Stichting Wind Energie Events

Rules for Racing Aeolus 2019

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Introduction

This document describes the rules for Racing Aeolus 2019 in Den Helder, The Netherlands. This version replaces all prior versions.

Changes to the 2018 final release:

2	major change	8.7	clarification
5.5	minor change	9.1	new
5.11	clarification	9.9	new
5.17	clarification	10.5	new
6.4	major change	11.1	clarification
6.7	minor change	11.7	new
6.15	clarification	11.8	new
6.17.4	clarification	12.3	major change
7.6	clarification	12.5	major change
7.9	clarification	Technical Report: changed	

Please note that minor wording changes are not highlighted in the text.

If any questions occur please contact:

- Hans Verhoef hans.verhoef@tno.nl (general information, organizational, registration etc.)
- Suell Mües RA@suell.net (rules)

Abbreviations

WPV	wind powered vehicle
SOC	state of charge
ROPS	rotor overspeed protection system
Wach number*	$\frac{avg\,.\,car\ speed}{avg\,.\,wind\ speed}$ with $avg\,.\,car\ speed = \frac{race\ distance}{charging\ time + race\ time}$

Contents

*Named after Gustav Winkler, one of the contemporary WPV pioneers

1. The Event

The idea of Racing Aeolus is to develop and build cars (WPV) that can generate energy from the wind as they drive against the wind and compete with other teams from across the globe. These rules give a basic framework to ensure the fairness and safety of the event while being as loose as possible to maintain room for innovation.

While developing your car keep in mind that fairness and sportsmanship are the backbone of this event. Come up with new ideas but do not twist the rules to generate an unfair advantage. If you are not sure about the details of a specific rule please come forward. The decision on how the rules are to be interpreted lies within the Racing Aeolus community which is represented by the captains meeting during the race. However and especially on safety issues the organizing committee has the final decision.

In order to be successful in the race a car has to be:

- Safe: Poses no threat to the driver or bystanders
- Efficient: Highest possible wach number
- Sturdy: Can race multiple times on several days

There are four different competitions during the event. In the endurance races, teams compete for the highest average wach number in multiple races on several days. The fastest run of a car (wach number) is regarded in the same-named competition. For the innovation award teams need to find creative and new ways to solve the manyfold problems that arise during the design of a WPV. During the drag race teams demonstrate their cars ability to self start and outrun the competiton on a short track. In addition to the winners award in each competition, the Racing Aeolus Cup will be awarded to the team that performs best in all four competitions. Details on that matter can be found in chapter 12.

2. Documentation

All documentation must arrive at the organizing committee at least four weeks prior to the race. The documentation contains the following items:

- One page highlight description for the Innovation Award panel
- Technical report according to the template. See inspection procedure 9.8
- In case of an electrical storage within the drivetrain: cell type and manufacturer data sheet

3. Definition of a wind powered vehicle

3.1 Land based vehicle driving on wheels and steered by a driver

3.2 Propelled by a device which is powered by wind and is coupled to the wheels (e.g. mechanical or electrical)

3.3 Storage of energy allowed, storage device must be empty at start (verifiable). Batteries for purposes other than the direct production of driving power such as sensors, actuators and communication means do not have to be empty.

4. Driver

4.1 Minimum age of driver is 18 years

4.2 Minimum weight of driver is 65kg (including protective gear). If the driver weighs less extra weight has to be added near the driver. See inspection procedure 9.7

4.3 Must remain inside the cockpit throughout the whole race

4.4 Equipped with radio

5. Design

5.1 The maximum dimensions of the WPV are: 2 meters wide, 4 meters long and 3.5 meters high (competition-box). See inspection procedure 9.2

5.2 When in racing configuration (no parts can be added or removed before or during the race) the car must fit completely (including all sensor masts) into the competition-box

