



RoboCupRescue Robot League 2021 Safety | Capabilities | Proficiency

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RoboCupRescue Robot League 2021

Safety | Capabilities | Proficiency

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Organizing Committee

International Chair: Adam Jacoff (NIST, USA)* Administrative Lead: Ann Virts (NIST, USA) Virtual LOC Lead: Raymond Sheh (Australia/USA)







Table of Contents Safety | Capabilities | Proficiency

Summary of 2021 Approach League Overview Objectives for 2021 Issues for 2021 **Dexterity and Strength Tests** Autonomous Mobility Tests Legged Mobility Tests Search and Inspect Tests **Exploration and Mapping Tests** Aerial Drone Pilot Proficiency Tests







Summary of Approach for 2021

RoboCupRescue Robot League





How RoboCupRescue Helps Emergency Responders?

Safety | Capabilities | Proficiency





ur arenas provide a tangible language between researchers, manufacturers, and emergency responders to refine, measure, and highlight breakthrough capabilities.





How RoboCupRescue Helps Emergency Responders? Safety | Capabilities | Proficiency

The RoboCupRescue Robot League develops and demonstrates robots with combined capabilities in mobility, dexterity, exploration, and mapping. These robots operate in three scales of standard test methods to measure their capabilities. The apparatus scales represent environments with passage widths of 120 cm (48 in), 60 cm (24 in), and 30 cm (12 in). Smaller robots can deploy through access holes into larger apparatus environments to show their operational relevance. The smallest size robots include 3-D printed robots that can be the first truly disposable robots for confined space exploration and hazardous materials sampling. RoboCupRescue is also incorporating small indoor aerial drones intended to fly through and map compromised or collapsed structure interiors, same as the ground robot tasks.

The RoboCupRescue Robot League has led an international effort to develop and validate standard test methods used worldwide by emergency responders. The standard tasks and environmental complexity measure system capabilities and remote operator proficiency that can be compared no matter where or when the testing occurs. Test trials are performed individually, in combinations, and in sequences to form repeatable tasks that are representative of operational missions.







Developing the Measurement and Standards Infrastructure Safety | Capabilities | Proficiency

RoboCupRescue competitions facilitate interactions between researchers, manufacturers, and responders around these standard tests and related mission requirements. All three communities collaborate to quantitatively measure whether the robotic systems being deployed are capable and reliable enough to perform hazardous operational tasks. Everybody learns what emerging technologies can do to improve performance. Then the local responders keep the tests after the competition to evaluate and purchase new robots, focus their training, and measure their proficiency for licensing to enable mutual aid during disasters.

RoboCupRescue is at the center of an international effort to develop the measurements and standards infrastructure necessary to:

- Communicate operational needs to robot researchers and developers.
- Promote innovation through commercial manufacturers.
- Enable responders to understand emerging robot capabilities.
- Guide robot purchasing and deployment decisions.
- Focus training and measure operator proficiency for licensing.





An Opportunity to Improve Safety | Capabilities | Proficiency



RoboCupRescue Championships

2021 Distributed/Remote 2019 Sydney, Australia 2018 Montreal, Canada 2017 Nagoya, Japan 2016 Leipzig, Germany 2015 Hefei, China 2014 Joao Pessoa, Brazil 2013 Eindhoven, Netherlands 2012 Mexico City, Mexico 2011 Istanbul, Turkey 2010 Singapore, Singapore 2009 Graz, Austria 2008 Suzhou, China 2007 Atlanta, USA 2006 Bremen, Germany 2005 Osaka, Japan 2004 Lisbon, Portugal 2003 Padua, Italy 2002 Fukuoka, Japan 2001 Seattle, USA 2000 AAAI Conf, Austin, TX

This year we have a unique opportunity to modify how we conduct our league to involve even more researchers, increase the statistical significance of our evaluations, and advertise more widely the state-of-the-science that RoboCupRescue is contributing.

Although this year's coronavirus pandemic makes these changes essential, we plan to turn these distributed evaluations into our new model for global outreach and a more rigorous qualification process for future competition years.

- Remote participation with video scoring for Preliminary round of trials.
- Remote Best-In-Class Awards for any team scoring above a threshold defined from aggregated data.
- Regional demonstrations at nearby responder organizations and/or test facilities (if available) to instantiate collaborations between researchers and responders using the same tests.

Regional competitions and the in-person International Championship. CANCELLED FOR 2021



Remote Participation Safety | Capabilities | Proficiency

These key upgrades will lower the barrier of entry for new smaller teams and use a distributed model of Preliminary trials to determine Best-In-Class robots in each of our categories: Mobility, Dexterity, Exploration and Mapping:

• Focus robot development and evaluations using the smallest/easiest/cheapest tests to fabricate and are on the critical path toward performing operationally significant tasks.

• Video scoring of trials conducted by all remotely participating teams so they learn from each other's implementations and verify each other's scores. Most tests are already compatible with video scoring. We'll mandate certain video views, clocks, etc. to help make the videos uniform across teams. These videos will also provide a historical archive showing the myriad of approaches and successes achieved by teams and the league in general. Scores and test names in the video filename or description will help sort the archive for others to view.

• **Remotely proctor trials** for the top teams through live teleconference with the organizing committee and/or others. This will add statistical significance to the team's overall body of trial data. These teams will be candidates for Best-In-Class Certificates in their chosen categories.



RoboCupRescue Championships





Remote Best-in-Class Awards

MRL

DEX2 DEX1 MOB5

EXP4

EXP3

DEX6

DEX5

DEX4

DEX3

Safety | Capabilities | Proficiency

MANA

MAN5

MANG

MOB1

MOB2

MOB3

MOB4

iRap Robot

EXP4 100

EXP3

EXP2

EXP1

DEX6

DEX5

DEX4

DEX3

DEX2 DEX1

MOB5

FXP

FXP5 MAN1 MAN2

- **Extensive participation** across more teams th Championships provides a real opportunity to much larger pool of robots, with more statistic typical cost of travel toward robot developme
- Best-In-Class Certificates can be awarded when robots achieve a threshold average across several video trials that are validated through remotely proctored trials with the Execs. Trials collected over months could be included to capture averages for each team/robot with the scores normalized as we do for our radar charts. Teams can submit as many trials as they want up to the deadline:
 - Gold: 90-100% of normalized points (as an example threshold yet to be set) ٠
 - Silver: 80-89% of normalized points (as an example threshold yet to be set) •
 - Bronze: 70-79% of normalized points (as an example threshold yet to be set) •

We can set the thresholds as usual based on average/best performance in each set given potential changes in difficulty year to year. But all Gold Medal robots are ex

re 2: The award winners in the 120cm (48in) test method class of ground robo







Functional MAN, DEX, and EXP







Demonstrations for Remote Responders Safety | Capabilities | Proficiency

- **Test Facilities:** There are many test facilities and emergency responder organizations around the world that host these tests. They can potentially accommodate visiting teams for interactive evaluations of research robots, commercial robots, bomb suit tactics, and training scenarios embedded with these same standard tasks and repeatable scoring metrics. But in the least, they can participate remotely by watching our Best-in-Class videos.
- **Regional Opens:** We'll encourage teams to attend regional opens that are functioning to improve upon their remotely scored Preliminary video trials and move on to more difficult tasks in proctored trials. The regional opens can extend the evaluations by conducting more difficult combinations and sequences of tests and host embedded scenarios where possible (maze, car, bus, etc.) to earn Regional Open Place Awards.
- International Championship: Teams that win Place awards in Regional Opens are qualified for that year's Championship as always. Other teams not near Regional Opens can qualify through their remote trial videos. The Championships can also extend the evaluations by conducting more difficult combinations and sequences of tests and host embedded scenarios where possible (maze, car, bus, etc.) to earn Championship Place Awards.





League Overview

RoboCupRescue Robot League





Our 20th Year Conducting Competitions League Overview

This is our 20th year conducting RoboCupRescue competitions. We pioneered the use of robot competitions to validate and disseminate standard test methods while guiding research toward operational tasks. We've established an extensive network of international collaborators. There are more than 15 test facilities that host the standards and contribute to their development, validation, and maintenance. They also facilitate testing of manufactures and emergency responders in their region. There are hundreds of academic and responder organizations worldwide that have replicated these same tests because of their participation or familiarity with RoboCupRescue competitions. There are far too many organizations to track.



