RoboCup Rescue 2022
Draft Rulebook
Part 1: Qualifications and Competition Logistics

Version 2022-04-14.

1. Introduction and Summary:

2022 presents unique challenges for the League. Leveraging the power of Standard Test Methods for reproducible testing, we plan to run a hybrid in-person and remote online competition. This will:

- Provide all teams, everywhere, with a way to compete remotely.
- Provide teams who participate in-person with the ability to have a viable competition, even if there are a limited number of in-person teams.
- Provide teams who plan to come to the in-person competition with a fall-back should they be prevented from participating at the last minute.

Awards:

The RoboCupRescue Robot League offers four categories of awards: Technical awards, Best-in-Class awards, Operator Proficiency awards, and the Championship. Note that an award may not be issued in a given year if no teams compete for, or achieve a competent level of performance in, that award. Awards may be given as a certificate, or as a trophy, depending on the number of teams competing. The criteria for each award is explained in more detail later in this document.

Technical Awards:

- Best TDP Award
- Innovation Award

Best-in-Class Awards:

- Best-in-Class Mobility
- Best-in-Class Dexterity
- Best-in-Class Mapping
- Best-in-Class Aerial
- Best-in-Class Autonomy
- Best-in-Class Outdoor Carrybot
- Best-in-Class Search and Inspect

Operator Proficiency:

- Operator Proficiency Mobility
- Operator Proficiency Dexterity
- Operator Proficiency Mapping
- Operator Proficiency Aerial

Championship:

- First Place
- Second Place
- Third Place

Qualifying:

For in-person competition:

- Team Participation Form (TPF) to declare intent to participate (NOW).
    - See https://rrl.robocup.org/forms-guides-labels/ for TPF and TDP details.
- Team Description Paper (TDP) describing their entry by the deadline on the website.
    - Most teams will need to include videos of their robot doing tests from at least 2 suites.

    - There will be a best TDP award. You may update your TDP for the best TDP award any time up until the deadline on the website.
- Regions with many teams should go to the local Regional Open, from which the best teams from the region will be selected.

For online competition:

- All teams welcome, TPF encouraged but not required.
- Teams must submit a TDP when they submit their preliminary video package.
    - There will be a best TDP award. You may update your TDP for the best TDP award any time up by the deadline on the website.

In-Person Competition:

The in-person competition will be run the same way as it was during RoboCup 2019 Sydney, with preliminary and final rounds.

Preliminary Rounds:

- Each day is divided into 30 minute synchronous time slots.
- Every day teams take turns selecting which time slot and test to run.
- Teams that have multiple robot configurations do not get extra time slots.
- At the end of preliminaries, for each test, scores are normalized to 100.
- Best total in each suite is awarded Best-in-Class.
- At a prescribed point in the run, the ‘Readiness Test’ is performed, which tests the sensors and manipulator that the robot would need downrange.

Final Rounds:

- Test methods are grouped into operationally relevant sequences that are performed one after the other.
- The readiness tests (representing “victims”) are performed at various locations during the sequence.
- Various manipulation tasks are also performed during the run (e.g. placing objects or turning valves).

Awards Eligibility:

Teams competing in-person are eligible for all awards:

- Best TDP Award
- Best-in-Class Awards
- Operator Proficiency Awards
- Autonomy Award

- Championship (1st, 2nd, 3rd)

Remote Online Competition:

The remote online competition will be held as a two-step process, representing RoboCup 2021 Worldwide.

- Pre-Recorded Remote Best-in-Class Preliminaries: Teams submit pre-recorded videos of performance in their own facilities.
- Live Telecon Remote Best-in-Class Finals: The best teams participate in live trials via telecon from their own facilities.
- Groups may run multiple robots or multiple robot configurations but each configuration is considered a separate team and registers separately (even if all the people on the team are the same).

Pre-Recorded Best-in-Class Remote Preliminaries:

- Teams build apparatuses for the tests that they wish to compete in.
- Teams upload uncut quadscreen video of their robots performing tests to a public, timestamped video sharing site, with their own scoring of the test.
- By the deadline, teams submit a list of their videos, scores, other details, and TDP if they haven't already (new requirement for 2022).
    - Teams only include their *best* run for each combination of test and setting.
    - See Appendix A for details on video requirements and submission.
- Teams attest to each others' scores and submit proposals for correction.
- Scores are normalized as before.
- Top teams in each suite progress to the Best-in-Class Remote Finals.

Live Telecon Best-in-Class Remote Finals:

- Teams perform runs live on video conference with judges and public before RoboCup week.
- Remote teams will get the same number of run slots as in-person teams.
    - We will try to accommodate teams who wish to have time between run slots to fix/recharge robots, perhaps by interleaving runs of teams in compatible timezones.
- Where relevant, the judges request last minute changes (e.g. asking for teams to move fiducials in mapping).
- Resulting performance in common tests are directly comparable to in-person Best-in-Class (preliminary) runs.

Awards Eligibility:

Teams competing remotely are eligible for the following awards:

- Best TDP Award

- Best-in-Class Awards
- Operator Proficiency Awards

Step-by-Step Summary:

Remote Only:

- Send us your TPF as soon as you know you may compete (no deadline).
- Register for RoboCup when registration opens. We will announce details when available.
- Submit a practice video early to make sure everything is OK. Check the forum for details!
- Submit your remote competition video package and TDP. See website for deadline.
    - Remember there is a best TDP award! You may update your TDP at any time up until 2 weeks before the competition.
- Participate in the remote attestation process.
- Be prepared to compete in the remote Best-in-Class finals. See website for dates.

