IEEE RAS Micro/Nano Robotics & Automation (MNRA) Technical Committee

Mobile Microrobotics Challenge (MMC) 2018

OFFICIAL RULES

Version 1.0
October 6, 2017

1. THE EVENTS

The IEEE Robotics & Automation Society (RAS) Micro/Nano Robotics & Automation Technical Committee (MNRA) invites applications to participate in the 2018 Mobile Microrobotics Challenge, in which microrobots on the order of the diameter of a human hair face off in tests of autonomy, accuracy, and assembly. Teams can participate in up to three events:

1.) *Autonomous Manipulation & Accuracy Challenge:* Microrobots must autonomously manipulate micro-components around fixed obstacles to a desired position and orientation superimposed on the substrate. The objective is to manipulate the objects as precisely as possible to their goal locations and orientations in the shortest amount of time.

2.) *Microassembly Challenge:* Microrobots must assemble a planar shape out of multiple microscale components located in a confined starting region. This task simulates anticipated applications of microassembly for medical or micromanufacturing applications.

3.) *MMC Showcase & Poster Session*: Each team has an opportunity to showcase and demonstrate any advanced capabilities and/or functionality of their microrobot system. Each participating team will get one vote to determine the *Best in Show* winner.

Each competing team must furnish its own microrobots. Each microrobot must fit within a virtual cube that is 500 µm on a side, and conform to the requirements in Section 3. Equipment used to power, operate, and control the microrobotic devices must be furnished by the competing teams. Each team must set up their equipment for each challenge event within a 10-minute window, and must take down their equipment in 5 minutes. Detailed information on the setup to be used in the competition, including the microscope, camera, and allowable auxiliary equipment for the teams are in Sections 3 and 4. Each team must also furnish its own micro-arenas, which must conform to the requirements detailed in the Challenge descriptions below and in Section 2.

Autonomous Manipulation & Accuracy Challenge

Microrobots must autonomously manipulate different shaped micro-parts from a set starting orientation in a starting region, around fixed obstacles in the workspace to a goal location and orientation. The winner will be the team that can manipulate the different parts the fastest and most accurately to their goal configurations. The micro-arenas for this event will be furnished by the teams and will consist of a substrate with clearly defined boundaries and fixed obstacles (Fig.1). The goal configurations for the different parts are to be superimposed on the substrate during actuation. Three different shaped parts are to be manipulated: a rectangle, circle, and triangle. The parts can be manually placed anywhere in the starting area but they must be in the starting orientations as shown. Precise dimensioning of the arena and goal configurations for the parts are provided in Section 2.

