RoboCup Rescue Rulebook

(as of 2019-06-17) Version 2.4 (with FAQ section)

Overview of Changes from v2.3 2019

- In 2019 100kg robots will still be allowed. From 2020 on the maximum weight is 80kg.
- Clarification on final qualifiation scores (5 MAN + 5 others).
- Nobody touches the readiness test board or extraction object after the mission has started => no replacement of the object if it fell out.
- .bt files are also allowed for providing 3D maps.
- Penalties for unsafe or distructive robots: 50% per major event.
- MAN 2: after falling down, robots can be placed back on the track by hand without penalty.
- There is a "RoboCup Rescue Judge Guide" (see the rrl website), which provides some more details on the scoring.

Overview of Changes from 2017

- Changed timing and autonomy points: 23 minute runs for everybody, double points for autonomy, 1.5 points for semi-autonomy (not for best in class); other timing adjustments
- Readiness Test is performed during the trial (from minute 18 on); minimum multiplier is 1
- Semi-autonomy: only defined capabilities allowed (more suggestions are welcome)
- Added "(MAN 6) Curb" test description
- Small robots maximum weight: 20 kg (2020: 15 kg); other robots maximum weight 80 kg
- System inspection on the first day with strict requirements (Emergency stop button, Operator Interface dimensions, radio communication)
- Autonomy only on robot computer (autonomy on the operator station counts as semi autonomy)
- More objects to recognize for "(EXP 3) Recognize Objects"
- Detailed description of Final competition
- The arena got a little bit narrower (110cm, previously 120cm)

Organizational:

- We will ask each team to nominate one team judge (very small teams with 3 or less participants are exempt). The team judge must have a decent level of English. The team judges will be trained during the last setup day and perform task adjudication. Team judges are not allowed to judge their own team, nor teams from the same country as their own team nor the country that they are citizen of.

- Wifi for RoboCup Australia 2019: Wireless LAN is limited to 5 GHz band. See the RoboCup 2019

Radio Policy. Your WiFi SSID has to be named as follows: "RRL*", e.g. "RRL*Hector".

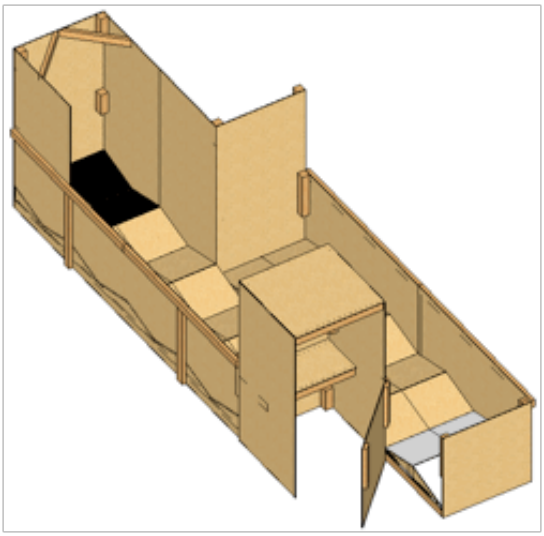
Concept for RoboCup Rescue

The main objective of our league is to conduct challenging and fair competitions that inform teams about the tasks necessary to be effective for responders. We also need to measure progress in our robotic systems to highlight breakthrough capabilities that responders can understand and appreciate. Ten or more successful repetitions begin to indicate a reliable capability. A series of trials across a suite of complementary tests begin to evaluate the system.

The RoboCup Rescue competition is organized in a format that resembles Response Robot Exercises. These have been effective in communicating capabilities between robot manufacturers and responders. Each robot will be evaluated in standard and draft standard test methods during Preliminaries to demonstrate functionality, reliability, operator proficiency, and autonomous/assistive capabilities. The resulting scores will qualify them for a "deployment" into a more complicated scenario in the Finals. This will enable concurrent testing opportunities for more robots to capture statistically significant performance. It will also encourage testing in more complex or difficult settings, challenging robots beyond their comfort level to compile more points. The Finals will remain a comprehensive search and identification of simulated victims in the overall maze for the best performing robots. Each qualified team is allowed one robot. The maze will consist of all the same test apparatuses and tasks. As always, the search scenario will be conducted from random start zone and performed in any order of tasks the team chooses. Again we will instantiate a rigorous, standardized process for practicing and measuring league capabilities throughout the year, with competitions being the public demonstration of those capabilities and sharing of results. So we encourage you to build and practice these tests during your development. Then demonstrate your capabilities at competition time for scores. This new structure will help our league communicate emerging capabilities to responders and allow them to guide such capabilities toward deployment. Local responders may come watch the competition and potentially demonstrate their own robots. This will familiarize them with the test methods and our emerging capabilities, making RoboCup Rescue a leading incubator for robots and test methods worldwide.

Test Suites

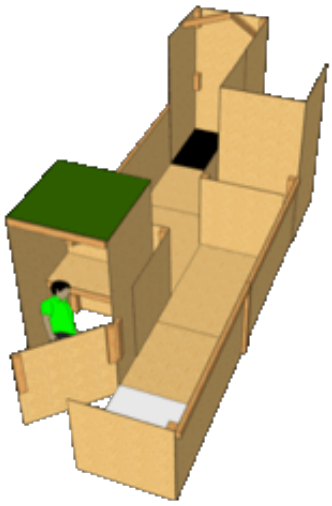
The RoboCup Rescue League competition is designed around standard robot test methods that evaluate each robot's capabilities individually in a systematic way. The new competition consists of 20 ground robot tests which are structured into four suites: Maneuvering, Mobility, Dexterity and Exploration. All bays are 7.2 m (24 ft) in length and minimum of 1.1 m (44 inch) in width.

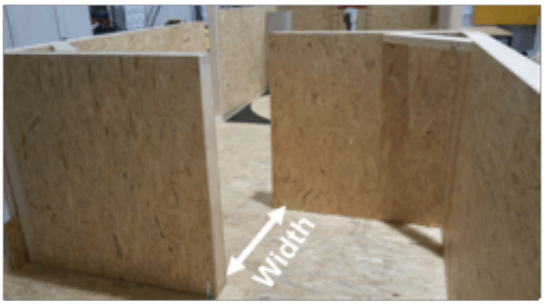


Maneuvering

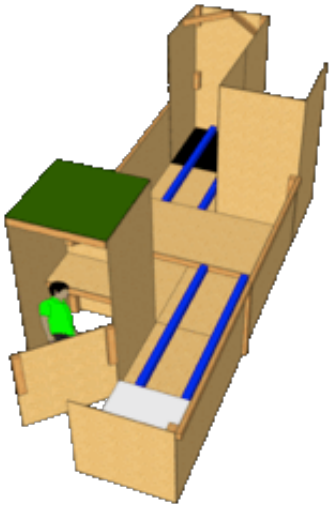
6 tests for basic driving over quite easy terrain completed in ***forward and reverse*** driving orientations for teleoperated robots. (Autonomous robots can choose the orientation freely.) All tests are mandatory for each robot.

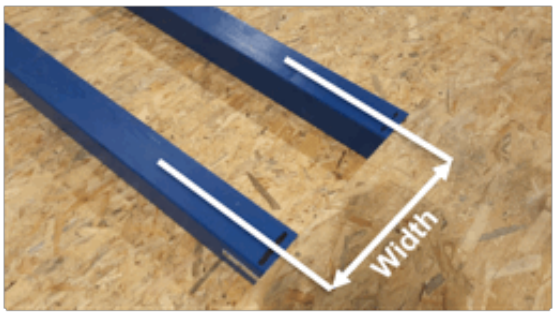
- (MAN 1) Center: A slalom with turn width set to the robot's diagonal ground contact dimension, challenging a robot's awareness of interactions across its width.



