Version: 2023D

RoboCupRescue Robot League

2023 Championship, Bordeaux, France

When disasters happen, emergency responders risk life and limb to save people and protect property all over the world. They need capable and easy to use robotic systems to improve their effectiveness and reduce risk as they selflessly provide aid to the rest of us in our time of need.

The RoboCupRescue Robot League gathers teams of researchers capable of developing robotic systems that enable emergency responders to perform extremely hazardous tasks from safer stand-off distances. These mobile robots need to demonstrate assistive and autonomous behaviors that can increase their reliability when operating remotely within complex environments, including even partially collapsed structures when necessary.

Established just prior to the World Trade Center collapse in New York City more than twenty years ago, the RoboCupRescue Robot League has hosted robot evaluations annually all over the world. In addition to demonstrating the state-of-the-science in robotics for unstructured environments, we help develop the standard test methods emergency responders use to objectively evaluate commercial robots, train with measures of remote operator proficiency, and compare results no matter where or when the evaluations happen.

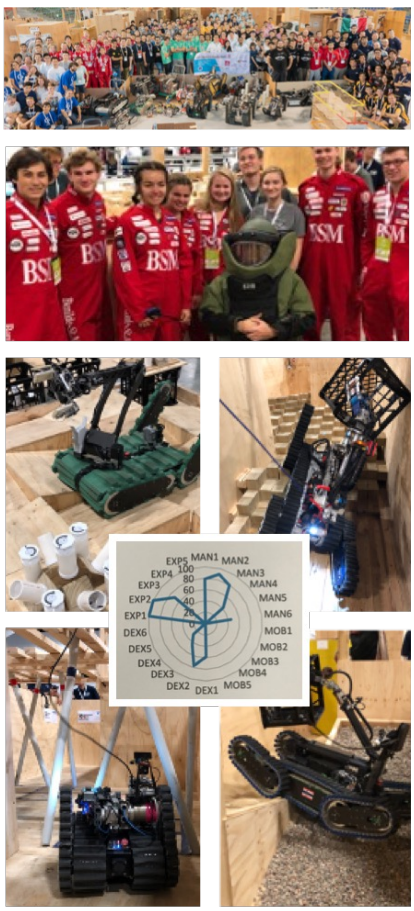
This is just the first step out of the laboratory for many of these robots and researchers. It is a long process to harden and commercialize robots for deployment into such difficult environments. But these League participants are determined to use their skills and energy to help emergency responders stay safe as they save lives.

Bringing Robotics Researchers Together to Collaborate

The RoboCupRescue Robot League conducts comprehensive evaluations involving essential mission tasks required by emergency responders worldwide. The arenas include a variety of reproducible terrains, obstacles, and tasks with increasing difficulty to challenge even the most capable robots.

We measure *Maneuvering, Mobility, Dexterity, and Exploration*, all with an emphasis on developing the assistive and autonomous behaviors necessary for remote operators to be effective and reliable in complex environments.

- ***Maneuvering (MAN)*** refers to terrains that can typically be driven FORWARD and REVERSE to demonstrate bi-directional situational awareness, fine motor control, precise steering, etc.
- ***Mobility (MOB)*** refers to terrains and obstacles that are typically too difficult to mandate a particular driving direction. These are reproducible tests abstracted from real-world situations that robots need to perform in emergency response operations.
- ***Dexterity (DEX)*** refers to manipulator tasks embedded within the various terrains and obstacles. They include some standard tests that are easy for everyone to replicate and compare performance along with other tasks that are more operationally relevant and variable. They are on linear rails to evaluate manipulator reach and omni directional objects to evaluate orientational dexterity.
- ***Exploration (EXP)*** refers to autonomous maneuvering tasks within complex terrains to generate 2D and 3D maps of the environment while identifying objects of interest. The resulting maps are scored for accuracy and quality as if they were about to be handed to an emergency responder for immediate use.



Competition Features

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Remote Operator Stations ensure the robot operators cannot see the robot inside the test lane. No communication with the operator is allowed. They must receive all their remote situational awareness through their system interface as if the robot is down range or in a structure.

Difficulty Settings for Test Lanes enable incremental challenges for robots with various capabilities. When the apparatus difficulty setting is the same for all teams, and the time limit is the same, the trial results are comparable.

