



# MESA USA NATIONAL ENGINEERING DESIGN COMPETITION

**2011-2012**

## **Prosthetic Arm Challenge (Pilot Version)**

### **CALIFORNIA ADDENDUM**

With the exception of the following, all the specifications in the document will be followed.

**Construction and Repair 1** (page 7): Teams WILL consider the cost of shipment of device to the local events. Teams MUST design their device to be disassembled for shipment in a large suitcase(s).

**Project Labeling** – Prosthetic Arm Challenge device and the Itemized Budget Sheet must be clearly labeled with student(s)' names, school and MESA Center.

A 25 point penalty will deducted from total score if either of the above is not properly labeled.

All other testing rules will still apply.

To preserve the integrity and the spirit of the competition, judges of the performance device of the Prosthetic Arm Challenge may ask questions of any student team competitors pertaining to the building of their device to validate the authenticity of their work. Failure to validate the work turned in may result in zero points for device performance.



**MESA USA  
NATIONAL ENGINEERING DESIGN COMPETITION  
2011-2012**

**Prosthetic Arm Challenge  
(Pilot Version)**

**MESA USA Code of Sportsmanship**

During the course of this event, MESA students, staff, advisors and supporting family members will be expected to act in a professional and courteous manner at all times. All judges' decisions are final. Staff, advisors and parents shall not engage judges during the event.

**Contents**

Competition Overview.....	2
Device Performance	
- Objective .....	3
- Materials.....	3
- General Rules .....	3
- Test Configurations and Equipment.....	4
- Task Details.....	5
- Construction and Repair.....	7
- Safety.....	7
- Inspection, Impound and Operation .....	7
- Measurement Equipment.....	7
- Assigning Scores to Performance.....	8
Scoring Criteria	
- Inspection and Performance Datasheet .....	10
Attachments	
- Itemized Budget Sheet.....	11
- Writing Sample.....	13
Resource Materials	
- Activity Feedback Form.....	14

**MESA USA**  
**NATIONAL ENGINEERING DESIGN COMPETITION**  
**PROSTHETIC ARM CHALLENGE (Pilot Version)**  
**2011-2012**



**Competition Overview**

MESA USA presents the engineering design competition specifications for the 2011-2012 year. As this is the *pilot year*, the specifications are used by staff and teachers as a baseline from which to evaluate and recommend improvements. The Prosthetic Arm Challenge involves the development of a low-cost prosthetic device to complete the pre-defined tasks. Device performance will be the only element judged during the pilot year.

1

**Performance** – Teams will research, design, build, test and compete using a prosthetic device designed to mimic the movement of the wrist, hand and fingers. Performance will be judged as it relates to the following tasks:

- a) Strength Efficiency Relay: greatest strength-to-mass ratio (total mass carried by the device divided by the mass of the device).
- b) Object Relocation Task: greatest number of olives moved and placed in an elevated can.
- c) Dexterity Task: greatest number of characters written within the character boundaries.

Middle school teams will compete in tasks “a” and “b”. High school teams will compete in all three tasks.

Each competing team must consist of 2-4 students who are active members of a MESA center program in a MESA USA state. Individual states should encourage their respective teams to participate in all performance components at the statewide level. Individual states will determine the dates and location of their respective events.

There will not be a national event for this design in 2011-2012. The first national event for this design is scheduled to occur in June 2013. Feedback and comments are welcome; please use the attached *Activity Feedback Form*.

**Scoring Summary**

Final team rankings will be based on the total score which is derived by adding all of the task scores.

**Technical Paper – Academic Display – Oral Presentation** – Not included for 2011-2012

<b>Middle School:</b>		<b>High School:</b>	
Strength Efficiency Relay	75 points	Strength Efficiency Relay	50 points
Object Relocation Task	75 points	Object Relocation Task	50 points
		Dexterity Task	50 points
<hr/>		<hr/>	
Total Points	150 points	Total Points	150 points

**Acknowledgement:**

MESA USA would like to thank Dr. Suzanne Olds, the VaNTH Engineering Research Center for Bioengineering Educational Technologies, and Northwestern University for allowing MESA USA to use the “Get A Grip!” curriculum as an inspiration and example for the development of these specifications.



