

# **NIST Mobile Microrobotics Challenge 2010**

## **Official Rules**

**Version 2.2**

**January 6th, 2010**

### **1. THE EVENTS**

#### Events Overview

The 2010 NIST Mobile Microrobotics Challenge will consist of three events:

1. The Two Millimeter Dash
2. Microassembly
3. Freestyle Competition

In the Two Millimeter Dash, a microrobot must traverse a distance of two millimeters in as short a time as possible. The Microassembly event requires a microrobot to insert tiny pegs into microscopic holes. The Freestyle Competition allows teams to highlight the capabilities of their microrobotic technologies by performing a task of their own design.

Microrobots used in the events must be furnished by the competing teams, and must fit within a 600- $\mu\text{m}$ -diameter sphere. Further requirements on the microrobots are listed in Section 3.

The micro-arenas in which the contests take place must also be furnished by the competing teams, and must conform to requirements listed in Section 3.

Equipment used to power, operate, and control microrobotic devices must be furnished by the competing teams, and must interoperate with the competition equipment as described in Section 2. Each team must set up their equipment for each event within a 15 minute window, and must take down their equipment in 5 minutes.

#### The Two Millimeter Dash

The arena for the Two Millimeter Dash will consist of a 3.5 mm  $\times$  2 mm region in which an unobstructed raceway lies between a starting line and a finish line. (See Section 2 for a full description.) The team will place a microrobot so that its entire body lies behind the starting line. Upon the signal of the referee, the microrobot will sprint to the finish, and come to a complete stop in a position where its entire body is past the finish line. The

trial is complete when the microrobot has come to a complete stop as identified by two consecutive frames of a competition-supplied digital camera. If the microrobot does not complete the task within 2 minutes, the referee will award a foul. Failing to come to a complete stop within the boundaries of the arena will result in a foul. Each team will perform three trials of the two-millimeter dash.

The microrobot's **finish time** for a trial of the two millimeter dash is measured with digital video at 100 fps or greater. The time will be measured from the last frame in which the microrobot is stationary after the referee's start signal to the first stationary frame after the robot has crossed the finish line.

If a microrobot moves out-of-bounds during the trial (see Section 2), the trial will be scored as a foul.

The microrobot's **score** for the event will be the root mean square of its finish times on each of the three trials. Lower scores beat higher scores.

Any trial of the Two Millimeter Dash that results in a foul will be assigned a finish time of 2 minutes.

## Microassembly

The arena for the Microassembly event will consist of a 3.5 mm × 2 mm region with an unobstructed raceway as in the Two Millimeter Dash, above. A set of microfabricated pegs are placed in the center of the raceway, and the microrobot begins at one end, behind a starting line. The far boundary of the raceway contains holes into which the microrobot must insert the pegs. Upon the signal of the referee, the microrobot retrieves the pegs and inserts them into the holes at the opposite end of the raceway. The trial ends after three minutes, or when the team informs the referee that they are done.

The pegs are to be furnished by the competing teams, and must have a shape consisting of two nominally equal-sized rectangles, with the short end of one rectangle centered on the long end of the other as shown below. Each rectangle should have a nominal length equal to twice its width. The shape, when viewed from above, forms a "pin and cap" configuration where the overall length of the peg is nominally 3/2 the width of the cap. The pegs must have a height less than 500 micrometers, and they can be any size so long as their largest dimension is no larger than 600 micrometers.

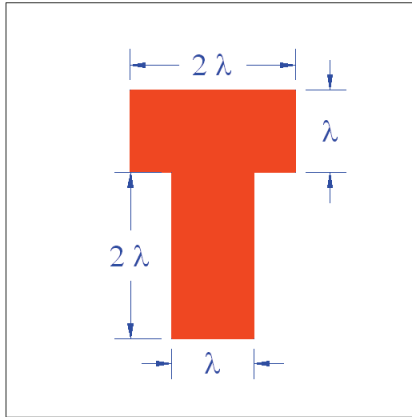
Nominal dimensions for the pegs are scaled to the width of the pin as follows:

Pin Width:  $\lambda$

Pin Length:  $2\lambda \pm 0.2 \lambda$

Cap Width:  $2\lambda \pm 0.2 \lambda$

Cap Length:  $\lambda \pm 0.1 \lambda$



**Dimensions for pegs in the Microassembly drill.**

The holes into which the pegs will be inserted must be located in the rightmost border of the arena, as described in Section 2, and should have a nominal width of  $1.3 \lambda$ . The width of each hole must be no greater than  $1.4 \lambda$ .