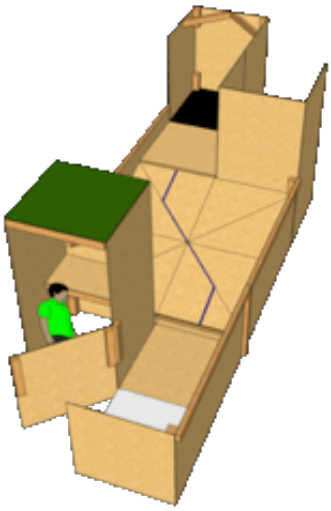


- (MAN 2) Align: Two bars (100 mm width) to cross which are set to the robot's outer ground contact dimension. The robot's tracks outer edges will be centered on each rail to limit left/right error similarly for various locomotion designs. If a robot falls down it has to return to the last start point. If a robot falls down it can be placed back on the rails at the same spot where it fell down by hand without incurring a penalty (and then go back to the last start point to try again).

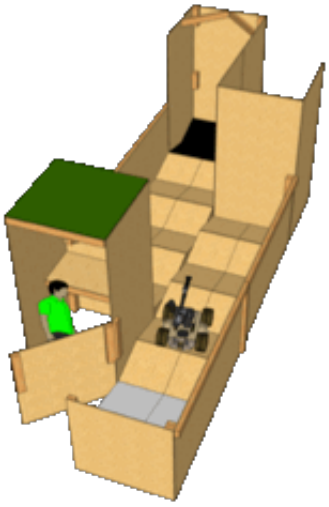


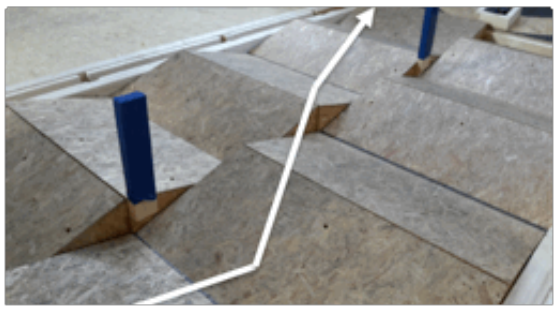


- (MAN 3) Traverse: A 30 degree inclined OSB surface to follow a dark line in a zig-zag pattern.

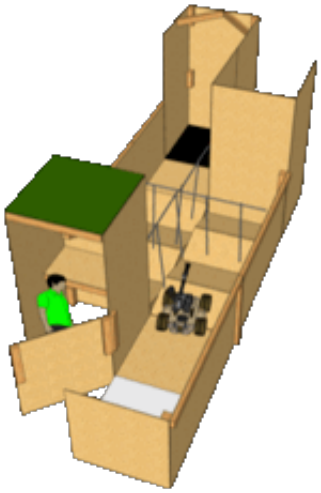


- (MAN 4) Crossover: A field of 15 degree ramps with a discontinuity to crossover.

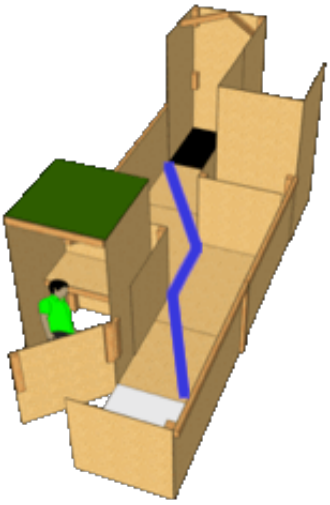




- (MAN 5) Negotiate: A set of movable vertical and diagonal sticks to push through (without breaking the sticks) or avoid.



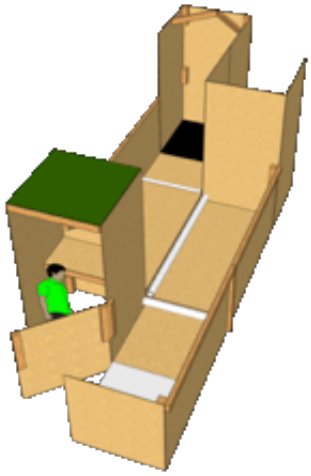
- (MAN 6) Curb: A 10 x 10cm bar on the ground, which the robot has to drive over.

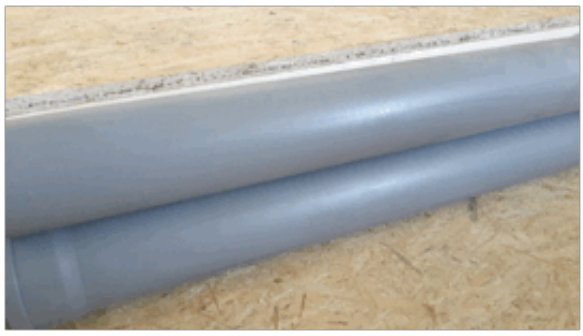


Mobility

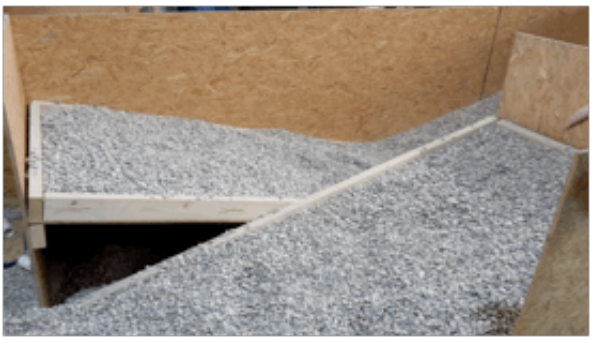
5 tests for driving over terrain with medium to hard difficulty (all tests are considered for a robot to win Best in Class Mobility). Robots are allowed to turn around (change direction).

- (MOB 1) Hurdles: A 20 cm tall rolling pipe obstacle to climb and descend.

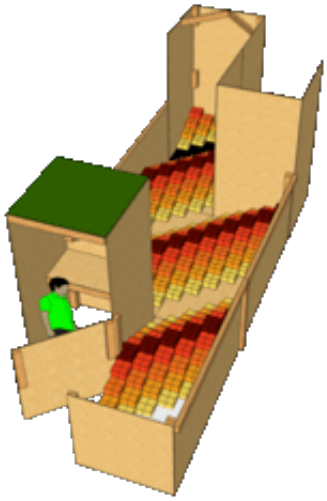




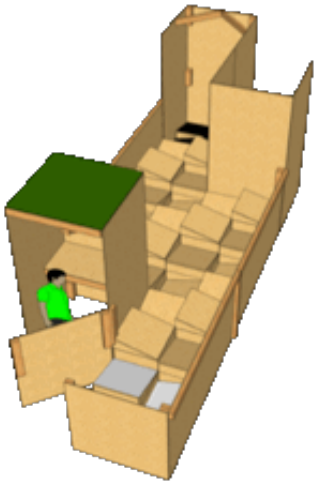
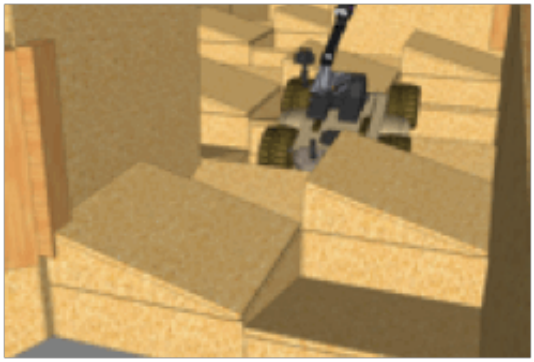
- (MOB 2) Sand/Gravel Hills: An alternating hill terrain with 15 degree slope.



- (MOB 3) Stepfields: A diagonal hill terrain consisting of 20 cm square steps made from posts with flat tops.



- (MOB 4) Elevated Ramps: A diagonal hill terrain consisting of 60 cm ramps with sloped tops.