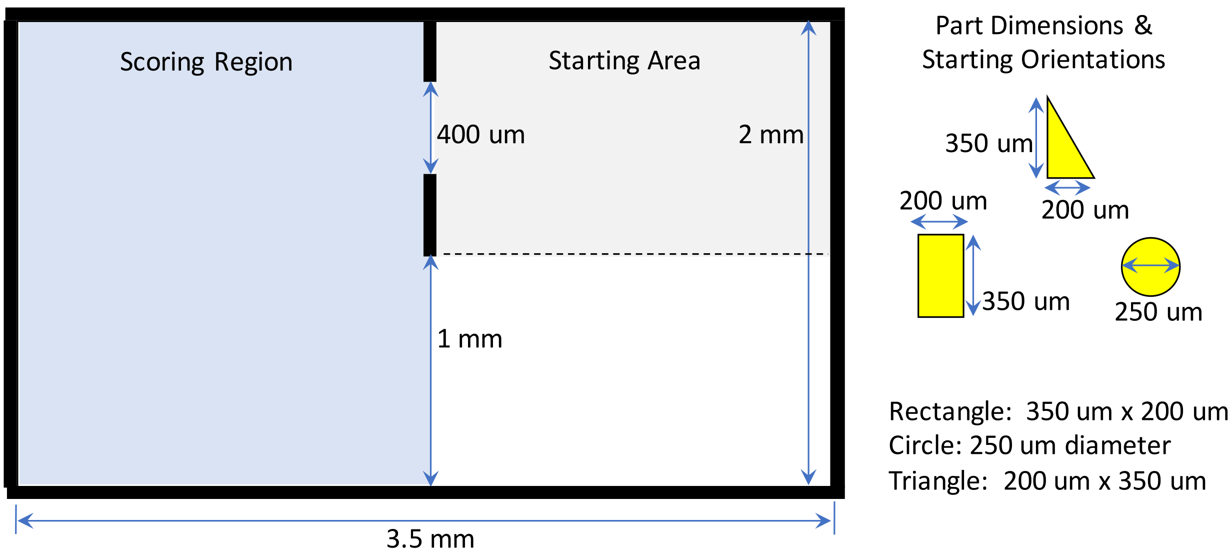
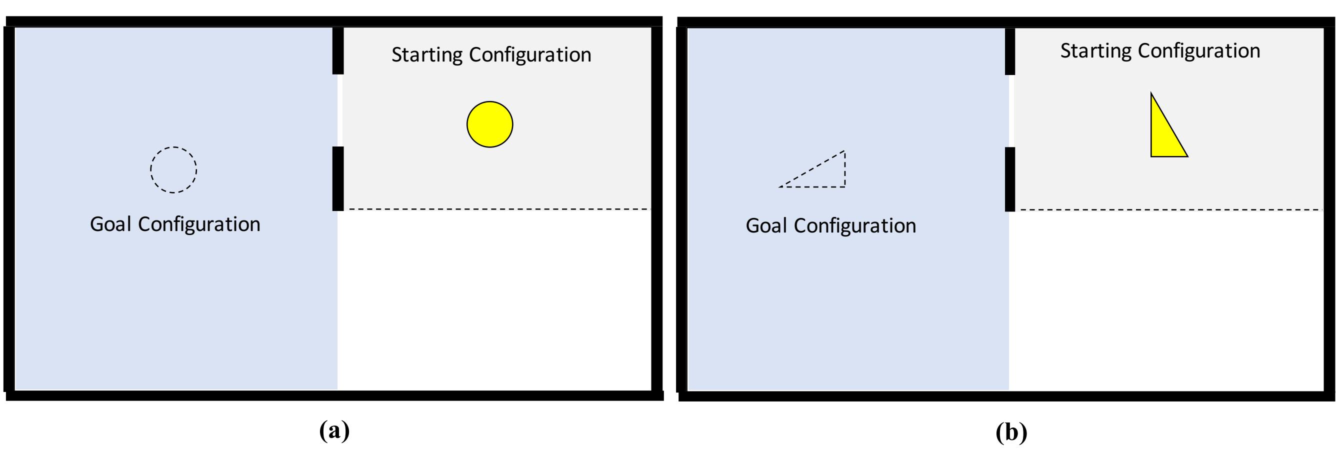
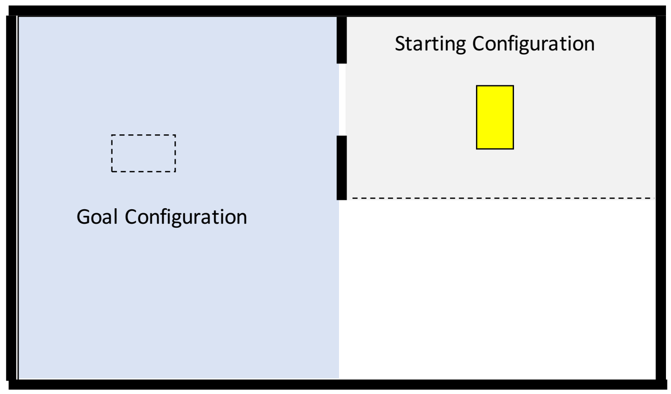


Figure 1. Autonomous Manipulation and Accuracy Challenge: Arena schematic; Part dimensions and starting orientations.

Each team will have 3 total trials to manipulate the parts to their goal locations and orientations, 1 trial for each part type. Each trial lasts 2 minutes. Once the trial begins, no human intervention is allowed. The parts goal configurations are shown schematically in Fig.2.





