scale; "device" for space representation only)

3.4 Main competition conditions – multiple targets

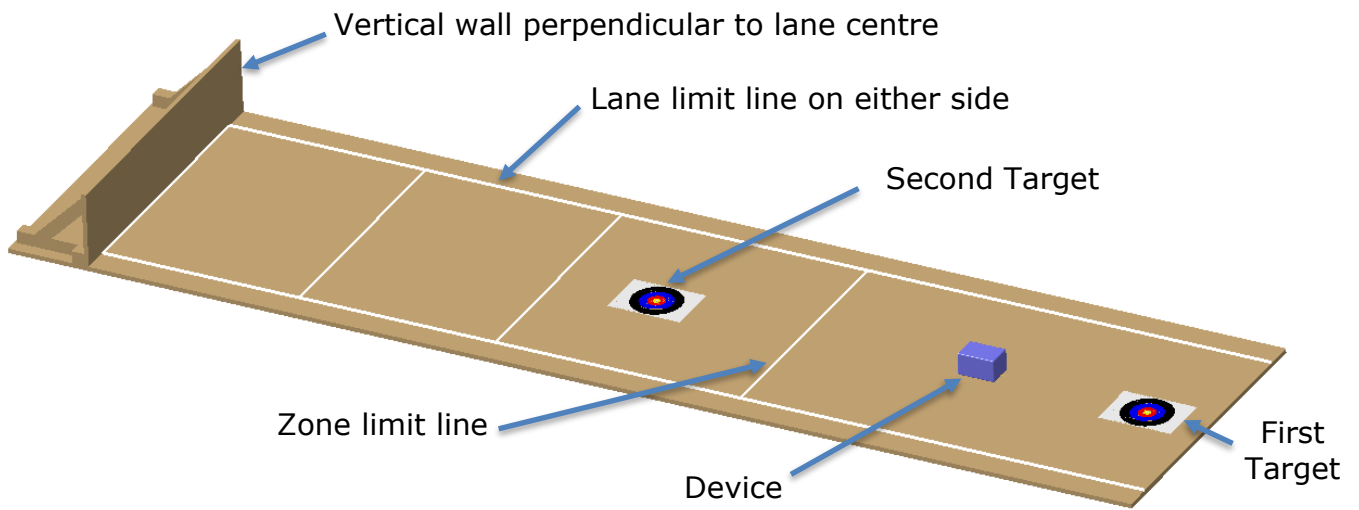


Figure 9 Typical lane set-up with the wall set at the maximum range distance

The aim of this competition is to design a vehicle that could start with the reference datum on the centre of the first target, travel towards the wall and return with the same datum as close as possible to the starting point on the first target and stop. Here it must pause for between 5 and 10 seconds, before starting a second phase, heading once again in the direction of the vertical barrier. This time, before reaching the wall, the vehicle must find a second target, and stop accurately on its centre. Note: in the first phase of the mission, the vehicle must travel beyond the second target. Both targets will be placed at the centre of the competing lanes. All the mission shall be performed without human intervention, except for the start switching operation.

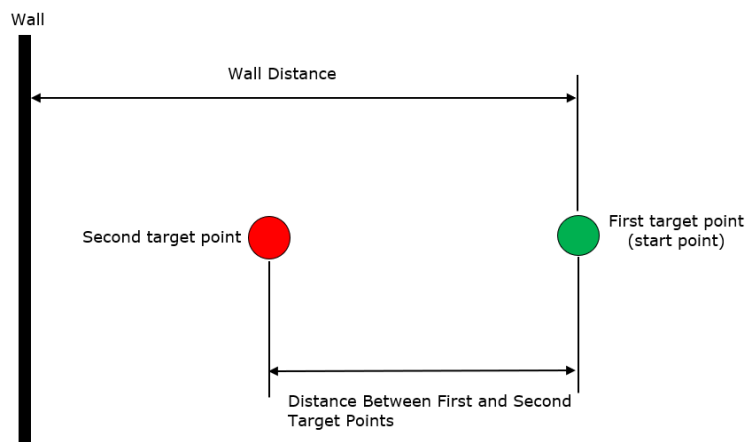


Figure 10 Schematic of the target points relative to the wall (not to scale)

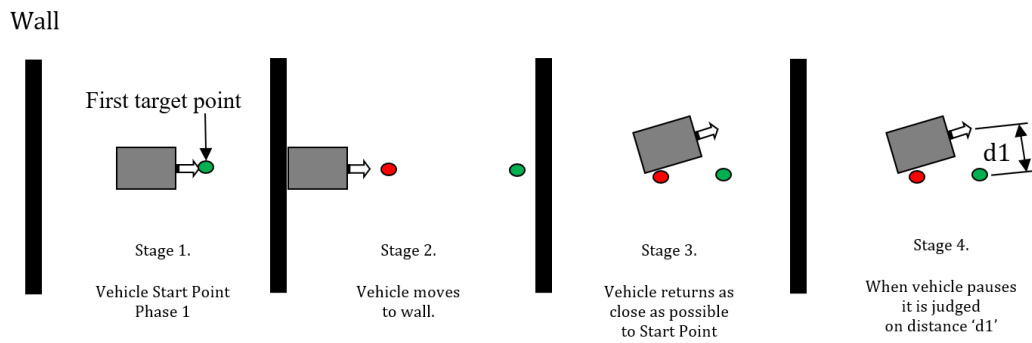


Figure 11 Schematic of the first phase shown in four stages (not to scale; "device" for space representation only)