RoboCupRescue Championships



RoboCupRescue Arenas

League Overview

- RoboCupRescue competitions focus on capturing statistically significant repetitions in standard test methods to measure the differences in autonomous behaviors vs. remote teleoperation in three different sizes of test apparatus.
- The arenas use more than 20 ground and aerial tests set up in a large maze so they can be conducted individually in concurrent Preliminary trials, then as more difficult combinations and sequences of tests in Semi-Final trials emphasizing each Best-In-Class category. More than a dozen trials prepare robots for comprehensive search missions in the Finals.



THE ARENA IN NAGOYA, JAPAN

LARGE MAZE FULL OF 20+ TESTS



RoboCupRescue Championships



RoboCupRescue Teams

League Overview

- More than 30 teams typically participate from all over the world, roughly 300 people each year. They deploy all kinds of innovative robots in all three scales of tests.
- The annual international Championships host qualified teams from several regional competitions. Most teams fabricate at least some of the test methods at their facilities to refine robot designs and practice.
- These competitions are recruiting tools for manufacturers and test facilities around the world.





RoboCupRescue Championships



RoboCupRescue Approach League Overview

The RoboCupRescue Robot League helps researchers and manufacturers push the state of the science by measuring progress and highlighting breakthroughs. The resulting quantitative performance data helps compare systems, specify purchases, and train with measures of remote operator/pilot proficiency. The process outlined below generates test methods at a pace necessary to address the various responder priorities.

- **Develop** reproducible test methods that are cheap and easy to conduct.
- Measure combinations of existing capabilities and emerging technologies.
- Inspire innovation using tests to communicate operational needs and gaps.
- Guide purchasing and deployment decisions with objective data.
 - *Focus* training with repeatable tasks to measure and compare proficiency.
 - **Identify** readiness issues with equipment and/or training through comparisons with local, regional, or national averages.



RoboCupRescue Championships





The Spectrum of Available Test Methods

League Overview







The Spectrum of Commercial Robots Being Deployed League Overview

Ground robots range from small throwable to rather huge. Note the new (largest) class of firefighting robots remotely spraying water on a fire. All need to be evaluated similarly.









ICOR Caliber Mini 27kg (65lbs)



Remotec Titus 61kg (135lbs)



2.4kg (5.2lbs)

ICOR Caliber T5 64kg (140lbs)



Telerob Telemax 80kg (175lbs)



ICOR Caliber MK3 84kg (185lbs)



Remotec HD-SEL 111kg (245lb)



iRobot 710 Kobra 166.5kg (367lbs)



Remotec F6B 220kg (485lb)



WM Robotics Knight 249kg (550lbs)



Remotec Mark 5-A1 Ear more inf 358kg (790lbs)



367kg (810lbs)



Howe & Howe Thermite RS1 & RS3 550kg (1200lbs) 1200 Gallons per Minute





Scales of Test Lanes: 120 cm (48 in) Wide League Overview

- 120 cm (48 in) lateral clearance guaranteed.
- Lanes for maneuvering, terrains, and obstacles with dexterity tasks in the terrains to add complexity.











Scales of Test Lanes: 60 cm (24 in) Wide League Overview

- 60 cm (24 in) lateral clearance guaranteed.
- Environments like dwellings, trains, busses, planes, or between parked cars, etc.









Standard Test Methods for Response Robots eachnoither scote at see The guarititative test methods make this practicate the team

Scales of presty administer Big remate sting with in Wither own laboratories. B) Each to trials per day to measure their progress. The daily test plan allows each team

- 30 cm (12 in) lateral clearance guaranteed and optional tests. The winners conducted at least 15 different t 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.







Robots Can Look Similar But Perform Very Differently League Overview

Robots can have similar designs – success is often imitated. Or they can be very different. All need to be evaluated, compared, and differentiated based on statistically significant capabilities data.







More than 300 Test Trials Conducted in Every Competition

League Overview

- RoboCupRescue has refined its massively concurrent scheduling of timed trials during three Preliminary days in individual tests.
- Teams proctor and score each other to practice conducting tests for their own team.
- Teams choose which tests they focus on to support their research goals.
- Teams participate evaluating their robots during all days but the Final day where the best teams conduct more difficult combined sequences of tests.
- This makes RoboCupRescue competitions astonishingly productive public evaluations with 300-400 test trials of data captured.







Objective Evaluations Measure the Differences

League Overview





(meters/minute)





Comparing Scores Across Various Suites of Tests League Overview

Maneuvering (MAN 1-5) forward/reverse, control, awareness.
Mobility (MOB 1-5) advanced terrains and obstacles.
Dexterity (DEX 1-5) manipulator reach, strength, and tool use.
Exploration (EXP 1-5) 2D/3D mapping and autonomous behaviors.





Functional MAN, DEX, and EXP

DEX5 DEX4 DEX3 DEX2 DEX1 MOB3 MOB3 MOB3 MOB4 DEX2 DEX1 MOB5

iRap Robot

EXP4 100

50

0

EXP3

EXP2

EXP1

DEX6

FXP5 MAN1 MAN2

AAN3

MAN4

MAN5

MAN6

MOB1



Functional MAN, MOB, & DEX Excellent DEX, Functional MAN

RADAR CHARTS FOR 20 TEST METHODS





Example Outreach to Responders That Perform Hazardous Tasks League Overview

These standard test methods help answer essential questions:

- Which commercial robots enable bomb technicians to operate from safer standoff distances?
- What emerging technologies improve performance, and are they ready for deployment?
- Where are the gaps in capabilities?
- How to focus operator training and improve proficiency to be successful?



Vehicle bombs are considered their highest emerging threat – bomb suits don't help.





Example Outreach to Responders That Perform Hazardous Tasks

League Overview

Remote Operator Training The robots and bomb suits performed the same test methods using whate Figure Brothe the Building Access converse included Mehility and Manauvoring test methods



Inspec

id D) Pick

and

Bomb Suit Training

A) Search tasks in) positions: B) Inst ks using a grasping

ed poin of interest required a million object of interest was performed with the same tool, or on their back underneath th

Project Report on Canadian Bomb

to provide a very modest standoff from a known

Standard Internetopt

navigestag dia e becoming more e powerates a division dasily av asmaessred do otstatisticate is grifing are within a wortershared test material

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Objectives for 2021

RoboCupRescue Robot League



> **Objective #1** Objectives for 2021

Maintain existing teams and entice new (smaller) teams

- Lower the barrier to entry by focusing on low-cost tests in each Best-In-Class category. This can become our new remote qualification process!
- Enable remote participation down to the smallest teams or individuals in case their schools are closed.
- Capture trials on video so teams can score their own performance with even more statistical significance than competitions allow given limited time/space.
- Trial videos enable other teams to "attest" to scores, practice their data collection, and advertise RoboCupRescue's world-beating capabilities.
- Facilitate remote proctoring by the Organizing Committee for the best performing trials either by region or internationally. This can be done with pairs of proctors to coordinate schedules and time-zones.
- This process can aggregate scores in each test for many more participants!



Dexterity & Strength



Maneuvering & Legged Mobility



PALLET TERRAINS

CRATE TERRAINS

Exploration & Mapping



EMBEDDED ACUITY TARGETS AND FIDUCIALS





Trial Video Scoring Objectives for 2021

TASK DETAIL



SAVE SCREEN TO VIDEO OR ZOOM IN WITH CAMERA AS SHOWN HERE

SHOW EASILY

TIMESTAMP, PRINTED

TRIAL INFO, AND ALL

OPERATOR ACTIONS

READABLE

SHOW THE OPERATOR IN THE BACKGROUND WITH BACK TOWARD THE APPARATUS

SHOW AS MUCH

DETAIL OF THE

TASK AS

POSSIBLE

OVERVIEW OF ROBOT & OPERATOR

ALL OPERATOR ACTIONS

ROBOT/INTERFACE VIEW

30





Trial Video Scoring Objectives for 2021



- 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
- $\textbf{B} \quad [\text{QTY 2}] \text{ 5 x 10 x 40 cm} (2 \text{ x 4 x 16 in}) \text{ SIDE ARMS}$
- $\boldsymbol{C}\quad$ [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



> **Objective #2** Objectives for 2021

Distributed Best-In-Class Trials

- **Dexterity and Strength:** New inexpensive and easy test apparatuses to fabricate, set up, and stow. Perform incremental horizontal and vertical tasks as a comprehensive classification of dexterity and strength.
- Autonomous Maneuvering and Legged Mobility: New inexpensive and easy test apparatuses based on purchased pallets and crates. The crate terrains evaluate legged robots in a variety of difficult configurations with 30 cm (12 in) steps and holes that start to resemble rubble piles.
- Search, Exploration and Mapping: New inexpensive and easy search tasks using purchased buckets with printed acuity targets along with our typical mapping fiducials all embedded into your house, school, office, plant, etc.
- Aerial: New aerial drone tests evaluate remote pilot proficiency either indoors or outdoors. They're being used by emergency responders to focus training and measure proficiency for licensing.