5.3 By turning the tower (yaw) or the wheels (for steering only) the competition-box may be exceeded.

5.4 Maximum diameter of rotor including cowling (diffuser) and net: 2m

5.5 Maximum rotor swept area (facing the wind, relevant for creating torque on the rotor axis): 4m²

5.6 Maximum distance of any parts that are fixed to the tower (and turn with the tower) from the center of the tower: 1.5m

5.7 Maximum length of diffuser: 1m in front and 1m behind the tower

5.8 For a dimensions example see appendix 1

5.9 Maximum turning radius of the car: 7.5m (15m diameter)

5.10 Contact between driver and the road or wheels should be prevented by an appropriate device

5.11 The vehicle must have an adequate steering device. It has to be sturdy enough to function safely well beyond the expected usage at the race.

5.12 The vehicle must have at least 3 wheels, not in line

5.13 There must be a rotor brake

5.14 There must be a vehicle brake

5.15 There must be a parking brake for the car and rotor (may be one break).

5.16 Good visibility for the sector from -110 to 110 degrees with the track. A total of 30° but no more than 10° at once in this sector may be blocked. Obstructive objects thinner than 2mm (e.g. rotor net) are not regarded.

5.17 Cars without energy storage: There must be no energy storage in the drivetrain. The drivetrain may be mechanical or electrical. Components of the drivetrain with high inertia are not regarded as storage as long as they are not dis-/engageable, always rotate while the car is running and have a purpose other than storing energy. Small capacitors required in the power electronics of electric drive trains are not regarded as energy storage.

5.18 Cars with energy storage: There may be an energy storage in the drivetrain. The energy storage may be electrical (e.g. capacitors), mechanical (e.g. flywheel) or a combination of both. The transformation between mechanical and electrical energy is allowed.

5.19 Cars with energy storage: There must be a display (easily readable from the outside) which displays the state of charge (SOC) of the energy storage. In case of a mixed energy storage (e.g. capacitors and flywheel) there must be a separate SOC-display for each storage. The SOC must be displayed in percent.

5.20 Cars with energy storage: The SOC of every storage must be 0% before every race.

Storage type	SOC 0% at
Electrical storage without physically conditioned minimum voltage (e.g. all capacitors except hybrid-capacitors)	Voltage: 0V
Electrical storage with physically conditioned minimum voltage (e.g. batteries)	minimum allowed voltage according to data sheet
Mechanical storage	No kinetic energy / ambient pressure

6. Safety

6.1 Two independent braking devices, one on each rotor axis and one on the wheel axis (vehicle brake).

6.2 The vehicle brake must be able to slow the car with a deceleration of at least 6.3m/s^2. See inspection procedure 9.5.

6.3 There must be a secondary way of stopping the rotor if the main rotor brake or any system powering the rotor brake fails (e.g. stopping the rotor via the drivetrain)

6.4 There must be a rotor overspeed protection system (ROPS) that prevents the rotor from exceeding the maximum design speed. The ROPS must engage instantly and automatically (no driver action required). The ROPS may either be aerodynamical (no pitch to stall) or mechanical. An electrical system that monitors the rotor speed and automatically activates the rotor brake is recommended. The braking device of the ROPS must be on the rotor axis. For electrical ROPS systems it is recommended to install an emergency ROPS switch on the outside within reach of the pushing person. See inspection procedure 9.9

6.5 The rotor (blades) must be contained inside a cage or net, made of steel wire of minimum 1 mm thickness or a material which can withstand 600N tension. The cage or net must not rotate. See inspection procedure 9.6

6.6 The net/cage must be made of squares with a maximum size of 10x10cm. Other forms than squares are allowed as long as the gaps in the mesh are not larger than 100cm² and the aspect ratio is smaller than 1.5:1. The net/cage has to fit into the competition-box

6.7 The driver must be able to vacate from inside the WPV without assistance within 10 seconds

6.8 Head forward position (of driver) is not allowed

6.9 Emergency evacuation markings on the outside of door(s) or unlocking mechanism if doors/unlocking mechanism are not obvious

6.10 The driver has to be protected from the dangers of the flipping of the car by a roll bar or a device with a similar effect

6.11 The driver must wear a helmet

6.12 The WPV has to be equipped with a horn, activated by the driver

6.13 The rotor has to be blocked (it must not rotate) while the car is parked

6.14 Minimum design wind speed: 18 m/sec (12 m/sec + 50% gusts, your car must be designed for at least 18 m/sec wind. Keep in mind that the inflow velocity will be higher if you drive in that wind).

