RoboCup Rescue Rulebook

(as of 2016-03-20)
Version 1.0

New 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. Complementary tests across a suite of tests begin to evaluate the system.

This year we plan to transition the competition into a format that more closely 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. The maze will consist of all the same test apparatuses and tasks. As always, the search scenario will be conducted from random start points and performed in any order of tasks the team chooses.

This year 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.

1 Test Suite

The new 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.

1.1 Maneuvering

5 tests for basic driving over quite easy terrain completed in forward and (for non autonomous robots) reverse driving orientations (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 it's width.

- (MAN 2) **Align**: Two bars (100 mm width) to cross which are set to the robot's outer ground contact dimension.

- (MAN 3) **Negotiate**: A set of movable vertical and diagonal sticks to push through (without breaking the sticks) or avoid.

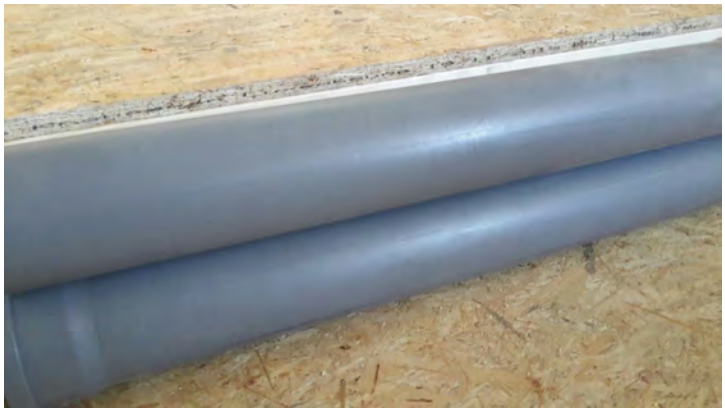
- (MAN 4) **Traverse**: A 30 degree inclined OSB surface to drive in 8 radial directions.

- (MAN 5) **Crossover**: A field of 15 degree ramps with a discontinuity to crossover.

1.2 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).

- (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 slopes.

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

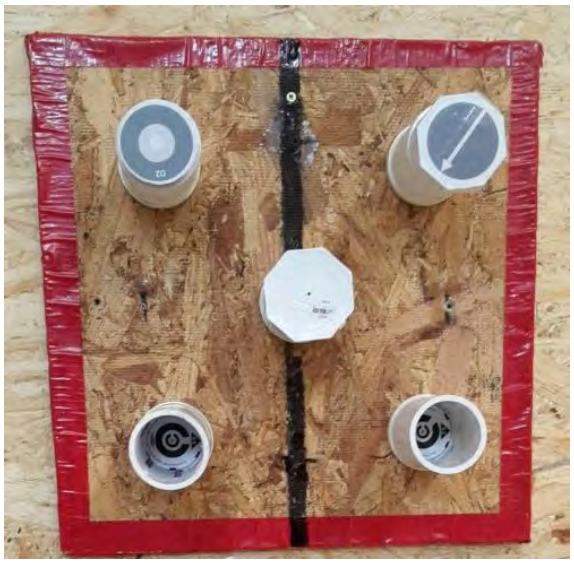
- (MOB 4) **Elevated Ramps**: A diagonal hill terrain consisting of 60 cm ramps with sloped tops (similar to the DARPA Robotics Challenge).

- (MOB 5) **Stair Debris**: 40 and 45 degree stair obstacle partly blocked with debris, e.g. angled bars in defined locations.

1.3 Dexterity

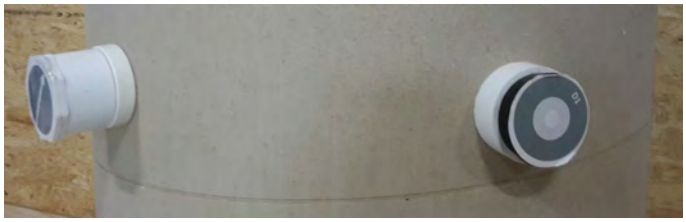
5 tests for manipulation and inspection (all tests are considered for a robot to win Best in Class Dexterity)

- (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.



- (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 and spring closures. 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. This test is conducted on on a flat surface.

1.4 Exploration

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

- (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:** Including QR codes, fire extinguishers, doors, simulated victims, and other items. This capability has to be an autonomous background service for teleop or autonomous robots.
- (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.

Additionally there will be a number of tests just for aerial robots and outdoor robots.