Dexterity and Strength



Maneuvering and Legged Mobility



PALLET TERRAINS

CRATE TERRAINS

Search, Exploration and Mapping



EMBEDDED ACUITY TARGETS AND FIDUCIALS

> **Objective #3** Objectives for 2021

Collaborate with the Virtual Robot Competition

- Implement ALL the available test methods into the Gazebo environment (most are there already).
- Validate the virtual models with physical friction tests to ensure they appear as close to correct as possible.
- Transfer our concurrent trial model:
 - Preliminaries in individual tests with statistical significance
 - Semi-Final sequences with difficult combinations of tests
 - Finals including all tests in a maze search.
- Start providing a model of each year's arena to establish a library of related but different challenges.

> **Objective #4** Objectives for 2021

Highlight Connection to Regional Emergency Responders

- Responders in the region probably don't have the same travel restrictions as international research teams. So they are more likely to be able to get involved, host tests, and highlight our connection to the community.
- Responders learn through RoboCupRescue how to fabricate and conduct standard tests to support their ongoing robot purchasing and training.
- This year we could add a distributed outdoor aerial drone evaluation using tests that are being replicated internationally to support training and evaluation of pilot proficiency for licensing.
- Remote trials could involve many more responder organizations along with industrial, commercial, and others
- We could also seek to collaborate with groups with disabilities interested in using our tests to measure their remote piloting skills align with various jobs requirements.

RESPONDER TRAINING

ROBOT MOBILITY

Timeline Objectives for 2021

May 15, 2021:Release the rule book showing how to fabricate the test apparatuses, capture video trials, and score results. Collect
interested teams to be registered.

Open team participation/registration for each robot configuration interested in submitting a set of trial videos for scoring with potential to win a Best-in-Class award certificate. Multiple robot configurations can participate. Commercial robot configurations can also participate, operated by the manufacturer, responders, or others. Their results will contribute to the overall averages across systems and provide comparable measures of proficiency for remote operators using the same system.

- June 7, 2021: Deadline for team registration.
- June 14, 2021: Deadline for teams to post uncut trial videos following the format guidance provided by the Execs. Other participating teams attest to the scores as viewed in the same trial video. It may be mandatory for each registered team to "attest" to scores of 5-10 other team videos to ensure the top scores are valid.
- June 22-28, 2021: Organizing Committee remotely proctor new test trials via video conference for the top teams to ensure they can reproduce their video scores and extend to harder tasks.
- July 2021 Highlight the best video trials on the RoboCupRescue website.

Issues for 2021

RoboCupRescue Robot League




Robot Configurations Issues for 2021

- Teams can use multiple robot configurations in this distributed model of competition.
- Robots operating in similar test apparatus can provide enough scale in the videos to understand the general size/weight of the robot.
- Separately submitted videos should include a 360° video tour of the robot configuration (1 minute) with details of key locomotion, sensors, dexterity, etc. Also include a 1minute tour of the apparatus.
- Commercial robots can get involved too. They'll form individual "classes" of systems to measure and compare the proficiency of different remote operators.







iRap Robot



Functional MAN, DEX, and EXP

Excellent MAN and MOB Functional MAN, MOB, & DEX Excellent DEX, Functional MAN





Scoring / Multipliers Issues for 2021

- **Time limits for trials are eliminated** this year because we want COMPLETE trials demonstrating all achievable tasks in an entire set of statistically significant repetitions. Autonomous robots can take as long as they need. Remotely operated robots should limit the fatigue of the operator. The tests are designed for good performance to take no more than 20 minutes or so per trial. The resulting RATE of task completions will be used as a tie-breaker for similarly complete trials, so more efficient performance is better. Incomplete trials will likely not be considered for awards.
- **Multipliers based on specific capabilities are eliminated** this year for simplicity. These are remotely conducted Preliminary trials only, so it is enough if we know that the configuration is the same even if we're not sure all the individual capabilities are functional at the end of a given trial.
- **Multipliers that were based on autonomy or semi-autonomy are also eliminated** this year for simplicity. The various levels and types of autonomy on display will be impossible to verify and monitor in trial videos. However, semi-autonomous behaviors are supposed to improve the rate of task completion or improve remote operator proficiency in some measurable way. We're hoping these benefits are reflected in the scoring of complete trials. Fully autonomous robots can take as much time as they need to complete trials, so effective systems should be in consideration throughout. Teams can highlight their autonomous behaviors during the second round of live teleconferencing trials.





Verify Remote Operation During Trials Issues for 2021

- Require uncut quad-screen video trials that can be scored after the trial by anyone watching. Teams are saving lots of money on travel this year, so asking to purchase a few camcorders is reasonable.
- 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.
- It is harder to be certain for wide area searches and mapping in throughout a scenario, so we'll need to figure that out. But the system interface and map building should be obvious along with the robot's camera views.







Mandatory Video Trials Issues for 2021

Teams are required to adhere to these rules for continuous, multi-view video capture of the trials. 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 rules 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.

- 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.





Sample Quad Video Capture to Score Trials

Dexterity and Strength Classification Tests

TASK DETAIL

CAMERA 4 US GARD ADD PLENTY OF LIGHTING CAMER CAMERA 1 New York 5:10:37 PM Wednesday, April 21, 202 Team: NIST Rabot: Telerob Telemas Config: Base Operator: RKS Test: Linear Inspect Position: Downward Grange 30 cm Trial #: 1

SAVE SCREEN TO VIDEO OR ZOOM IN WITH CAMERA AS SHOWN HERE

SHOW EASILY READABLE TIMESTAMP, PRINTED TRIAL INFO, AND ALL OPERATOR ACTIONS

SHOW AS MUCH DETAILOF THE TASK AS POSSIBLE

SHOW THE OPERATOR IN THE BACKGROUND WITH BACK TOWARD THE APPARATUS

OVERVIEW OF ROBOT & OPERATOR

ALL OPERATOR ACTIONS

ROBOT/INTERFACE VIEW





Operator Station Camera Mount Issues for 2021

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
- $\textbf{C} \quad [\text{QTY 1}] \ 10 \ x \ 10 \ x \ 60 \ \text{cm} \ (4 \ x \ 4 \ x \ 24 \ \text{in}) \ \text{POST WITH} \ 45^\circ \ \text{TOP}$
- **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 1] 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







Trial Video Submission Issues for 2021

Submission Process:

- We need a naming convention, title, or tag that includes a sortable score. *Key terms include: RRL2021-*(*Mobility/Dexterity/Mapping/Aerial*)-*TestName-Score92*-RobotConfigurationName-Organization-Country-Trial#-Date.
- 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.
- "Team A" 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 can be set entry for each team to capture discussions if we want.





Worldwide Responder Metrics of Operator Proficiency Issues for 2021

- Including commercial robot configurations, operated by the manufacturer, responders, and others can provide aggregated data to determine average and excellent operator proficiency. When the robot configuration is exactly comparable (purchased), the resulting scores represents the proficiency of the operators.
- This year's process is essentially also setting up a distributed emergency responder proficiency evaluation using the same tests and metrics as RoboCupRescue within their own facilities. If they choose to get involved in sending scoring videos, they will presumably submit the best of their squad to be compared with other squads internationally. Hopefully, they'll run all their personnel through the same tests. These participating responders would also get to see developmental robots and their scores, so they can see emerging capabilities in action.





