

Stichting

Wind Energie Events



Rules for Racing Aeolus 2015

Status: final

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Introduction

This document describes the rules for Racing Aeolus 2015 in Den Helder, The Netherlands. This version replaces all prior versions.

Changes to the last release: no prior release

If any questions occur please contact:

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- Suell Mües mail@suell.net (rules)

Note: There have been changes throughout the document. Please make sure to read each section carefully!

Abbreviations

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

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

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 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:

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

2. Documentation

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

- Design report containing:
 - general description of the car
 - all safety measures and safety critical calculations. See chapter 9
 - calculation of the rotor blade connection and rotor hub
 - In case of an electrical storage in the drivetrain (with physically conditioned minimum voltage): cell type and manufacturer data sheet
- 2m sample of the rotor net/cage material. See chapter 9.5

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.
- 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)
- 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): 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
- 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 break 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 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 (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.

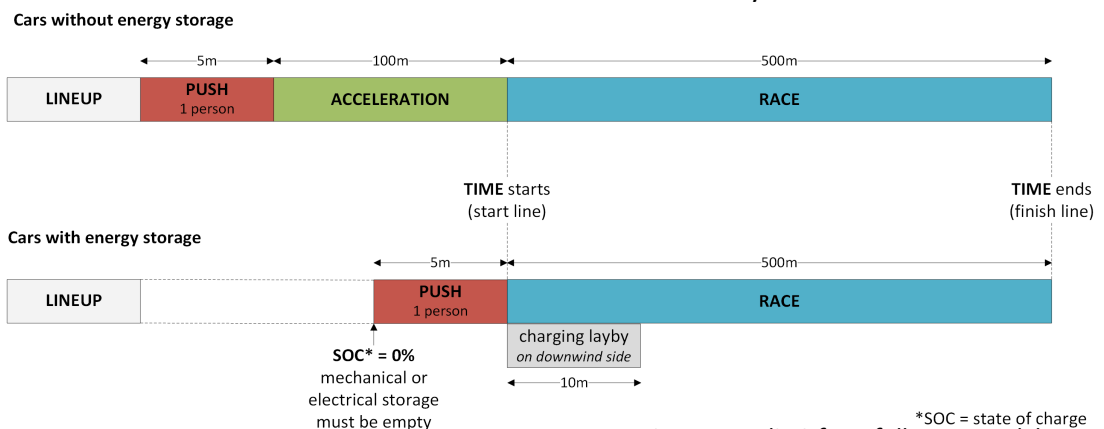
Storage type	SOC 0% at
Electrical storage without physically conditioned minimum voltage (e.g. all capacitors except hybrid-capacitors)	Voltage: 0V
Electrical storage with physically conditioned minimum voltage (e.g. batteries)	minimum allowed voltage according to data sheet
Mechanical storage	No kinetic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

6. Safety

- 6.1. Two independent braking devices, one on the rotor axis or in direct contact with the rotor axis (via proven technology, no clutch in between) and one on the wheel axis (vehicle brake)
- 6.2. The vehicle brake must be able to prevent the car from rolling down the dyke (forward, angle 20°)
- 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 or mechanical. An electrical system that monitors the rotor speed and automatically activates the rotor brake is allowed.
- 6.5. The rotor (blades) shall be contained inside a cage or net, made of steel wire of minimum 1 mm thickness or material which can withstand 600N tension. The cage or net must not rotate.
- 6.6. The net/cage shall be made of squares with a maximum size of 10x10cm. Other forms than squares are allowed as well 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 30 seconds
- 6.8. Head forward position (of driver) is not allowed
- 6.9. Emergency evacuation markings on the outside of door(s)
- 6.10. The driver has to be protected from the dangers of the flipping of the car by a roll bar or another device
- 6.11. The driver must wear a helmet
- 6.12. Provided with horn, activated by driver
- 6.13. The rotor shall 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 (without adjustment of tower/yaw!)
 - Driving in any direction on an aslope surface (angle 20°)
- 6.16. Cars with high electric voltage (more than 24V) 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.