(c)

Figure 2. Schematics of part goal configuration and placement locations

Scores for each trial will be computed according to the equation below. The sum of all trial scores will be used to determine the winner, with the lowest score winning. Unsuccessful trials will be given a maximum score penalty. Successful trials are defined as trials that end with the entire manipulated part residing in the scoring (left side) region of the arena.

$$\text{Score} = \frac{D_{max}}{500}[time + error]$$

The factors in the equation are:

- D_{max}: the diagonal (in µm) across a rectangle that completely contains the footprint of the microrobot. (e.g. If the robot can be fully contained in a 500 µm x 500 µm footprint, then D_{max} $\sqrt{500^2 + 500^2}$= 707 µm).
- *time*: the duration from when the microrobot starts motion until it stops, during a single trial (in seconds). See "Event Timing" section for more details.
- *error*: this is the error in the x, y, and angular position of the part from the goal configuration. It is calculated as:

  $$error = \sqrt{(error\_x)^2 + (error\_y)^2} \cdot (error\_\theta)$$

  where the error in angle is measured in degrees. In the case of no error in angular orientation, error_θ is set to 1.

Microassembly Challenge

The arena for the Microassembly Challenge will consist of a 1.75 mm × 2 mm starting region, connected to a narrow channel having dimensions of 2 mm x 0.75 mm. A set of triangular microfabricated components is placed in the starting region with the microrobot(s). Upon the signal of the referee, the microrobot begins assembling the components into the far end of the channel. The trial ends after 2 minutes, or when the team informs the referee that they are done.

The assembly components are to be furnished by the competing teams, and must be in a right triangular shape. The long leg of the component must be 350 μm while the short leg must be 200 μm. The components can be no more than 500 μm high, and must be clearly visible with high contrast to the surrounding area under an epi-illuminated white light microscope.

Components have to be assembled against the assembly channel wall (far right) or against other components with line contact, i.e., edge-to-edge Components only assembled against the two assembly channel side walls do not receive a score (score of zero). In addition, components must be densely packed, so that no gap between components, or between components and the channel wall, is larger than 50 μm.

For example, in Figure 3 there are 4 densely packed components, earning a trial score of 4 points. If a trial ended with just the triangle labeled 1 densely packed against the right wall of the channel, a trial score of 1 will result. Alternatively, if just the triangles labeled 1 and 3 were in the positions shown, that is also a score of 1 since triangle 3 does not have line contact with the (right) assembly wall or triangle 1. However, if the trial results with only a single triangle in the assembly channel and not closely packed to any of the walls (like the position of the triangle labeled 5), the trial score would be zero.

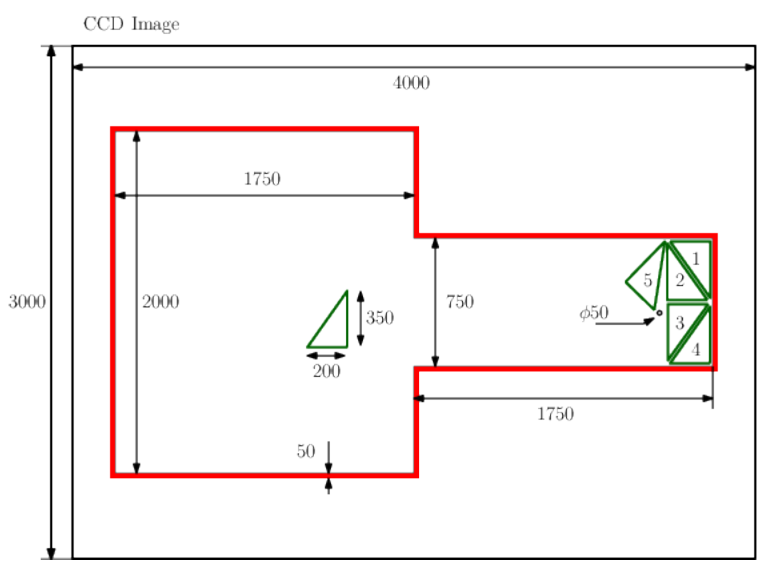


Figure 3. Arena dimensions in microns for the Microasembly Challenge. This particular final arrangement of assembly triangles will result in a trial score = 4.