Dexterity and Strength Classification Tests

RoboCupRescue Robot League





Measure Robot Capabilities and/or Operator Proficiency Dexterity and Strength Classification Tests

- Validate a comprehensive and easy to replicate set of classification tests for manipulator dexterity and strength.
- Encourage coordinated joint control with inverse kinematics using Linear and Omni tasks at various reaches along with weighted Stow-Carry-Place tasks.
- Include the diagonal rail terrain to add limited ground complexity with easy fabrication (they drop in):
 - Compensate for unknown chassis orientation with dexterous manipulation and auto-leveling features.
 - Encourage stability at maximum reach with uncertain ground contacts that affect the center of gravity.
 - Maintain situational awareness of the surrounding ground terrain during all dexterity tasks.



Responders with larger robots use this zig-zag lane with K-rail terrain and tall task shelves abutting the center square "room." Surrounding walls are typically added to contain the robot.





Incremental Task Elevations and Orientations

Dexterity and Strength Classification Tests



A full-size shelf apparatus and square center "room" terrain can contain all the dexterity and strength tasks.



Smaller robots need only one corner of the "room" terrain and shorter elevations.





Even Smaller Stowable Apparatuses to Get Started Dexterity and Strength Classification Tests

Incremental 30 cm (1 ft) settings both horizontally and vertically



Crates, bolts, and wingnuts support incremental shelf elevations





Even Smaller Stowable Apparatuses to Get Started

Dexterity and Strength Classification Tests

Incremental 30 cm (1 ft) settings both horizontally and vertically



Crates, bolts, and wingnuts support incremental shelf elevations





Complementary Tasks in Similar Trials Dexterity and Strength Classification Tests

Individual trials are 5 tasks at each horizontal and vertical reach







Incremental Horizontal and Vertical Reaches

Dexterity and Strength Classification Tests

Trials are 5 tasks at each 30 cm (1 ft) increment

LINEAR TASKS

OMNI TASKS

STRENGTH TASKS







Incremental Horizontal and Vertical Reaches

Dexterity and Strength Classification Tests

Trials are 5 tasks at each 30 cm (1 ft) increment

LINEAR TASKS

OMNI TASKS

STRENGTH TASKS







Incremental Horizontal and Vertical Reaches

Dexterity and Strength Classification Tests

Trials are 5 tasks at each 30 cm (1 ft) increment

LINEAR TASKS

OMNI TASKS

STRENGTH TASKS













55

Omni Tasks

Purchase List and Cut Tips Dexterity and Strength Classification Tests

PURCHASE LIST:

[QTY 7] 30 x 120 cm (12 x 48 in) shelving wood for walls and floor pieces (or 1 full sheet of OSB/Plywood to cut up into a single floor and 3 walls)
[QTY 15] 5 x 10 x 240 cm (2 x 4 x 96 in) lumber rails
[QTY 1] 10 x 10 x 240 cm (4 x 4 x 96 in) lumber post
[QTY 100] 40 mm (1-1/2 in) screws – torx/star bits preferred
[QTY 50] 80 mm (3 in) screws - torx/star bits preferred
[QTY 2] bolts with wing nuts approx. 12 mm x 130 mm (1/2 x 4 in)
[QTY 5] plastic cubic stacking crates approx. 30 x 30 x 30 cm (12 x 12 x 12 in)









Partial Terrain Apparatus with Drop-In Diagonal Rail **Dexterity and Strength Classification Tests**

PARTS LIST:

- [QTY 7] 30 x 120 cm (12 x 48 in) walls and floor pieces can be (A)made from purchased shelving of any thickness. Or cut from a plywood sheet with the floor being one square piece.
- **B** [QTY 3] 5 x 10 x 120 cm (2 x 4 x 48 in) horizontal beams at the base of each wall attaches to the floor with screws up from underneath. This also holds multiple flooring pieces together.
- (C)[QTY 2] 5 x 10 x 130 cm (2 x 4 x 51.5 in) posts hold the front of the shelf in place at all elevations. They have a hole pattern every 30 cm (12 in) to attach the shelf with bolts and wing nuts.
- [QTY 1] $10 \times 10 \times 157$ cm (4 x 4 x ~62 in) drop-in diagonal rail (D)should be cut to fit because it depends on the thickness of your walls and side rails. So measure the diagonal length then cut. Note that this diagonal rail has pointed tapers on both ends to drop into place.
- E [QTY 1] 5 x 10 x 10 cm (2 x 4 x 4 in) block holds the drop-in diagonal rail in place. It should be affixed to the side wall so the drop-in diagonal rail can be easily removed vertically.



NOTE: The task shelf frame NEEDS to fit snugly between these posts to affix to them. So measure this dimension before fabricating the task shelf. ⁵⁶





Task Shelf Apparatus Dexterity and Strength Classification Tests

PARTS LIST:

- [QTY 2] 5 x 10 x 100 cm (2 x 4 x 39.5 in) or longer side beams to affix the transverse slats shown in colors by reach distance.
- G [QTY 4] 5 x 10s (2 x 4s) cut to size as measured so the OUTSIDE DIMENSION OF THE OVERALL SHELF ASSEMBLY FITS INSIDE THE TERRAIN POSTS. These transverse slats hold the dexterity tasks in place. Use two screws on both ends to ensure they do not rotate.







Linear Task Apparatus **Dexterity and Strength Classification Tests**

LUMBER

- The linear apparatus has 5 different positions and orientations along a line. There are 3 perpendicular positions at different elevations and 2 angled orientations.
- It measures the basic reach and dexterity of the robot at 30 cm (1 ft) incremental reach distances and elevations.
- The apparatus should have 8 mm (5/16 in) holes at the dimensions shown.
- Inserting similar sized T-Nuts protect the holes from damage from tools and provide a consistent clearance between the tool and the hole diameter.



T-Nuts 8 mm (5/16 in) threaded https://www.amazon.com/gp/product/B06XCK35C1/









Omni Task Apparatus Dexterity and Strength Classification Tests

- The omni apparatus has 5 different positions and orientations around a point. There is 1 center position that is similar to the center of the linear apparatus. There are 4 more angled orientations.
- It measures the advanced reach and dexterity of the robot at 30 cm (1 ft) incremental reach distances and elevations.
- The apparatus should have 8 mm (5/16 in) holes centered on each face.
- Similar sized T-Nuts protect the holes from damage from tool placements and provide a consistent clearance between the tool and the hole diameter.











Strength Apparatus Dexterity and Strength Classification Tests

- The strength task apparatus has 3 positions along a line in which to place the weights with lumber borders to lift over. The weights are placed manually in the center location at the start of the trial.
- Any weights with handles can be used, including typical exercise plates of 1 or 2 kg (2.5 or 5 lbs) that fit easily into the center with at least 5 cm (2 in) space all around.
- Choose the maximum weight for each reach distance and elevation that enables COMPLETING ALL 5 TASKS.
- The Pipe T shown holds incrementally increasing stacks of weighted plates. It can made from typical 19 mm (3/4 in) plumbing pipes with outer diameters of less than 25 mm (1 in) fit into the center holes of the weighted plates. The pieces shown all threaded so screw together by hand.
- An optional rope can be looped through the top pipe and knotted to make a more universal grasp handle.

