



**Joint Ground Robotics Enterprise
ROBOTIC RANGE CLEARANCE COMPETITION
(R2C2)**

COMPETITION RULES AND METRICS

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Document Change Summary

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Introduction

Purpose

The purpose of the Robotic Range Clearance Competition (R2C2) is to quickly tap into the innovation and ingenuity of the commercial robotic technology sector to improve the safety and effectiveness of any or all of the four tasks traditionally associated with range clearing operations:

1. Vegetation removal
2. Surface clearance
3. Geophysical mapping
4. Sub-surface clearance

Background

Range clearance operations as currently conducted are manpower intensive, time consuming, dangerous, and expensive. Initial data from robotic range clearance technology development efforts indicate the strong potential for significant reductions in the time and cost required to conduct range clearing operations. Experiments to date indicate the possibility of reducing range clearance times by two thirds and costs by one third if automated clearing equipment is used.

Additionally, there are no automated “commercial off the shelf” solutions available for the Department to procure. The traditional approach of establishing an R&D program that can be transitioned into a development and acquisition program is not possible within the desired quick turn-around timeframe as none of the uniformed services have programmed funding for this traditional approach. By exercising statutory authority under Section 2374a of title 10 United States Code as amended by Section 212 of the John Warner National Defense Authorization Act for Fiscal Year 2007 Public Law 109-364 to offer a cash prize for development robotic range clearing application, it may be possible to provide the desired capability in a significantly shorter amount of time.

Scope

The tasks associated with range clearance that likely have the greatest potential for applying ground robotics technology include automated vegetation clearance, automated surface debris clearance, automated geophysical mapping, and automated Sub-surface anomaly excavation. The competition will assess the ability of competitor systems to provide increased safety and operational effectiveness to range clearance operations. The competitor systems are expected to have applied robotics technology to all or some appropriate combination of the inherent range clearance tasks in a range clearance operation. Because the competition is focused on increasing safety and operational effectiveness via robotics automation as well as reducing time and cost, competitors are not expected to attempt to develop improved vegetation removal tools or geophysical detection and identification sensor technology.

Objective

The objective of this competition is to advance robotic technology used in range clearance operations in order to increase operational effectiveness while providing greater safety for range clearance team members.

General Competition Objectives

Operations should be as automated as practical. Full automation is desired but not required to compete in the competition. Unmanned tele-operation is the minimum acceptable system requirement to compete in the competition.

No downrange manual operations are authorized with the sole exception of deliberate system recovery operations.

The pre-existing grade shall not be changed more than +/- 15 cm.

Leave each site with no surface damage that would prevent a light truck from traversing the site.

In addition, systems will demonstrate the following category objectives:

Vegetation Removal Objectives

The competition is intended to demonstrate the following Vegetation Removal Objectives:

- A. Remove all vegetation to a height no greater than 8 cm above surrounding grade. This will include trees up to 36 cm in diameter (measured at 122 cm height).
- B. Vegetation residue must be mulched or removed from the site. Vegetation residue left on the site must be mulched to a height not greater than 15 cm in depth. Residue removed from the site must be placed in a designated area within 300 meters of the site.

Surface Clearance Objectives

The competition is intended to demonstrate the following Surface Clearance Objectives:

- A. Remove all seeded metallic items from the surface of the contest site in the areas designated.
- B. The site will be seeded with items 20 mm in width or greater.
- C. All metallic items removed from the clearance site shall be placed in a designated surface items collection area within 300 meters of the site.

Geophysical Mapping Objectives

The competition is intended to demonstrate the following Geophysical Mapping Objectives:

- A. Navigate a digital geophysical mapping platform within the designated area to collect digital geophysical data so that buried metallic objects can be detected and located to 30 cm or better positional accuracy.
- B. Collect raw geophysical data with an objective noise level to be determined at the site.
- C. Deploy a time domain electromagnetic induction metal detector and record its data over 100% of the designated area at a line spacing of 50 cm.

The geophysical mapping platform shall be operated at a consistent speed to be determined by the competitor.

Sub-surface Clearance Objectives

The competition is intended to demonstrate the following Sub-surface Clearance Objectives:

- A. Remove all seeded metallic items identified in a supplied dig list from the designated area in the contest site. Item depths shall not exceed 1 meter.
- B. The site will be seeded with items 20 mm in width or greater.
- C. All items removed from the clearance site shall be placed in a designated sub-surface clearance collection area within 300 meters of the site.

Competition Metrics

The metrics for the competition will be derived from the following areas:

- A. System task performance
- B. Level of human interaction
- C. Man-hours to perform the task

Determination of Cash Prize Competition Winner

Competitors may choose to participate in all or some smaller combination of the 4 Events: (1) Vegetation Removal, (2) Surface Clearance, (3) Geophysical Mapping, and (4) Sub-surface Clearance.