Trial Time Limits are not intended to make it a race. Rather, there is enough time for a capable robot to demonstrate a statistically significant number of task repetitions. This provides a measure of reliability that the task can be performed. Trials begin every 30 minutes:

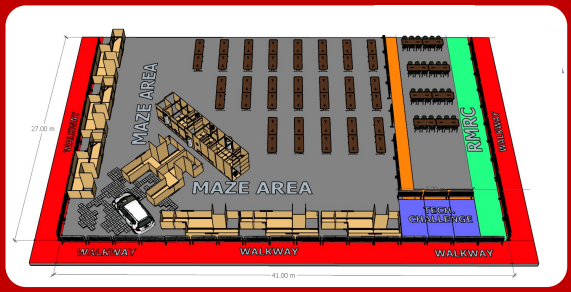
- 5 minutes to set up
- **20 minutes of operation**
- 5 minutes to exit

Assistive/Autonomous Behaviors are encouraged for maneuvering through complex environments with no guidance from the remote operator – **hands-off the interface throughout**. Assistive behaviors can use onboard sensors to help remote operators center through obstacles, coordinate manipulator joints, or control flippers to maintain contact with ground terrains. All such features help remote operators perform more reliably.

Radio Communications Degradation happens inside intact and partially collapsed structures. Assistive and autonomous behaviors are needed to improve the effectiveness and reliability of robots being operated from safe locations outside the structure. We provide scoring incentives to encourage teleoperated robots to work with intermittent and unpredictable communications.

Tethers are always allowed because they can provide secure communications and ongoing power to drive the robot or recharge batteries over time. Imagine finding a trapped victim and establishing communications, then running out of battery power! Tethers can avoid that while providing other benefits. For example, tethers can glow in the dark with arrows identifying the route the robot took. This can lead people who find it out through smoke. To avoid getting snagged on obstacles, tethers should be spooled on the robot and act as a winch when necessary to help descend stairs then climb back up if necessary. If tethers are dragged behind the robot within the test lanes, they must be managed from the lane door by a helper, not guided over the walls.

Test Methods within the Arena



MOBILITY

Terrains

- Continuous Ramps (Flat)
- Crossing Ramps (15° slopes)
- K-Rails (15° slopes)
- Sand & Gravel (15° slopes)

Obstacles

- Traverse & Center (15° incline, variable width)
- Pallet Hurdles with Pipes (20cm elevations)
- Stairs (35°/40°/45° incline, 2/4 occlusions)
- Doors (square room or narrow hallway)

DEXTERITY

Sensing Tasks (stackable crate, downward access)

- Thermal Image Acuity (5 pts)
- Hazmat Label Identification – Auto Only (4 pts)
- Motion Detection - Auto Only (3 pts)
- Proximity Sampling Magnetometer (2 pts)
- Visual Image Acuity (1 pts)

Classification Tasks

- Inspect (linear 1 pts, omni 2 pts)
- Touch (linear 2 pts, omni 4 pts)
- Insert (linear 3 pts, omni 6 pts)

Operational Tasks

- Push E-Stops (omni 10 pts)
- Rotate Valves (omni 10 pts)
- Insert Keys (omni 10 pts)
- Shore Blocks (stack 10 pts)

EXPLORATION

- Avoid Holes (elevated path to follow)
- Mapping Labyrinth (round fiducial, objects)

Innovate, Evaluate, and Compare

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The main objective for teams is to challenge their robotic system capabilities and refine their approaches. Teams learn what it takes for their robots to succeed in real-world applications.

Inclusiveness: Teams get as many trials as possible within the time available, so they can rigorously evaluate their robots across the terrains, obstacles, and tasks that support their research objectives. Teams schedule their own test plan each day to manage their own risks.

Resilience to Failure: Robot resets are allowed during trials to ensure some level of measurable success. A 2-minute penalty allows the robot to be safely carried and reset in the **previous end zone** to continue. After the penalty the trial continues as usual. No talking to the operator is allowed during the trial except to reset a robot. The operator or team member with the best view of the robot should declare a reset.

Every team get to comprehensively evaluate their robot. Teams seeking to accumulate scores can win awards to recognize their accomplishments.