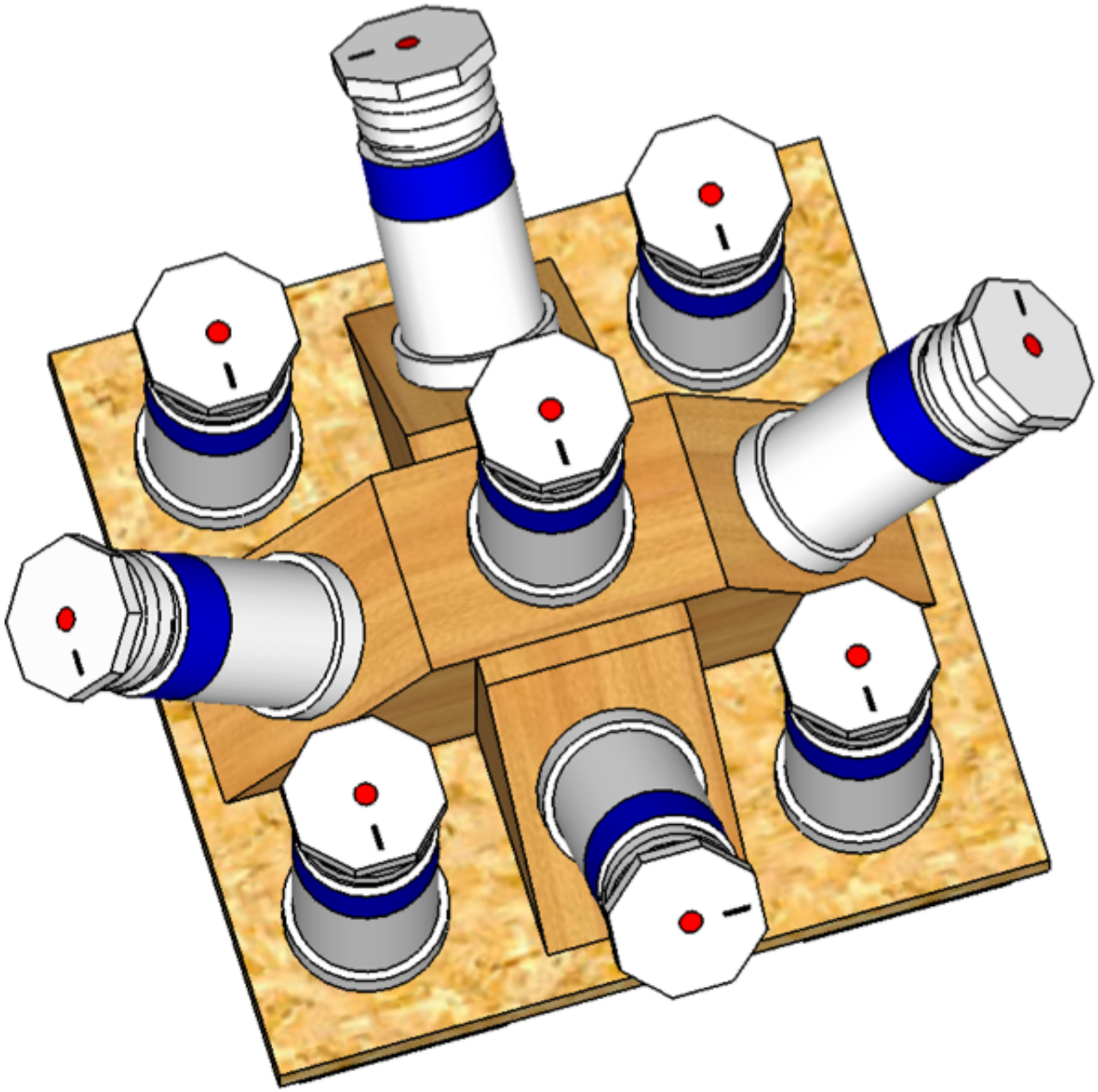



- (MOB 5) Stair Debris: 35 and 45 degree stair obstacle partly blocked with debris, e.g. angled bars in defined locations.


Dexterity

5 tests for manipulation and inspection (all tests are considered for a robot to win Best in Class Dexterity). Pipes are 10 cm (4 in) in length and 5 cm (2 in) in diameter. Extract and rotate caps have 8 facets which are approximately 2 cm (1 in) wide.

- (DEX 1) Parallel Pipes: Inspect, Touch, Rotate and/or Extract in total 20 parallel mounted pipes (mounted on 4 boards with 5 pipes on each board). This test is conducted within a terrain with ramps that requires mobility. The robot has to drive from some start point onto the terrain in front of the test element.



The same board is used for DEX 1 and DEX 2. 

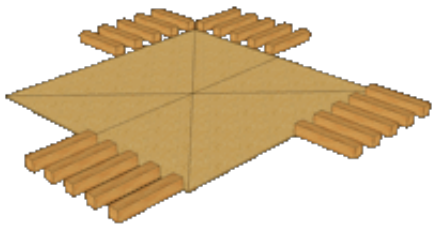
- (DEX 2) Omni-Directional Pipes: This is the Pipe Star variant of Parallel Pipes, but mounted in an omnidirectional orientation (tasks include Inspect, Touch, Rotate, Extract). This test is conducted on an

inclined surface.

- (DEX 3) Cylindrical Pipes: Same as Parallel Pipes, but pipes are mounted within a 60 cm diameter cylinder placed horizontally on the ground (tasks include inspect victims inside the cylinder through holes). This test methods is conducted on a flat surface.

- (DEX 4) Door Opening: Open and drive through push and pull doors with lever handles. Doors will not have spring closures during the preliminaries. One door will have springs during the finals. The doors may be accessible from open 240 cm square areas or more confined 120 cm x 240 cm hallways.

- (DEX 5) Shoring: Build a shoring structure composed of two wooden blocks in each layer of a vertical tower. The blocks are 600 mm (24 in) in length and approximately 1.8 kg (4 lbs) in weight. This test is conducted on on a flat surface 2.4 m x 2.4 m area.



(As an optional alternative of the shoring task a so called "wall building" task might be provided. Details will be presented during the competition.)

Exploration

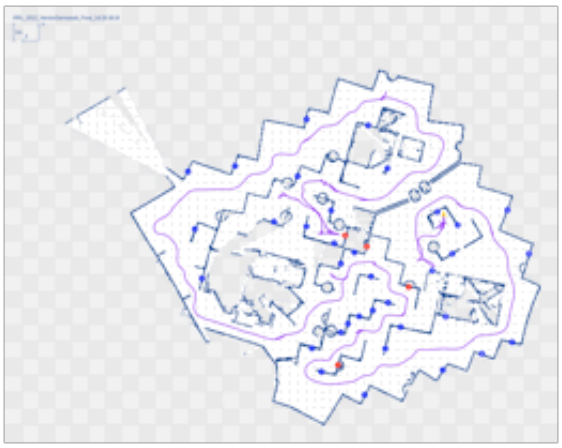
5 tests for mapping, object/terrain recognition and detection (all tests are considered for a robot to win Best

in Class Autonomy, but only if the tests are performed autonomously).

For all mapping tasks the following rules apply:

- Provide a geotiff in the correct format (see below). We will only accept a single 2D map; if your robot produced multiple maps, provide us the best one. Turn in the map not later than 10 minutes after you finished your mission.
- Areas mapped in 3D will get extra points. For that provide 2 files: 1) a 3D point cloud either as (pcd) [http://www.pointclouds.org/documentation/tutorials/pcd*file*format.php] or as (Octomap .ot or .bt) [https://github.com/OctoMap/octomap]. 2) provide a slice of a 2D map in geotiff at a height of 2.2m.

- (EXP 1) Map on Continuous Ramps: Create a 2D and/or 3D map of a dark labyrinth while traversing modest ground complexity. This capability has to be an autonomous background service for teleop or autonomous robots.



- (EXP 2) Map on Crossing Ramps: Create a 2D and/or 3D map of a dark labyrinth while traversing increased ground complexity. This capability has to be an autonomous background service for teleop or autonomous robots.

- (EXP 3) Recognize Objects: This capability has to be an autonomous background service for teleop or autonomous robots. Some items will be multiple times in the maze (e.g. hazmat signs), others rather rare (e.g. door). Points will be adjusted accordingly (for example, hazmats might get 1 point, doors 5). The points are doubled if the identified object is marked at the correct location in the map (within 1 m of the true position). The identified objects in the map have to be numbered and colored according to the standard (see above). There has to be a corresponding text file with the object type, the time they where found, their number and location. See the file format below.