BOTTOM PIECES 5 x 10s (2 x 4s) FIT BETWEEN SHELF SLATS











Montgomery County Police Drone Training & Evaluati Safety | Capabilities | Proficiency

DOJ/DHS National Unmanned Aircraft Systems Program Evaluatio









"Touch/Insert Tool" Tasks Dexterity and Strength Classification Tests

- The "Touch/Insert Tool" tasks measure the reach space of the robot for using tools of various kinds. They are performed in both Linear and Omni orientations at 30 cm (1 ft) incremental reach distances and elevations.
- The task requires the robot to position and orient the tool tip perpendicular to the hole in the apparatus, then insert the tool into the hole. A Torx T-25 tool, a window-breaker tool, or any shaft with 4-5 mm diameter can be easily inserted into the 8 mm (5/16 in) hole diameter.
- Successful insertion requires the tool tip to recess at least 25 mm (1 in). Partial points are awarded for simply touching the tool tip to the hole at some angle that doesn't allow insertion.
- Score up to 5 points per task = 25 points total:
 - 1 point for touching the tool tip to the hole at any angle.
 - 4 points for inserting the tool 25 mm (1 in) into the hole.



https://www.amazon.com/dp/B08GKSF247/ ?coliid=I2PMBEMS0TZA5X&colid=3RUGTGF8 AJBSU&psc=1&ref =lv ov lig dp it im

T-Nuts 8 mm (5/16 in) threaded





"Extract and Place" Tasks **Dexterity and Strength Classification Tests**

- The "Extract and Place" tasks measure the reach space of the robot for precisely grasping objects. They are performed in both Linear and Omni orientations at 30 cm (1 ft) incremental reach distances and elevations.
- The task requires the robot to position and orient the gripper to grasp and extract the objects pre-placed in the apparatus. Any grasp object with a 6 mm (1/4 in) diameter shaft can be used to fit into the 8 mm (5/16 in) hole or T-Nut diameter.
- Successful extraction requires the the object to be completely removed from the hole. Successful placement of the object requires it to be in the crate. Dropped objects cannot re-grasped and placed in the crate.
- At the start of the trial the crate must be pre-positioned behind the start area at least 120 cm (4 ft) from the terrain. It can be moved by the robot anywhere at any time during the trial.
- Score up to 5 points = 25 points total:
 - 1 point for extracting the object from the apparatus.
 - 4 points for placing the object in the crate.





Small Round Abrasive Flap Wheel Sanders Grasp Object: 25 mm (1 in) diam high friction cylinder Shaft: 6 mm (¼ in) diameter, at least 25 mm (1 in) long



Large Round Abrasive Flap Wheel Sanders Grasp Object: 50 mm (2 in) diam high friction cylinder Shaft: 6 mm (¼ in) diameter, at least 25 mm (1 in) long



Glue your own grasp object onto a disc pad holder ANY SOLID/CONVEX SHAPE (not magnetic, sticky, etc.) Shaft: 6 mm (¼ in) diameter, at least 25 mm (1 in) long ttps://www.amazon.com/dp/B07D33NG4M/?coliid=I32UQSG0QLD8Q6&colid=3RUGTGF8AJBSU&psc=1&ref =ly o lig dp i





PLACE IN A CRATE ANYWHERE BEYOND

120 cm (4 ft) FROM

"Lift-Stow-Carry" Tasks

Dexterity and Strength Classification Tests

- This "Lift-Stow-Carry" tasks measure the maximum weight the robot can hold with its gripper within the terrain. The tasks are performed at incremental reach distances and elevations.
- Choose a weight for the intended reach distance and elevation that allows for COMPLETION OF ALL FIVE TASKS. Note the stow and carry tasks may be equally challenging because the terrain can change robot orientations quickly.
- Each chosen weight must be measured with a spring scale and captured at the start of the trial video.
- Pre-position the weight in the center tray. It should fit easily inside the containment. Farther reaches can use less weight.
- Pre-position the crate behind the start area at least 120 cm (4 ft) from the terrain.
- Score the maximum weight (kg/lb) to complete all 5 tasks.

THE TERRAIN STOW & CARRY Pre-position the chosen weight in the center. Weights probably get at longer reaches. GRASP-LIFT-MOVE 3 2 1. 2. 3.

- Pipe T with optional rope handle

- Weight-lifting plates with 25mm (1 in) center holes – Use any weights that fit easily into center containment such as 1 or 2 kg (2.5 or 5 lb) plates.

- Grasp and lift in center
- Place in left side
- Place in right side
- Stow and carry out 4.
- 5. Place in the crate





CORRECTLY STACKED

Shoring Tasks Dexterity and Strength Classification Tests

- This Shoring task is intended to measure the robot's pick and place capabilities while avoiding contact with the post. This is an actual task performed by emergency responders trying to shore a compromised structure in which they are deployed.
- It is performed on the same diagonal rail terrain as the other tests to encourage dexterous and strong grippers.
- Pre-position a hollow pipe as the post at any distance along the centerline in front of the terrain. Use a 5 cm (2 in) diameter x 60 cm (24 in) PVC pipe standing on end, not secured to the ground or weighted in any way. Show the placement of the pipe and the initial blocks at the start of the trial video.
- Pre-place two initial 10 x 10 x 30 cm (4 x 4 x 12 in) blocks on two sides of the post and parallel to each other so the the surrounding square base dimension is correct. All other blocks can be pre-placed anywhere except in front of the terrain.
- Score the number of blocks stacked without knocking the post over. The stacked blocks should be easily visible in the video.



The pipe can be at any distance along the terrain centerline and the blocks can be anywhere around the terrain (not in front)





Optional Tasks Dexterity and Strength Classification Tests

- These are not included in the Preliminary round of trials, so that every robot performs the same Linear, Omni, and Strength classification tasks.
- However other operationally relevant task apparatuses can be fabricated and practiced within the same dexterity apparatus. The omnidirectionality of these tasks provides even more generality in task performance, as if the relative orientation of the robot chassis to the task in the scenario is completely unpredictable. Consider turning doorknobs while the chassis is angled on steps, as many external house doors require. If you can turn all the omni doorknobs, your robot's dexterity can probably compensate for any inconvenient chassis orientation.
- Some examples that could be highlighted in demonstrations.
 - Touch e-stop buttons
 - Rotate shut-off valves (90 degree)
 - Rotate doorknobs
 - Insert keys into doorknobs
 - Place water bottles
 - Hook carabiners with a secondary tow line







Quad Video Capture to Score Trials

Dexterity and Strength Classification Tests

TASK DETAIL

US GART ADD PLENTY OF LIGHTING New York 5:10:37 PM Wednesday, April 21, 202 Team: NIST Rabot: Telerob Telemas Config: Base Operator: RKS Test: Linear Inspect Position: Downward Grange 30 cm Trial #: 1

SAVE SCREEN TO VIDEO OR ZOOM IN WITH CAMERA AS SHOWN HERE

SHOW EASILY READABLE TIMESTAMP, PRINTED TRIAL INFO, AND ALL OPERATOR ACTIONS

SHOW AS MUCH DETAILOF THE TASK AS POSSIBLE

SHOW THE OPERATOR IN THE BACKGROUND WITH BACK TOWARD THE APPARATUS

OVERVIEW OF ROBOT & OPERATOR

ALL OPERATOR ACTIONS

ROBOT/INTERFACE VIEW

68





Quad Video Capture to Score Trials

Dexterity and Strength Classification Tests

TASK DETAIL

ROBOT/INTERFACE VIEW

SHOW AS MUCH DETAILOF THE TASK AS POSSIBLE

SHOW THE

OPERATOR IN THE

WITH BACK TOWARD

BACKGROUND

THE APPARATUS



SAVE SCREEN TO VIDEO OR ZOOM IN WITH CAMERA AS SHOWN HERE

SHOW EASILY READABLE TIMESTAMP, PRINTED TRIAL INFO, AND ALL OPERATOR ACTIONS

69

OVERVIEW OF ROBOT & OPERATOR

ALL OPERATOR ACTIONS



Standard Test Methods for Response Robots ASTM International Standards Committee on Homeland Security Applications;

Response Robots (E54.09) | Website: RobotTestMethods.nist.gov



Example Linear Test Form

ROUND TIME TO NEAREST 0.25 MINUTES (15 SECONDS)

DECIMAL MIN

COMPLETE

PARTIAL MISSED

POINTS

LP LA C RA RP



START (2400): END (2400): ELAPSED (MIN:SEC):



Standard Test Methods for Response Robots ASTM International Standards Committee on Homeland Security Applications;

Response Robots (E54.09) | Website: RobotTestMethods.nist.gov







TRIAL INFO

ELEVATION

Standard Test Methods for Response Robots ASTM International Standards Committee on Homeland Security Applications;

Response Robots (E54.09) | Website: RobotTestMethods.nist.gov



ROUND TIME TO

(15 SECONDS)

DECIMAL MIL

NEAREST 0.25 MINUTES

COMPLETE

5 1 0

PARTIAL MISSED

POINTS

55



(LP) **Dexterity and Strength Classification Tests**



START (2400): END (2400): ELAPSED (MIN:SEC):




Autonomous Mobility Tests

RoboCupRescue Robot League





Pallet Terrains with Adjustable Doorways Autonomous Mobility Tests

30 pallets builds all variants

- Variable doorway widths (120% robot width)
- Negative obstacles (don't fall off)
- Steps up/down at any point (different stacks)
- Solid or slatted surfaces









Pallet Terrains with Adjustable Doorways Autonomous Mobility Tests

Variable width doorways between pallets set to 120% of robot width.