The microrobot's **trial score** is the number of pegs that are fully inserted into holes at the end of the trial. A peg is considered to be fully inserted if its cap touches the boundary of the hole on both sides of the pin. Any peg that moves out-of-bounds during the course of the trial will not be counted toward the trial score. If the robot moves out-of-bounds during the course of the trial, the trial will be scored as a foul.

Any trial of the Microassembly event that results in a foul will receive a trial score of 0.

The microrobot's **score** for the event will be the quadratic mean of its three trial scores. Higher scores beat lower scores.

## Freestyle Competition

The arena used for the freestyle competition can be designed by the each competing team to meet the unique requirements of its own microrobots, but must fit within a  $3 \text{ mm} \times 4 \text{ mm}$  rectangle. Within this area, the team's microrobots will perform a task of the team's own choice and design that highlights the system's reliability, level of autonomy, power management, and task complexity. The maximum time allowed for each team to perform the selected task is five minutes. Only one trial will be performed per team.

The freestyle competition will be scored by a team of four judges, each responsible for evaluating one of four key elements of the task performance:

- System Reliability
- Level of Autonomy
- Power Management
- Task Complexity

Teams may present each judge with a one-page description of their chosen task and technology. This description page may be different for each judge. The description page must be no longer than one  $8.5'' \times 11''$  page.

Each judge will evaluate his or her assigned element of the task performance on a scale of 1 to 10, with higher numbers beating lower numbers. The team's **element score** will be the value assigned by the judge responsible for that element.

The team's **score** for the event will be the arithmetic mean of its four element scores.

## **Event Timing**

Each trial will be filmed using a digital camera at 100 fps or greater. The 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. When the trial has ended, the referee will stop the camera. The maximum time for each trial of the Two Millimeter Dash is 2 minutes, the maximum time for each trial of the Microassembly event is 3 minutes, and the maximum time for the Freestyle Competition is 5 minutes. Teams need not use all the available time.

The elapsed time for each trial will be measured from the last stationary video frame before the microrobot begins moving until the first stationary frame after the robot has ceased moving. If the trial ends before the robot has ceased moving, the elapsed time will be measured from the last stationary frame before the robot begins moving to the last collected frame.

## **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.

### **Two-Millimeter Dash Arena Dimensions**

Any arena used for the Two-Millimeter Dash must be a flat rectangular surface nominally 3.5 mm in length by 2 mm in width. The height of the surface must vary by no more than 500 micrometers across its area.