- **Best-In-Class Awards** are given for teams that demonstrate the most capable and reliable robots within a class of tests: Mobility, Dexterity, and Exploration/Mapping. The trials are captured during the Preliminaries when all teams are involved.
- **1st, 2nd, and 3rd Place Awards** are given to teams that combine all three categories of capabilities to demonstrate the best performance across the entire arena. These teams perform the most challenging mission sequences on the final day.
- **Certificate Awards** recognize important contributions across the league such as the most **intuitive operator interface** or particularly **effective design functionalities** and the **Tech Challenge**.

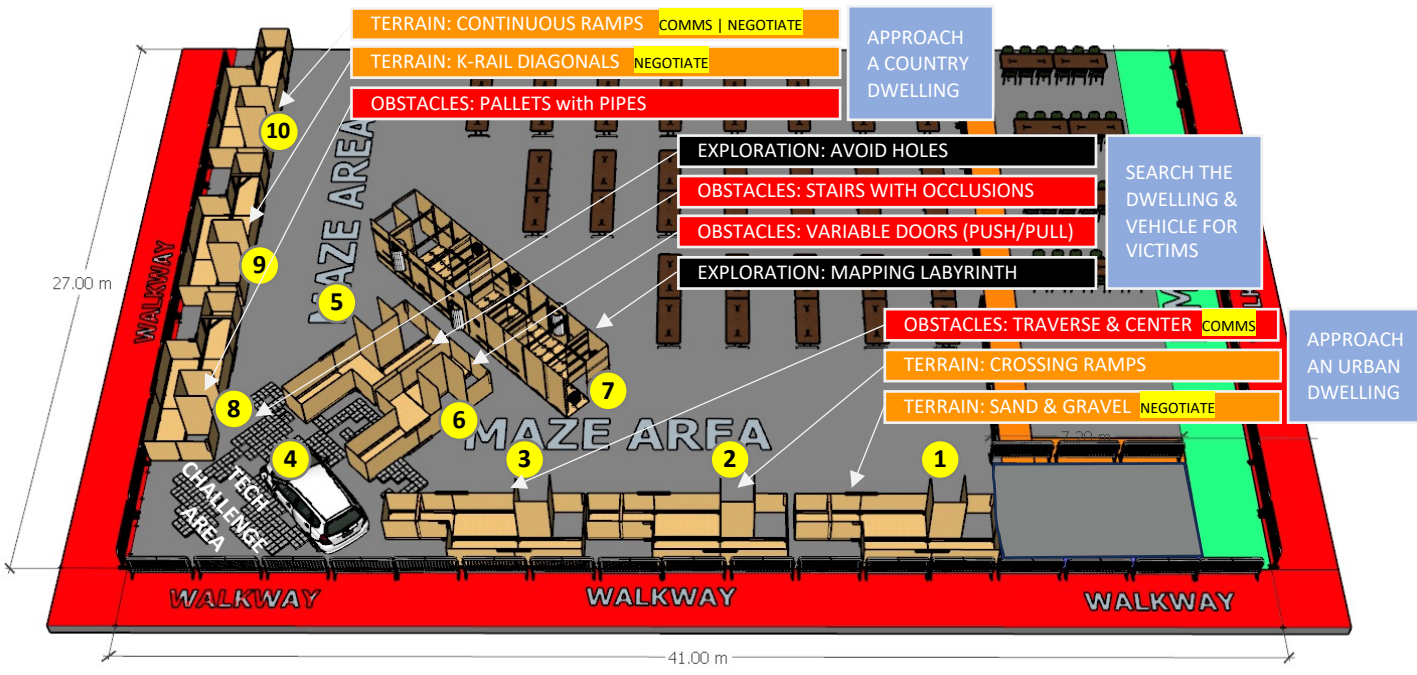
New Challenges This Year
(Optional)

Negotiate Leaning Obscles:
Perform additional maneuvering tasks in the EASIEST and HARDEST lanes to earn Negotiate points toward the Best-In-Class Mobility Award. Negotiate scores augment Mobility scores in the Prelims.