6.15 The car must not flip under the following circumstances:

- Permanent wind of 18 m/sec from any direction. The yaw/tower is assumed to be in the worst possible position for the given wind direction. See inspection procedure 9.3
- Driving and turning in any direction on an aslope surface (angle 20°). See inspection procedure 9.4

6.16 Bare electrical contacts must not be accessible from the outside.

6.17 Cars with an electrical system with more than 24V:

6.17.1 Must have the international safety symbol "Caution, risk of electric shock" (ISO 3864) on the outside visible from both sides. The warning sign must be at least 10 by 10cm big and must state the maximum voltage and whether it is AC or DC.

6.17.2 Must be equipped with an emergency switch for the driver that makes the car safe to approach. The emergency switch has to be clearly marked and easily accessible for the driver.

6.17.3 Must be equipped with an emergency switch accessible from the outside that makes the car safe to approach. The switch has to be located at the rear of the WPV as far away from the rotor as possible while still being easily accessible. It must not be very close to any uncovered rotating parts. The switch has to be clearly marked and labeled “emergency off”.

6.17.4 Any electrical parts carrying more than 30V AC or 60V DC have to be double insulated (e.g. single insulation plus chassis).

7. The Race

7.1 The race should be against the wind

7.2 The maximum wind speed for the race is 12 m/s on a 10min average

7.3 The race will not take place in heavy rain or storm. It may take place in light rain.

7.4 The track length is 500m. It may be reduced to 250m in case of very low winds.

7.5 The track may not be completely straight

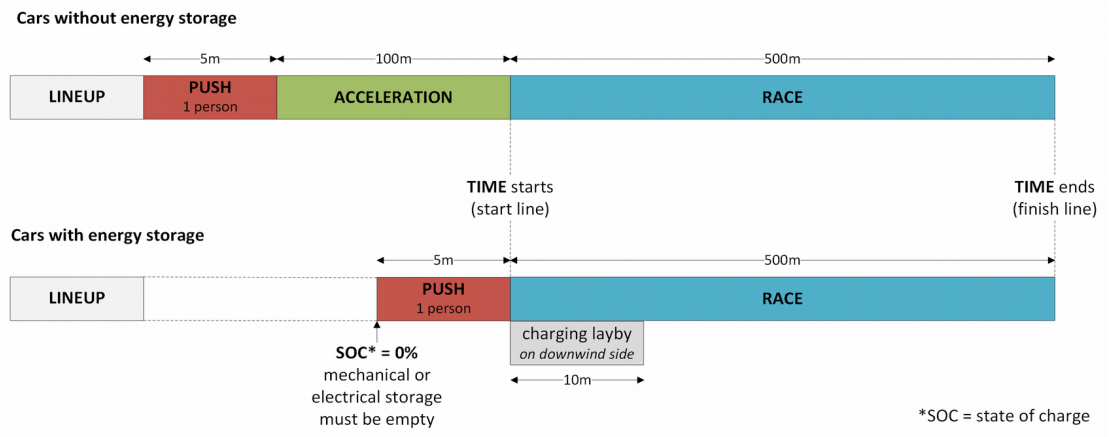
7.6 A race may be canceled by the start marshal if the car comes to a complete standstill and is unable to restart within 10 seconds. If the car cannot restart within this timeframe it has to vacate the track immediately.

7.7 If a car is very slow (below wach 0.30) the start marshal may decide to let the next willing team start. The slow car must drive on the downwind side and let the faster car overtake.