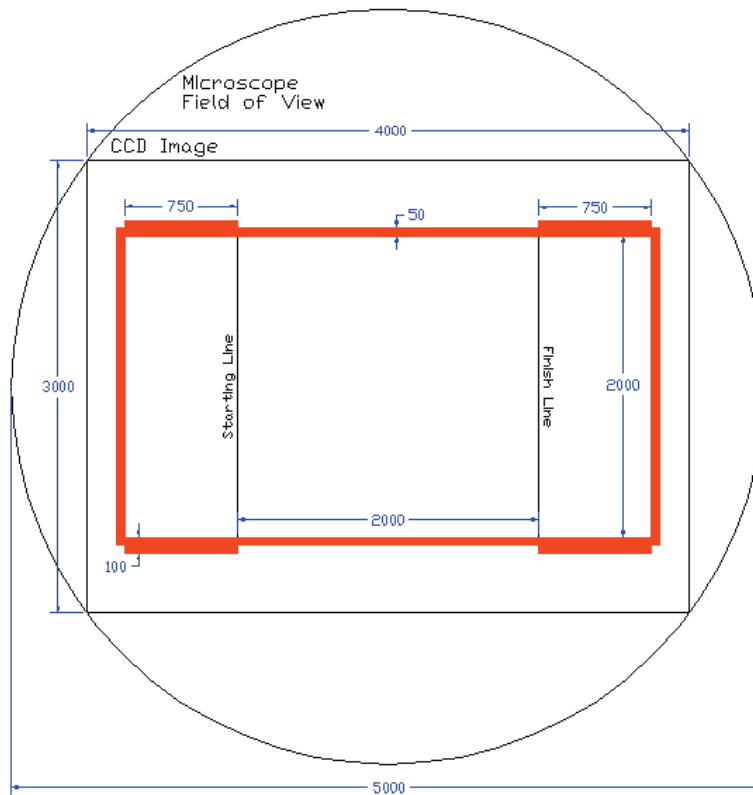
Boundary lines should have a nominal width of 50 micrometers, and must be between 40 micrometers and 60 micrometers wide, except where varied to define regions described here. Boundary lines must be clearly visible with high contrast to the surrounding area under an epi-illuminated white light microscope.

The length of the arena will be divided into three regions by a starting line and a finish line, such that the distance from the start to the finish is 2 mm, and the distance behind the starting line is 750 micrometers.

The regions behind the starting line and beyond the finish line must be marked by boundary sidewalls (“marker lines”) having a nominal width of 100 micrometers, with a specified tolerance of  $\pm 10$  microns.

The dimensions of the arena do not include boundary lines. Specified dimensions are as follows:

|                                     |                                       |
|-------------------------------------|---------------------------------------|
| <b>Length of Raceway:</b>           | $2000 \mu\text{m} \pm 20 \mu\text{m}$ |
| <b>Width of Raceway:</b>            | $2000 \mu\text{m} \pm 20 \mu\text{m}$ |
| <b>Length Behind Starting Line:</b> | $750 \mu\text{m} \pm 20 \mu\text{m}$  |
| <b>Length Beyond Finish Line:</b>   | $750 \mu\text{m} \pm 20 \mu\text{m}$  |
| <b>Width of Boundary Lines:</b>     | $50 \mu\text{m} \pm 10 \mu\text{m}$   |
| <b>Width of Marker Lines:</b>       | $100 \mu\text{m} \pm 10 \mu\text{m}$  |



**Arena Dimensions for the Two Millimeter Dash**

### Microassembly Event Arena Dimensions

Any arena used for the Microassembly event must be a flat rectangular surface nominally 3.5 mm in length by 2 mm in width. The height of the surface must vary by no more than 500 micrometers across its area.

Boundary lines should have a nominal width of 50 micrometers, and must be between 40 micrometers and 60 micrometers wide, except where varied to define regions described

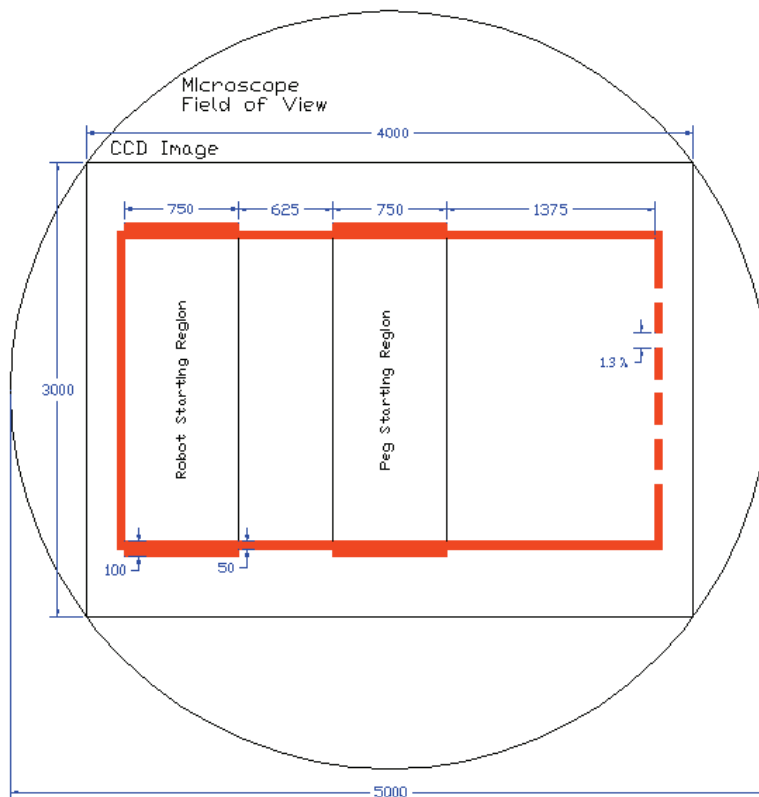
here. Boundary lines must be clearly visible with high contrast to the surrounding area under an epi-illuminated white light microscope.