**2011-2012 MESA USA  
National Engineering Design Competition  
Prosthetic Arm Challenge - Pilot  
Device Performance  
150 points**

### Objective

Teams will build a low-cost Prosthetic Arm for Laila, a fictional 12-year old girl living in Afghanistan who has had her arm amputated below the elbow. The device should be designed to be low-cost and easily maintained given a limited amount of resources and ability to maintain complex modern prosthetics. The device must meet the criteria outlined in the rules and be designed to perform the following tasks:

- | Middle School                                                                                                                                             | High School                                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| (1) Strength Efficiency Relay:<br><u>greatest</u> strength-to-mass ratio (total mass carried by the device divided by the mass of the device). (2 trials) | (1) Strength Efficiency Relay:<br><u>greatest</u> strength-to-mass ratio (total mass carried by the device divided by the mass of the device). (2 trials) |
| (2) Object Relocation Task:<br><u>greatest</u> number of olives moved and placed in an elevated can. (2 trials)                                           | (2) Object Relocation Task:<br><u>greatest</u> number of olives moved and placed in an elevated can. (2 trials)                                           |
|                                                                                                                                                           | (3) Dexterity Task:<br><u>greatest</u> number of characters written within the character boundaries. (2 trials)                                           |

### Materials

- Hazardous materials may not be used in the construction or operation of the device, including but not limited to lead.
- All other materials to build the device are legal and optional
- There will be a \$20 pre-tax price limit for materials. Teams may use on-line national retail prices for materials as long as they provide the site and a link for the materials as reference.

### Rules

#### General Rules

1. Teams must design, build and operate their own prosthetic arm. This device will include all parts necessary to accomplish all defined tasks.
2. The device must be designed as a trans-radial (below-the-elbow) prosthetic. The device must attach half way between the elbow and wrist. The device must cover the hand completely and extend beyond the hand.
3. The device should be designed to be low-cost and easily maintained given a limited amount of resources and ability to maintain complex modern prosthetics in Afghanistan where the client resides.
4. Devices cannot exceed the \$20 pre-tax price limit for materials.
5. Teams must complete the provided itemized budget sheet for their device and provide documentation to support the prices listed.
  - a. The budget must include a list of all parts and their retail prices.
  - b. All parts received through barter, trade, donation, recycling, etc. must be included in the itemized budget. Retail prices for these items must be researched and fully documented.
  - c. The cost will be based only on the actual materials used in the construction of the device. Therefore, teams will need to calculate the cost per unit for their budget.  
- e.g. a 3 pack of foam board (20 in x 30in) cost \$9.00. This breaks down to \$3 per sheet and \$0.005 per square inch. If a team uses 25 square inches on their device the cost would be \$0.125.
6. The device, include all parts of all configurations, cannot weigh more than 2 kilograms.
7. The device cannot utilize the team member's wrist, hand, or fingers in any way.



8. All parts that will be used during competition must be impounded and inspected prior to the start of competition.
9. Reconfiguration or adjustment of impounded parts between tasks will be allowed.
10. All designs that conform to the rules will be allowed to participate.
11. Once performance competition begins, student teams may not have contact with non-competitors. Student teams are solely responsible for interaction with judges and addressing problems with their devices.
12. Participating team members will have their wrist, hand and fingers immobilized for the tasks. The suggested method for immobilization is a wrist guard and an ace bandage wrapped over the closed fist. These materials will be provided by the host center on the day of competition.
13. Team members may use their unencumbered hand to assist in preparing the device for each task, but they will **NOT** be allowed to use their unencumbered hand to assist in completing the tasks.