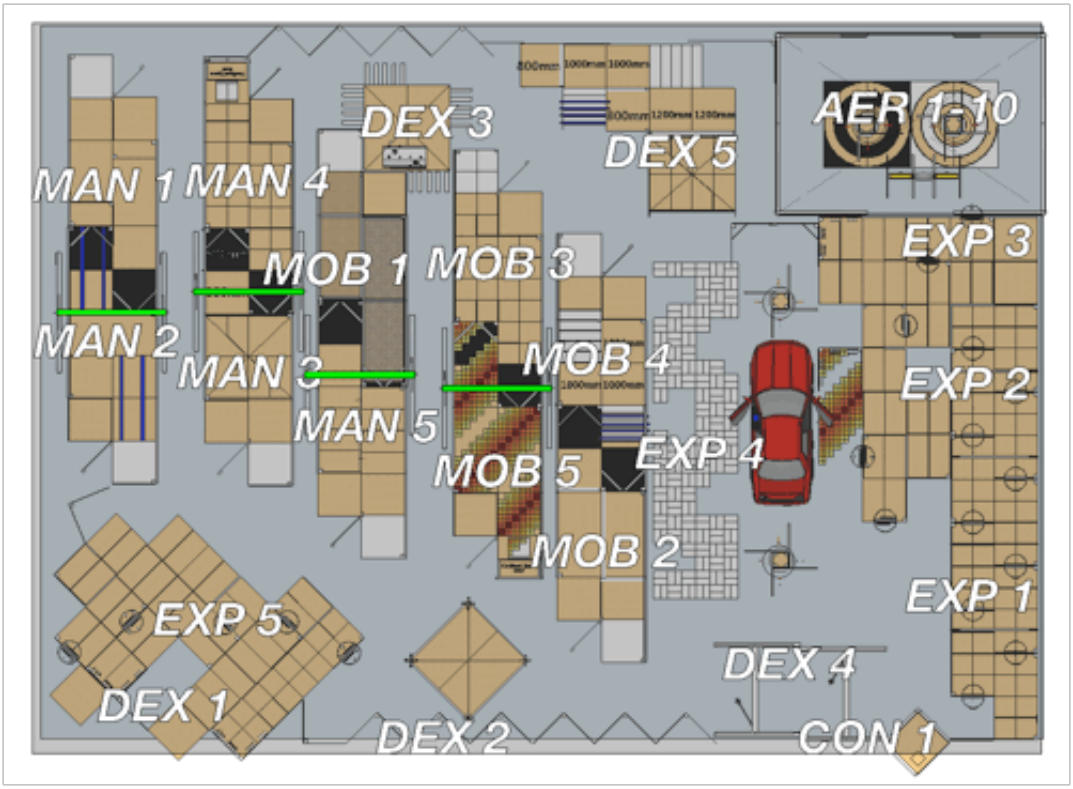
- Objects to be recognized in 2019:

    - Fire Extinguisher,
    - Door,
    - Valves,
    - Baby dolls,
    - Live humans (a volunteer will sit or lay in the arena),

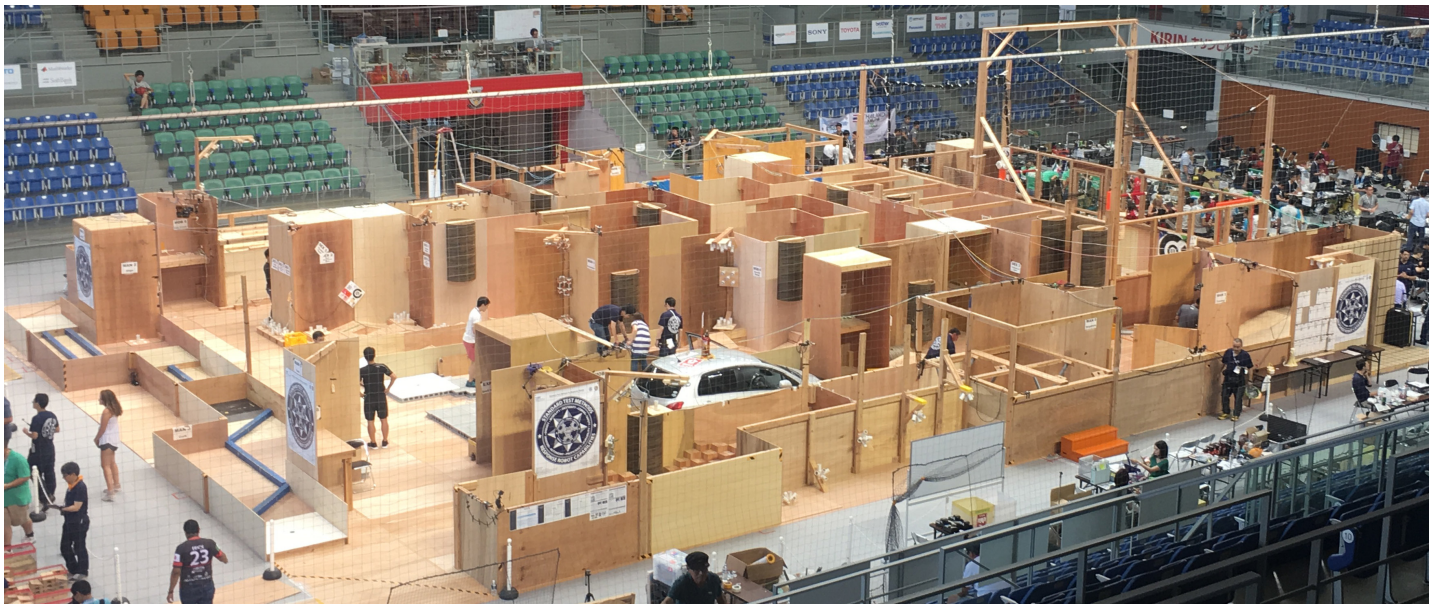
- Hazmat Signs,
- QR codes,
- Exit signs; green (according to the standard if the country the competition is held in; 2019 for example: https://www.australiansafetysigns.net.au/products/exit-landscape-exit-symbol-left-arrow)
- Fire Extinguisher signs; red (according to the standard if the country the competition is held in; 2019 for example https://www.australiansafetysigns.net.au/products/fire-fire-extinguisher),
- Heat source.

- (EXP 4) Avoid Holes: Drive and map while avoiding amorphous negative obstacles along a robot's path - augmenting capabilities demonstrated in Align test method. This is for autonomous robots only.

- (EXP 5) Avoid Terrains: Drive and map while avoiding amorphous terrain obstacles without enclosing walls (e.g. stepfields, small obstacles). This is a test for autonomous robots only.



(Sample arena layout showing locations of all the test lanes set up for concurrent operation, limited only by the number of available test administrators and radio channels.)



(RoboCup 2017 in Japan Arena)

System Inspection

On the morning of the first day every team will get 30 minutes for system inspection of their primary robot:

- measurements for "(MAN 1) Center" (diagonal and width with all parts),
- measure the weight of the robot and the operator equipment,
- picture in photo booth,
- radio inspection (frequency, power, bandwidth, protocol) (will also be monitored during the competition),
- emergency stop buttons (remote e.g. from the GUI and locally on the robot),
- Operator Interface restrictions,
- Mapping capabilities and map format,
- Output format for found victims, QR codes, hazmat signs,
- Autonomy using robot computing,
- Semi-autonomous functions.

Only teams that completed all (applicable) checks are allowed to do missions.

Emergency Stop

- All robots need a big GUI element (button) to do an emergency stop, which is always visible and accessible.
- All robots also need an easily accessible physical button (big, red color) on the robot to perform an emergency stop.

Operator Interface

- The Operator Interface has to fit into the operator booth (max 110 cm width).
- The operator booth will have only 1 AC power plug (220 V or 110 V, according to the national standard) for the team.
- The maximum number of monitors (Laptop counts as 1) is 2.
- The maximum weight of the operator equipment is 30 kg. The operator interface has to be placed onto the table of the operator booth.

Mapping Capabilities and 2D Map Format

Format:

- Fileformat: Geotiff

- FILENAME: DARK BLUE (RGB: 0, 44, 207) TEXT For example, “RoboCup2019-TeamName-Mission1.tiff” displayed in the upper left corner to identify the map, make it sort properly in a directory, and findable on a computer.

- MAP SCALE: DARK BLUE (RGB: 0, 50, 140) TEXT AND EXACTLY 1 METER LONG LINE Display this in the upper right corner to indicate the scale of the map.