The length of the arena will be divided into four regions, having nominal lengths of (in left-to-right order) 750 micrometers, 625 micrometers, 750 micrometers, and 1375 micrometers. The leftmost region defines the allowable starting area for the microrobot, and the third region defines the allowable starting area for the pins.

The first and third regions must be marked by boundary sidewalls (“marker lines”) having a nominal width of 100 micrometers, with a specified tolerance of  $\pm 10$  micrometers.

The dimensions of the arena do not include boundary lines. Specified dimensions are as follows:

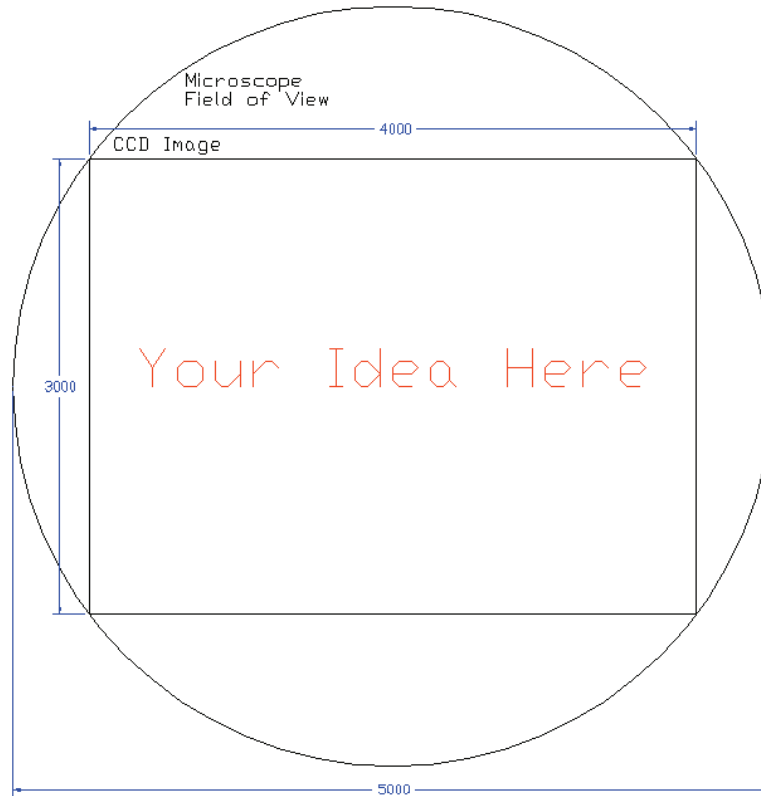
|                                 |   |
|---------------------------------|---|
| <b>Length of Arena:</b>         | $3500 \mu\text{m} \pm 35 \mu\text{m}$       |
| <b>Width of Arena:</b>          | $2000 \mu\text{m} \pm 20 \mu\text{m}$       |
| <b>Length of Region 1:</b>      | $750 \mu\text{m} \pm 20 \mu\text{m}$        |
| <b>Length of Region 2:</b>      | $625 \mu\text{m} \pm 20 \mu\text{m}$        |
| <b>Length of Region 3:</b>      | $750 \mu\text{m} \pm 20 \mu\text{m}$        |
| <b>Length of Region 4:</b>      | $1375 \mu\text{m} \pm 20 \mu\text{m}$       |
| <b>Width of Boundary Lines:</b> | $50 \mu\text{m} \pm 10 \mu\text{m}$         |
| <b>Width of Marker Lines:</b>   | $100 \mu\text{m} \pm 10 \mu\text{m}$        |
| <b>Width of Peg Holes:</b>      | $1.3 \lambda$ , not to exceed $1.4 \lambda$ |