Figure 4 shows two components assembled against the assembly channel wall. This configuration will receive a trial score of 1. This corresponds to having a triangle assembled against the right channel wall. However, since the two triangles are not edge-to-edge connected the second triangle does not count as being densely packed with the first.

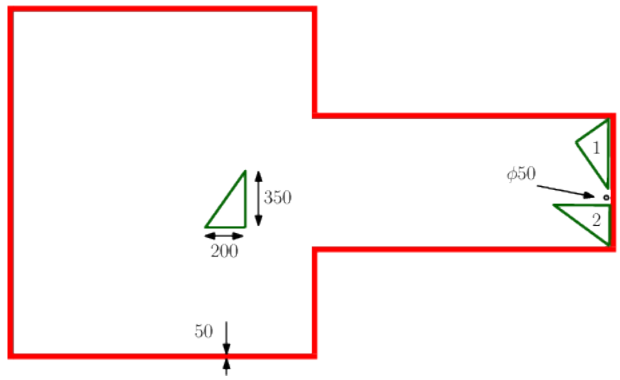


Figure 4. Microassembly trial final configuration resulting in a trial score = 1.

Figure 5 shows two components (3 and 4) assembled against the assembly channel wall and one component (5) assembled against a side wall. This would receive a score of 2 corresponding the placements of triangles 3 and 4. However, since triangle 5 is not edge-to-edge connected with the right assembly wall or to another triangle it does not count as being densely packed.

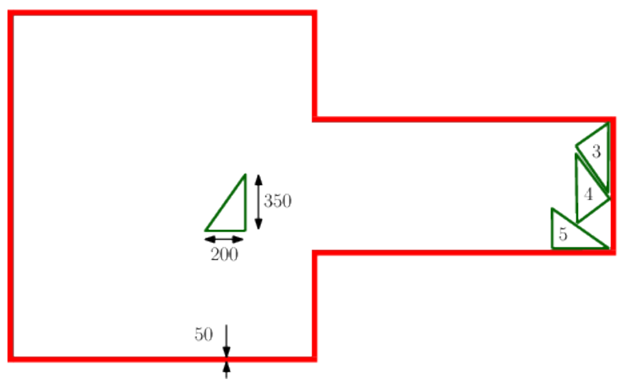


Figure 5. Microassembly trial final configuration resulting in a trial score = 2.

Any component that moves out-of-bounds during the course of the trial will be counted as a gap in its final position at the end of the trial. If a robot moves out-of-bounds during the course of the trial, the trial will be scored as a foul.

Any trial of the Microassembly Challenge that results in a foul will receive a trial score of 0. The microrobot's score for the event will be the mean of its trial score on each of three trials. Higher scores beat lower scores.

Event Timing

Each trial will begin upon a verbal signal from the referee, and will end either when the team informs the referee that the trial is complete, or when the maximum time has elapsed, whichever comes first. The maximum time for each trial is 2 minutes for each event. Teams need not use all the available time.

Teams will be responsible for recording video of each trial (see Section 4 for requirements). Competition video of each trial will be captured beginning approximately 3 seconds prior to the referee's verbal start signal. The elapsed time for each trial will begin at the last stationary video frame before the microrobot begins moving, provided that this frame occurs within 8 seconds of the first video frame. Otherwise, the elapsed time will be measured from the first video frame. The end of the elapsed time will be measured at the first stationary frame after the robot has ceased moving.

MMC Showcase & Poster Session:

Each team has an opportunity to showcase and demonstrate any advanced capabilities and/or functionality of their microrobot system. Each participating team will get one vote to determine the *Best in Show* winner.