- MAP ORIENTATION: DARK BLUE (RGB: 0, 50, 140) TEXT (“X” AND “Y”) AND ABOUT 50 cm LONG ARROWS Display this next to the map scale. It gives the orientation for the victim location in the victim file. Must be a righthanded coordinate system: X points upwards, Y to the left.

- UNEXPLORED AREA GRID: LIGHT/DARK GREY (RGB: 226, 226, 227/RGB: 237, 237, 238) CHECKERBOARD WITH 100CM SQUARES This solid checkerboard pattern should show the unexplored area and provide scale on all sides of the mapped area. It should also print in black and white without ambiguity with other areas potentially turned grey in the process.

- EXPLORED AREA GRID: BLACK (RGB: 190,190,191) GRID WITH 50CM GRID AND ABOUT 1 CM THICK LINES (use a one pixel line in the map) This grid should only appear in the explored area, behind any walls, victim locations, or other information. The grid should be aligned with the checkerboard pattern of the unexplored area, but twice as fine to allow visual inspection of wall alignments.

- INITIAL ROBOT POSITION: YELLOW (RGB: 255, 200, 0) ARROW This should mark the initial position of the robot and always be pointed toward the top of the map.

- WALLS AND OBSTACLES: DARK BLUE (RGB: 0, 40, 120) FEATURES This should indicate the walls and other obstacles in the environment. The color should make the walls stand out from everything else.

- SEARCHED AREA: WHITE CONFIDENCE GRADIENT (RGB: 128, 128, 128 to RGB: 255, 255, 255) This should be based on the confidence that the area is really free. It should produce a clean white

when seen as free by all measurements and nearly untouched when undecided, that is, nearly equally seen as occupied as free, to produce a dither effect.

- CLEARED AREA: LIGHT GREEN CONFIDENCE GRADIENT (RGB: 180, 230, 180 to RGB: 130, 230, 130) This should be based on a history of 1-50 scans to show the area cleared of victims with confidence. This should also factor in the actual field of view and range of onboard victim sensors – noting that victim sensors don't typically see through walls!

- VICTIM LOCATION: SOLID RED (RGB: 240, 10, 10) CIRCLE WITH ABOUT 35CM DIAM CONTAINING WHITE (RGB) TEXT "#" This should show the locations of victims with a victim identification number such as "1" in the order they were found. Additional information about this victim should be in the victim file noted below. Make sure the victim location is always on top of everything else!

- HAZARD LOCATION: SOLID ORANGE (RGB: 255, 100, 30) DIAMOND WITH ABOUT 30CM SIDES CONTAINING WHITE (RGB) TEXT "#" This should show the locations of hazards with an identification number such as "1" in the order they were found. Additional information about this hazard should be in the hazard file noted below.

- ROBOT PATH: MAGENTA (RGB: 120, 0, 140) LINE ABOUT 2CM THICK This should show the robot path.

See: http://wiki.ros.org/hector*geotiff*plugins?distro=kinetic

Output Format for Found Victims, QR Codes, Hazmat Signs, Identified Objects

- Naming convention for the file: RC[Year]*[Teamname]*[Mission]*pois.csv` where Mission is Prelim1, Prelim2, Semi1, Semi2, Final, BC*Autonomy and so on. Format for the file header:

```
"pois"
"1.2"
"[Your team name]"
"[Your country]"
"[Start Date]"
"[Start Time]"
"[Mission]"

id,time,text,x,y,z,robot,mode,type
```

Of course, replace the placeholders `[...] with your data. Please use the quotes in the file, but not the brackets. Format for the file body: [ID; must be unique for each object; must also be printed on map],[Time found],[QR code text],[x position in m],[y position in m],[z position in m],[Name of the robot that found the

landmark],[Mode of the robot when it found the object: A for autonomous, T for teleoperated],[type of the object: victim,qrcode,door,hazmatsign,...] Strings which include spaces should be enclosed with double quotes. Example for a QR code file which might be named 'RC2018*ReskoKoblenz*Semi2_pois.csv':

```
"pois"
"1.2"
"Resko Koblenz"
"Germany"
"2018-06-23"
"14:37:03"
"Semi2"

id,time,text,x,y,z,robot,mode,type
1,14:28:01,,-8.29994,-2.29014,0.4,"Robbie 1",A,victim
2,14:28:02,Y_1_2_chair_yokel,-8.29994,-2.29014,0.45610,"Robbie 2",T,qrcode
3,14:28:05,,-5.74523,-7.08499,0.21304,"Robbie 1",A,door
4,14:30:14,Y_2_1_ball_yeahs,-6.08457,-0.125154,0.35610,"Robbie 1",A,qrcode
5,14:32:56,Y_3_1_table_yolks,-9.28176,0.0496882,0.75610,"Robbie 2",T,qrcode
```

The file has to be produced automatically by the robot.

Autonomy using robot computing

The robot has to perform autonomy on the on board computer (if it is using the operator station computer the team can still get semi-autonomous points). To test this all teams interested in autonomy have to run a short exploration without being connected to the operator. After starting the robot, we will deactivate wifi or pull the network plug.

Readiness Test of System Sensors and Dexterity

The preliminary test trials have no victims. In order to reflect expected performance in the finals, where robots are expected to locate victims, the robot will perform a set of 6 inspection and 4 dexterity tasks. This happens towards the end of the trial, in order to show the robustness of the system. The number of successfully completed tasks will form a multiplier on the test trial score. This encourages more capable systems toward the finals and expects less capable systems to be much more efficient in performing each task. Teams may trade off between spending longer on this task to yield an increased multiplier, or spending more time performing repetitions in the trial. The minimum multiplier is 1 - so even if no readiness test is performed, a repetition will get one point. For the identification tasks no part of the robot maybe closer than 40 cm to the test board (so also the robot arm is not allowed to be closer). This is a sensor test, not a manipulation test! Think of a virtual glass panel 40 cm in front of the board. The 6 identification tasks, worth 1 point each:

- Video Image Resolution: Use any camera to teleoperatively identify the 3rd biggest concentric C gap.

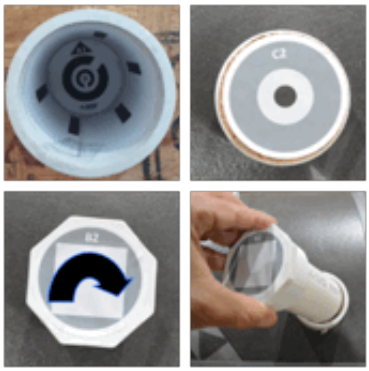
- Motion Detection: Use any camera and integrated video processing to correctly identify the number of moving targets (1-4) automatically, not by operator. Highlight (e.g. draw a rectangle around the area) and track the identified motions in the OCU display and textually or audibly warn the operator about such motions. Teleoperatively initiating this capability for a stationary robot is permitted.
- Thermal Image Resolution: The operator identifies the concentric Landolt C with a 2 cm gap to evaluate thermal resolution (regardless of the robot being teleoperated or autonomous).
- Audio Acuity: Use system microphones and speakers to correctly identify 2 lines which consists of 5 random numbers for each line. Random number strings (5 single digits each) will be articulated by a computer voice in .
- Color/Pattern Recognition: Use any camera and integrated video processing to correctly identify both labels from a known set of 12 possible. Highlight and track the identified labels in the OCU display and textually or audibly warn the operator about such hazards. The labels can be found at https://rrl.robocup.org/forms-guides-labels/
- Gas: Operator demonstrates active display of increase in CO_2 concentration when a team-mate breaths into the robot's sensor or a CO_2 cartridge is opened near the sensor.
- Potentially there may be an additional test for the color acuity. Please make sure you have a good color camera.

Identification Tasks:


B
5
6
7
8
ORGANIC PEROXIDE
5.2
FLAMMABLE SOLID
4
1
2
3
4
A

(^ for Finals ^)

Dexterity tasks:



The 4 dexterity tasks, worth 1 point each:

- Touch: Touch a 1 cm diameter circular target on the end of a pipe.
- Rotate: Grab a 5 cm octagonal pipe cap and rotate 180 degrees.
- Extract: Grab a 5 cm octagonal pipe cap and pull out of the pipe.
- Inspect: Identify the number of bars placed on the internal walls of a 5 cm pipe.