7.8 During the race a team member (with radio contact to the driver) must be near the start marshal to relay information to the driver (e.g. race aborted, return to start, measurement not working)

7.9 The start procedure is different for cars with and without energy storage:

- Without energy storage:
  - Total standstill of rotor and car at the start of the pushing zone
  - 5m: pushing with one person (with helmet) to overcome the standstill resistance
  - 100m: acceleration to bring the car to an equilibrium state of driving speed
  - 500m: race
- With energy storage:
  - Total standstill of rotor and car 5m before the start line, SOC = 0%, SOC-check by start marshal
  - 5m: pushing with one person (with helmet). Standstill or extremely slow pushing is not permitted. The 5m are not meant to charge the storage but to accelerate the car enough that it can cross the start line and roll to the charging layby.
  - 500m: race
  - The cars may charge their storage in the marked charging layby which is on the downwind side of the track just after the start line. The charging time will be included in the race duration. The other races continue. When the charging is completed the team gets clearance by the start marshal and may finish the race. The car must not enter the racetrack without clearance by the start marshal.



See appendix 3 for a full page track layout

8. Traffic Rules

8.1 The basic idea is that no team will influence the other

8.2 If you are not racing, keep on the downwind side! Even if you are just taking pictures.

8.3 Upon completion or abortion of the race immediately move the car to the downwind side, off the track and return to the start, keep on the downwind side as far away from the track as possible. If the wind direction is in line with the track keep on the dyke side.

8.4 Parking/stopping near the finish line is not permitted

8.5 The start order in the line-up area is first-come-first-serve.

8.6 Once a car is cleared to start it has to attempt a run within 30 seconds. If the car does not start within that timeframe it has to leave the lineup area. It may directly return to the last place of the lineup queue.

8.7 If a car stops in the acceleration segment or on the race track it has to resume racing without pushing within 10 seconds or clear the race track immediately. Outside help like putting blocks on the wheels to stop the car from rolling backwards is not permitted.

8.8 During every race there must be at least one team member running or biking next to the racing car to help getting the car quickly off the track.

8.9 If a car consistently runs at Wach numbers below 30% the start marshal may order it to stay on the downwind side of the track for the whole length of the track.

8.10 Further rules may be set by the event committee during the race

9. Inspection Procedures

9.1 The inspection will be performed mostly at the Hotel Den Helder with some parts happening on the dyke. It is split into five sub-inspections which can be done independently:

- Safety inspection (Hotel Den Helder)
- General inspection (Hotel Den Helder)
- Competiton box (Hotel Den Helder)
- Dyke tests (on the dyke)
- Drag race qualification (on the dyke)

There will be time slots posted for when inspections can be done at the Hotel or on the dyke. There should not be any inspections outside of the published time slots.

9.2 Competition-box

- There shall be a framework which is 2m wide and 3.5m high
- The car must fit through this framework
- The length of the car will be measured separately

9.3 Flipping

- The mass and center of gravity of the car will be determined with a scale which will be placed under every tire. The drivers weight may be simulated with a weight of max. 65kg in the drivers seat.
- The momentum of inertia of the car will be calculated with the mass of the car and the distance between the center of gravity and the next flipping edge (for classic design cars this will probably be the rear axis, for 3 wheel cars this will probably be the line connecting the front wheel and one rear wheel).
- The drag-momentum created by both the rotor and the diffusor must each be smaller than the momentum of inertia of the car with:

- Drag-momentum rotor: $M_R = \frac{1}{2} \rho v^2 \pi r^2 c_{th.rot} h_{hub}$

  r = rotor radius h_{hub} = height of rotor hub from ground

  $\rho = 1.225 \frac{kg}{m^3}$ $v = 18 \frac{m}{s}$

  $c_{th.rot} = 1$

- Drag-momentum diffuser: $M_D = \frac{1}{2} \rho v^2 l d c_{d.diff} h_{hub}$

  l = length of diffuser d = diameter of diffuser

  $\rho = 1.225 \frac{kg}{m^3}$ $v = 18 \frac{m}{s}$

  $c_{d.diff} = 0.5$ h_{hub} = height of rotor hub

- Drag-momentum rotor in case a rotor with a vertical rotor axis:

  $M_{R.Vertical} = \frac{1}{2} \rho v^2 \cdot width \cdot height \cdot c_{th.rot} h_{middle}$ with $c_{th.rot} = 1$

- For multi-rotor cars the momentum is the sum of the momentums for each rotor/diffuser.