**Arena Dimensions for the Microassembly event**

## Freestyle Competition Arena Dimensions

Any arena used for the Freestyle competition must fit within a 3 mm × 4 mm rectangle. The height of the arena surface must vary by no more than 500 micrometers across its area.



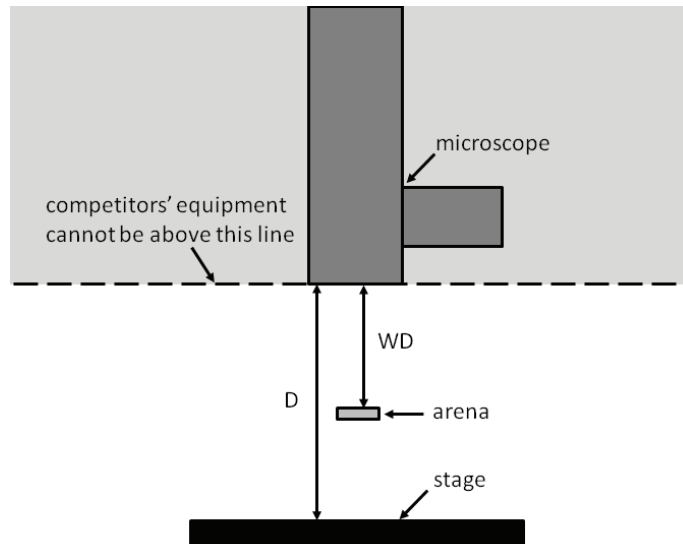
**Arena dimensions for the Freestyle competition**

## THE OPTICS

### The Microscope

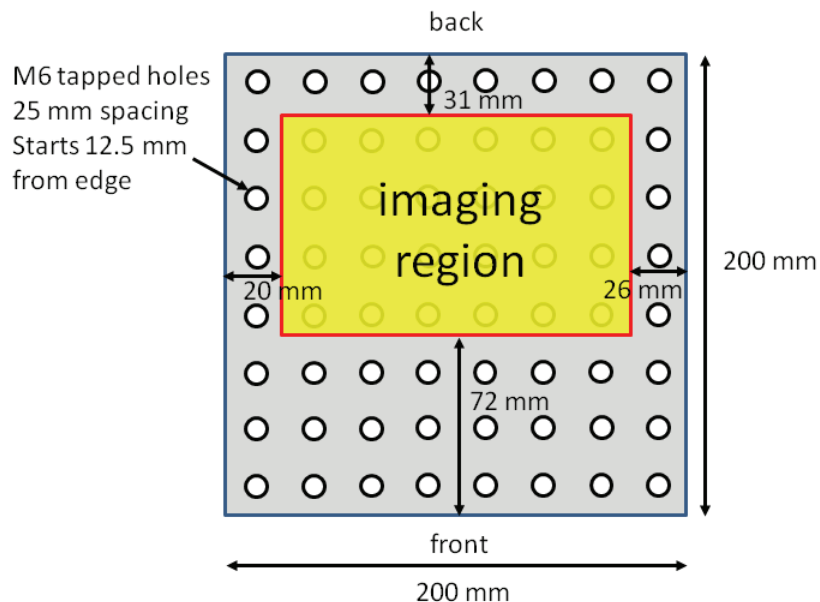
An upright microscope is used to observe the motion of the microrobots and provide visual feedback for closed-loop control. The microscope is a simple zoom microscope with a magnification range of 0.58X to 7X. It is mounted on a microscope stand, which consists of a base and a post on which the microscope is attached. A manual XY motion stage is mounted on the base and sits below the microscope. Competitors' equipment must conform to the dimensions and specifications for the microscope, as outlined here.