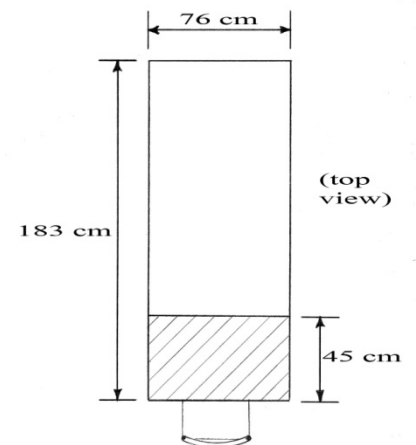
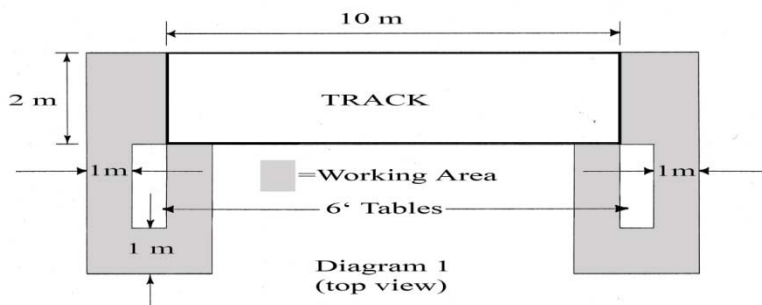
**Test Configurations and Equipment**

**14. Working Areas**

- a. For the Strength Efficiency Relay, a 10 meter by 2 meter track will be used. There are no restrictions on the type of flooring for this track. On both ends of the track a six foot table\* will be placed as the start and end corner points. (See diagram 1) The water container used for this task will be Home Depot’s “Homer’s All –Purpose Bucket” (Model# 05GLHD2) plus the

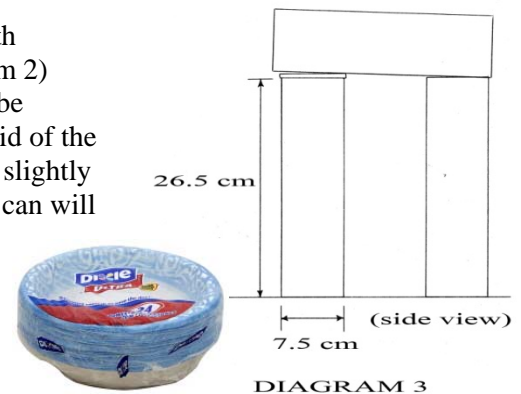


Argee Homer 5-Gallon Bucket Lid (Model# RG5503). Both are pictured to the right and can be found at [www.homedepot.com](http://www.homedepot.com).



- b. For the Object Relocation Task, a six foot table\* and chair will be used.

- i. The chair will be placed at one end of the table.
- ii. Teams will be limited to a task area on the table top with approximate dimensions of 76 cm x 45 cm. (see diagram 2)
- iii. Three 6.38 oz Pringles cans will be used. One can will be secured horizontally on top of the other two cans. The lid of the horizontal can will be placed over the top of one can to slightly elevate the horizontal can opening. Only the horizontal can will be filled. (see diagram 3)
- iv. The bowl used for the task will be the Dixie Ultra Brand 20 oz paper bowls. Pictured to the right.
- v. The olives used at the national level, will be Lindsay brand large pitted black olives. For product information, visit [www.lindsayolives.com](http://www.lindsayolives.com).





### Test Configurations and Equipment – continued

- c. For the Dexterity Task, a six foot table\* and chair, writing prompt, and No. 2 pencil will be used.
- d. A one meter perimeter will be set-up around each table. This area will be referred to as the working area.
- e. Teams will be allowed 2 minutes to configure their device before each trial.

\* Six foot tables will have approximate dimensions of 76 cm x 183 cm x 74 cm.