Teams are not allowed to touch the robot during the Readiness Test. If you need to touch the robot (e.g. remove a lens cover), the robot has to return to the start point (points already acquired so far are kept) and a 2 minute penalty for resets applies. The pen for the touch test can be given to the robot - without touching the robot (i.e. no taping it on the robot).

If the robot damages the test method during the readiness check (e.g. breaking of the pipe) the test method will not be repaired. The readiness check should be continued (to the best ability of the robot). So if the pipe breaks of during the extraction task, the inspection task cannot be completed.

Nobdoy is allowed to touch the test board after the mission has started. If the test object fell out during the mission no touch, rotate and extract test are possible! It is thus also not possible to first to inspect and then the other tests.

Teams may choose to only do the inspection task. This will have to be announced to the judge before the robot enters the arena. Only in this case the team may remove the pipe cap from the dexterity test beforehand.

Robot Classes

Autonomous, Semi-Autonomous, Teleoperated and Small Robots are compared together as they compete the exact same terrain, obstacle, or task repetitions. ()Outdoor CarryBot and MicroAerial will be compared separately on a subset of terrains/obstacles.) A repetition consists of successful completion of a terrain or obstacle from start zone to end zone, or a dexterity task. A robot may be in more than one class. The classes are:

- Small Robot (60 cm Vertical Entry or 50 cm Pipe Entry): A small robot that enters the test lane through confined space. Either vertically through a 60 cm square hole 2.4 m above the starting zone. The robot

then may be lowered on a tether or removable rope by a handler on the floor. Alternatively the robot may enter through a 50 cm pipe. Only the team's Primary robot can qualify for the Best in Class "Small robot" awards. The maximum weight for a small robot is 20 kg (in 2020: 15 kg)
- Regular Robot: Any robot too big or heavy to be a Small Robot. The maximum weight is 80 kg (2019: 100kg). Robots that are heavier cannot participate for safety reasons (and because they will damage the wooden arena).
- Outdoor CarryBot: A suite of test methods for autonomous robots with reasonable payload or trailer towing capacity, a GPS receiver for waypoint following, and/or line following capabilities as the simplest level of autonomy. This does not need to be the Primary robot.
- MicroAerial Robot: For aerial robots. This does not need to be the Primary robot.

Robot Operation Modes

During a test, each repetition can be done in one of three operation modes: Autonomous, Semi-Autonomous or Teleop.

- Autonomous Repetition: A repetition without intervention by an operator in a remote operator station. Autonomous repetitions receive double points (for both: Best in Class as well as ranking to reach the finals). Any repetition (which is a subtask such as driving from the start zone to the end zone or the other way) that requires operator intervention is considered a teleoperation repetition (or semi-autonomy if eligible). Only the team's Primary robot can qualify for the Best in Class "Autonomous Robot" award. The autonomy has to be performed on the robot (i.e. work without connection to the operator computers).
- Semi-Autonomous Repetition: A repetition that is completed with operator intervention but under the active support of a semi-autonomous function. The semi-autonomus function has to be approved by the Judges during the robot inspection and has to be one of the accepted semi-autonomous functions. The robot will receive normal points for any "Best in Class" competition but 1.5 points (so 50% bonus) towards the ranking after the preliminary competitions. No extra points during the finals.
- Teleoperated Repetition: A repetition that is completed with any intervention by an operator in a remote operator station if no semi-autonomy operation is granted.

Semi-Autonomy Mode

Each year the RoboCup Technical Committee will publish a set of semi-autonomous functions that will be eligible to receive the 50 % bonus for a semi-autonomous repetition. During the robot inspection on the first day teams have to demonstrate their semi-autonomous functions to the judges, who will then decide if they implement those functions satisfactory.

In order to receive the 50 % bonus for a repetition, the semi-autonomous function has to be active and used in that repetition. (of cours, a robot running an autonomous repetition cannot get the 50 % bonus for semi-autonomy.)

The already approved semi-autonomous functions for RoboCup 2019 are:

- Way point following: Define waypoints in the GUI (graphically on the map), maximum 3 points per repetition. No other mode of control (e.g. joystick or keyboard) is allowed (if manual control is needed the repetition will count as a normal teleop repetition (i.e. no bonus points). Eligible tests: MAN 1-6, MOB 1-5, EXP 1-3.
- Inverse Kinematics: Move the end-effector in cartesian coordinates (gripper coordinates or robot coordinates). No joint angle based control may be used in the repetition. Eligible tests: DEX 1-5
- Autonomy performed on the operator laptops: Fully autonomous functions that do the computing on the operator machines (e.g. streaming the laser data) can get semi-autonomous points. The same rules as full-autonomy applies (i.e. no touching the operator interface). Eligible tests: all (if done fully autonomous)
- Autonomous Flippers: The robot can see or sense the terrain (with the camera, laser, torque sensor and so on) and adjust the flipper angles accordingly. The flippers should always have contact with the ground unless a) the robot is approaching an obstacle or b) the robot is turning. Tests:
    - Robot drives on flat ground: the flippers should go flat and stay there.
    - On the ground the robot approaches an obstacle (e.g. 10 cm raised platform), the front flippers should lift accordingly.
    - Robot is put on a ramp: the flippers should have full contact with the ramp.
    - The robot is put on the edge between ramp and top of the ramp (robot on ramp). All flippers should have full contact.
    - The robot is put on the edge between ramp and top of the ramp (robot on top). All flippers should have full contact.

Every year the RoboCup Rescue Technical Committee will ask for suggestions for additions or changes regarding semi-autonomous functions. For 2019 please send your suggestions to Sören Schwertfeger (soerensch@shanghaitech.edu.cn) until Feb 15 2019. This rules document will then be updated after discussion with the committee.

Primary robot / CarryBot / MicroAerial

One major objective of the new competition is to encourage teams to combine capabilities onto a single robot. The new competition structure measures the overall capability per robot. Teams will declare a single primary robot to compete for awards. A sticker will be affixed to it at the configuration identification station (photo booth) to identify it. The sticker has to stay on this robot during the whole competition for test administrators to reference. Teams may bring additional robots for two of the Best in Class competitions: Outdoor CarryBot and MicroAerial. Furthermore, teams may bring as many additional robots as they like and self- evaluate them (without being eligible for a certificate or trophy) in unused lanes if they are tethered (no Wi-Fi communications).

Trophies and Certificates

RoboCup Rescue Championship

The following trophies result from multiple Final trials: * First Place * Second Place * Third Place

Best-in-Class Certificates

The team/ robot with the highest score in a specific robot class wins the according Best in Class certificate.

- Only the runs in the preliminary round count for Best in Class.
- To win any Best in Class certificate, you need a positive, non zero score in 4 of 6 maneuvering tests (MAN 1 to 6).
- It is possible that a team could win more than one Best in Class certificate.
- A certificate is only given if at least three teams compete in the same test bracket / robot class.
- Best in Class Mobility: best scores of 5 different tests from Mobility.
- Best in Class Dexterity: best scores of 5 different tests from Dexterity.
- Best in Class Autonomy: best scores of 5 different tests from autonomous Exploration (only exploration tasks performed fully autonomously can be used). An additional requirement is that 2 out of 6 maneuvering tests must have a non zero autonomous score.
- Best in Class Small Robot: best scores of 5 different tests from Mobility, Dexterity or autonomous Exploration. Only for Small Vertical Entry robots class: Entry through a 60 cm square (vertical) or 50 cm diameter pipe (horizontal). There is an extra normalization of the scores for the small robots that only takes small robots into account.
- Best in Class Aerials: Pass all Aerial safety tests; then the best 5 aerial tests count. (The aerial competition is run in its own area, separately from the ground robot competition.)
- Best in Class Outdoor CarryBot: Best score in the outdoor transport competition.