7. The Race

- 7.1. The race should be against the wind
- 7.2. The minimum wind speed for the race is 3 m/s on a 10min average
- 7.3. The maximum wind speed for the race is 12 m/s on a 10min average
- 7.4. The race will not take place in heavy rain or storm. It may take place in light rain.
- 7.5. The track length will be 500m. It may be reduced to 250m (50m acceleration, 5m pushing) in case of very low winds.
- 7.6. The track may not be completely straight
- 7.7. A race may be canceled by the start marshal if the car comes to a complete standstill and is unable to restart within a short time span. The time span has to be announced to the team upon standstill of the car if a team member is available.
- 7.8. If a car is uncommonly slow (below wach 0.15) the start marshal may let the next willing team start. The slow car must drive on the downwind side and let the faster car overtake.
- 7.9. During the race a team member (with a radio) must be near the start marshal to relay information to the driver (e.g. race aborted, return to start, measurement not working)
- 7.10. 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 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. 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. Further rules may be set by the event committee during the race

9. Inspection Procedures

9.1. 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

9.2. Flipping

- The drag-momentum created by the rotor and diffuser (cowling) will be calculated with the following formulas:

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

$r = \text{rotor radius}$

$h_{hub} = \text{height of rotor hub}$

$$\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$$

$$v = 18 \frac{\text{m}}{\text{s}}$$

$$c_{th.rot} = 1 \quad *$$

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

$l = \text{length of diffuser}$

$d = \text{diameter of diffuser}$

$$\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$$

$$v = 18 \frac{\text{m}}{\text{s}}$$

$$c_{d.diff} = 0.5 \quad *$$

$h_{hub} = \text{height of rotor hub}$

- The bigger momentum (test-momentum) will be used for testing
- The drivers weight may be simulated with a weight of max. 65kg in the drivers seat
- A rope will be fixed to the tower to apply the test-force which is the test-momentum divided by the height of the rope fixpoint. The rope fixpoint should be as close to the rotor hub as possible.
- The rope leads horizontally from the tower to a deflection pulley and from there vertically to a weight which is the test-force divided by $10 \frac{\text{m}}{\text{s}^2}$

* If a team presents properly measured values this value may be adapted to the maximum measured value plus a safety factor of 1.25 for measurement uncertainties.

- The test-force will be applied in the following directions (one at a time):
 - parallel to the shortest lever
 - perpendicular to the axis closest to the tower (for classic design cars this will be the rear axis).
 - The car fails this test if it flips (not if single wheels lift off).
 - Teams with a multi-rotor concept must provide a device to load both rotors at the same time.
 - In case a rotor with vertical axis is used the test momentum will be

$$M_{R,Vertical} = \frac{1}{2} \rho v^2 \cdot width \cdot height \cdot c_{th,rot} h_{middle} \quad \text{with } c_{th,rot} = 1 \quad *$$
 - For multi-rotor cars the test momentum for sideways flipping is the sum of the test momentums for each rotor. For front and backward flipping only the closest rotor is regarded.
- 9.3. The car will be placed on the aslope part of the dyke just below the parking site on the sea side and parallel to the dyke. The car must not flip.
- 9.4. The car will be placed on the aslope part of the dyke just below parking site facing the sea. The vehicle brake has to be able to hold the car (with driver) in place.
- 9.5. A sample of the rotor-net-material will be tested with a weight of 60kg
- 9.6. The driver will be weighed completely dressed and with full protective gear (once)
- 9.7. Before the actual inspection the delivered report on the car will be discussed with the team captain

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 the overall rating and will not be recognized for the speed record. There may be a side competition (category D) if there is more than one car that does not meet the design requirements. See paragraph 12.3 for an overview of the categories.
- 10.4. Teams whose car returns on the upwind rather than the downwind side of the track while there is an ongoing race: 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. Further rules may be set by the event committee and announced to the teams during the race

* If a team presents properly measured values this value may be adapted to the maximum measured value plus a safety factor of 1.25 for measurement uncertainties.

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)
- 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. Further rules may be set by the event committee during the race

12. Judging

- 12.1. The judging will be based on the results of both racing days (Friday and Saturday). If the weather conditions do not allow racing or the wind is very low on one of the racing days the results from the last training day (Thursday) will be taken instead. Whether a car has an energy storage or not makes no difference.
- 12.2. There will be a captains meeting (1-2 persons per team) after breakfast at the rugby club on the last training day and each race day where the minimum required number of runs for the day will be set.
- 12.3. There are four categories in which the cars will be placed:
 - Category A: Minimum number of runs met on both days
 - Category B: Minimum number of runs met on one day
 - Category C: Minimum number of runs met on no day
 - Category D: Car does not meet all design requirements
- 12.4. During each run the following data will be generated:
 - start time
 - duration
 - average car speed
 - average wind speed of at least three measurement masts
 - average wind speed (weighting: 25% start mast, 50% center mast, 25% final mast)
 - Wach number $\frac{\text{avg. car speed}}{\text{avg. wind speed}}$ with $\text{avg. car speed} = \frac{\text{race distance}}{\text{charging time} + \text{race time}}$

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	15:32:35.047	165.536	3.020	6.445	6.231	6.412	6.654	0.468	finished
Team II	15:41:21.412	0.000	0.000	5.818	5.478	5.832	6.021	0.000	canceled
Team III	15:45:45.680	85.338	5.859	6.901	6.587	6.890	7.128	0.849	finished
Team II	16:00:31.050	90.547	5.522	7.125	6.895	7.105	7.311	0.775	finished

- 12.5. The score for the day is the mean wach number for the required races. If a team completed more runs than required the slowest races will not be considered. If a team fails to complete the number of required runs it gets no score for the day.