The Ultimate Cash Prize will be awarded based on best performance against metrics, not one system against another. Competitors will score points based on their system's performance within each of the Events. The competitor that performs in all four categories and receives the highest score across all of the events will be declared the Overall Competition Winner. Additional cash prizes will be awarded to the best performance in each of the four events.

A Cash Prize of \$1M will be awarded to the Overall Competition Winner having met competition objectives and participated in all four events. A Cash Prize of \$250K will be awarded to the best performance having met competition objectives in each of the events. It will be possible for the Overall Winner of the \$1M cash prize to also win the event cash prizes. The possible cash awards can range from one competitor winning the entire \$2M (overall and best in each of the four events) to one competitor winning the Overall Cash Prize and four different competitors each winning a \$250K Event Cash Prize. Therefore anywhere from one to five competitors could finish the competition with a cash prize. It is possible that no cash prize is awarded in one or more of the competition events if system performance does not meet the minimum requirements, which will be defined by mid-September 2010.

Rules Modifications

Robotic technology advancement is a key objective of the R2C2. Competitors are invited to communicate directly with R2C2 regarding any rule that restricts their ability to demonstrate technical achievement and innovative solutions.

The R2C2 has the authority to modify the rules at any time. Rules may be modified for many reasons, including accommodation of a promising technical approach that would have been prohibited by the rules.

R2C2 will communicate any modifications to the rules through the competitor SharePoint site and the Competition website.

Clarification questions fielded by the R2C2 shall be answered in the Competition Rules Frequently Asked Questions (FAQ). Questions that have been received but not yet answered will also be posted in the FAQ.

The R2C2 may revise the schedule at any time and interpret the rules in any manner to best meet R2C2's objectives. The R2C2's decisions are based on a number of factors such as fairness, safety, statutes, program goals, environmental protection, and efficient operations.

Schedule

Below is a notional schedule of competition activities.

Activity	Location	Date
Kick Off Event	Crystal City	22 October 2009
Industry Day	Tyndall AFB	10 Dec 2009
Signed Letters of Intent	Online	3 May 2010
Category Registration	Online	3 May 2010
Optional Competitor Testing	Camp Guernsey	1 Aug to 1 Nov 2010 and 1 May to 1 July 2011
Competitor In-Process Reviews	Competitor site	1 November to 19 November 2010
Prize Competition Packets Issued	Online	90 days prior to Prize Competition
Prize Competition Packets Due	Online	45 days prior to Prize Competition
Prize Competition	Camp Guernsey	4 August through 30 September 2011

Eligibility & Participation

Participation Process

In order to participate and be prize eligible, interested parties must do the following:

1. Form a team (team is defined as one or more competitors)
 - a. Team leader signs a Letter of Intent
 - b. Receive access to team SharePoint
2. Choose competition categories
3. In-process Review (IPR)
 - a. Host IPR meeting
4. Compete
 - a. Submit Prize Competition Packet
 - b. Participate in Prize Competition

Team Requirements

The R2C2 is a competition between competitor teams. Competitors will form teams on their own and said teams will meet the following requirements.

Team Leader

Competitor teams must have a team leader. The team leader must be an individual and must sign the Letter of Intent.

Team Members

Individuals may only be on one team.

Vendors

There are no vendor restrictions. Government Furnished Equipment (GFE) is limited to R2C2 approval.

Team Name

Teams must be given a name. R2C2 reserves the right to disapprove names. Names will be granted on a first come first served basis.

Letter of Intent

Letters of Intent (LOI) will be posted at www.roboticrangeclearance.com when available. The team lead for each competitor team must complete and turn in the LOI. The LOI establishes who the competitor teams are. The LOI is not a binding agreement that compels participation in the R2C2. Teams may withdraw from the competition at any time, in writing, without penalty.

Competitor SharePoint

Once a team's LOI is received a SharePoint account will be created. The SharePoint is the primary communication clearinghouse for the competition. Up to two individuals may be given access per team. The Competitor SharePoint is not intended for use as an internal team tool but for external team interaction with the competition oversight.

The Competitor SharePoint has two parts:

- An all competitor level that includes competition documents, the competition calendar, and discussion board.
- A team folder that can only be accessed by your team and the competition oversight.

Category Registration

Teams may choose to participate in all or some smaller combination of the 4 performance categories: (1) Vegetation Removal, (2) Surface Clearance, (3) Geophysical Mapping, and (4) Sub-surface Clearance. Once teams are given access to the SharePoint site they must inform R2C2 of the categories the team will be participating in.