- Continuous Ramp Terrain
- Sand & Gravel Terrain
- K-Rails Terrain

Radio Comms Degradation:
Use old WiFi (802.11B) settings in the EASIEST two test lanes to earn a 2x points multiplier. Just connect to the league's new ***Radio Attenuation Box***. The Tech Challenge simulates even harsher degradation:

- Continuous Ramp Terrain
- Traverse & Center Obstacle



Zig-Zag Lane Overview

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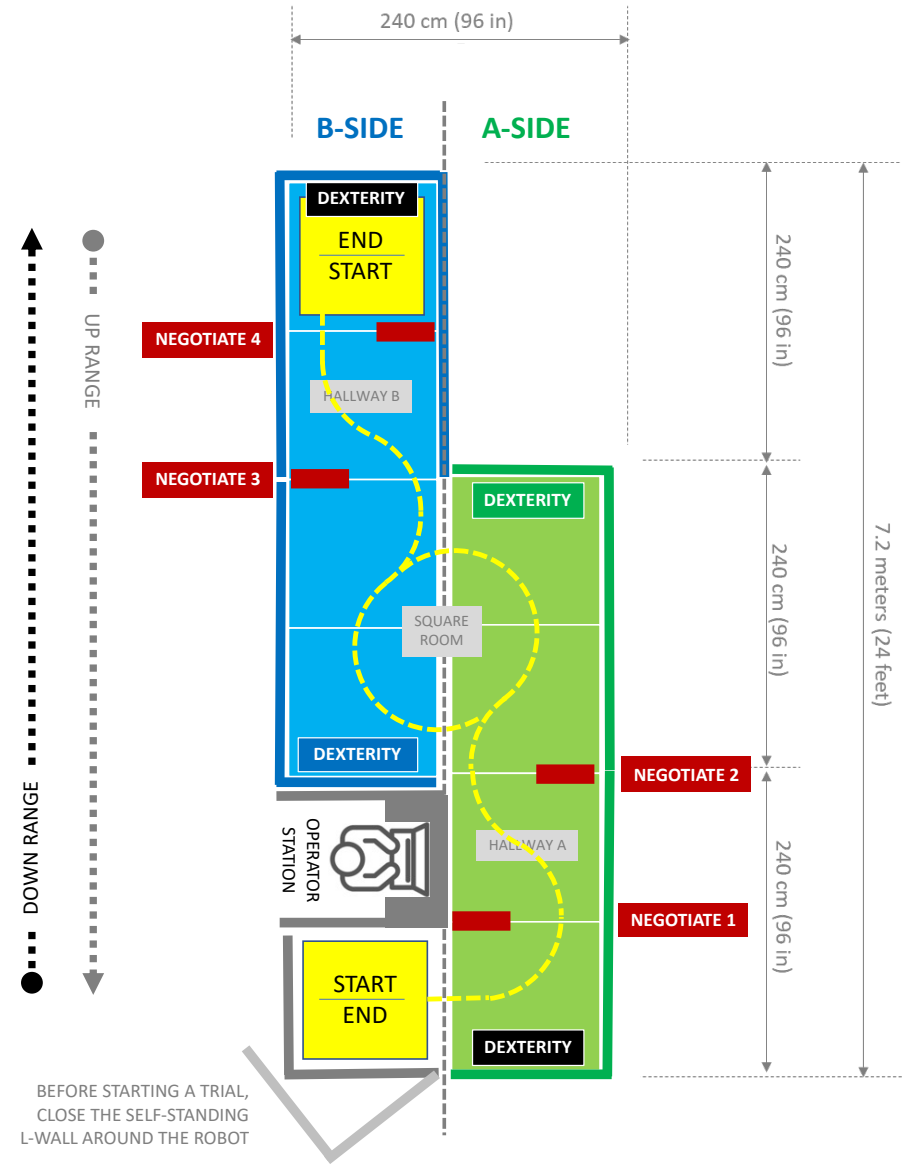
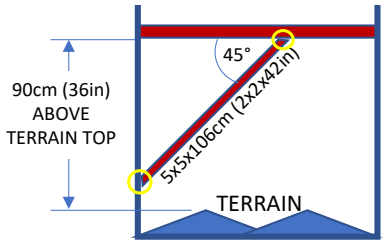
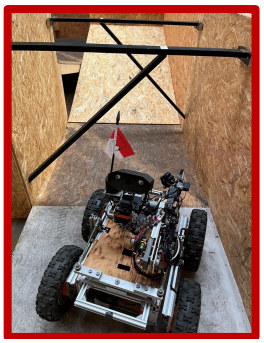