12.6. The final score is the mean score of both days (for category A). Teams with only one score will be placed into category B, teams with no score in category C, cars that do not meet all design requirements will be placed into category D.

Place	Team	Score	Friday	Saturday
1 (A1)	TurbiTwin	54.2	49.0	59.4
2 (A2)	InVentus	51.9	51.8	51.9
3 (A3)	Anemo 4	23.0	26.0	20.0
4 (A4)	Spirit of Amsterdam 2	19.0	11.9	26.2
5 (B1)	Chinook	69.8	69.8	no score
6 (B2)	Baltic Thunder	37.9	no score	37.9
7 (B3)	Emden / Leer	36.8	no score	36.8
8 (B4)	Spirit of Amsterdam 1	26.1	no score	26.1
9 (B5)	Anemo 5	14.5	no score	14.5
10 (C1)	windTURbine racer	---	no score	no score (almost one run)
11 (C2)	Bora ++	---	no score	no score
11 (C2)	Anemo High Voltage	---	no score	no score

Example results of 2013

12.7. Fastest run during Racing Aeolus 2015

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 race-runs automatically qualify for this award.

12.8. Gerard Broers Innovation Award

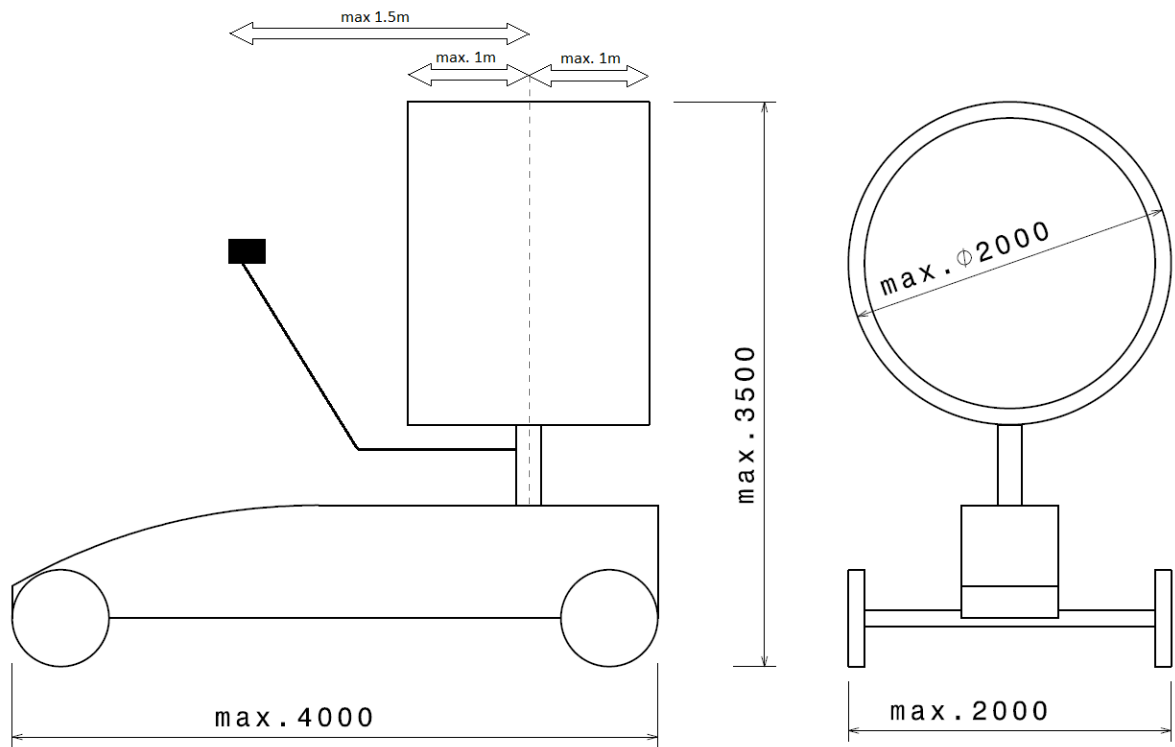
The winner of the Innovation Award will be selected by the team captains. They will vote for what they consider the best innovation. You cannot vote for your own team.