This will allow R2C2 adequate time to resource, approve, and build the surrogate ranges for the prize competition.

Optional Competitor Testing

Any team that does not have access to adequate developmental test facilities may utilize Camp Guernsey with prior approval. Use of Camp Guernsey for optional competitor team testing will have no bearing on the outcome of the prize competition. Packets will be posted on the SharePoint with all required information due 45 days before your requested test period. Packets contain forms that must be filled out and returned to Camp Guernsey that will allow the oversight team to appropriately resource and schedule the testing. Testing space will be available from 1 Aug to 1 Nov 2010 and 1 May to 1 July 2011. No billeting is available in this period. A list of available Camp Guernsey resources will be posted on the SharePoint.

In-Process Review

Participation is required for entrance to the prize competition.

The team shall present a technical briefing to the R2C2 Competition representatives who will review technical approach, progress, schedule, and risks at a time to be scheduled between the R2C2 Oversight Team and each Competitor Team.

Rules

The rules are intended to promote the widest variety of technical solutions.

The competition is structured to represent active range clearance prior to new range construction on an Army facility.

Safety is the number one priority.

Operational Safety

During operation, no personnel shall be closer to a moving Unmanned Ground Vehicle (UGV) than the operator and personnel will comply with their team's approved safety plans at all times.

Safety Officer

Teams shall designate a safety officer for the duration of the competition. Safety shall be his/her sole responsibility while the UGV is operating. UXO technicians are not required.

Emergency Stop (E-Stop)

The system shall have an Emergency Stop (E-Stop). The system must halt within 15 meters and cease all equipment operations when the E-Stop is initiated.

Warning Devices

Each vehicle shall be equipped with a warning light that is activated according to the state of the E-Stop system.

Each vehicle shall display one or more flashing amber warning lights, the combination of which results in visibility 360 degrees azimuthally around the vehicle. The warning light(s) shall operate when the vehicle is in E-stop RUN mode. The vehicle may not commence movement until the warning light(s) has been in operation for 5 seconds. The warning light(s) shall comply with SAE Class 1 standards for warning lights and shall not produce light(s) than can be confused with those of public safety vehicles such as law enforcement, fire, or ambulance.

Loss of Communications Stop

The system shall automatically halt and cease operations if communications with the system are lost or interrupted for a maximum of 2 seconds and may travel no farther than 30 meters.

No Freewheel

The systems shall not be capable of motion when stopped or un-powered.

For example, systems that would roll downhill if shut off are considered freewheeling and are un-safe for competition.

Speed Limit

The Camp Guernsey North Training Area speed limit is 30 MPH. Systems must comply with regulated speed limits.

Applicable Safety Documents

DA-PAM 385-10 Army Safety

EN 385-1-1

Radiated Energy Safety Standards

- Competitors are directed to OSHA 29 CFR 1926.54 and OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 6 (1999, January 20) for relevant laser safety standards.
- Competitors are directed to OSHA 29 CFR 1910.97 (Non-ionizing Radiation) and Department of Defense Instruction 6055.11 (1995, February 21) for relevant RF safety standards.
- Competitors are directed to OSHA 29 CFR 1910.95 (Occupational Noise Control) and OSHA Technical Manual (TED 1-0.15A), Section III - Chapter 5 (1999, January 20) for relevant acoustic safety standards.

Operational Activities

Exclusion Zone

While the robots are moving on the range no team personnel may be within 870 meters of the robot. This is intended to represent the surface danger zone of large munitions. In addition the command locations shall not have guaranteed direct line of sight to the operation sites.

No personnel on range

No team personnel may enter the range at any time without R2C2 Management Team and Range Safety Officer authorization. Violations will result in team member disqualification.

Area of Operation boundary

No system shall be more than 3 meters outside the perimeter of the area of operation (AO) or a penalty will be assessed (based on Army Form-144 REC). The AO boundaries will be defined in a SHAPE file provided to the competitor team.

Mapping data

All raw geophysical data is to be delivered to the R2C2 in the raw data format defined in Section 4 of Data Item Description (DID) MMRP-09-04.

This DID can be found at the following web site address:

http://www.hnd.usace.army.mil/oew/policy/dids/FY09_MMRP_DIDS/MMRP-09-004.pdf.

The data shall be provided by the competitor in two forms.

First the raw unfiltered geophysical data shall be provided after the conclusion of daily data gathering operations before departing the range. Next the competitor shall provide the raw data in a format where it has been merged with the navigation data. The raw geophysical data shall NOT be filtered in any manner.