They should be high enough act as shoulder width obstacles.



Solid OSB panels on top make for consistent friction surface and minimize tripping.



- Double high stacks of pallets, or higher as steps provide a "fall off" avoidance of negative obstacles (holes).
- Double length pallets make "hallways."
- Four stacks together make square "rooms."





Pallet Terrains with Adjustable Doorways Autonomous Mobility Tests

Variable width doorways between pallets set to 120% of robot width.

They should be high enough act as shoulder width obstacles.







Pallet Terrain Purchase List

Autonomous Mobility Tests

30 Pallets x \$30 US each = \$900 US

Used pallets work the same!



NEW WOOD PALLETS

This economical alternative is the workhorse of the industry.

- Tough, durable wood.
- Stackable, reusable.
- H-1218 and H-1260 meet standard GMA specifications.
- H-1618 fits Bulk Cargo Container.
- Heat-Treated new wood pallets meet ISPM 15 export specifications.

NEW WOOD	PALLETS							So	ld in mu	ltiples of
MODEL	WOOD	WOOD SIZE CAPAC	CAPACITY	FORK S	SHPG.	PRI	ADD TO			
NO.	TYPE	LxW	(LBS.)	ACCESS	WEIGHT	5	10	20+	_	CART
<u>H-3445</u>		36 x 36"	3,500	2-way	30 lbs.	\$22	\$21	\$20	5	ADD
H-1218	New Wood	48 x 40"	2,500	4-way	42 lbs.	29	28	26	5	ADD
<u>H-1125</u> *		48 x 48"	3,500	2-way	52 lbs.	30	29	27	5	ADD
<u>H-1627</u> *		90 X 48"	7,000	4-way	IU4 IDS.	58	55	52	5	ADD

of 5





Issues to Resolve Autonomous Mobility Tests

- It will be hard to challenge large robot mobility in the typical RoboCupRescue terrains and obstacles this year. Those robots should focus on dexterity and mapping.
- The pallet terrains are not particularly challenging for teleoperative robots.
- The crate terrains are not compatible with tracked robot of any size and weight. They intended for lightweight legged robots. The crates are only cable tied to each other vertically.
- We always encourage teams to fabricate smaller scale 60 cm (24 in) wide mobility apparatuses that are intended for confined environments like dwellings, between parked cars, bus/train/plane, etc. They fit into a single shipping container or parking spot. All the dexterity tasks also scale down to 60 cm (24 in) wide environments too.

Pallet-Based Terrains (Negative Obstacles and Steps)



Crate-Based Terrains (Negative Obstacles and Hills)







Legged Mobility Tests

RoboCupRescue Robot League





Pallet and Crate Terrains Legged Mobility Tests

- Validate easy to replicate legged and autonomous mobility tests to augment existing tests.
- Focus on reconfigurable task apparatuses based on pallets and crates that are ubiquitous worldwide and easy to lay out temporarily in a parking lot, then stack and store between trials.
- This is an excellent opportunity to introduce FOUR LEGGED ROBOTS into our league, with demonstrations of extremely promising systems coming available commercially and for research.
- Encourage onboard manipulators to perform detailed search tasks and dexterity tasks while in the terrains.

Pallet-Based Terrains (Negative Obstacles and Steps)



Crate-Based Terrains (Negative Obstacles and Hills)







Adding New Terrains for Legged Robots

Legged Mobility Tests







Crate Terrains Legged Mobility Tests



Diagonal Hill – Solid Steps (all crate stacks upside-down) Pyramid Hill – Checkered Surfaces (every other crate stack upside-down)





Crate Terrains Legged Mobility Tests



Diagonal Hill – Solid Steps (all crate stacks upside-down)

Pyramid Hill – Checkered Surfaces (every other crate stack upside-down)



m (20 ft)

ഗ























Crate Terrain Purchase List

Legged Mobility Tests

150 Crates x \$7 US each = \$1000 US

Used crates work the same!

Nylon Natural Cable Ties - 12", 50 lb



Tamperproof ties secure bags, cords and cables permanently.

- · Locks tightly Won't stretch or slide.
- UL Listed 6.6 nylon.
- Free Offer



Rigid Milk Crates - $12 \times 12 \times 10^{1/2}$ ", Blue

Sturdy storage for trunk, closet, shop or shed.

- Strong high-density polyethylene.
- · 40 lb. load capacity.
- Stackable.

SPECIFY COLOR:										
MODEL	OUTSIDE DIM.	INSIDE DIM. L x W x H	CU. CAPACITY FT. (LBS.)	APACITY WT.	PRICE EACH (MIN. 3)			00100	IN STOCK	
NO.	LxWxH			(LBS.)	(LBS.)	3	12	24+	COLOR	SHIPS TODAY
S-16317BLU	13 ¹ /8 x 13 ¹ /8 x 11"	12 x 12 x 10 1/2"	0.9	40	3	\$9	\$8	\$7	Blue -	3 ADD

MODEL NO.	ITHOTH	MIDTH	TENSILE	QTY./	PRICE PER PACK			IN S	STOCK	
	LENGIH	WIDTH	STRENGTH	PACK	1	5	10	20+	SHIP	S TODAY
S-7740	12"	.19"	50 lbs.	1,000	\$76	\$72	\$68	\$64	1	ADD





Crate Terrain Fabrication Legged Mobility Tests

Contain the center "room" of the zigzag lane with a tall 5x10 cm (2x4) border around the crates sitting on the ground. No underlayer of plywoodis needed.

Put 7 crates side by side all touching to see the ACTUAL DIMENSION, then cut the lengths of wood to contain them with an extra 1 cm or so plus the width fo the wood so the joints overlap and screw together with 2 screws in each corner. The oversized dimension should allow the crates to pull out easily in the vertical direction.

Cable tie the vertical stacks of crates to each other using 2 cable ties (zip ties) on opposite sides. Make stacks of 2, 3, 4 crates tall. That's fewer individual pieces to move around when reconfiguring the hills. Plus they don't get kicked up by the robot.

When adding the "hallways" to both sides of the "room" just add more wood border on three sides, so the threshold isn't a double width wood layer, not that it would matter any. It might be easier to simply make two more rectangle borders (again, oversized slightly in both directions to contain whatever crates you're using) and attach them to the room border. Try it either way and let me know which is easier.





Search and Inspect Tests

RoboCupRescue Robot League





Measure Robot Capabilities and/or Operator Proficiency Search and Inspect Tests

- Establish a comprehensive and easy to replicate set of classification tests for exploration, 2D/3D mapping, and search.
- Focus on embeddable search targets and mapping fiducials in scenarios at any team locations. Scenarios can be houses, workplaces, schools, industrial, outdoors, etc.
- No need to fabrication the labyrinth, maze, or extensive terrains. Although some simple terrains should be introduced periodically throughout the scenario if only flat (see K-rails in Dexterity).
- Embed bucket targets instead of typical victim crates to focus on visual/color acuity in a comprehensive search layout.
- Encourage onboard manipulators to perform detailed search tasks at different elevations in the environment as well as under objects and over objects.
 - 1/3 of targets are open for any zoom camera to identify.
 - 1/3 of targets require directional points of view.
 - 1/3 of targets require close-proximity inspections.

Typical Labyrinth with Various Terrains



VICTIM CRATES AS DIRECTIONAL SEARCH TASKS

Typical Maze with Various Terrains







Measure Robot Capabilities and/or Operator Proficiency Search and Inspect Tests

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 - 1/3 of targets require directional points of view.
 - 1/3 of targets require close-proximity inspections.