In-Person with Remote Fallback:

- You should have sent us your TPF by now (we can be a little bit flexible, send it in ASAP).
- Qualify for the in-person competition:
    - Submit your TDP via EasyChair. See website for deadline.
        - Remember the qualification video requirement!
        - Remember there is a best TDP award! You may update your TDP at any time up until 2 weeks before the competition.
- Attend a regional open if your region has more than 5 teams (you should already be in contact with your regional RoboCup organization).
- Submit a practice video early to make sure everything is OK. Check the forum for details!
- Register for RoboCup when registration opens. We will announce details when available.
- Submit your remote competition video package. See website for deadline.
- Participate in the remote attestation process.
- If you find out before the remote Best-in-Class Finals that you can't travel to RoboCup (or you don't qualify for the in-person competition), be prepared to compete in the remote Best-in-Class finals.
    - If you find out after the remote Best-in-Class Finals that you can't come, we will try and accommodate you on a case-by-case basis.
- If you qualify for the in-person competition and can still travel, come to RoboCup!

In-Person Only:

- You should have sent us your TPF by now (we can be a little bit flexible, send it in ASAP).
- Submit your TDP via EasyChair. See website for the deadline.

    - Remember the qualification video requirement!
    - Remember there is a best TDP award! You may update your TDP at any time up until 2 weeks before the competition.
- Attend a regional open if your region has more than 5 teams (you should already be in contact with your regional RoboCup organization).
- Register for RoboCup when registration opens. We will announce details when available.
- If you qualify, come to RoboCup!

Note: If you follow this process (without submitting a video package by the deadline on the website) and change your mind at the last minute and want to participate remotely, we will try to accommodate you on a case-by-case basis but cannot guarantee that we will be able to. If we are, you are likely to be at a significant disadvantage due to time constraints. If you think there is any chance you might want to compete remotely, please follow the process on the slide "Step-by-Step for In-Person with Remote Fallback".

Contact and Sources of Additional Information:

- Please join our forum at https://rrl.forum.robocup.org to ask any general questions.
- For questions specific to your team, or to join our announcements mailing list, please email us at rescue.robot.league@nist.gov .
- Keep an eye on the website at https://rrl.robocup.org and https://2022.robocup.org for updates.
- Join our Facebook group https://www.facebook.com/groups/robocuprescue.
- To keep up to date with news across the RoboCup Federation, please email robocup-worldwide@lists.robocup.org.

2. Qualification Process:

See Qualification Process document, available from https://rrl.robocup.org/forms-guides-labels/ , for an overview of the Qualification Process. This document provides additional detail for specific requirements.

Summary:

See the website at https://rrl.robocup.org/ for the relevant due dates.

- For in-person competition:
  - Team Participation Form (https://rrl.robocup.org/forms-guides-labels/) to declare intent to participate.
    - See https://rrl.robocup.org/forms-guides-labels/ for TPF and TDP details.
  - Team Description Paper (TDP) describing their entry, by the deadline stated on the website.
    - Most teams will need to include videos of their robot doing tests from at least different 2 suites.
    - There will be a best TDP award. You may update your TDP for the best TDP award at any time up until the deadline stated on the website.
  - Regions with many teams should go to the local Regional Open, from which the best teams from the region will be selected.
- For online competition:
  - All teams welcome, TPF encouraged but not required.
  - Teams must submit a TDP when they submit their preliminary video package.
    - There will be a best TDP award. You may update your TDP for the best TDP award at any time up until the deadline stated on the website.

Team Description Paper:

TDPs for teams wishing to qualify for in-person competition, and for teams submitting videos for online competition, must follow the template available from https://rrl.robocup.org/forms-guides-labels/ . The best TDP award will be judged based on how informative the TDP is to new and existing teams.

Qualification Video (for in-person competition):

By the TDP due date, all teams wishing to qualify for the in-person competition must submit videos, no more than one in-person competition year old, of a robot performing in at least two of the following tests (must be from different suites).

- Dexterity: Non-Contact Linear Inspect
- Maneuvering: MAN2: Align (linear rails)
- Mobility: (We prefer you build TER2 ~~MOB3~~ if at all possible Note: do not perform both for qualification)

    - OBS1 ~~MOB1~~: Variable Height Rails (new)
      OR
    - TER2 ~~MOB3~~: K-Rail Crossover Slope (teams may elect to build just the center section)
- Mapping: A hallway with one or two rooms and containing at least 5 half fiducials visible on their map. At least one set of fiducials must line up on either side of a wall and be shown on the resulting map as a completed circle to demonstrate good localization.

Teams do NOT need to use the same robot or scale that they will compete with - we know that the robot will change anyway. This is to demonstrate the team's ability. New teams who do not have a working robot may elect to skip this requirement and be judged only on their TDP but team members/organization must not have competed before.

Please see Appendix A for the requirements that these videos must follow. The videos must be uploaded to a timestamped public video sharing site (e.g. Youtube) and a link provided in the TDP document.

3. Robot Configurations:

A **Robot Configuration** is a specific robot, with any mounted accessories (e.g. lights, cameras, gripper attachments, payloads) and settings (e.g. manually adjusted arm positions). Scores in the competition accumulate per robot configuration.

In general, any modification to the robot that requires physical access to the robot (e.g. adding, removing, or adjusting something physical) is considered to be changing the configuration. Any modification that can be performed remotely (e.g. software changes that can be performed remotely, or a physical change that is accomplished by the robot, without external physical intervention, in the course of the run, such as the robot using its own manipulator to move something on the body of the robot) is not considered changing the configuration.

The reason for this distinction is that the standard test methods represent decompositions of operational missions. For instance, an operational mission that requires a robot to climb stairs, open a door at the top of the stairs, and inspect a package on the other side of the door, does not allow the robot to be swapped out or touched by a human between accomplishing these tasks. Therefore, the equivalent tests of climbing stairs, opening a door, and inspecting a package, should be accomplished by the same robot, without modification[1].