9.4 The car will be placed on the aslope part of the dyke below the parking site on the sea side, facing the sea. The car must perform a 90° turn inside the 15m turning diameter. The car must not flip. Outside support is not permitted. The car must come to a complete still stand at the end of the 90° turn.

9.5 Braking test

9.5.1 The car (with driver) will be placed on the steepest part of the dyke below the parking site facing the sea (angle ~13°). The vehicle brake has to be able to hold the car in place. The driver has to open the vehicle brake and let the car roll for 2m directly down the dyke. He must then stop the car within 3.8m.

9.5.2 The car will be placed backwards on the dyke, facing the dyke (same place as in 9.5.1). The vehicle brake has to be able to hold the car in place.

9.6 A sample of the rotor-net-material will be tested with a weight of 60kg.

9.7 The driver will be weighed completely dressed and with full protective gear (once).

9.8 Before the actual inspection the technical report will be discussed with the team captain.

9.9 The functioning of the ROPS must be demonstrated (e.g. by driving the rotor with a power drill).

10. Penalties

10.1 Vehicles that do not comply with all safety rules must not participate in any race. If the team manages to change their car so that it complies with all safety rules it may participate when cleared by a race official.

10.2 Teams that violate any safety rules on purpose will be disqualified with all their cars by the race officials

10.3 Vehicles that are unable to meet all of the design requirements may participate in the races but will not be taken into consideration for any competition. There may be a side competition (category D) if there is more than one car that does not meet the design requirements.

10.4 Teams that violate any traffic rule: The best run of the day will be canceled (at the end of the day). It will be regarded as if it never took place.

10.5 Teams that do not hand in the highlight description for the Innovation Award panel together with a complete technical report in time will get zero points for the Innovation Award.

10.6 Further rules may be set by the event committee and announced to the teams during the race

11. Race Safety

11.1 When working on the car or in the workshop appropriate safety measures must be taken. (e.g. safety glasses when drilling or abrasive cutting, protective mask when working with carbon fiber – OUTSIDE ONLY!)

11.2 The team member pushing the car is obliged to wear a helmet

11.3 When parked the rotor must not rotate

11.4 Fences will be placed near the starting line for safety reasons

11.5 The consumption of alcohol in the maintenance area is not permitted

11.6 During a race only one team member is allowed to be on the track next to the racing car. Other team members must stay off the track. However, other team members are encouraged to run or bike off the track to help the car vacate the track (pushing) in case it stops during a race.

11.7 A team must not attempt any kind of test run on the dyke before it passed the sub-inspection “safety”

11.8 The participation in timed test runs is possible after a car passed the sub-inspection “safety”. These runs will not be counted.

11.9 Further rules may be set by the event committee during the race

12. Judging

12.1 Endurance

12.1.1 The judging will be based on the weighted average score from the racing days Thursday, Friday and Saturday. Whether a car has an energy storage or not makes no difference.