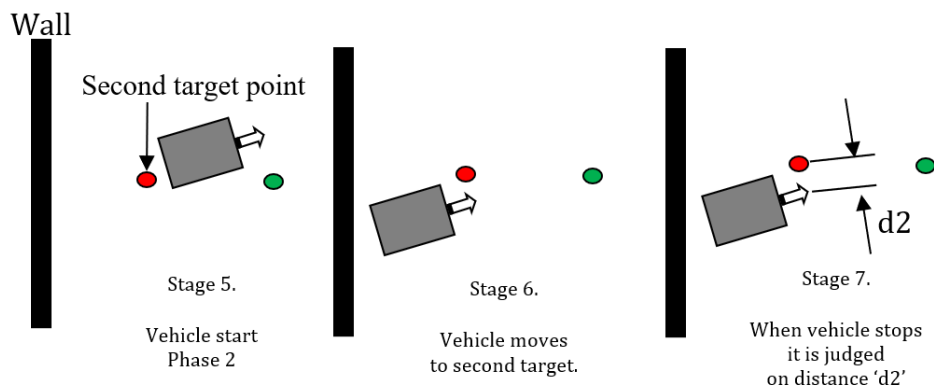


Figure 12 Schematic of the second phase shown in three stages (not to scale; "device" for space representation only)

The positions shown in Figure 10, Figure 11 and Figure 12 are for illustration only. The distance between the first and second target points will be different for each range and may be different between heats and finals. It will be agreed and verified by the judging panel present at the competition.

The location of the second target centre will be no closer than 0.5m to the wall and at least 0.9m from the first target. The second target position does not have to be in the same range as the wall.

4. Technical Regulations for the device

- 4.1 The device can be of any type, but it must be totally self-contained, and fit within a working envelope of 400mm x 400mm x 400mm.
- 4.2 The device must fit within the maximum working envelope at all times during competition, even when in motion
- 4.3 The starting and final position of the device will be determined from the datum point on the rear of the device. The datum point shall always be held and retained in vertical position, pointing downwards. Any repair eventually needed shall be performed within the given time, either before or between runs.
- 4.4 In the categories *Concept Challenge* and *Foundation Challenge* no programmable circuitry is allowed. All the electric, electronic and mechanical layout shall be based on analogue circuitry principles.
- 4.5 In the category *Advanced Challenge*, programmable devices such as Raspberry Pi, Arduino, NodeMCU, Teensy and similar are allowed. Such devices shall be purchased as non pre-programmed. The team shall show evidence of independent coding techniques capacity.
- 4.6 In the category *Advanced Challenge*, the code shall not include any length, distance or measurement that require editing between runs.
- 4.7 In the category *Advanced Challenge*, no software re programming is allowed between runs.
- 4.8 Parts from existing commercial devices (i.e. chassis, drive systems, suspension, etc.) are not permitted.
- 4.9 The device cannot be operated with a remote control of any sort.
- 4.10 A single main fuse shall be installed between the battery and any other wiring. If the maximum current draw cannot be proven, a maximum current fuse of 10A is permitted.

5. Rules for the Main Competition

- 5.1 The devices shall not be modified between scrutineering and runs, in any form that may invalidate the features evaluated during the scrutineering process.
- 5.2 No practice runs are permitted on the lanes. The competition organisers will provide dedicated areas for setup activities
- 5.3 Clear instruction on the running order for the heats and finals will be given at the event.
- 5.4 All teams must display an A4 sheet detailing the teams name and college or university and this must be clearly displayed as instructed during any run in which the team is taking part.
- 5.5 There will be multiple competition lanes in the Main Competition, set at different wall distances.
- 5.6 The wall distances will be the same for all teams, but will not be known in advance, and will be determined on the day.
- 5.7 Organisers will not announce the target distances during the competition and teams are not allowed to measure the distance using a tape or any other means. The organisers will show the equivalence between different lanes, by showing the measurements taken. The teams cannot make a note of it and use it for any physical adjustment or software input in the device.
- 5.8 Teams will compete head-to-head in heats for a place in the final. The relative performance will be determined by teams' scores.
- 5.9 A heat or final will involve running on different lanes, as selected by the judging panel.
- 5.10 Heats may consist of multiple teams' devices running in parallel on different lanes.
- 5.11 Participating teams will have a maximum of 3 minutes before a heat to prepare and position their device on the target centre.
- 5.12 Teams not ready within the allotted time before a run will forfeit that attempt.
- 5.13 The time limit for runs in the heats and final will be 2 minutes. Time will start from the end of the timekeeper's starting countdown. Devices that don't complete the mission within the limit time will forfeit that attempt.
- 5.14 In each a run, the device will have one attempt only to perform the mission. The run is scored on accuracy alone.
- 5.15 Each team must appoint a 'Device Controller' who will be the only person to attend to the device during the preparation and start of each run. This includes any form of repair, tuning or alteration.