Modifications:

In general, any modification to the robot described above is considered a new configuration. In limited circumstances, where it is demonstrated that the team has encountered an unexpected aspect of the competition (such as local conditions requiring apparatuses to be built in a way that was not expected), the committee may, on a case-by-case basis, allow for small modifications to be made to the robot partway through the competition. The team must consult with the committee before performing such modifications. The team must demonstrate to the committee that the modifications to the robot would not *reduce* performance in tests that the robot has already performed. The committee may require that the robot re-perform a select number or portion of relevant tests to demonstrate this.

Repairs:

If the robot is damaged and requires repair partway through the competition, the team should take care that their repair does not *reduce* the performance of the robot in tests that it has already performed. Such repairs would also be considered modifications and be subject to the requirement of the previous paragraph. In limited circumstances, where a team lacks the resources to fully repair a robot, the committee may allow a degraded robot to continue as the same configuration but may require certain modifications to the robot to prevent an unfair

[1] To keep things simple, in recent years we have stopped considering co-operative and marsupial robots. The test process may be adjusted in the future if there is demand.

advantage, and/or may require the team to re-do certain, relevant tests. If in doubt, the team should consult with the committee prior to performing repairs.

For example:

- A team performs the Dexterity tests and then breaks the arm in such a way that it cannot be re-stowed and must remove it to continue the competition. The committee may require that the robot carry an object of similar size and weight, in the same position that the stowed arm would have taken up, prior to continuing with the competition as the same robot configuration.
- A team has purchased new tracks for their robot to run in the competition, and has brought their old, worn-out tracks, of the same specification, as spares. The team performs some tests and breaks one of the new tracks. The team may install one of the old tracks, despite their potential to degrade performance, as long as there is no advantage in other tests.
- A team has purchased new tracks for their robot to run in competition, which are wider and grippier than their old, worn-out tracks, which they also bring as spares. The team performs some tests and breaks one of the new tracks. The committee may require that if the old (narrower) tracks are fitted to the robot, that objects be secured to each side of the robot so that it maintains the same width (and ability to fit through gaps) as the robot did prior to the tracks breaking. The committee may also require that the team re-do certain tests as relevant.

Number of Permitted Configurations:

For the **remote online competition ONLY**, as the competition process scales readily, teams may compete with as many robots and robot configurations as they like. Each robot and robot configuration is regarded as a separate team, competes separately, accumulates scores separately, and must be registered for RoboCup separately (even if the people on the teams are the same). Teams will be expected to attest to a number of videos proportional to the number of robot configurations that they enter.

For the **in-person competition**, due to space limitations, during the preliminaries, each team will have the same opportunities for test slots and may allocate these among however many robots and robot configurations that they bring. Teams should be strategic as all teams will have the same opportunities for test slots - a team will not be preferentially granted extra spots just because they have additional robots. Each robot configuration accumulates scores separately. Only the best performing robot that a team brings will be considered for the finals.

Commercial Robots:

We welcome commercial robots, and particularly companies who wish to demonstrate the capabilities and ease of use of their robots, and to compare their capabilities against research robots. In order to provide for a vibrant competition of both commercial and research robots,

where ease of use and research advancements can be shown off, we classify robots into Research robots and Commercial robots for each of the three ground robot suites - Mobility, Dexterity (incorporating Search and Inspect), and Mapping (incorporating Exploration).

Award eligibility:

The award eligibility for Research and Commercial teleoperated ground robots is as follows.

- Research robots are eligible for the Best-in-Class awards in each suite.
- Both Research and Commercial robots are eligible for the Operator Proficiency awards in each suite.
- Robots that are considered Research in at least two out of the three suites are eligible for the Championship.
    - Scores from all three suites are considered for robots that are eligible for the Championship, even if the robot is considered Commercial for one of them.

Similarly, Research Aerial robots are eligible for Best-in-Class and Operator Proficiency awards while Commercial Aerial robots are only eligible for Operator Proficiency awards. Aerial robots are not eligible for the Championship.

Only Research implementations of Autonomy are eligible for the Autonomy awards. It doesn't matter if the robot hardware implementation is considered Research or Commercial as long as the implementation of the autonomy software is the team's own work. As this is a difficult line to draw, we highly recommend that Research teams seeking to make this distinction contact the Committee as soon as possible to discuss their implementation.

Please see Appendix B for a detailed description and examples of what is considered a Research and a Commercial robot.

4. Scoring and Multipliers:

Multipliers are applied to scores for demonstration of capabilities in sensing, manipulation, and autonomy. Sensing and manipulation are assessed during each run using the Readiness Test while autonomy is assessed per repetition.

Sensing and Manipulation (Readiness test):

The purpose of the Readiness test is to verify that the robot's capabilities and configuration have not changed.

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 both the in-person preliminaries and the Remote (Live Telecon) Best-in-Class Finals, robots perform the Readiness test at a time of the team's choosing, during the time period that the readiness test is available (see the section on Competition Schedule). This is generally when the robot next passes the location of the readiness test crate, or when the robot is at a convenient stopping point in its current test. Note that teams should not delay in performing the readiness test or the end of the run may cut it short. The time spent performing the readiness test should be recorded and subtracted from the run time when calculating the task rate (which is not used for scoring, but is useful for comparing performance against standard testing).