Competition Schedule

The competition is structured as follows:

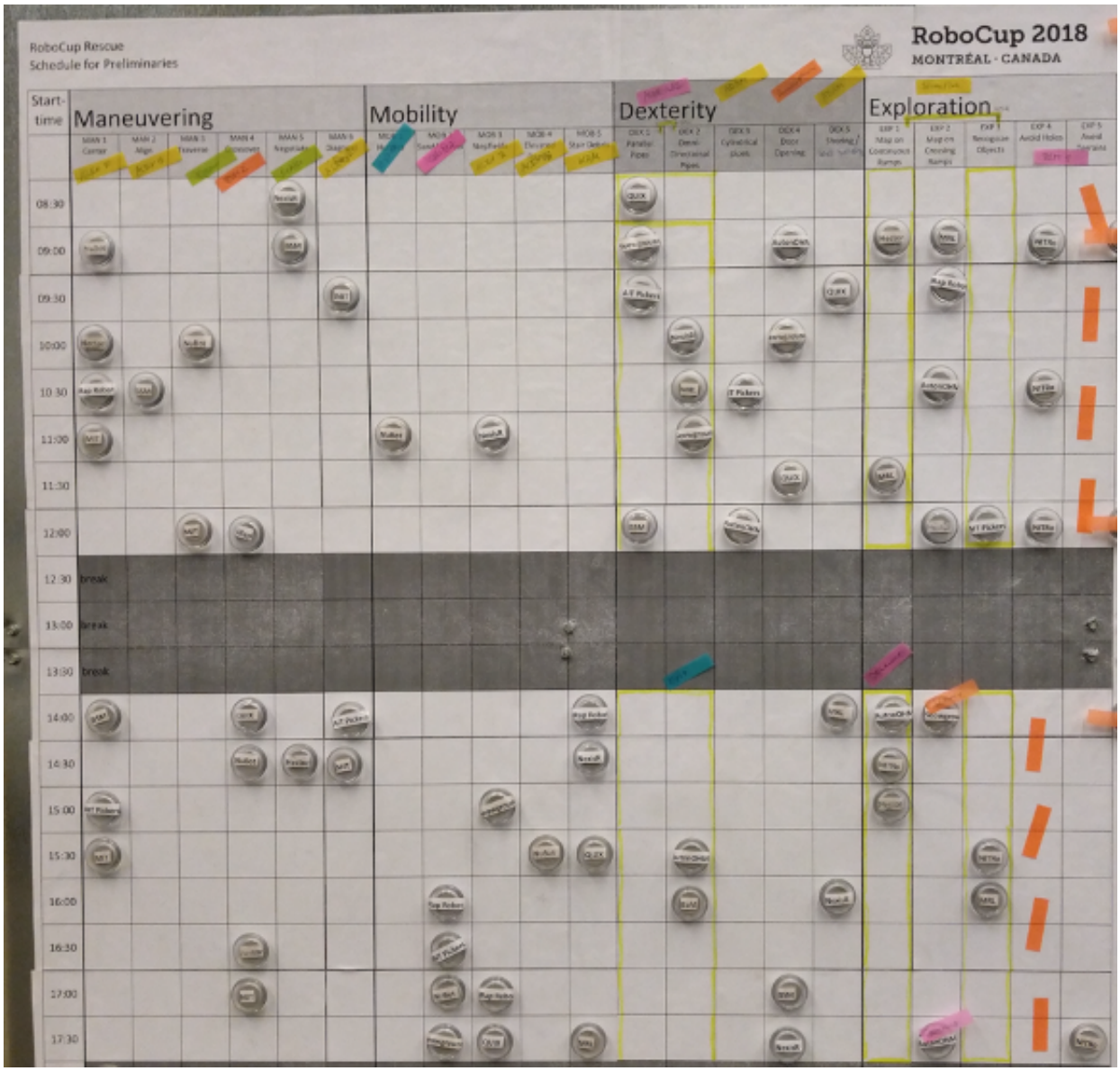
- Preliminaries: At least 10 missions (time slots) per primary robot are assigned to the teams; up to 20 min each. The goal here is to score as many points as possible in the test methods. In general, you get one point for getting from the start zone to the end zone and another point for the way back from the end zone to the start zone (and so on). The result of the 5 maneuvering tests plus 5 other best test results are added up for the qualification. See below for details.
- Finals: Each mission lasts 30 min. The goal here is to score victims with the Primary robot. See below for details.

Preliminaries

Your team will select a certain subset (at least 10) of the 21 test methods and perform in 20 minute test runs. You will get at least 10 time slots to perform the selected tests, such that you may have the chance to improve your score of two (or more) tests.

Scheduling for the preliminaries

This is an example of the dispatch board for day 1:



Procedure for the scheduling

- Each team gets 4 magnetic tokens with their team name on it.
- The evening before each preliminary test days the following procedure will define the schedule for the following day:
    - A random order of the teams is drawn.
    - According to that order, the teams pick one free test method/time slot to reserve a free test

method/time slot in the morning and place one of the tokens.
    - Not more than c tokens can be placed in one row, where c is the number of test administrators.
    - After each team has placed their first token, in a second round (same order) the teams pick another free test method/time slot and place a second token.
    - Then the order of teams is reversed and according to this new order teams place a third token for the afternoon session.
    - After each team has placed the third token, in a fourth round the team picks another free test method/time slot and places a fourth token.
    - At this point, each team has selected four test runs for the next day.

- A team should not place more than one token in the same row, since only the primary robot is allowed in the main competition and cannot be in two test methods at the same time.

Rules for changing the token after the selection: - Swapping or moving to a free spot during the initial assignment phase (i.e. the team leader meeting) is not allowed. - Swapping or moving to a free spot is allowed after the initial assignment phase until the first mission starts the next morning (e.g. 9 am). A TC member has to be contacted and informed about the intended swapping or moving, since judges have to be assigned to the now time slot. - Later swapping or moving to a free spot (e.g. because the robot has to be repaired) is not allowed, unless two TC members decide otherwise.

Test execution

Overview:

- :00 “prepare for next mission” team gets to start position of lane
- :03 “start mission”
- :18 “readiness test available”
- :26 “end of mission” team clears the arena

Details:

- Each time slot is 30 minutes.
- Before your mission, move your robot to one of the provided waiting areas outside the arena.
- 3 minutes robot setup: place your robot at the start point of the arena, prepare everything, but don't drive yet.
- 23 minutes Run Phase which includes the Readiness Test.
- From minute 18 on the Readiness Test becomes available. For that point in time on, during a repetition, the team may choose to stop at the readiness board and perform the readiness test.
- Once the Readiness Test is finished and there is still time the team may complete the repitition and continue to do more repetitions.
- When the time is up the team has to stop performing (either readiness test or repetitions). The maximum time for the Readiness Test is thus 8 minutes.
- A team can perform each repetition (i.e. move from the start zone to the end zone or move from the

end zone to the start zone) either teleoperated or autonomously.
- Each successful complete repetition is counted as one point.
- Only if a repetition is done completely autonomously, it will receive double points.
- Only if a repetition is done completely autonomously, it counts as an autonomous repetition (for the Best in Class Autonomy award).
- If the operator switches back within a repetition from autonomous mode to teleop mode, the repetition is still valid, but is considered as done teleoperated.
- A repetition may be also done in semi-autonomous mode (see the details above).

- 4 minutes to clear the arena. Be quick to clear the test method and the operator booth. Penalty points for leaving the arena too late: 20% points of this run per 30 seconds.

- There will be a global clock, so all tests in all test lanes start and stop at the same time.

- If your robot has radio issues, you are free to use a tether / cable to communicate with the robot. The cable handler has to stand outside the test method at the start point of the arena: Exception: In EXP tasks one cable handler is allowed in the arena (the maze).

Scoring

- Every team can repeat a test, as often they want if it is available and the team has a free token to place. Only the best result will be kept for the task and team.
- All scores will be normalized per test method, so that the best team gets 100 points. This calculation is done after all teams have completed all tests in the preliminary round. The other teams get points proportionally. Example: For test method Dexterity 1: If team A scored 20 points and team B scored 10; then at the end of the preliminaries the score of team A will be set to 100 and the score of team B to 50. This way, for each test method the best team gets 100 points. This normalized score is also used for the comparison of the small robots (no separate normalization for small robots).