### Task Details -

1. Strength Efficiency Relay – Lifting and carrying a mass
  - a. The specified water container will be placed on the starting table. The amount of water in the container will be chosen by the team.
  - b. The team will be given two minutes to prepare its device and fill the container to the desired amount for each trial.
  - c. The judge will measure and record the device mass
  - d. At the end of the two minutes, the team will place both the prosthetic arm and the container on the table before starting the trial.
  - e. The first designated team member will stand outside the working area of the start table. The member cannot touch the table or the device until given the start order from the judge.
  - f. The judge will give the start order and begin the timer.
  - g. The relay will proceed as follows:
    - i. The member will enter the working area, attach the device, lift the water container off of the table and carry it 10 meters across the track and place the container on top of the second table.
    - ii. The member will remove the device, place it on top of the second table and step out of the working area.
    - iii. The next member will enter the working area, attach the device, pick up the water container and walk back to the start table. When the member reaches the start table, the member will set down the water container on top of the table, remove the device, set it on the table, and step out of the working area.
  - h. The above three steps will be repeated so that **at least** two team members have carried the water container across the track a combined total of four times or until the water container falls or is placed on the ground by the team member.
  - i. Teams will have a total of 5 minutes to complete all four crossings across the track.
  - j. The judge will measure and record the trial mass. The trial mass will be calculated by multiplying the mass of the container (including both mass of water and container) by the number of track crossings completed within the five minutes allotted.
  - k. The trial will end when the team completes four crossings or when the water container falls or is placed on the ground by the team. Only complete crossings of the entire track will be considered for scoring.
  - l. Repeat procedure for 2<sup>nd</sup> trial.
  - m. The best performance of the two trials will be used in the scoring.



**2011-2012 MESA USA  
National Engineering Design Competition  
Prosthetic Arm Challenge - Pilot  
Device Performance  
150 points**

2. Object Relocation Task – Lifting Olives

- a. The specified bowl containing pre-inspected olives will be placed on the table. The Pringles can tower will be placed on the table.
- b. The opening of the Pringles' can will be horizontal, facing to the team member's left or right. The member will be allowed to choose which direction it faces.
- c. The team will be given two minutes to prepare its device and the placement of the Pringles can tower and bowl within the task area for each trial.
- d. At the end of the two minutes, the team will place the device on the table before starting the trial.
- e. One designated team member will sit in a chair facing the table. This member cannot touch the table or the device until they are given the start order from the judge.
- f. The judge will give the start order and begin the timer.
- g. The team member will then attach the device and move the olives, **one at a time**, and place them into the horizontal can.
- h. The judge will call "time" after one minute has passed.
- i. If the team member knocks over the tower before the one minute has passed that will end the trial
- j. At the end of the trial, the judge will check each olive for signs that the skin has not been broken. Such undamaged olives will be counted and the number will be recorded on the score sheet.
- k. Repeat procedure for 2<sup>nd</sup> trial.
- l. The best performance of the two trials will be used in the scoring.

3. Dexterity Task - Writing

- a. A writing prompt and no. 2 wooden pencil will be provided for each trial. The writing prompt will be an 8.5" x 11" sheet of paper with a MESA State determined phrase written on it in all capital letters in outlined, 100 point, Arial Black font (see "Writing Sample" on page 12).
- b. The writing prompt and pencil will be placed on the table. The prompt will be placed face down.
- c. The team will be given two minutes to prepare its device for each trial.
- d. At the end of the two minutes, the team will place the device on the table before starting the trial.
- e. One designated team member will sit in a chair facing the table. The member cannot touch the table or the device until given the start order from the judge.

Preparation of Pencil

- f. The judge will give the preparation start order and begin the timer.
- g. The member will then have one minute to attach the device and prepare the pencil for writing.

Writing

- h. When the member is ready or when one minute has elapsed the judge will give the start order and restart the timer.
- i. The member can then turn over the prompt and begin writing, starting with the left uppermost character and continuing from left to right and from the top down. Teams will not be allowed to re-visit characters that were skipped. The team member is allowed to turn over the prompt with his or her unencumbered hand.
- j. The judge will stop the student after one minute has passed.
- k. The judge will review the prompt and count how many characters were written within the character boundaries.
- l. Repeat procedure for 2<sup>nd</sup> trial.
- m. The best performance of the two trials will be used in the scoring.