For the first 4 sensor tasks no part of the robot may be closer than the opening of the readiness test crate. This is a sensor test, not a manipulation test! Think of a virtual glass panel 40 cm in front of the board. The 5th sensor task (magnet orientation) may be undertaken with the arm extending closer into the crate. The 5 sensor tasks, worth 1 point each are:

1. Video Image Resolution: Use any camera to automatically read the QR codes.
2. Thermal Image Resolution: The operator identifies the orientation of the rectangular heat pad or rectangular bag of warm water (regardless of the robot being teleoperated or autonomous).
3. 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 from a Bluetooth/MP3 speaker or mobile phone in speaker mode.
4. Color/Pattern Recognition: Use any camera and integrated video processing to correctly identify both hazmat labels from a known set of 12 possible. Highlight and track the identified labels in the OCU display and notify the operator about such hazards by

overlaying onto the image a text notification identifying and locating the label. The labels can be found at https://rrl.robocup.org/forms-guides-labels/

5. Magnet polarity: Operator demonstrates the detection of a bar magnet, placed 2.5 cm (1”) down the dexterity post, as the robot moves its sensor close to it, and shows the polarity of the end closest to the robot.

Note that movement and CO^2 gas detection have been removed.

The 5 dexterity tasks, worth 1 point each:

1. Inspect: Report the orientation of 1 mm gap Landolt-C optotypes in 50 mm (2”) inspection pipes placed at the four corners of the readiness test crate.
2. Touch: Touch the shaft of a manipulation object, held in the gripper (not taped or similar), to the precise touch target, which is the head of a screw 5-7 mm (0.2” - 0.3”) in diameter and at least 12.5 mm (0.5”) from the surface. The touch must be precise and controlled. Raising the target above the surrounding area prevents robots from hitting the surface nearby and then dragging onto the target.
3. Rotate: Rotate manipulation object.
4. Extract: Extract manipulation object.
5. Place: Drop object into the crate.

See the Dexterity tasks section and the Construction Guide for a description of the manipulation object, and the hole that it should fit in.

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.

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).

Nobody is allowed to touch the test board after the mission has started. Nobody is allowed to touch the robot or assist the robot in gripping the manipulation object after the mission has started unless the robot is back at the start point. The robot may start with the manipulation object in its gripper (held, not taped), somewhere on the robot chassis, or with the manipulation object in the test environment (e.g. the robot may use a manipulation object that is already in the readiness board and perform Rotate and Extract, then use that object to Touch while it’s already in the gripper).

The team is free to choose the location of the readiness test crate on the floor in or around the test apparatus, as long as it is upright and does not interfere with the test. It is just to verify that the robot is of the same configuration and capability, rather than as a simulation of a victim. However, for safety, it must be placed prior to the start of the trial and stay in that location for the duration of the trial.

*NOTE: The readiness test is **NOT** used for remote pre-recorded trials. It is only used for the live telecon remote trials and the in-person competition.*

Autonomy:

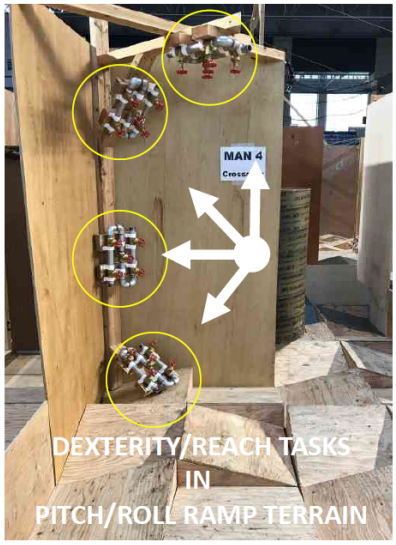
During a test, each repetition can be done in one of two operation modes: Autonomous or Teleop.

- 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.
    - The robot has to perform autonomy on the on board computer. 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.
- Teleoperated Repetition: A repetition that required the remote operator to take over control of the robot, or otherwise intervene in the robot's operation.

Note that the Semi-Autonomous category has been removed temporarily to reduce complexity associated with the need for both remote and in-person competition. It may be re-introduced in the future.

5. Scales of Test Lanes:

- 120 cm (48 in) Wide:
  - 120 cm (48 in) nominal lateral clearance.
  - Lanes for maneuvering, terrains, and obstacles with dexterity tasks in the terrains to add complexity.
  - A class of small robots operating in the 120 cm scale is defined by the robot fitting through an access hole. See the Robot Classes section for further details.



- 60 cm (24 in) Wide:
  - 60 cm (24 in) nominal lateral clearance.
  - Environments like dwellings, trains, buses, planes, or between parked cars, etc.

- 30 cm (12 in) Wide:
  - 30 cm (12 in) nominal lateral clearance.

- Small throwable robots, potentially disposable, are deployed through access holes into large scale tests.
- Emphasis on 3D printed robots with effective designs that can be readily disseminated or improved.
- The Rapidly Manufactured Robot Challenge (RMRC) for high school students operates mainly at this scale (with some operation at 60 cm). See http://rrl-rmrc.org for further details.

6. 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 following tests and suites are available. *Note that some of these have changed from previous years so please read the descriptions carefully.*

Maneuvering suite (Part 2):

- MAN0: Sustained Speed on a Line (new)
- MAN1: Center Between Objects (updated)
- MAN2: Align Ground Contacts (updated)
- MAN3: Traverse Incline
- MAN4: Negotiate Leaning Objects
- MAN5: Positive and Negative Obstacles (formerly Pallet Terrains)

Mobility suite (Part 3):

Obstacle tests:

- OBS1: Variable Height Rails
- OBS2: Hurdles
- OBS3: Stair (with optional Debris)

Terrain tests:

- TER1: Sand/Gravel on Crossover Slope
- TER2: K-Rails on Crossover Slope
- TER3: Pinwheel Ramps on Crossover Slope
- TER4: Crate Terrains (legged and lightweight robots)

Dexterity suite (Part 4):

- DEX1: Directed Inspection
- DEX2: Touch/Insert
- DEX3: Extract/Place
- DEX4: Strength Tasks
- DEX5: Shoring
- DEX6: Door Opening

Search and Inspect suite (Part 5 - currently being updated):

- SIT1: Standard Labyrinth Search and Inspect
- SIT2: Embedded Search and Inspect

Mapping and Exploration suite (Part 6 - currently being updated):

- EXP1: Mapping on Continuous Ramps
- EXP2: Mapping on Crossing Ramps
- EXP3: Recognize Objects
- EXP4: Avoid Holes
- EXP5: Avoid Terrain

Outdoor Carrybot (Part 7 - currently being updated):

Aerial suite (Part 8 - currently being updated):

- AIR1: Obstructed Tasks (representing open areas)
- AIR2: Confined Tasks (representing indoor areas)

Each test suite is described in more detail in its own document. Please see https://rrl.robocup.org to download the rulebook part for each suite that you are interested in.