Second, positioning data may be filtered and merged with positional data to produce what the competitor believes to be the best representation of where geophysical data

measurements were actually recorded. All such filtering must be documented in the metadata file(s) accompanying the geophysical data delivery. The merged data must be delivered to the R2C2 Oversight Team within 48 hours of the completion of the geophysical data collection.

Metrics

General Scoring

Competitors may choose to participate in all or some smaller combination of the 4 Performance Areas: (1) Vegetation Clearance, (2) Surface Debris Clearance, (3) Geophysical Mapping, and (4) Sub-surface Debris Clearance. Metrics and scoring methods will be discussed for each of the performance areas.

The overall philosophy of the scoring is that for each event, teams will begin with the maximum points for each category and will lose points as solutions fail to achieve the objective requirements. Each event is worth a maximum of 250 points and will be evaluated with three categories of metrics (system performance, level of human interaction, and man-hours to perform.) The metric and scoring breakdowns for each of these categories and how they apply to each event are described below.

Event and Competition Scoring

Each event is valued equally in the overall competition score, with each event worth 250 points. A team's overall competition score will be determined by the sum of the individual event scores for a maximum total of 1000 points.

Scores in individual events will be accumulated from evaluation of metrics in three categories.

Metrics Categories

Each event has three categories of metrics.

A. System task performance

System task performance metrics will address the objectives related to system performance specific to each event. Higher levels of performance will result in higher scores.

B. Level of human interaction

Level of human interaction metrics will address competition objectives related to encouraging higher levels of autonomy. Lower levels of human interaction will result in higher scores while higher levels of human interaction will result in lower scores.

C. Man hours to perform the task

The Man-hours to perform the task metric will address the competition objective of reducing manpower required to perform the tasks. As man-hours to perform a task or event remain low, points deducted will be low (resulting in a higher score). As man-hours to perform a task increase, via either increased personnel or increased task duration, points deducted will increase (resulting in a lower score).

Metrics Category Weights

Each metric category will have a different weight for each event score. The breakdown is as follows:

- A. System task performance (50%)
- B. Level of human interaction (40%)
- C. Man hours to perform the task (10%)

System Task Performance is the most important factor in the evaluation. Level of Human Interaction is significantly less important than System Task Performance. Man Hours to perform the task is significantly less important than Level of Human Interaction. Metric weighting is consistent across events.

Penalties in Scope of the Entire Competition

These are penalties that are assessed at the event level, but are the same for each event.

- A. Teams will be assessed a 50 point penalty each time a robot leaves the range perimeter or enters a no-go area on the range except when going to the pit area or disposal area.
- B. Team members will be disqualified from the competition for entering the 870 meters exclusion zone during robotic clearance operations.

Surface Damage

- A. The site will be divided into grid areas for assessment.
- B. Any surface damage will be measured. Depths greater than 15 cm will be penalized.
- C. Points will be deducted for any instance in a grid area.
- D. Maximum is one penalty per grid area.

Surface Grade

- A. A survey of a pre-determined set of points before and after operations will be conducted by R2C2. The survey points are notionally the corners of the range, where the gridlines would intersect the range boundary and where the gridlines would intersect on the range itself.
- B. Points will be deducted if the absolute value of the difference between each measurement from the survey points is more than 15 cm.

Tie-breaking Procedures

- A. Tie-breaking procedures are only invoked to determine an event or overall winner.
- B. In the event of a points tie the team with the fastest time will be the winner.
- C. In the event of a point and time tie then the solution with the greatest autonomy will be the winner.

System Task Performance Metrics

Vegetation Clearance

Vegetation Tree Removal (maximum 125 points)

- A. Scoring will be determined by measuring tree stumps on the event range. Teams will begin the event with 250 points. Points will be deducted for each tree or stump remaining greater than 8 cm above the surrounding grade.

- B. The vegetation removal score will be difference between 125 and the deductions.

Small Vegetation and Vegetation Residue Removal (maximum 125 points)

- A. The site will be divided into grid areas.
- B. Points will be deducted for each grid area where remaining vegetation or vegetation residue is greater than 15 cm.
- C. The small vegetation and vegetation residue removal score will be difference between 125 and the deductions.

Geophysical Mapping

Delivery of Raw data

Raw data should be provided to the judges immediately following the event. The merged data should be delivered to the R2C2 Oversight Team within 48 hours of the completion of the geophysical data collection. If the team does not deliver the merged data by the deadline, the score for the entire geophysical mapping event shall be zero.

Noise Level (70 Points)

- A. Using Oasis Montaj's QC tools determine the average level of RMS noise in the raw data.
 - a. Baseline noise will be determined by the R2C2 Competition Team.
- B. Score will be determined by the following

Noise Range	Points Awarded
Low RMS noise level	Most
Moderate RMS noise level	Some
High RMS noise level	Least

- C. Noise ranges to be determined.