12.9. Drag Race

- The drag race takes place after the official end of the races on Saturday
- The length of the drag race track is 100m
- 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
- The cars have to stay in line
- Pushing is not allowed
- If the rotor cannot self-start one team member may give the rotor a slight nudge
- The race will be repeated with start-positions reversed
- The winning team of both races gets 3 points, in case of a draw both teams get one point
- The team with the most points will be drag champion
- A racing order will be set up during a special drag race captains meeting on Thursday

Appendix

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



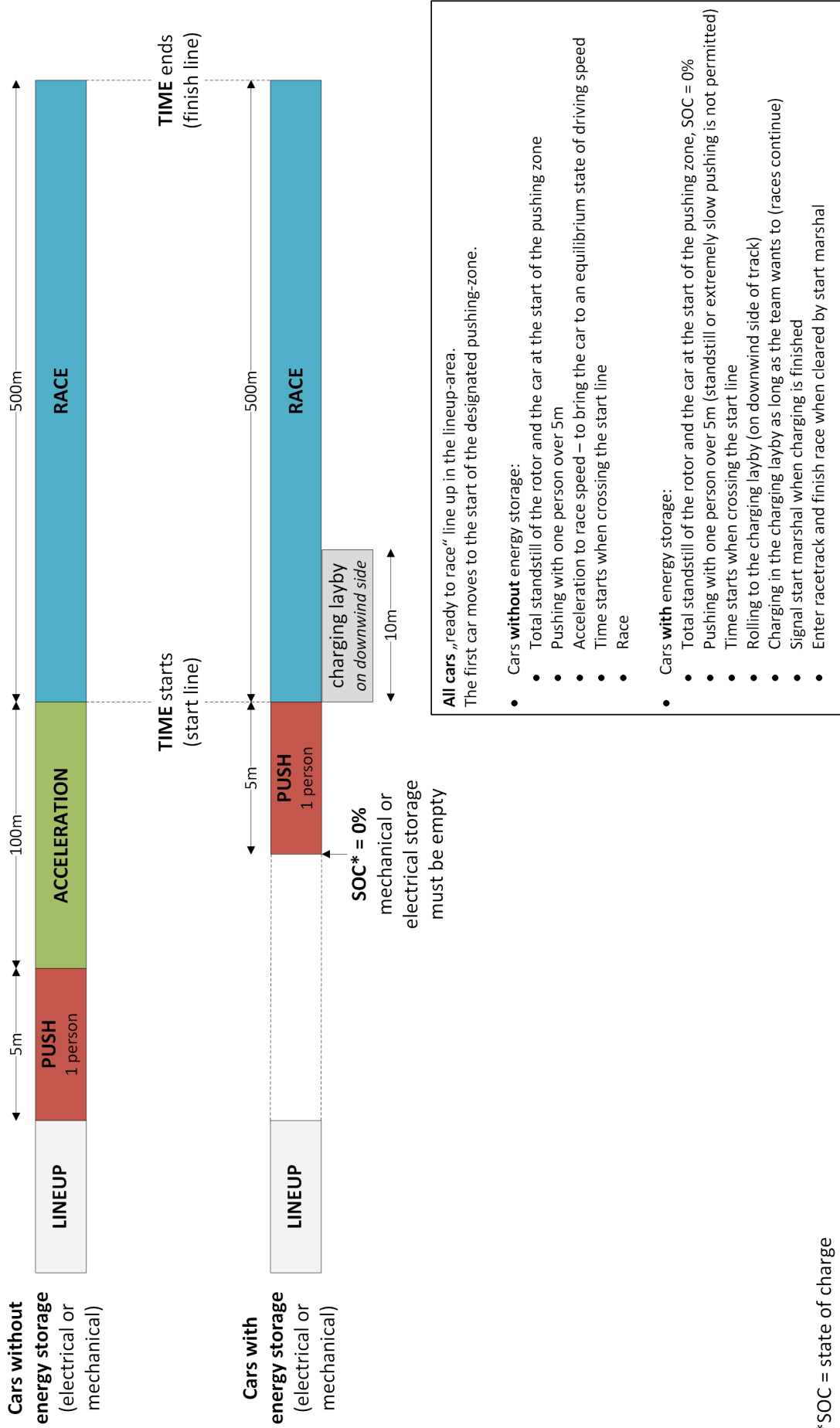
Appendix 2 – The two race tracks in Den Helder (both tracks may be used in both directions)



Image from Google maps

Appendix 3 – Track layout with comments

Racing Aeolus 2015 Track layout



*SOC = state of charge