7. Standard Faults:

The standard fault conditions are as follows. Some tests have additional fault conditions, or modifications to some of these fault conditions.

Full Reset:

The following conditions cause a full reset:

- Robot unable to continue (e.g. tipped over, high centered, other failure that cannot be corrected remotely).
- Manual contact with the robot for whatever reason.
- Damage to the apparatus, caused by the robot, that requires repair prior to the next test trial (beyond sticking a label back onto the wall) to make it compliant with the construction guide.

The team may elect to end the test trial, or call a full reset. Teams are allowed to call a reset for safety or strategic reasons.

- End of Trial: The score achieved thus far is recorded.
    - Note that for pre-recorded trials, teams are free to run as many trials as they like so it is expected that these faults will always be considered “end of trial”.
- Full reset: The robot is returned to the start point, taking at least 2 minutes, points for this trial reset to zero, and the trial re-started. The team only has the remaining trial time to complete the trial. The team may use the best score achieved in these multiple trials within the allocated trial time.

8. System Inspection:

On the morning of the first day every team will get 30 minutes for system inspection of their primary robot. Teams participating remotely should submit a short video showing this inspection (except for radio inspection).

- measurements for "(MAN 1) Center" (width with all parts).
- measure the weight of the robot and the operator equipment.
- picture in photo booth - at least front, top, side, angled, as well as any views necessary to show features of the robot such as cameras, arms, tracks, flippers, etc..
    - Remote teams should take these pictures and/or walkaround videos in front of a background (wall and floor) that is marked with a 20 cm square grid that is at least the size of their robot so that scale is obvious. This grid may be marked temporarily using masking tape
- radio inspection (frequency, power, bandwidth, protocol, ESSID, etc.) (will also be monitored during the competition) (in-person teams only).
- Operational emergency stop buttons (remote e.g. from the GUI and locally on the robot).
- Operator Interface dimension restrictions.
- Mapping capabilities and map format.
- Output format for found victims, QR codes, hazmat signs.
- Demonstrate autonomy using robot computing, including object and AR Code detection/identification.

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, 50 cm depth).
- 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 weight of the operator equipment is 30 kg. The operator interface has to be placed onto the table of the operator booth.

9. Robot Classes:

Autonomous, Teleoperated, and Small Robots are compared together as they compete in 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.

10. 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.
- 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 from Mobility suite (OBS and TER).
- Best in Class Dexterity: best scores from Dexterity suite (DEX).
- Best in Class Autonomy: best total score counting all autonomous repetitions in in-person preliminaries or remote live finals.
- 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.

11. Competition Schedule:

The competition is structured as follows:

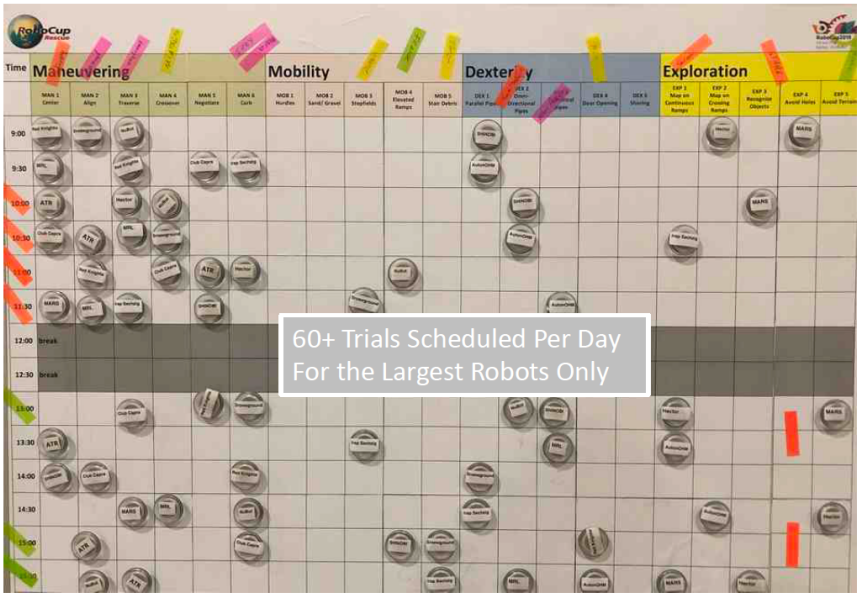
- Preliminaries: At least 10 missions (time slots) per primary robot are assigned to the teams; up to 20 min each. The goal here is to score as many points as possible in the test methods. In general, you get one point for getting from the start zone to the end zone and another point for the way back from the end zone to the start zone (and so on). The result of the 5 best 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 repetition 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.
- 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).

12. 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 allowed 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 destructive robots: The judges can penalize unsafe or destructive robot behavior during preliminary tests (see the penalties for such behavior 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: Exploration and Mapping tasks: one cable handler is allowed in the test method). For ALL other tasks no safety person is allowed in the arena. Only at the stairs there will be a safety rope that can be operated by a team member. In the maze 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 Exploration and Mapping 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: (UPDATED) Shoring now requires an arm that is capable of lifting the wooden 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 (UPDATE: Now crate) 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.