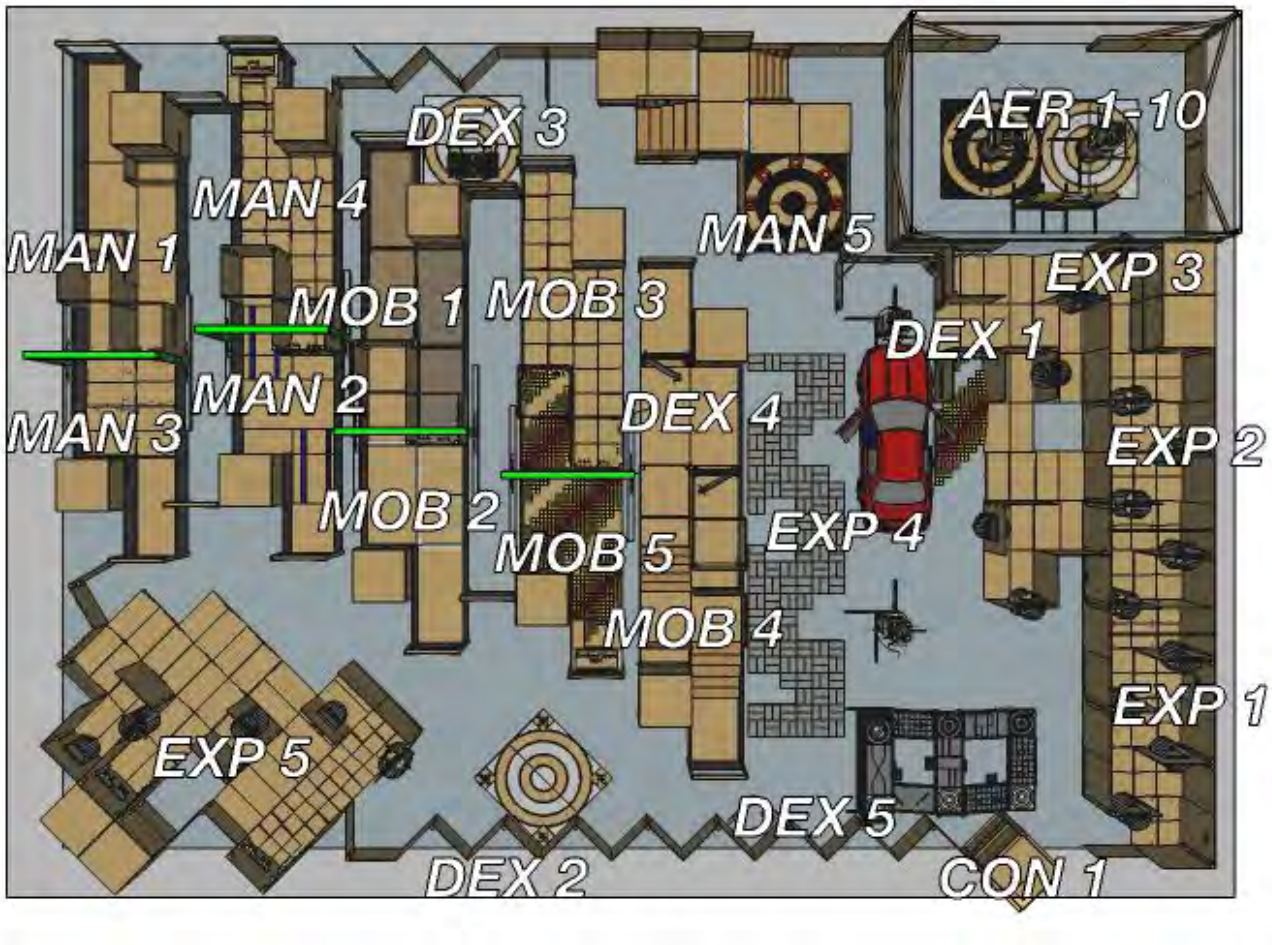


Figure 1: Sample arena layout showing locations of all the test lanes set up for concurrent operation, limited only by the number of available test administrators and radio channels.

2 Robot Configurations

Configuration Identification prior to all test trials

The preliminary test trials have no victims. In order to reflect expected performance in the finals where robots are expected to locate victims, at the start of each trial, the robot will perform a set of 5 inspection and 5 dexterity tasks. 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 5 identification tasks, worth 1 point each:

- **Visual Acuity**: Teleoperated robot identifies the concentric Landolt C with a 1 cm gap, autonomous robot identifies the hazmat label or QR code with a 1 cm square size.
- **Motion**: The system automatically identifies the number of motion signatures present (regardless of the robot being teleoperated or autonomous).
- **Heat**: The operator identifies the concentric Landolt C with a 2 cm gap to evaluate thermal resolution (regardless of the robot being teleoperated or autonomous).
- **Sound**: Identify 10 letters and numbers spoken through the robot system. Half points for one-way, full points for two-way.
- **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.