New Search Targets Instead of Victim Crates

Search and Inspect Tests

PURCHASE

- 30 printed targets (paper or stickers)
- 20 black buckets
- 20 black bucket lids



Triple Target Apparatus (mounted on wood rail or panel)

MUST SEE THE ENTIRE INNER EDGE OF THE COLOR RING TO SCORE



TARGET ON LID

VISIBLE PAPER TARGET OR STICKER ON A FLAT LID

VIEWABLE FROM **ALMOST ANY DIRECTION AND ELEVATION**

OPEN BUCKET

RECESSED TARGET IN A BLACK BUCKET

ALIGNED AND VIEWABLE ONLY WHEN ROUGHLY **CENTERED**

BUCKET WITH LID HOLE

RECESSED TARGET IN A BLACK BUCKET WITH A 10 cm (4 in) HOLE IN THE LID

ALIGNED AND VIEWABLE **ONLY WHEN ROUGHLY CENTERED AND IN CLOSE PROXIMITY**

FABRICATE

10 triple target apparatuses mounted on wood rail or panel

F4B

- 10 targets on lids
- 20 targets in buckets
- 10 black lids with 10 cm ٠ (4 in) holes (TR) TOP RIGHT TOP LEFT (TL) (R) RIGHT LEFT (L) 3 BOTTOM LEFT (BL) (BR) BOTTOM RIGHT (B) BOTTOM









Example point of view



10 Search Elevations and Orientations

Search and Inspect Tests

from a small robot: "FORWARD" "OVER" "UNDER" CEILING 240 cm (8 ft) BUCKET пр ноге OPEN BUCKET TARGET OPEN BUCKET 0 ON LID BUCKET LID HOLE **ALIGNED** 6 NOT SHELF 180 cm (6 ft) ALIGNED BUCKET гір ноге OPEN BUCKET TARGET OPEN BUCKET The open buckets and ONTID LID HOLF buckets with lid holes OPEN BUCKET Ø () BUCKET LID HOLE require different COUNTER 120 cm (4 ft) elevations, orientations, BUCKET гір ноге OPEN BUCKET and proximities to align TARGET OPEN BUCKET ON LID LID HOLE with and identify BUCKET OPEN () all targets. BUCKET LID HOLE NOT TABLE 60 cm (2 ft) **ALIGNED** ALIGNED TARGET OPEN BUCKET ON LID LID HOLF BLICKE. OPEN BUCKET 6 BUCKET LID HOLE FLOOR 0 cm (0 ft)





10 Search Elevations and Orientations

Search and Inspect Tests

Example point of view	CEILING 240 cm (8 ft)	"FORWARD"	"OVER"	"UNDER"
from a small robot:	SULLE 190 cm (6 ft)			
ALIGNED NOT ALIGNED				
The open buckets and buckets with lid holes				
elevations, orientations, and proximities to align with and identify all targets.	COUNTER 120 cm (4 ft)			
	TABLE 60 cm (2 ft)			
NOT ALIGNED	FLOOR 0 cm (0 ft)		and a	





Distribute As Described Throughout Your Scenarios

Search and Inspect Tests

10 triple target placements

"Forward" Placements

180 cm	(6 ft)	Shelf
120 cm	(4 ft)	Counter
60 cm	(2 ft)	Table

(0 ft)

60 CM 0 cm

Table Ground

"Over" Placements

- 120 cm (4 ft)
- 60 cm (2 ft)
- 0 cm (0 ft)

"Under" Placements

- 240 cm (8 ft)
- 180 cm (6 ft)
- 120 cm (4 ft)

- Counter Table
- Ground
- Ceiling Shelf

Counter

More capable robots score more search points in EVERY scenario using these rules.



Various scenario layouts are repeatable and directly comparable over time for any robot that attempts them. Results are notionally extensible to other scenarios using the same robot, targets, and placement rules in other locations.





Search Scenario Procedure, Scoring, and Metrics Search and Inspect Tests

PROCEDURE

- Capture an initial image of a clock with a time/date stamp to identify the trial sequence of images.
- Align with each visual acuity target so you can see the entire inner edge of the colored ring to score any acuity points.
- Capture an image showing the correct target alignment.
- Zoom into the target to identify as as many smaller ring gap orientations as possible.
- Capture a second image of the smallest possible acuity ring. Each target has 5 increasingly small ring gaps to their orientations (random combinations of 8 orientations).
- Score up to 5 points per target x 30 targets = 150 points max:
 - 1 point for each smaller gap orientation identified correctly.
 - Save the captured images for scoking after the trial.
 - 0 points scored if the target image is not aligned.



YOU MUST SEE THE ENTIRE INNER EDGE OF THE COLOR RING TO SCORE







Search Target Purchase List Search and Inspect Tests

C Eridige

MODEL

NO.

DESCRIPTION

PURCHASE

- 20 black buckets 7.5 L (2 Gal) 20 cm (8 in) diameter <u>https://www.uline.com/Product/Detail/S-9941BL/Pails/Plastic-Pail-2-Gallon-Black?model=S-9941BL&RootChecked=yes</u>
- 20 black lids 7.5 L (2 Gal) 20 cm (8 in) diameter <u>https://www.uline.com/Product/Detail/S-9947BL/Pails/Standard-Lid-for-2-Gallon-Plastic-Pail-Black?PDPRelatedItem=S-9941BL</u>
- Stickers 20 cm (8 in) diameter polyester waterproof https://www.onlinelabels.com/products/ol3033lp
- (50) screws to attach buckets to wood rail.
- (50) Washers to attach buckets to wood rail.

DOWNLOAD

• Visual acuity target file (pdf)

https://www.nist.gov/el/intelligent-systems-division-73500/standardtest-methods-response-robots/robot-competitions-0



Plastic Pail - 2 Gallon, Black

- Safely store or ship your products in these durable pails

 High density polyethylene construction withstands temperatures up to 180°F.
 - Stackable with lid. Empty palls nest for storage

IN STOCK

SHIPS TODAY

ADO

FDA compliant.

SPECIFY COLOR

S-9941BL 2 Gallon Pall 65 \$3.50 \$3.25 \$2.95 ■ Black ~ 5

PRICE EACH MIN.

5 10 50+

Lids sold separately.
 Optional <u>Companion Box</u> available
 Free Offer





	5	PECIFY COLOR		
MODEL NO.	FITS PAIL SIZES	PRICE EACH own, to	COLOR	ADD TO CART
S-9947BL	2 Gallon	\$.85	Block -	Temporaril Unavailable







Search Target Fabrication Search and Inspect Tests

FABRICATE

- Attach 1 lid and 2 buckets left to right on wood rail.
- Affix visual acuity targets to attached lid buckets. You can used sticker targets of cut printed paper and tape them.
- Drill 10 cm (4 in) hole in the center of the spare lid.
- Attach the lid to the bucket opposite the exposed lid.







Exploration and Mapping Tests

RoboCupRescue Robot League





Measure Robot Capabilities and/or Operator Proficiency

Exploration and Mapping Tests

- Validate easy to replicate exploration and mapping tests in YOUR scenarios.
- Focus on reconfigurable task apparatuses that are easy to lay out temporarily and store between trials.
- Compare your 2D and 3D map results over time in variable/repeatable layouts within the same scenario.
- Try different scenarios using all the same layout rules, in houses, workplaces, industrial facilities, outdoor settings.



Distribute QR codes (all the same or all unique) and/or half round shape fiducials in pairs on both sides of walls to measure map consistency and accuracy.









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Distribute Fiducials Throughout Your Scenarios

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Distribute Lower Fiducials Throughout Your Scenarios

Exploration and Mapping Tests

Lower Fiducial Map

5 pairs of fiducials shown in a 3D map layer at 1 m (3 ft) elevation. The fiducial pairs should form circles in 2D maps.

- Coverage (how many of 10 are visible?)
- Consistency (how close are the pairs?)
- Local Accuracy (by room)
- Global accuracy (average overall)









Evaluative 2D/3D Maps with Lower Fiducial Layer

Exploration and Mapping Tests

Lower Fiducial Map

5 pairs of fiducials shown in a 3D map layer at 1 m (3 ft) elevation. The fiducial pairs should form circles in 2D maps.