12.1.2 During each run the following data will be generated:

- start time
- duration
- average car speed
- average wind speed of at least three measurement masts measured at a height of 2.5m
- average wind speed (weighting [may be subject to change]: 17% start mast, 33% center mast, 50% final mast)
- Wach number $\frac{avg\,.car\,speed}{avg\,.wind\,speed}$ with $avg\,.car\,speed = \frac{race\,distance}{charging\,time + race\,time}$

Team	Start	Duration [s]	Avg. car [m/s]	Avg. wind [m/s]	Wind1 [m/s]	Wind2 [m/s]	Wind3 [m/s]	Wach	Status
Team I	15:32:35	165.536	3.020	6.445	6.231	6.412	6.654	0.468	finished
Team II	15:41:21	0.000	0.000	5.818	5.478	5.832	6.021	0.000	canceled
Team III	15:45:45	85.338	5.859	6.901	6.587	6.890	7.128	0.849	finished
Team II	16:00:31	90.547	5.522	7.125	6.895	7.105	7.311	0.775	finished

12.1.3 Every car has to complete at least 3 runs on every racing day. If a car fails to complete 3 runs a Wach number of 0.00% will be regarded for the remaining runs. If a car completes more than 3 runs only the 3 runs with the highest Wach number will be regarded.

12.1.4 The day score is the average Wach number from the 3 runs mentioned in 12.1.3

12.1.5 The total endurance score will be calculated with the following formula where $n_{total\,runs}$ describes the total number of completed races by all teams on all racing days and $n_{total\,runs\,THU/FRI/SAT}$ describes the total number of all races completed by all teams on that day. $s_{THU/FRI/SAT}$ is the day score for the team in question.

$$s_{total} = s_{THU}\frac{n_{total\,runs\,THU}}{n_{total\,runs}} + s_{FRI}\frac{n_{total\,runs\,FRI}}{n_{total\,runs}} + s_{SAT}\frac{n_{total\,runs\,SAT}}{n_{total\,runs}}$$

12.2 Fastest Run

Since a run faster than the current world record will only be recognized as a world record if the wind direction during the race is within +/- 15° there is a special prize for the fastest run, regardless of the wind direction. All officially timed runs automatically qualify for this award.

12.3 Gerard Broers Innovation Award

The ranking for the Innovation Award will be equally based on the following two factors:

- Ranking by the Innovation Award panel
- Ranking by the other participating teams

The Innovation Award panel will get an introduction to Racing Aeolus provided by Racing Aeolus to serve as a common knowledge base. In addition to that every team has the chance to hand in a one page highlight description per vehicle. Based on this document the panel will rank all participating WPV.

For the team ranking all teams will vote for what they consider the best innovation. You cannot vote for your own team. Every team has to sort all other cars by their worthiness of the innovation award and state a brief explanation for the first three ranks.

12.4 Drag Race

- To qualify for the drag race a car must demonstrate its drag racing capability to a race official:
  - The qualifying car has to complete a 10m track under drag race conditions. There is no time limit for the completion of the track.
  - The qualification can take place on any of the racing or training days prior to the drag race day.
  - The qualification may be attempted multiple times. Teams with less or no qualification attempts will be allowed to go first.
- The date, time and race mode of the drag race will be set at a captains meeting. Possible days are Thursday, Friday and Saturday.
- The length of the drag race track is 100m. It may be reduced to 50m in low winds
- The weather conditions must accord to the racing conditions stated in chapter 7.
- Two cars will stand on the start line next to each other with still rotors, SOC=0% and start racing upon hand signal of the start marshal
- Pushing is not allowed
- The cars have to stay in line
- If the rotor cannot self-start one team member may give the rotor a slight nudge
- Possible race modes are single elimination (single k.o.) and double elimination (double k.o.)
  - In case of single elimination: Points for the Racing Aeolus cup will be awarded corresponding to the stage a car reached before being eliminated.
  - In case of double elimination: The first four teams will be awarded points according to their ranking. All other cars will receive points corresponding to the stage they reached before being eliminated.
  - In case of a relevant side wind component: The expected underdog will race on the upwind side. The classification will be based on the impression from the qualification.
  - In case of a very strong side wind component: Each race may be hold as a two-out-of-three race with reversed starting positions at every set.
- In case of very low winds there might be a push and roll contest instead of the drag race. The points for the Racing Aeolus Cup would be half those of the drag race.