Figure 2: Identification tasks (left), dexterity tasks (right).

The 5 dexterity tasks, worth 1 point each:

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

3 Robot Classes

Robots are compared within five classes as they complete the exact same terrain, obstacle, or task repetitions. A repetition consists of successful completion of a terrain or obstacle from end zone to end zone, or a dexterity task. A robot may be in more than one class. The classes are:

- **Autonomous Robot**: A robot that completes a repetition without intervention by a single operator in a remote operator station. Any repetition (which is a subtask such as driving from the start point to the end point or the other way) that requires operator intervention

is considered a teleoperation repetition. This could be a robot that entered the test lane either through the 120 cm door or 60 cm vertical entry. Only the team's Primary robot can qualify for this Best in Class award.

- **Teleoperated Robot**: A robot that completes a repetition with any intervention by a single operator in a remote operator station. This could be a robot that entered the test lane either through the 120 cm square door or the 60 cm square vertical entry hole. Only the team's Primary robot can qualify for this Best in Class award.
- **Small Robot (60 cm Vertical Entry)**: A robot that enters the test lane vertically through a 60 cm square hole 2.4 m above the starting point. The robot may be lowered on a tether or removable rope by a handler on the floor. Only the team's Primary robot can qualify for this Best in Class award.
- **Outdoor CarryBot**: A suite of 5 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.

4 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).

5 Trophies and Certificates

5.1 RoboCup Rescue Championship

The following trophies result from multiple Final trials:

- First Place
- Second Place
- Third Place

5.2 Best in Class robot certificates

Best in Class robot certificates will be awarded within each test suite in three classes:

- All robots class (Entry through 120 cm square; also autonomous and small robots)
    - Best In Class Mobility
    - Best In Class Dexterity
    - Best In Class Exploration

- Autonomous robots class (Entry through 120 cm square)
    - Best In Class Autonomous Robot Mobility
    - Best In Class Autonomous Robot Dexterity
    - Best In Class Autonomous Robot Exploration

- Small Vertical Entry robots class (Entry through 60 cm square)
    - Best In Class Small Robot Mobility
    - Best In Class Small Robot Dexterity
    - Best In Class Small Robot Exploration

In addition, there will be the following Best in Class certificates:

- Outdoor CarryBot (not included in the RoboCup Rescue Championship)
- MicroAerial Robot (not included in the RoboCup Rescue Championship)

6 Competition Schedule

The competition is structured as follows:

- Preliminaries: At least 12 missions (time slots) per primary robot are assigned to the teams; up to 15 min each plus an additional 5 min for pure autonomy. 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 point to the end point and another point for the way back from the end point to the start point (and so on). The result of the 5 maneuvering tests plus 5 other best test results are added up for the qualification. See Sec. 6.1 for details.
- Finals: Each mission lasts 30 min. The goal here is to score victims. See Sec. 6.2 for details.

6.1 Preliminaries

Your team will select a certain subset (at least 10) of the 20 test methods and perform in up to 20 minute test runs. You will get at least 12 time slots to perform the selected tests, such that you 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:

	Number of admins / max. teams per line: c		Maneuvering (mandatory)					Mobility					Dexterity					Exploration				
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
			Center	Align	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
MORNING	P1	9:00	Team 1							…					…							
	P2	9.30						…						…								
	P3	10:00								…												
	P4	10:30													…							
	P5	11:00	Team 2	Team 1															…			
	P6	11:30																				
	P7	12:00		Team 2																	…	
	P8	12:30	Team 3																			
	P9	13:00																				
AFTERNOON	P10	13:30	Team 3						…													
	P11	14:00		Team 1										…					…			
	P12	14:30																			…	
	P13	15:00		Team 3						…						…						
	P14	15:30																				
	P15	16:00	Team 2						…										…			
	P16	16:30	Team 1												…							
	P17	17:00		Team 2																…		
	P18	17:30																				

Procedure for the scheduling

- Each team gets 4 (magnetic) tokens with their team name on it.

- The evening before each preliminary test day 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 of the above table 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.
- After a team has finished a run, they are free to place the token representing the completed run to a later free test method/time slot for the same half day.
- A team may elect to move a token from a timeslot that has not yet occurred to another free test method/time slot, freeing the original slot.
- 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.