Sensor Coverage (60 points)

- A. Score will be determined by the percent of the range covered.
- B. Score will be determined by the following
 Percentage of coverage multiplied by 60 points = Score
 Less than 95% coverage results in no points.

Anomaly Location Accuracy (60 points)

- A. Determine anomaly peak response locations using Oasis Montaj's UX-Detect automatic anomaly detection algorithm on the submitted merged data.
- B. Number detected scoring
 $(\# \text{ of Detections within } 30\text{cm of actual burial location} / \# \text{ seeded}) * 60 = \text{detection score}$

Survey Speed (60 points)

- A. Using Oasis Montaj, the point-to-point velocities will be calculated for all data collected.
- B. Scoring will be based on percentage of the data collected at the specified design speed.
 - a. Design speed will be determined by competitor team prior to event.
- C. The scoring will be determined by the following table:

Design speed range	Points
98% to 100% within + or - 0.3MPH of design speed:	60 points
95% to 98% within + or - 0.3MPH of design speed:	40 points
75% to 95% within + or - 0.3MPH of design speed:	20 points
50% to 75% within + or - 0.3MPH of design speed:	5 points
less than 50% within + or - 0.3MPH of design speed:	0 points

Surface Clearance

Surface Debris Removal (250 points)

Site will be seeded with material representing surface debris. The objective is to remove all seeded material and to place just the seeded material removed from the site into a designated collection area.

- A. Percent removed score
 - a. After surface clearance operations are complete, the site will be Quality Control (QC) swept to determine remaining seeded debris.
 - b. Percent removed score will be calculated as follows:
 - c. $(\text{Weight of seeded debris} - \text{Weight of QC pickup}) / \text{Weight of seeded} * 125$ points
- B. Pile cleanliness score
 - a. Pile cleanliness score will be calculated as follows:
 - b. Average pile percent clean * 125 points, where average pile percent clean is determined by sampling the collection pile and determining the percent of the pile that is seeded materials as a function of the total material in the samples.
- C. Surface debris removal score will be sum of percent removed score and pile cleanliness score.

Sub Surface Clearance

Sub-surface Debris Removal (250 points)

- A. Teams begin the event with 250 points
- B. Each competitor team will be given a set of dig coordinates
- C. Points will be deducted for each item not recovered and placed in the collection area.
- D. No sub surface item intended for removal will be at a depth greater than 1 meter.

Level of Human Interaction

Human Interaction, for the purpose of the R2C2, is defined as: any time an operator or team member uses any human-machine interface device such as, but not limited to, joystick, keyboard, or voice recognition software to control any machinery engaged in a competition task.

- A. Teams will begin each event with 250 points in this category.
- B. Competition team members will be observed by a R2C2 judge and will be filmed for reference.
- C. According to the professional judgment of a R2C2 robotics expert (judge), the Level of Human Interaction involved with the performance of the task of the total system will be determined according to the following table:

Percent Score	Description of Level of Human Interaction
100%	Near zero human interaction
75%	Minimal Interaction
50%	Moderate Interaction
25%	Frequent Interaction
0%	Continuous Interaction (completely tele-operated.)

- a. This judgment will account for number of operators and number of robotic systems.
- D. Scores will be computed by the percent score * 250 as a function of the level of human interaction judged to have been achieved by the expert judge.
- E. Complete tele-operated solutions will get zero points for this metric.

Man Hours to Perform the Task

- A. Defined as Total time to perform the task multiplied by the number of people on site.
 - a. The number of people on site will be defined as the number of people actively involved in the operation.
 - b. Team observers or spectators will be allowed, but any observers/spectators will not be allowed to interact with the competition team during the event.
- B. The R2C2 Range Manager will call start time after team captain indicates the team is ready.

- C. End time will be called when the competitor team captain says they have finished (and when the system has returned to the pit area) or when the time limit of the event is reached.
- D. Active team members will be designated by the team prior to the competition event and each member will receive identification (referred to as a “pit pass”) designating that status.
- E. Any team member without a pit pass who is deemed by the competition to be engaged in assisting the team during the event will be added to the team roster and will be included in the man-hours calculation.
- F. The robot must be in the pit area for the end of the exercise to be called prior to the expiration of the time limit.
- G. Event durations will be capped.
- H. “Phone a friend” does not count against man hours metric.
- I. Safety officer does not count against man hours.
- J. Score will be calculated as (man hours allotted (baseline) / man hours required) * 250 with a 250 point maximum.