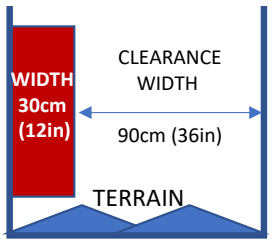
NEGOTIATE

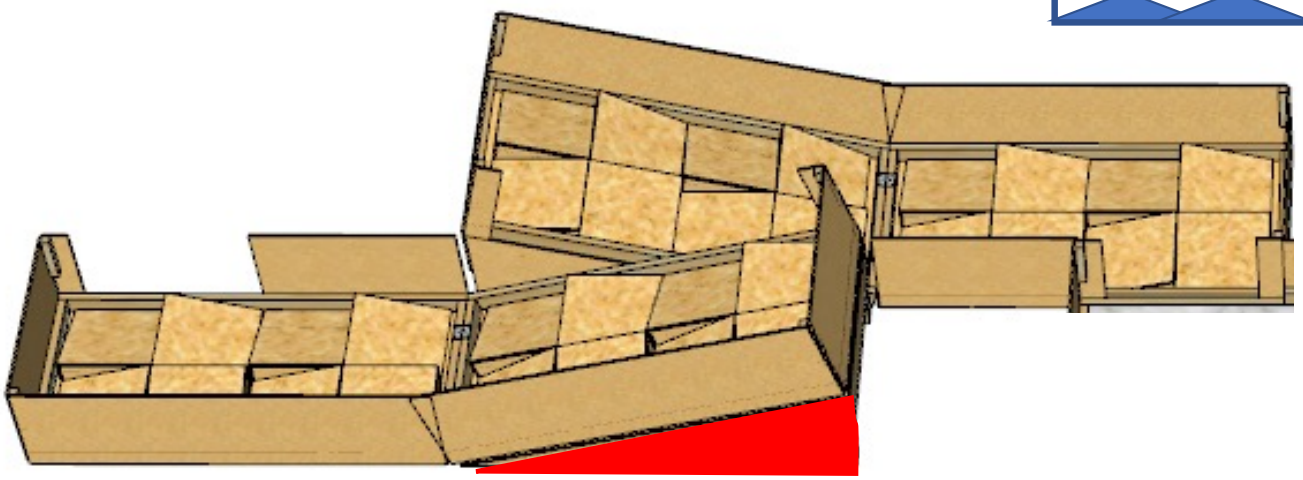
ROBOT VIEW OF "NEGOTIATE" OBSTACLES



ANGLED BEAM HANGS FROM THE CROSSBAR AND IS AFFIXED TO THE SIDE WALL WITH A MAGNET AND WASHER SO IT CAN RELEASE IF BUMPED.







Trial Scoring for Missions

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Scoring Mobility

- Mobility scoring is based on continuous driving **end-to-end traverses** in the lane. The robot must **start** and **end** each traverse completely within the designated squares (see Zig-Zag Lane Overview).
- Driving teleoperatively **scores 1 point** for successful completion in each direction.
- Driving autonomously (hands off the interface) **scores 4 points** for successful completion in each direction. The remote operator may take over control at any time to finish a traverse teleoperatively for 1 point and try again autonomously on the next repetition. Teleoperation is allowed in both end zones in any case to set waypoints, evaluate maps, etc.
- *Single Lane Missions* perform up to **10 end-to-end traverses** in the first 10 minutes of the trial. If finished early, use the elapsed time as a measure of efficiency. Wait for the Dexterity time to start before performing any Dexterity tasks.
- *Multiple Lane Missions* perform a **sequence of end-to-end traverses** in each lane by entering and exiting from the same doorway. Teams may choose the order of lanes based on risk, but may need to drive further to complete all. No repeated lanes are allowed until all lanes are completed.
- Mobility scores are normalized relative to the best score so the results can be combined with other lanes that are easier/harder for teams in general.

Scoring Dexterity

- The difficulty of moving the robot within the terrains and obstacles encourages multi-joint manipulators with coordinated control to compensate for unknown chassis orientations.
- After completing the designated Mobility repetitions or when Mobility time expires, perform the Dexterity tasks starting anywhere and in any order. No repeated tasks are allowed.
- Dexterity scores are normalized for comparison.

Scoring Exploration/Mapping

- Exploration/Mapping tasks are scored based on the accuracy and quality of the maps produced within a single lane or sequence of lanes.
- If using 3D scanners, produce two maps at two different elevations: low is 1m (3ft) and high is 2m (6ft). The scored features are split between both map elevations. They include half-round mapping fiducials, QR codes as search gaze tasks, and other objects of interest to identify from a known set.