- 5.16 During each phase of the finals, all other team members must be outside the test area. A judge will be allocated to each test area to ensure the correct procedure is followed.
- 5.17 If a device is started before the starter's order, it will forfeit that attempt.
- 5.18 If a device fails to start within 10 seconds of the START command during a run it will score 0 points for that attempt.
- 5.19 Repairs and minor alterations are allowed to the device between each run within a 2-minute time limit.

6. Main Competition Run Procedure

- 6.1 Team Device Controllers put devices in the test area with the device aligned and the datum point over the target centre.
- 6.2 Allocated lane judges check position of datum point and device readiness.
- 6.3 Device Controllers will raise their hand clearly to show readiness within the three-minute period. If all the teams are ready, a run can commence.
- 6.4 When teams are ready or when the preparation time has lapsed, the 'Timekeeper' will give a clear "3,2,1 Go!"
- 6.5 The Device Controller will start the device manually and then stand clear of the test lane.
- 6.6 The attempt ends when all the devices have stopped or when the 2 minute run time has lapsed.
- 6.7 Judges will check the position of the datum point relative to the target and record the score for that run.
- 6.8 The device cannot be touched until the judge signifies that the run is complete. This means that the device cannot be switched off manually until this point.
- 6.9 The Device Controllers will collect their devices when authorised by the judges. Minor repairs and adjustments can be made at this stage.
- 6.10 The run procedure is repeated on different lanes to complete a heat.

7. Scoring for the Main Competition

- 7.1 After each single run the distance from the device datum to the target point on the board will be scored and recorded.
- 7.2 Judges will determine points from the scoring rings around the target area.
- 7.3 After the three single runs, the three scores recorded in the heat will be added together.
- 7.4 If the judging panel agree a vehicle stops with the datum pointer falling on the boundary between two different zones, the highest score between the two zones will be recorded for that run.
- 7.5 If a device, or its team, does not comply with the competition rules, it will be disqualified from the Main Competition.

Regional Finals - Foundation Challenge

- 7.6 A maximum of 30 points is available in the heats. The top three teams in the heats returning the highest scores will progress to the final.
- 7.7 Points from the heats will not be carried forward. A maximum of 30 points is available in the final. The winner will be the team achieving the highest score in the final.
- 7.8 In the event of a tie in the Regional Final, a re-run between the tied teams will take place as detailed in sections 7.20 - 7.22.

Regional Finals - Advanced Challenge

- 7.9 A maximum of 60 points is available in the heats. The top three teams in the heats returning the highest scores will progress to the final.
- 7.10 Points from the heats will not be carried forward. A maximum of 60 points is available in the Final. The winner will be the team achieving the highest score in the final.
- 7.11 In the event of a tie in the Regional Final, a re-run between the tied teams will take place as detailed in sections 7.20 - 7.22.

National Finals - Foundation Challenge

- 7.12 A maximum of 30 points is available in the heats. The top three teams in the heats returning the highest scores will progress to the final.
- 7.13 Points from the heats will be carried forward. 30 points are available in the final, meaning a maximum of 60 points is possible for the Main Competition.
- 7.14 In the event of a tie of overall points in the National Final, the team with the highest points in the Main Competition will be the winner.
- 7.15 In the event of a further tie on points, a re-run between the tied teams will take place as detailed in sections 7.20 - 7.22.

National Finals - Advanced Challenge

- 7.16 A maximum of 60 points is available in the heats. The top three teams in the heats returning the highest scores will progress to the final.
- 7.17 Points from the heats will be carried forward. 60 points are available in the final, meaning a maximum of 120 points is possible for the Main Competition.
- 7.18 In the event of a tie of overall points in the National Final, the team with the highest points in the Main Competition will be the winner.
- 7.19 In the event of a further tie on points, a re-run between the tied teams will take place as detailed in sections 7.20 - 7.22.

Re-Run Procedure

- 7.20 In the event of a tie affecting qualification to the final, the tied devices will be retested in the selected lanes. Points will be accumulated as in the heats.
- 7.21 If a winner cannot be determined after the tie re-run, there will be a head-to-head run off on the longest distance lane for a single score.
- 7.22 If this does not determine a winner on points the distance to the datum point will be measured and the device with the shortest distance will be the winner of the tie.

Zero Points

- 7.23 A team will score zero points:
 - if a device does not hit the wall,
 - if a device leaves the lane
 - if a device does not stop within the target area around the datum point
 - if a device has not come to a stop after 2 minutes
- 7.24 A device disqualified from one of its runs can still take part in the other attempts, unless it is disqualified from the whole competition

Appendix 1 - Target Area

A larger version of the target is shown below