- Coverage (how many of 10 are visible?)
- Consistency (how close are the pairs?)
- Local Accuracy (by room)
- Global accuracy (average overall)









Distribute Upper Fiducials Throughout Your Scenarios

Exploration and Mapping Tests

Upper Fiducial Map

5 pairs of fiducials shown in a 3D map layer at 2 m (6 ft) elevation. The fiducial pairs should form circles in 2D maps.

- Coverage (how many of 10 are visible?)
- Consistency (how close are the pairs?)
- Local Accuracy (by room)
- Global accuracy (average overall)









Evaluative 2D/3D Maps with Upper Fiducial Layer

Exploration and Mapping Tests

Upper Fiducial Map

5 pairs of fiducials shown in a 3D map layer at 2 m (6 ft) elevation. The fiducial pairs should form circles in 2D maps.

- Coverage (how many of 10 are visible?)
- Consistency (how close are the pairs?)
- Local Accuracy (by room)
- Global accuracy (average overall)









Purchase Mapping Fiducials

Exploration and Mapping Tests

OPTION A Purchase enough sign panels to make 20 half-cylinders roughly 60 cm (24 in) diameter x 120 cm (48 in) tall.



Wood beam on top, middle, and bottom maintains the diameter and enables hanging.

The middle beam is be shared by both the upper and lower panels.

Bend the panels as smoothly possible

Need 40 panels this size, or 5 packs as shown = \$180 US plus wood beams



Juvale 8-Pack Blank Corrugated Plastic Yard Lawn Signs, White, 24 x 36 Inches Visit the Juvale Store 🛊 🚖 🚖 🙀 🖌 🛛 147 ratings for "corrugated plastic sheet" Amazon's Choice

Price: \$35.99 & FREE Returns

Get \$50 off instantly: Pay \$0.00 \$35.99 upon approval for the Amazon Rewards Visa Card. No annual fee.

Available at a lower price from other sellers that may not offer free Prime shipping.

- Includes 8 blank plastic corrugated sign boards (stakes not included)
- White; 4 mm Density, 650gsm
- Ideal for garage sales, open house, estate sale, parties, etc.
- Customize signs using markers and stickers
- Dimensions: 24H x 36L Inches


OPTION B

Standard Test Methods for Response Robots ASTM International Standards Committee on Homeland Security Applications; Response Robots (E54.09) | Website: <u>RobotTestMethods.nist.gov</u>



Purchase Mapping Fiducials

Exploration and Mapping Tests

Purchase 10 concrete form tubes (cylindrical) then CUT THEM IN HALF to make half-round pairs.

60 cm (24 in) diameter fiducials are preferred, although they can be expensive. These could work for finer resolution maps.



40 x 120 cm (16 x 48 in) = \$16 US

\$160 US TOTAL



45 x 120 cm (18 x 48 in) = \$31 US \$320 US TOTAL



Standard Test Methods for Response Robots

ASTM International Standards Committee on Homeland Security Applications; Response Robots (E54.09) | Website: <u>RobotTestMethods.nist.gov</u>



Issues to Resolve Exploration and Mapping

- The scale and difficulties of various environments make it difficult to compare different scenarios at different locations.
- Fix the purchase/fabrication of fiducials the same scoring and rules are embedd additional costs involved for larger scen
- Each scenario layout using these appara considered repeatable and directly considered repeatable and directly considered that attempts them.
- Results are notionally extensible to other robot, targets, and placement rule.
- Experiment with harder scenariousing the same rules.
- Maybe try to classify environmental or a sparse/dense distance between fiduci between fiducials.

Standard Test Methods for Small Unmanned Aircraft Systems ASTM International Standards Committee on Homeland Security Applications; Response Robots (E54.09) | Website: RobotTestMethods.nist.gov

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Montgomery County Police Drone Training & Evaluation Facility Safety | Capabilities | Proficiency

DOJ/DHS National Unmanned Aircraft Systems Program Evaluation, August 2020





Standard Test Methods for Response Robots

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Issues to Resolve Exploration and Mapping

- This approach emphasizes mapping and not autonomy, because we can't ensure the systems are autonomous in the videos).
- There is no extra benefit for autonomy MORE TIME for the robot to explore for video of the map being generated in fact how long it takes.
- Add time-synced clocks on interface A viewing.
- Add overview cameras at interface and the environment for eyes-on contr
- Watch the maps get generated i map.
- There is likely no Ground Truth to the need to be EXCELLENT showing all fiduce all victims marked (and doors, windows)

Standard Test Methods for Small Unmanned Aircraft Systems ASTM International Standards Committee on Homeland Security Applications; Response Robots (E54.09) | Website: RobotTestMethods.nist.gov

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Montgomery County Police Drone Training & Evaluation Facility Safety | Capabilities | Proficiency

DOJ/DHS National Unmanned Aircraft Systems Program Evaluation, August 2020







Aerial Drone Pilot Proficiency Tests

RoboCupRescue Robot League





Spectrum of Drones for Outdoors and Indoors

Aerial Drone Pilot Proficiency Tests



Initial focus is VTOL, but some tests apply to forward flying aircraft when scaled up to the appropriate orbit radius.





Scalable Test Lanes For Outdoors and Indoors

Aerial Drone Pilot Proficiency Tests

MEASURE & COMPARE

SMALL SYSTEMS

INTERFACES

SENSORS







SCALABLE TEST LANES (ALTITUDE = SPACING)







Open Test Lane Has 5 Different Tests – Simulated and Physical

Aerial Drone Pilot Proficiency Tests





MAN/PAY 1

Traverse

MAN/PAY 2

Orbit MAN/PAY 3



MAN/PAY 4

Recon MAN/PAY 5



SEE THE SIMULATION INSTRUCTIONS AT https://drive.google.com/drive/folders/1NWanue38NvczrB4hrA0yesenoZmd9Tsx 115





Scalable For Outdoors and Indoors Aerial Drone Pilot Proficiency Tests







Scalable For Outdoors and Indoors

Aerial Drone Pilot Proficiency Tests







Scalable For Outdoors and Indoors Aerial Drone Pilot Proficiency Tests









Easy to Fabricate, Set Up, and Stow Aerial Drone Pilot Proficiency Tests 2 Gallon Buckets – Printed Stickers – Transportable













Open Test Lane Prepares for Related Scenarios

Aerial Drone Pilot Proficiency Tests



REMOTE PILOT TRAINING - CANADIAN POLICE COLLEGE, ONTARIO, CANADA









Other Test Lanes Prepare for More Difficult Scena Aerial Drone Pilot Proficiency Tests



LENGTH: 30/60 M (100/200 FT)

OBSTRUCTED TEST LANE







PERCH







Examples of Embedded Tests in Scenarios Aerial Drone Pilot Proficiency Tests

"Dual Bucket Alignments" near or on objects of interest



Hover in proximity to objects with measures of visual acuity and other features to identify. Capture 20 bucket alignment images, each worth up to 5 points = 100 points total.





Examples of Embedded Tests in Scenarios Aerial Drone Pilot Proficiency Tests

Structure/Window Inspection



Hover in proximity to objects with measures of visual acuity and other features to identify. Capture 20 bucket alignment images, each worth up to 5 points = 100 points total.





Examples of Embedded Tests in Scenarios Aerial Drone Pilot Proficiency Tests

Structure/Window Inspection



Hover in proximity to objects with measures of visual acuity and other features to identify. Capture 20 bucket alignment images, each worth up to 5 points = 100 points total.





Aerial Test Fabrication Pointers Aerial Drone Pilot Proficiency

These tests are being replicated worldwide based on the fabrication documents on our website. <u>https://www.nist.gov/el/intelligent-systems-division-73500/standard-test-methods-response-robots/aerial-systems</u>

Those files and plus instructive webinars, movies, and the simulation instructions are available on our g-drive repository : <u>https://drive.google.com/drive/folders/1NWanue38NvczrB4hrA0yesenoZmd9Tsx</u> (SEE THE OPEN TEST LANE FOLDER)

There are instructional courses people can attend virtually and in person to learn how to fabricate and conduct the tests: https://publicsafetyaviation.org/events/uas-training

The first in-person class is in Texas on May 22-24, 2021: https://www.txpsrobots.com/