2. THE ARENAS

The arenas will be provided by the competing teams, and must conform to the contest specifications described here. Arenas that are shown to not conform to these specifications will be disqualified from use in the competition. For this reason, teams are strongly encouraged to track all nominal dimensions as closely as possible to ensure their ability to compete.

It is recommended that arena boundaries be fabricated in such a way that they physically prevent microrobots and manipulated objects from going out-of-bounds, in order to avoid fouls.

Autonomous Manipulation & Accuracy Challenge Arena Dimensions

Any arena used for the Autonomous Mobility & Accuracy Challenge must be a flat rectangular surface nominally 2 mm in width by 3.5 mm in length. The height of the surface must vary by no more than 500 µm across its area. The boundary sidewalls that enclose the arena and obstacle walls in the arena should have a nominal width of 50 µm, with a tolerance of ±10 µm. These should be physical structures visible under the microscope. The important arena dimensions are shown in Fig. 6. The part dimensions and also shown in this figure along with the goal configurations in the arena.

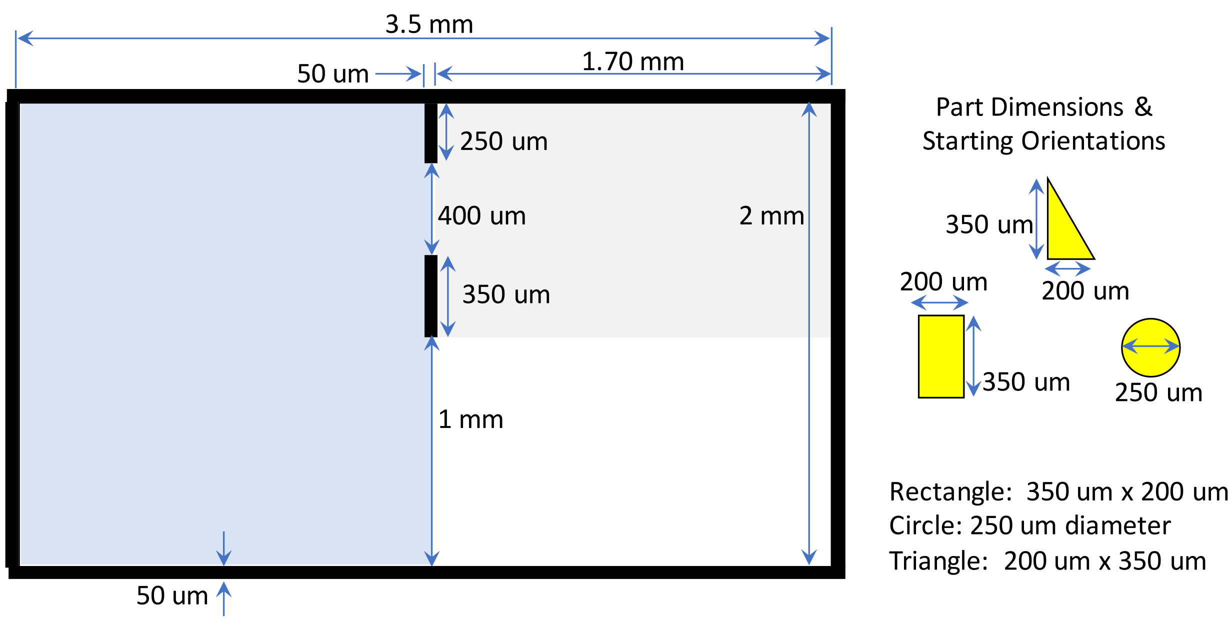


Figure 6: Arena and part dimensions for the Autonomous Manipulation & Accuracy Challenge

The goal configurations should be clearly superimposed on the recorded/collected image and visible during each trial. Their dimensions are shown in Fig.7.