Appendix A: Trial Videos:

Teams are required to adhere to these requirements for continuous, multi-view video capture of the trials and for the qualification videos. This ensures that test trials are similarly captured so they can be scored by other teams solely from the video itself. Any trial video that does not adhere to these requirements will not be scored. Camcorders are recommended because they have zoom and a display to frame images. See the camera mounting frame fabrication guide for the operator interface camera. The others can use tripods.

Video Requirements:

- Require uncut quad-screen video trials that can be scored after the trial by anyone watching.
- Require the operator station in the background of one of the video overviews showing the operator's back toward the terrain (out of sight at least).
- Require a clock in continuous view at the operator station along with all their inputs to the system.
- Require audio from one of the cameras to capture the sound of the robot in the apparatus and ensure no verbal help from the audience.
- The robot should be clear enough to verify that it is of the same configuration (no components added/removed). The apparatus should be clear enough to verify that it is of the correct settings and dimensions.
    - The (uncut) video can start or end with a brief tour of the robot and apparatus if it is difficult to get an angle that shows this during the test.
- Videos from the four views should be merged into a time-synchronized quad-screen.
    - See later in this appendix for examples of how to do this.
- It is harder to be certain for wide area searches and mapping throughout a scenario. But the system interface and map building should be obvious along with the robot's camera views.

The four camera views are as follows:

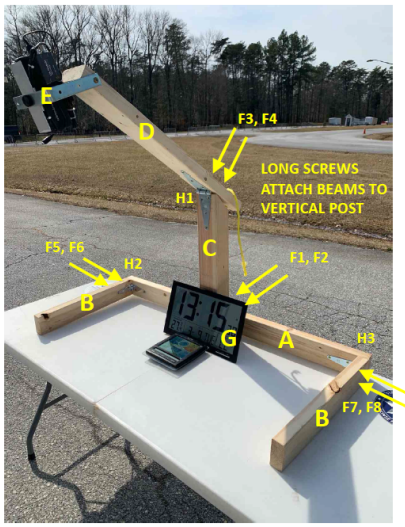
- **Camera 1: Overview of the Operator Interface, All Operator Inputs, the Time-Synced Clock, and Printed Trial Info.**
  Suspend the camera over the operator interface and zoom in as necessary to capture as much detail as possible:
  - A) Capture the time-synced clock co-located with the operator interface and a page of text showing trial details.
  - B) Capture the interface display clearly enough to show the robot's view.
  - C) Capture all operator inputs to the system via joysticks, buttons, typing, etc.
- **Camera 2: Overview of the robot from the start position with operator in the background (back turned to the apparatus).**
  This camera can be stationary to show the robot's relative position within the apparatuses.
- **Camera 3: Detail of the robot and task interactions from the opposite end of the apparatus.**
  This camera can be stationary or actively zoomed to show details of the robot's interactions with the apparatus (i.e. dexterity tasks).
- **Camera 4 or Video Capture of Interface: Showing the robot's point of view as presented to the operator.**

An example for the OCU setup:

- Use tripod mounted cameras for robot overviews and task details.
- Use this apparatus to mount a camera over the operator interface.

PARTS LIST

A [QTY 1] 5 x 10 x 90 cm (2 x 4 x 36 in) HORIZONTAL RAIL
B [QTY 2] 5 x 10 x 40 cm (2 x 4 x 16 in) SIDE ARMS
C [QTY 1] 10 x 10 x 60 cm (4 x 4 x 24 in) POST WITH 45° TOP
D [QTY 1] 5 x 10 x 60 cm (2 x 4 x 24 in) CAMERA ARM
E [QTY 1] 15 x 15 cm (6 x 6 in) angle bracket,
[QTY 1] Washer head screw, and
[QTY 1] Threaded screw for camera mount
F [QTY 20] short screws 35 mm (1-1/2 in) length,
[QTY 6] long screws 100 mm (4 in) length
G [QTY 2] Time-synced clock with 10 cm (4 in) numbers
H [QTY 3] Optional hinges to enable folding and stowing
[QTY 1] Optional strap or rope to secure camera arm upright



Video Submission Process:

The process for submitting trial videos is as follows:

- Teams upload their multiple trial videos to any publicly hosted video with a date stamp with no revisions possible. YouTube, Vimeo, or we'll provide a list.

- The description field of the video should have the following information:
    - (To fill in)
- Each team sends links to each trial video via Google forms. Those forms populate a Google Spreadsheet sorted by best score in each category. This read only Google Spreadsheet is used by teams and Execs to navigate the list of available trial videos.
- Any other team goes to that read-only Google Spreadsheet to watch any trials, focusing on high scoring trials first. They fill in a separate Google Form as a trial score attestation with comment section and potential HIGHLIGHT repetition as interesting even if not scoring well.
- That read only Google Spreadsheet should include the related score attestations and comment forms for all to see, even if only a pointer to an icon showing there are several attestations.
- A separate Forum thread can be created for each team to capture discussions if we want.

Combining videos:

Teams may use video editing software, live hardware “quad boxes”, live video composition software (e.g. OBS Studio[2]), record video from multiple cameras (all in one take) and combine them after the fact, or any other technique as long as it adheres to the requirements above. The following is an ***example*** of a process that teams may find convenient and requires only the four cameras (which may be phone cameras if they can record for the required duration) and free software on a moderately powerful computer.

1: At the start of a set of runs, start all 4 cameras (the screen recorder, if present, counts as a camera) at roughly the same time. It is not necessary to start/stop the cameras between each run, it may be easier to just record a long video on each camera and cut them up later (see below). If the cameras will run for a whole test period (several hours) on a card/battery (or perhaps plugged in) this will save some logistics and editing time.