12.5 Racing Aeolus Cup

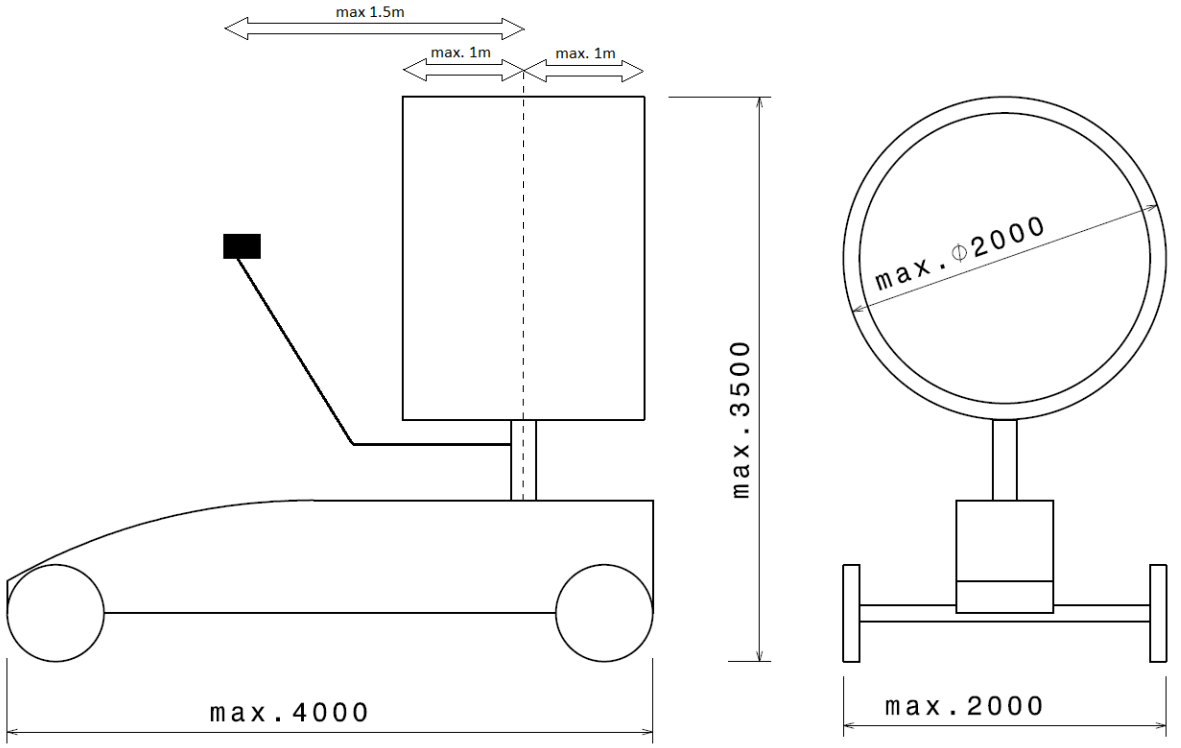
Each car receives points in the different competitions, relative to its performance. The car with the most points will earn its team the Racing Aeolus Cup title. Points will be awarded according to the table below down to the last place. On those places that get points below 10 the delta between ranks is one for the innovation award and drag race. The minimum number of points in a category is 0. In the event of a draw for any position the fastest run decides. Not participating in a challenge will lead to 0 points in that challenge. Further penalties are set out in chapter 10.

Challenge	Delta between ranks	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Endurance		Overall Wach number * 100 (x)					*(e.g.: 84,49% * 100 = 84 points)*				
Fastest run		Fastest run Wach number * 50 (x)					*(e.g.: 93,42% * 50 = 47 points)*				
Innovation	5 points	60	55	45	40	35	30	25	20	15	10
Drag race	5 points	40	35	30	25	20	15	10	9	8	7

(x) Round half up

Appendix

Appendix 1 – Dimensions example WPV (all dimensions in mm if not stated otherwise)



Appendix 2 – The two race tracks in Den Helder (both tracks may be used in both directions)

Image from Google maps

Appendix 3 – Track layout with comments