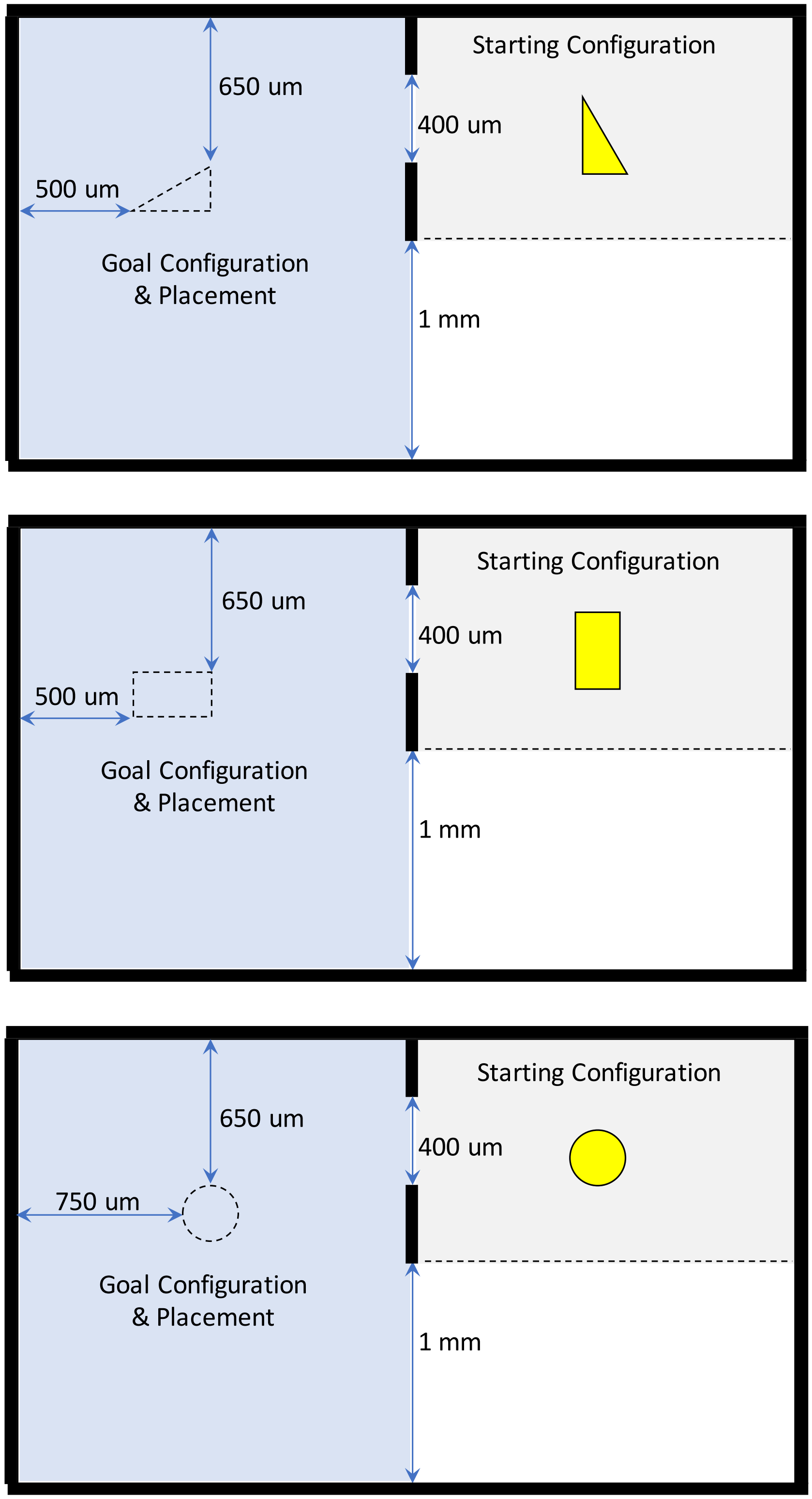


Figure 7. Goal configuration and placement locations for parts

Microassembly Event Arena Dimensions

Any arena used for the Microassembly event must be a flat rectangular surface nominally 4 mm in length by 3 mm in width. The height of the surface must vary by no more than 1 mm across its area.