2: When all the cameras are started but before the start of the runs, turn a light on that is visible to all of the cameras (directly or via the robot). This marks the “start” of the final video. It’s easier to scan through the start of the video looking for the frame that the light turns on, rather than trying to figure out when a clap happens in the sound track.

3: When the light turns on, start a normal (hour/minute/second/millisecond) stopwatch and keep it running for the length of the video.

4: At the start and end of each run, note the time on the stopwatch (but don’t start/stop it). It might be useful to record this in a spreadsheet, along with a filename that describes the run.

[2] https://obsproject.com/

5: When done with all the runs for this set of recordings (e.g. after a half-day or a day) stop all the cameras and download the files. If the camera splits long recordings across multiple files (e.g. due to file length limits) it may be necessary to combine them (this is not considered 'editing' or a 'cut' for the purpose of the rules as long as the recombination is **only** to recombine files that the camera automatically splits up). The "ffmpeg" program can be used to do this in different ways[3] depending on the type of video file the camera creates.

6: For each of the 4 videos, look through the start of the video until you find the frame that the light turns on. Write this frame down (in hour:minute:second.frame).

7: Use the freely available, open source "ffmpeg"[4] program (available for Windows, Mac, and Linux) to combine the videos into a quad video. Depending on your computer, this might process at close to realtime but you can batch this up and run it overnight unattended without needing to actually watch the whole video. Here's an example of a command line to do it. This should all be on one line, it is split up to make it easier to read.

```
ffmpeg
-ss 00:00:00.00 -i DetailVideo.mp4
-ss 00:00:00.00 -i OverviewVideo.mp4
-ss 00:00:00.00 -i OCUVideo.mp4
-ss 00:00:00.00 -i OperatorVideo.mp4
-filter_complex "
[0:v] scale=960x540 [upperleft];
[1:v] scale=960x540 [lowerleft];
[2:v] scale=960x540 [upperright];
[3:v] scale=960x540 [lowerright];
nullsrc=size=1920x1080 [base];
[base][upperleft] overlay=shortest=1 [tmp1];
[tmp1][upperright] overlay=shortest=1:x=960 [tmp2];
[tmp2][lowerleft] overlay=shortest=1:y=540 [tmp3];
[tmp3][lowerright] overlay=shortest=1:x=960:y=540
" -vcodec h264 -acodec aac Output.mp4
```

where:

ffmpeg : call to the ffmpeg program. Replace this with the full path to where your ffmpeg executable is if it isn't in your path.

-ss 00:00:00.00 -i DetailVideo.mp4 : The input detail video. The "-ss" flag indicates when to start the video - in this case the frame that the light turns on. So if the light turns on at the 1

[3] https://trac.ffmpeg.org/wiki/Concatenate
[4] https://www.ffmpeg.org/

minute, 2 second, 5 frame mark, this should be “-ss 00:01:02.05”. *Note, placing this before the video it refers to does keyframe parsing so it doesn’t need to actually decode the whole video*[5].
-ss 00:00:00.00 -i OverviewVideo.mp4 : As above for the overview video. Note that the time will be different (because the camera would have been started at a slightly different time).
-ss 00:00:00.00 -i OCUVideo.mp4 : As above for the OCU video. Note that the time will be different (because the camera would have been started at a slightly different time).
-ss 00:00:00.00 -i OperatorVideo.mp4 : As above for the operator interface/hands video. Note that the time will be different (because the camera would have been started at a slightly different time).

-filter_complex" : defines a complex filter, the subsequent part of the command (within quotes) defines the filter.

[0:v] scale=960x540 [upperleft]; : Sets the “zero’th” video scale to half of full HD (960x540) and calls it upperleft. Similar for the other 3 videos.

nullsrc=size=1920x1080 [base]; : Create a blank frame on which to paste all the others.

[base][upperleft] overlay=shortest=1 [tmp1]; : Add the first video to the blank frame and assign it to video stream called “tmp1”. The command “shortest=1” means that the result stops when the first video stops.

[tmp1][upperright] overlay=shortest=1:x=960 [tmp2]; : Take the video stream “tmp1” from above, add the “upperright video” to it, output to video stream called “tmp2”.
[tmp2][lowerleft] overlay=shortest=1:y=540 [tmp3]; : Similar to above.
[tmp3][lowerright] overlay=shortest=1:x=960:y=540" : Similar to above. Note the lack of semicolon and the close quote (matching the quote at “filter_complex”). This is not assigned to any subsequent video which means it becomes the output.

-vcodec h264 : Use the h264 codec to encode the resulting video.
-acodec aac : Use the AAC codec to encode the resulting audio. Might need to go “-acodec libfaac” on some systems.

Output.mp4 : The final filename is the desired output file.

8: You now have one long quad screen video. You can use ffmpeg to break this up using the times from the stopwatch that you recorded previously, without re-encoding. The command line is as follows. This is broken up to make it more readable, it should all be entered in a single line.

```
ffmpeg
-ss 00:00:00.00
-i input.mp4
```

[5] https://trac.ffmpeg.org/wiki/Seeking

```
-t 00:10:00.00
-vcodec copy
-acodec copy
output.mp4
```

where:

ffmpeg : call to the ffmpeg program as before.

-ss 00:00:00.00 : the start time from the stopwatch. If this run is at the 2 hour, 13 minute, 3 second mark, this would be “-ss 02:13:03.00”.

-i input.mp4 : the long input file.

-t 00:10:00.00 : the length of the video (the end time minus the start time from the stopwatch). If the run was 13 minutes and 26 seconds, this would be “-t 00:13:26.00”.

-vcodec copy -acodec copy : Copies the raw data rather than re-encoding so it’s a lot faster. It should still be frame accurate as ffmpeg is smart enough to reconstruct the necessary frames at the start and the end of the trim points.

output.mp4 : the output file.

You can write yourself a little batch script, or even do some spreadsheet text manipulation to automatically run this.