The working distance, WD, of the microscope is approximately 95 mm. The distance between the bottom of the microscope and the motion stage, D, has the following range:  $95 \text{ mm} < D < 300 \text{ mm}$ . These parameters are shown on the following figure. All equipment used by the competitors must be sit below the bottom of the microscope to avoid interaction with the microscope.



**Front view schematic of the microscope and microscope stage**

The top plate on the motion stage measures 200 mm wide and 200 mm deep and has an array of tapped M6 holes for mounting equipment (see following figure). Arenas, associated packaging and actuation hardware should be attached to this top plate with M6 screws. Mounted hardware may not protrude past the back edge but it can protrude over the other three edges. Based on the range and kinematic constraints of the motion stage, an imaging region has been mapped out, as shown in the following figure. Teams must ensure that their arenas sit in this region so that the microrobots can be observed during the competition.



**Top view schematic of the microscope stage with a highlighted area indicating the region in which samples can be imaged**

The first two events will be observed with a magnification of 1.5X. When using a ½” CCD camera with 1392 x 1040 pixels the field of view is approximately 4.1 mm W x 3.2 mm H and the pixel resolution is 2.95 μm/pixel. At the lowest magnification (0.58X) the field of view is approximately 10.66 mm W x 7.5 mm H. The field of view for the third event will set according the size of the associated arena.

### The Camera

Each team will provide its own camera system as needed for machine vision capability. The camera must be compatible with the C-mount on the microscope and it should have a ½” sensor (CCD or CMOS) so that the field of view is the same for the competition camera and the team camera. The camera must weigh no more than 1 kg.

## **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 600-μm-diameter sphere. The microrobot may separate or expand outside of this volume as necessary once the event has begun.

### Control Systems

A robotic system may include a machine vision subsystem to be mounted on the competition microscope. Power and instructions may be provided to the robot through any means that does 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. This equipment must fit either on the stage of the competition microscope, or to the side of the microscope. Equipment placed on the microscope stage must fit in a box 25 cm long by 25 cm wide by 15 cm high. Equipment placed to the side of the microscope must fit in a box 80 cm long by 80

cm wide by 50 cm high. The nearest edge of the available area to the side of the microscope will be no more than 150 cm away from the microscope stage. Connections between these two areas may be made with tubes and wires whose combined cross section does not exceed 25 cm<sup>2</sup>.

## 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. 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.
- Collects element scores from judges in the Freestyle competition.
- Assigns scores for each trial, and for each event.
- Provides a report of each trial to the Technical Committee, to include trial times, scores, and any disqualifications.

All decisions of the referee are final.

## **5. QUALIFICATION**

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

1. Submitting a written proposal to participate.
2. Submitting video demonstrating microrobot mobility.

### Team Proposals

To apply to the NIST Mobile Microrobotics Challenge, submit a proposal by **January 15th, 2010**. The proposal may be submitted by electronic mail to [microrobotics2010@nist.gov](mailto:microrobotics2010@nist.gov), or by post to:

NIST Microrobotics Challenge, 2010  
c/o Craig McGray  
National Institute of Standards and Technology  
100 Bureau Dr., MS 8120  
Gaithersburg, MD 20899

The proposal must identify:

1. The individuals contributing to the team.
2. Contact information for exactly 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 organizers' discretion, and may be used by the organizers for publicity or other purposes.

Proposals will be accepted or rejected within two weeks of receipt.

## Video Submission

Teams whose proposals are accepted must demonstrate satisfactory progress on developing their microrobotic system by submitting a short video of their microrobot in motion. Videos must be submitted on CD or DVD to the address above by April 15<sup>th</sup>, 2010.

These qualification videos will not be shared outside of the event organizers before the competition without express permission of the Primary Contact. After the competition, qualification videos become the property of the National Institute of Standards and Technology.