Boundary lines should have a nominal width of 50 µm, and must be between 40 µm and 60 µm wide. Boundary lines must be clearly visible with high contrast to the surrounding area under an epi-illuminated white light microscope. The length of the arena will be divided into two regions, having nominal lengths of 1.75 mm. The left-hand region defines the allowable starting area for the microrobot and assembly components, and the right hand region defines the channel in which the components must be assembled. Boundary sidewalls for both regions should have a nominal width of 50 µm, with a specified tolerance of ±10 µm. The dimensions of the arena do not include boundary lines. Specified dimensions are as follows:

Length of Arena	3500 µm ± 35 µm
Length of Starting Region	1750 µm ± 20 µm
Width of Starting Region	2000 µm ± 20 µm
Length of Assembly Channel	1750 µm ± 20 µm
Width of Assembly Channel	750 µm ± 10 µm
Width of Boundary Lines	50 µm ± 10 µm
Length of Triangular Component Long Leg	350 µm ± 10 µm
Length of Triangular Component Short Leg	200 µm ± 10 µm

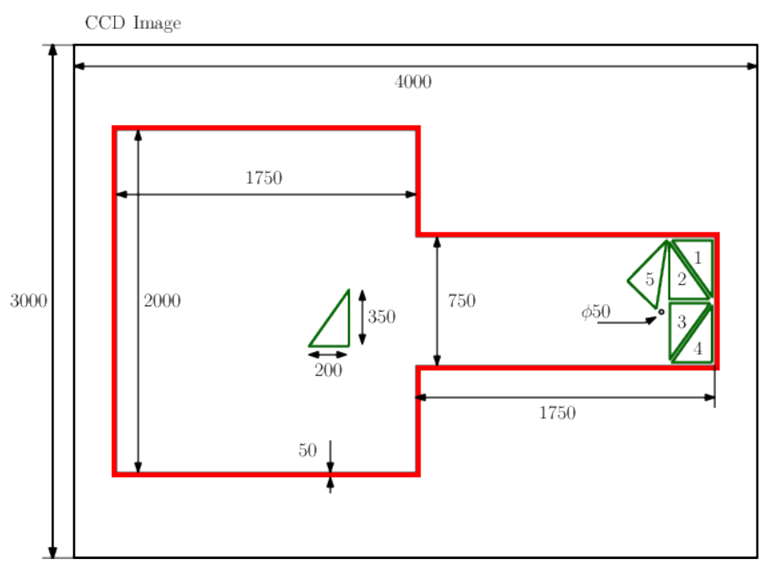


Figure 8: Arena Dimensions (in microns) for the Microassembly event

3. THE MICROROBOTS

Safety
Microrobots are to be provided by the competing teams. Microrobots and any associated equipment must not pose a danger to contest participants, spectators, or contest equipment. Any participating team whose equipment is deemed to be unsafe will be disqualified from the contest until such time as it can demonstrate to the contest organizers that the safety hazard has been eliminated.

Dimensions
At the start of each event, the entire microrobot must fit within a virtual cube that is 500 μm on a side with two faces parallel to the arena. The microrobot may separate or expand outside of this volume as necessary once the event has begun.

It is the team's responsibility to demonstrate compliance with the size requirement, and conservative choice of microrobot size is recommended. Teams can demonstrate compliance by imaging their micro-robot with its longest dimension perpendicular to the optical axis, provided that it can be shown that the longest dimension is perpendicular to within 5 degrees. A suitable size reference should be present in the image. It is also acceptable to image the microrobot in its operating orientation, and determine the peak height using a focal distance measurement.

Control Systems
A robotic system may include a machine vision subsystem. Power and instructions may be provided to the robot through any means that do not physically tether the microrobot. Off-board computers may be used to process data generated by these systems, and to generate signals to the microrobots and the competition timing system.

Auxiliary Equipment
The microrobotic system may include auxiliary equipment to control the ambient environment of the microrobot, to perform off-board computation, to generate electromagnetic signals, or for other necessary functions.

Manipulation of Objects
Only the microrobot is allowed to manipulate objects within the arena during the competition events. If an object is manipulated by any other means during any event trial, the trial will be scored as a foul.