Single Lane Missions

Prelims (30 minute rotations, 20 minute trials)

Each test lane can be conducted individually to capture a statistically significant set of repetitions from end-to-end. This enables teams to refine their systems and tactics for the challenges in each test lane.

There are 10 concurrent start points and operator stations at each lane. Teams schedule their own test plan each day to balance their objectives with related risks. Teams must try every lane in the Preliminaries but several scores can be dropped from the totals.

Each team provides a “Proctor” to score and attest to the results of other team trials. This ensures all teams go home with experience conducting objective evaluations for their ongoing development process.

Multiple Lane Missions

Semis (30 minute rotations, 20 minute trials)

These sequences challenge teams to optimize their systems across different capabilities. There are 3 concurrent lane sequences with different operational objectives. The lanes are conducted in any order but no repeats are allowed until all lanes are completed.

Approach an Urban Dwelling in a Disaster

- Traverse & Center
- Pinwheel Ramps
- Sand & Gravel

Approach a Country Dwelling in a Disaster

- Pallet Hurdles
- Continuous Ramps
- K-Rails

Search the Dwelling and Vehicle for Victims

- Avoid Holes
- Stairs
- Doors
- Labyrinth (Mapping)

Combined Scenario Missions

Finals Challenge the Best Robots to Their Limits

A final combined scenario mission can challenge teams to optimize their systems across a wide variety of different capabilities, much like an operational deployment with various phases.

This is intended for the best few teams because it requires traversing ALL the available test lanes. Teams may choose their own order to minimize risks.

The time limit should be set to enable the best teams to finish the set of lanes, perform one dexterity task within each, and map their path for a total score.

Single Lane or Multi Lane Mission Form

ROUND	DATE	COUNTRY	TEAM / ROBOT	PROCTOR: FULL NAME (COUNTRY)

CIRCLE SUCCESSFUL TASKS AND STRIKE THROUGH UNFINISHED OR PENALIZED TASKS. USE A NEW FORM FOR ROBOT RESETS.

TERRAINS (TER)

- ❑ Continuous COMMS NEGOTIATE
- ❑ K-Rails NEGOTIATE
- ❑ Crossing Ramps
- ❑ Sand/Gravel NEGOTIATE

OBSTACLES (OBS)

- ❑ Traverse/Center COMMS
- ❑ Stairs
- ❑ Hurdles with Pipes
- ❑ Doors

EXPLORATION (EXP)

- ❑ Avoid Holes (Auto)
- ❑ Labyrinth (Mapping)

MOBILITY: Drive TELEOPERATIVELY or AUTONOMOUSLY (no hands on interface) end-to-end in the lane.

CIRCLE A SINGLE LANE IN THE LIST ABOVE OR WRITE SEQUENCE OF LANES IN ORDER	TELEOP	COMMS x2	AUTO x4	NEGOTIATE 1	2	3	4
1	1	2	4	N	N	N	N
2 RETURN UP RANGE TO START POINT	1	2	4	N	N	N	N
3	1	2	4	N	N	N	N
4 RETURN UP RANGE TO START POINT	1	2	4	N	N	N	N
5	1	2	4	N	N	N	N
6 RETURN UP RANGE TO START POINT	1	2	4	N	N	N	N
7	1	2	4	N	N	N	N
8 RETURN UP RANGE TO START POINT	1	2	4	N	N	N	N
9	1	2	4	N	N	N	N
10 RETURN UP RANGE TO START POINT	1	2	4	N	N	N	N

MOBILITY
TOTAL POINTS

ELAPSED TIME
MM : SS

NEGOTIATE
TOTAL Ns

DEXTERITY: Perform the available SETS OF TASKS starting anywhere and in any order. No repeated tasks.