Test execution

- Each time slot is 30 minutes.
- Before your mission, move your robot to one of the provided waiting tables.
- **5 minutes Setup Phase**: place your robot at the start point and establish the connection to the operator station. Do not start the readiness test or run. Your robot should point towards the open victim box, which is placed near the start point.
- **15 minutes Readiness Test and Run Phase**.
- During the readiness test teams may obtain up to 10 points:
    - 5 for sensing acuity tests:
        - either manual Landolt C or automatic hazmat sign or automatic QR code detection
        - motion,
        - heat,
        - sound,
        - gas (CO_2).
    - 5 dexterity tests:
        - inspect,
        - touch,
        - rotate,

    - extract,
    - place.

  These points serve as a multiplier for the results.
- A team can perform each repetition (i.e. move from the start point to the end point or move from the end point to the start point) either tele-operated or autonomously.
- Each successful complete repetition is counted as one point.
- 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.
- **Extra 5 minutes Autonomous Operation only**. Teams can use extra 5 minutes to perform the same task autonomously to gain autonomously scored points. In that phase no switch to tele-operation is allowed; switching back to teleoperation mode would end the run automatically. At the start of this 5 minute time slot, if the robot is not autonomous since it left the start point, the robot has to be driven back to the start point and continue autonomous for the rest of the run.
- **5 minutes to clear the arena**.
- 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.

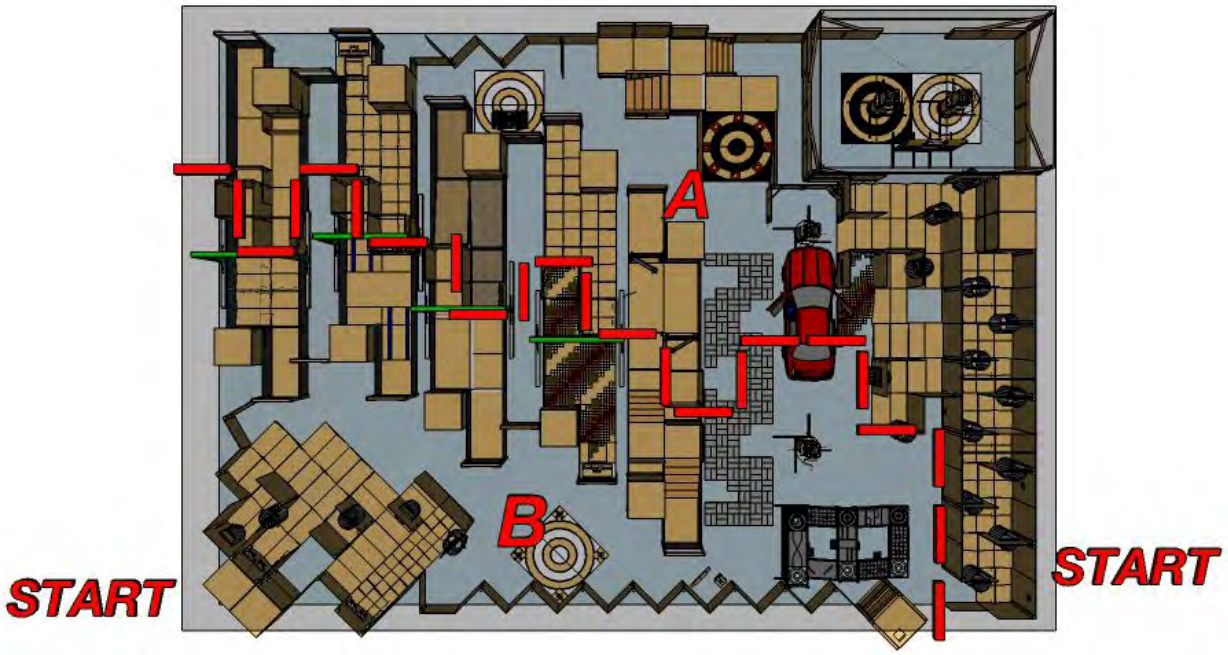
Scoring

- 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.
- There is no multiplier for autonomous operation, but autonomous robots get extra time (5 minutes) in each test method in which only autonomous operations are allowed. Also robots that worked teleop during the mission get this extra time if they switch to autonomy.

6.2 Finals

- The best teams qualify for 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).
- There will be an even number of final missions; each robot will see arena A and arena B (each half of the total arena) the same number of times.
- If the robot is able to find all victim locations during the final run, it can start over the search to gain more points.



6.3 Best in class

The team/ robot with the highest score in a specific bracket 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 5 maneuvering tests.
- 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 Exploration: best scores of 5 different tests from Exploration.
- 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.

7 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 point again. The robot keeps the points achieved so far.
- For some test methods, 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.