4. MICROROBOT IMAGING

Microscope and Camera Setup
Each team should provide their own microscope and camera setup. The microrobots and the arenas must be clearly visible at all times. The camera must have a sufficiently wide field-of-view to image the entire arena area. The camera should have a resolution of at least 1024 pixels

by 768 pixels, and a frame rate of 30 fps or greater. Each team must have a way of recording the camera video feed during competition trials, and will be requested to provide the recorded videos to the competition judges via USB drive or portable hard drive. Each team must also output the live feed of the camera to a computer projector during the trials runs, using a VGA projector input.

5. The Referee

The Authority of the Referee

Each trial will be controlled by a referee who has full authority to enforce these rules and award scores to competitors.

Powers and Duties

The referee:

- Enforces these rules.
- Controls each trial in cooperation with any assistants.
- Starts each trial as described in these rules.
- Stops a trial if a situation is deemed to be unsafe to participants.
- Stops a trial if a situation is deemed to be unsafe to spectators.
- Stops a trial if a situation presents a hazard to competition equipment.
- Stops a trial if competition equipment is not operating correctly.
- Assigns scores for each trial, and for each event.

All decisions of the referee are final.

6. Qualification

Teams intending to compete in the RAS MNRA Mobile Microrobotics Challenge must qualify by:

1. Submitting a written proposal to participate.
2. Submitting video demonstrating controlled microrobot motion as identified below.

To apply to the RAS MNRA Mobile Microrobotics Challenge, submit a proposal by **December 15th, 2017**. The proposal may be submitted by electronic mail to:
RAS_MMC_Organizers@googlegroups.com

The proposal must identify:

1. The individuals contributing to the team.
2. E-mail, telephone, and postal contact information for one individual who will serve as a Primary Contact.
3. The facilities available for fabrication, operation, and characterization of microrobots.
4. An overview of the microrobot design.

5. An overview of the intended capabilities of the microrobot.
6. An overview of the fabrication process to be used.

The purpose of the proposal is to convince the contest organizers that the team has a credible plan for bringing operational microrobots to the competition. Proposals will not be shared outside of the event organizers before the competition without express permission of the Primary Contact. After the competition, all proposals may be shared with others at the organizer's discretion, and may be used by the organizers for publicity or other purposes. Proposals will be accepted or rejected by **December 31st, 2017.**

Video Submission

Teams whose proposals are accepted must qualify for live competition by submitting a short video that demonstrates the functionality of their microrobotic system. Videos must be submitted by **February 16th, 2018.** Videos may be submitted by e-mail or by posting on an accessible web location controlled by the team. Videos submitted by electronic mail must be no more than 5 Mb in size.

The qualification video must show the team's microrobot performing the following task:

Autonomous Manipulation Task: The microrobot must autonomously manipulate one of the micro-parts from the starting area to the scoring region in the arena following the rules described in the *Autonomous Manipulation & Accuracy Challenge* task description. The part must be traversed on an arena meeting the competition specifications. Videos must be time stamped showing that the traversal is completed in less than 2 minutes. The robot must be controlled autonomously. A sample goal configuration must be superimposed on the video. The qualification video must be accompanied by a demonstration that the microrobot meets the dimensional requirements listed in the official rules.

Teams invited to compete in the 2018 Microrobotics Challenge will be selected based on the video submissions and notified by **March 1st, 2018**. Microrobotic systems shown completing more competition tasks will be selected prior to those completing a lower number of competition tasks.

Travel Funds

In past years, the National Science Foundation in the USA has provided funding to support the travel costs of up to two participants for each qualifying US team. The funds covered the ICRA registration, hotel stay, and transportation (airfare). Students from all US-based institutions are eligible. We are hoping to arrange for the same travel funding this year. Stay tuned for information if/when travel funds are available and if so, how to get reimbursed. Typically, students submit receipts for all reimbursable costs to the competition organizers to be eligible for reimbursement. Teams from other countries have also received travel support from their home organizations, and we encourage every team to pursue local sources of funding for this event.