Appendix B: Research and Commercial Robots:

As discussed earlier, Research robots are eligible for all awards, including those for operator proficiency. Commercial robots, which are intended to be robots that are currently reasonably available to end users who are not researchers, may participate for awards relating to operator proficiency. In this appendix we describe in further detail the distinction between these two types of robot. This line is hard to define completely; we highly recommend that any team who is in any doubt please contact the Committee to make sure that everyone is on the same page.

Research Robots:

For a given suite, a robot is considered a Research robot if any of the following hold:

- The robot is entirely built by the team, out of components that (apart from the addition of basic sensing, power, and control) would not by themselves be capable of performing in the given suite. For example:
    - A robot that is constructed from a frame the team designs and builds, with commercially available servos.
    - A robot that is constructed from commercially available track segments or wheel/gearbox/motor modules that are mounted to a frame that the team designs and builds.
- The robot is purchased commercially with minimal modifications, and carries a module (e.g. dexterity, mapping, etc.) that is built by the team to handle that particular suite. For example:
    - A commercially available robot that has no mapping capability of its own, with a mapping module that the team built, would be considered a Research robot for the Mapping suite.
- The robot is purchased commercially and has been modified to improve its capability in the suite ***as long as it demonstrates improved performance with the team's contribution enabled***. For example:
    - A commercially available tracked/flippered robot that has no autonomy of its own, where the team has added autonomous flipper control (using existing or additional sensors), would be considered a Research robot for the Mobility suite. If it included autonomous pathfinding to complete the Autonomous Mobility test, it would also be eligible for the Autonomous Mobility award.
    - A commercially available legged robot has its autonomy improved by the team to better handle the mobility test methods would be considered a Research robot for the Mobility suite. If it included autonomous pathfinding to complete the Autonomous Mobility test, it would also be eligible for the Autonomous Mobility award.
    - A commercially available mobility robot (or "blind" robot base) where the team has added sensors, integrated into the user interface, that improve the operator's situational awareness when performing mobility tasks.

Adding a modification to a Commercial robot that provides no/minimal improvement does not make it a Research robot. Teams may be asked to explain in detail their contribution and demonstrate this improvement to the RRL Committee.

Commercial companies wishing to join RoboCupRescue as a Research team are most welcome to; please contact the Committee as soon as possible to describe how your approach differs from your Commercial offerings to make sure we're all on the same page and avoid misunderstandings.

Commercial robots:

For a given suite, a robot is considered a Commercial robot if the robot capability for that suite is entirely off-the-shelf with only modifications and additions that would be reasonably available to an end user. For example:

- A commercially available robot with simple additions such as flexible rods in front of the gripper (for making proximity to objects more obvious), custom preset arm positions in the stock operator control unit, and guidelines overlaid onto the operator interface screen.
- A commercially available robot arm, controlled with stock or only lightly modified/integrated software, would be considered a Commercial robot for the Dexterity suite regardless of the robot base it was attached to.
- A commercially available robot that is equipped with accessory cameras that are sold to work with that particular robot, or robots of that type, and mounted in a way consistent with the manufacturers' intent/guidance.
- A commercially available robot that is equipped with additional software that is sold to work with that particular robot, or robots of that type.

Examples:

Here are some examples of robots and the awards for which they are eligible:

- A team buys a commercially available robot with manipulator and mobility, on which they mount a mapping module that they developed. The mapping module produces maps that are displayed in the user interface and are presented at the end of the run.
    - Mobility: Commercial, Operator Proficiency only.
    - Dexterity: Commercial, Operator Proficiency only.
    - Mapping: Research, Best-in-Class and Operator Proficiency.
    - Championship: Not eligible.
- A team buys a commercially available robot with manipulator and mobility, on which they mount a mapping package that they developed. In addition to presenting in the user interface and producing maps at the end of the run, the mapping module is integrated into the manipulator interface, warns the operator when they are about to collide with the surroundings, and is integrated into the inverse kinematic control of the arm, allowing it to choose configurations in null-space that avoid environmental collisions.
    - Mobility: Commercial, Operator Proficiency only.

    - Dexterity: Research, Best-in-Class and Operator Proficiency.
    - Mapping: Research, Best-in-Class and Operator Proficiency.
    - Championship: Eligible.
- A team builds a robot base and mapping package themselves and installs a commercially available arm, with the manufacturer's user interface (that the team may or may not have integrated into a window or panel in their own user interface).
    - Mobility: Research, Best-in-Class and Operator Proficiency.
    - Dexterity: Commercial, Operator Proficiency only.
    - Mapping: Research, Best-in-Class and Operator Proficiency.
    - Championship: Eligible.
- A team builds a robot base and mapping package themselves, installs a commercially available arm, and builds their own user interface for controlling the arm (such as a particularly smart inverse kinematics implementation, a mimicking controller, or a virtual reality interface).
    - Mobility: Research, Best-in-Class and Operator Proficiency.
    - Dexterity: Research, Best-in-Class and Operator Proficiency.
    - Mapping: Research, Best-in-Class and Operator Proficiency.
    - Championship: Eligible.
- A team buys a legged robot, complete with its stock (autonomous) mobility and pathfinding, tunes its user-adjustable parameters, and adds basic waypoints.
    - Mobility: Commercial, Operator Proficiency only. Not eligible for Autonomous Mobility award.
    - Dexterity: (N/A)
    - Mapping: Commercial, Operator Proficiency only.
    - Championship: Not eligible.

We highly recommend that teams who don't believe their robot fits into the above categories, or who intend on integrating commercially available capabilities and modifying them with the aim of considering them Research robots, contact the RRL Committee by email or the forum well ahead of the competition to explain their approach and to verify that their modifications and improvements are sufficient for their robot to be considered a Research robot.