Finals

- The best teams (based on their score) qualify for the finals.
    - Calculating the score: The admins will select the best 5 out of the 6 MAN normalized scores and the 5 best normalized scores from the other tests (MOB, DEX, EXP) and summ all 10 up.

- Only a single robot (the qualified Primary robot) is allowed in the finals.
- Score is reset to 0 before the finals (i.e. points from the preliminaries do not count for the finals).
- Goal of the finals is to score as many victims as possible, and to gain as much information about each victim as possible (e.g. vision, heat, audio, mapping).
- The test methods will be re-modeled into three separate arenas for the finals. Each arena will have opportunities for all robots, but each arena will emphasize one of the three main test categories: Mobility, Dexterity and Exploration.
- Each robot will see each arena (Mob, Dex and Exp) the same number of times, typically only once

(depending on available time and number of teams in the finals).

- The arenas will feature virtual "victims", which are the readiness test boards. The boards are placed somewhere in the test methods. The test boards may also be placed inside barrels or in other difficult locations. The locations of the victims (boards) will be announced during the team leader meeting.
- For each found victim a "readiness test" can be performed to get points, using the same rules (5 points for each sign of life: Visual, Thermal, Audio, Gas, Motion, Hazmat).
- Additionally you can get up to 20 mapping points per victim: up to 10 points for the quality of the geotiff map; up to 10 points for the correct location of that victim in the map. The rules follow the "(EXP 3) Recognize Objects" task.
- Additionally you can get 20 points for placing an object in the victim box/victim hole, only once per victim.
    - You are free to start the competition with one object in the gripper. The robot may (additionally) carry up to 2 objects with it. Further objects to be placed can be found in the arena.
    - More objects are provided by the judges (typically 500 ml water bottles). Each victim has a designated object (so unless you use an object the robot brought from the start, you have to grab one specific object).
    - If the robot kicks an object over it may not be placed at the proper point by a human - the robot has to deal with the kicked object.
- Some victims may have valves close by. Those victims cannot receive objects. Instead the 20 manipulation points for this victim can be gained by turning the valve by at least 180 degrees.
- The robot may score each victim only once. Only if a certain number of victims (approx. 80%) have been found, the robot may return to the start point and then start scoring previously seen victims again - in any order.
    - You may not deploy manipulation objects on the robot when the robot is starting another round.
    - You may not deploy manipulation objects on the robot during resets.
    - Manipulation objects from the arena will be placed at the proper locations at the start of another round.
- The robot is free to choose the order in which the victims are approached.
- In order to score, the robot main body (so the arm and flippers don't count) has to be within 60 cm of the victim box or victim hole.
- Certain victims may only be accessed by an autonomous robot (autonomy on the operator station does not count!). Once the victim is reached it can be scored using teleoperation (think of a radio dropout zone on the way to the victim, but now the radio communication is back).
- For all victims, autonomous operation will score double points. The autonomy hast to take control from the start of that test method till the victim is reached (60 cm distance).

- There is no need to drive backwards in MAN test elements.
- Tethered operation is possible. Use a very long cable. Up to two cable handlers are allowed. They are allwed inside the arena, but have to stay out of the test lanes (except in the maze).
- PENALTIES (-10 pts per event): Assessed when arena elements need to be replaced or repaired.
- PENALTIES (-50 pts per event): Assessed when the victim is violently touched or moved.
- Resets (touching or repairing the robot) in finals are the same as in the preliminaries (2 minute minimum time penalty). The robot re-starts from the start point. Points are kept.
- Points are normalized for each arena (Mob, Dex, Exp).

Remarks

- Resets: 2 min time penalty for each touching and/or moving of robot. After a reset, the robot has to start from the last start zone again. The robot keeps the points achieved so far.
- Unsafe or distructive robots: The judges can penalize unsafe or distructive robot behaviour during preliminary tests (see the penalties for such behaviour in the finals above). The default is a 50% deduction of the scores in this test per major event.
- For some test methods (MAN), the robots have to drive in reverse mode. So make sure you are able to do that by either having backwards looking cameras or other sensors on the backside of the robot.
- The competing robots can be tethered.
- Radio regulations of the host country have to be respected.
- Rules and arena layouts are subject to change.
- The pictures of the test method in this document do not guarantee the actual implementation of this test method.
- During a run, there should be nobody in the arena with the robot. Cable handlers have to stand outside near the start point (exception: EXP tasks: one cable handler is allowed in the test method). For MOB tasks no safety person is allowed in the arena. Only at the stairs there will be a savety rope that can be operated by a team member. In the maze (EXP tasks) one team member is allowed for safety. If there is a cable handler already, this person is also the safety person. Photo or video taking inside the arena by the teams is typically not allowed (but the judge may allow it). Other persons (e.g. journalists) are only allowed in with the permission of the judge. The judge may ask a referee to help with the adjudication of a task (especially EXP tasks) - the referee is allowed in the arena.

FAQ

Q (2016-06-10): Are the specific wheels part of the "fixed configuration"? Our robot would remain the same (all sensors, robot arm, computers, actuators, etc), but we planned on using different wheels if required for different tasks. They are passive wheels, just climbing stairs require different wheels than the other tasks. Is

this ok?

A: No. Fixed configuration means fixed configuration, i.e. no modification is allowed. Think of the test lanes be combined in one big scenario. Then you also have to decide which configuration you pick to bring your robot to the end of this single scenario.

Q (2016-06-10): We've planned on using our primary robot in the outdoors test, with different wheels installed (larger diameter means more speed, which might matter when we have to travel hundreds of meters). Is this ok?

A: Yes. We do consider the outdoor arena as a completely separate test. You can even show up with a completely new robot. So using the primary robot with new wheels is OK. Remember to change the robot back to its original configuration before you use it indoors again.

Q (2016-06-10): When radio problems occur, and one must fall back to wired networking, can someone help manage the cables (to not constrain the movement of the robot)?

A: (Updated 2018) Yes, a second person for the cable management is allowed. In most lanes the cable management person can (and then must) do this from outside of the test lane, standing at the start point. Only in EXP tasks is the cable handler allowed in the arena. However, the cable cannot be used to steer the robot by pulling it in a specific direction (the cable handler might have a good direct view on the robot.) Communication between the operator and the cable management person is of course forbidden.

Q (2016-06-10): Our robot arm most probably won't handle the weight of the 1.8 kg wooden blocks of the shoring task, as they were designed with the balsa blocks in mind (long before the rules came out).

A: We might provide a second, lighter set of wooden blocks (e.g. made of balsa wood). However, using this second set of lighter blocks will give significantly fewer points compared to the 1.8 kg blocks.

Q (2016-05-25): Can we use two wifi networks to communicate with the robots from the operator station?

A: If you use only one radio channel, you can use multiple wifi networks.

Q (25.05.2016): Can we use multiple wireless channels (different frequencies) to communicate with the robot?

A: No. We will have several teams running at the same time, therefore each team is allowed only one channel for the communication between the operator station and the robot.

Q: Can we use multiple robots in the finals?

A: No. Only the primary robot in its fixed configuration is allowed in the finals.

Q (2016-06-02): It is denoted in the rulebook that small vertical entry robots would enter the test lane vertically through a 60 cm square hole 2.4 m above the starting zone. So is there any structure like a stair for us to elevate the robot to 2.4 m above? Or should we bring our own elevating machine?

A: (updated 2018) You have bring your own deployment mechanism. Since the maximum weight of the robot is 20 kg, it shouldn't be something too complicated or heavy.

Q (2016-06-15): The readiness check section shows the readiness check both (a) mounted at a wall unobstructed and (b) inside a barrel. What is the configuration that will be used at the competition?

A: During the preliminaries (when the identification test is performed) the board is uncovered and sits next to the start point. During the finals the board is behind a fiducial and can be inspected only through some holes (it then simulates a hidden victim).

Q (2016-06-16): Regarding the "fixed configuration": If parts of the robot break, or the whole robot fails, can we repair it or replace it?

A: If you replace broken parts of the robot by identical parts (e.g. you replace a motor), you are free to do so. However, the Technical Committee has to be informed and decides if the replacement is acceptable. Since the fixed configuration rule is intended to measure the reliability of the robot, replacing the whole robot is not allowed.