SENSOR TASKS	VISUAL	PROXIMITY	MOTION	HAZMAT	THERMAL
VICTIM CRATE (ALWAYS)	1	2	3	4	5

LINEAR TASKS	L 90°	L 45°	CENTER	R 45°	R 90°
INSPECT (ALWAYS)	1	1	1	1	1
TOUCH (PRELIMS)	2	2	2	2	2
INSERT (SEMIS, FINALS)	3	3	3	3	3

OMNI TASKS	L BOT	L TOP	CENTER	R TOP	R BOT
INSPECT (ALWAYS)	2	2	2	2	2
TOUCH (PRELIMS)	4	4	4	4	4
INSERT (SEMIS, FINALS)	6	6	6	6	6
PUSH E-STOPS (FINALS)	10	10	10	10	10
CLOSE VALVES (FINALS)	10	10	10	10	10
INSERT KEYS (FINALS)	10	10	10	10	10

DEXTERITY
TOTAL POINTS

ELAPSED TIME
MM : SS

MAPPING: Display 3-D scanned walls and features on TWO DIFFERENT 2-D MAPS at elevations of 1m (3ft) and 2m (6ft).

QUALITY AND ACCURACY	MAP SET 1	MAP SET 2	MAP SET 3	MAP SET 4
FIDUCIALS (COVERAGE)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
QR CODES (SEARCH GAZE)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
OBJECTS (LEXICON)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

MAPPING
TOTAL POINTS

Technology Challenge

Version: 2023E

Motivation

The new Technology Challenge provides teams with an opportunity to showcase advanced capabilities in RoboCup Rescue. It encompasses a range of tasks that require supervised autonomy under conditions of severe radio degradation.

In addition to the predefined tasks, the challenge offers an open field where research teams can demonstrate new capabilities relevant to rescue robotics within their respective fields of study. Examples include alleviating operators' stress in repetitive tasks or introducing assistive functions.

The team that performs the best in this challenge will be awarded the Technology Challenge Certificate. The score obtained in this challenge does not contribute to the overall championship or other "best in class" certificates.

Scenario

The objective is to deploy a smart robot into an apartment and enable it to autonomously search for victims with supervision from the operator.

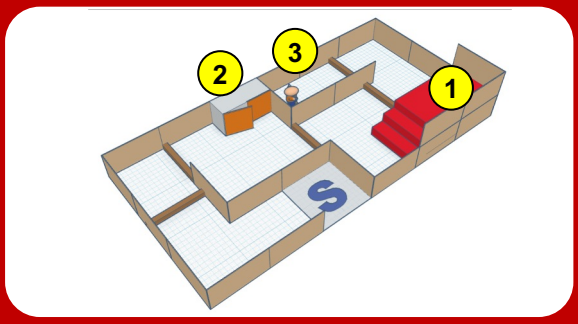
Four Challenging Tasks

- Traverse stairs, open a cabinet door, find and map a victim.
- Open Stage: Teams are encouraged to showcase their own capabilities and demonstrate new technologies relevant to the field.

Environment, Setup and Scoring

- The robot must traverse uneven terrain, with 10 cm x 10 cm beams on the ground.
- All tasks must be performed with high radio degradation (bandwidth < 1 Mb/s), but full connectivity is ensured within the 1.2 m x 1.2 m start zone.
- Tasks can be performed with human-in-the-loop supervision, emphasizing supervised autonomy.
- All 4 tasks must be performed in a single 30 minutes mission: 5 minutes to set up, **20 minutes of operation,** 5 minutes to exit.
- The maximum score for the challenge is 100 points, with each task worth 25 points.
- Each task can be skipped. The order of the task execution can be determined by the operator.
- Detailed scoring sheets will be used to evaluate the fixed tasks, while technical experts will assign points for the Open Stage demonstration.

Arena Layout



MOBILITY: Stair Traversal (25 pts) 1

Go up and down a set of stairs

- Align with the stairs (5 pts)
- Go up the stairs and reach the top area (5 pts)
- Rotate robot more than 90°, then align again with stairs (5 pts)
- Go down the stairs and reach the bottom area (10 pts)

DEXTERITY: Cabinet Door (25 pts) 2

Open a cabinet door, look inside and read the QR code

- Drive into area in front of cabinet door (5 pts)
- Detect handle (5 pts)
- Open door at least 90° (10 pts)
- Read QR code which is located inside the cabinet automatically (5 pts)

EXPLORATION: Victim Mapping (25 pts) 3

Detect and localize one victim based on heat (automatic)

- Automatic victim identification (10 pts)
- Location in a 2D map (10 pts)
- Location in a 3D map (5 pts)

OPEN STAGE (25 pts)

Demonstrate new technologies and research

- Usefulness (0 - 10 pts)
- Novelty (0 - 10 pts)
- Technical maturity (0 - 5 pts)