**2011-2012 MESA USA  
National Engineering Design Competition  
Prosthetic Arm Challenge - Pilot  
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150 points**

**Construction and Repair**

1. Teams should consider the device's shipment cost of device for local events. It is recommended that teams design their device so that it can be disassembled for shipment in a large suitcase(s).
2. Repairs are allowed, but only using replacement parts and materials. All repairs must be done in the impound area under supervision of a judge. The addition of new or alternate parts not previously impounded is NOT allowed.

**Safety**

1. Standard safety practices including the use of protective eyewear must be observed.
2. Students must operate their device in a safe manner. The device may only be activated when directed by the judges. Teams using UNSAFE PROCEDURES may have trials disqualified at the discretion of the judges.
3. The device must not pose a danger to students, officials, spectators or cause damage to the host facility, as determined by the judges.

**Inspection, Impound and Operation**

1. The trial order for performance events will be randomly selected.
2. Device inspection will take place prior to being impounded for the performance events. Inspection will include demonstration of device operation for all tasks to the judges.
3. Devices must be in testing condition prior to device inspection. If devices are disqualified during inspection check, design changes will not be allowed. Only devices passing inspection will be allowed to participate in the performance tasks.
4. The itemized budget with documentation must be submitted at inspection and will be reviewed by the judge. Any device that is over budget will be disqualified.
5. All repair materials and parts to be used during the competition must be impounded with the device. Devices will be released for trials but will remain impounded between tasks.
6. Each device must be ready for competition when called or forfeit that trial.
7. After teams arrive at task station, Judges will direct them to setup for the task.
8. Setup is limited to 2 minutes for each trial, except Task # 3 where member will also be given one minute to attach device and prepare the pencil for writing (see "Task Details 3g").
9. The team member responsible for operation of the device will indicate to the judge that the device is in the "ready-to-operate" position.
10. If, during the operation of a device, it is found to violate rules those trials will be disqualified.

**Measurement Equipment**

1. Strength Efficiency Relay:
  - Stop watch
  - 5 lb (2.2 kg) postal scale
  - 10 lb (4.4 kg) postal scale
  - 75 lb (34 kg) postal scale
2. Object Relocation Task:
  - Stop watch
3. Dexterity Task:
  - Stop watch
  - Writing Prompt
  - No. 2 Pencil



**Assigning Points to Performance**

1. The Total Performance Score will be determined by the sum of the points earned in each task.
2. Scores for each task equal the ratio of each device’s performance relative to the winning device’s performance on that task. Those scores are weighted according to the maximum points for each task:  

**Middle School Tasks: 75 points each**
**High School Tasks: 50 points each**
3. Ties are allowed in each task

Strength Efficiency Relay – Lifting and carrying a mass (Middle and High School)

1. Team Efficiency Score ( $E_{tm}$ ) = Strength-to-Mass Ratio or greatest trial mass (g) divided by the device mass (g)  
 - Trial mass is equal to the mass of the container, including water, times the number of crossings completed.
2. Task Winner = Greatest team efficiency score ( $E_{wm}$ ) receives maximum points (75 or 50).
3. Team Task Points = Team Efficiency ( $E_{tm}$ ) divided by ( $E_{wm}$ ), times max points or

$$\text{Team Task Points} = \frac{E_{tm}}{E_{wm}} \times 75 \text{ or } \frac{E_{tm}}{E_{wm}} \times 50$$

<b>Example</b>		
Task Winner Winning Efficiency ( $E_{wm}$ ) = 14000 g/700 g = 20	Team 5 Trial 1: 15000 g/1000 g = 15 Trial 2: 18000 g/1000 g = 18 Team Efficiency ( $E_{tm}$ ) = 18	Team 5 Points Middle School Score = (18/20) x 75 = 67.5 pts High School Score = (18/20) x 50 = 45 pts

Object Relocation Task –Lifting Olives (Middle and High School)

1. Team score ( $L_t$ ) = greatest number of undamaged olives moved by team
2. Task winner ( $L_w$ ) = greatest number of undamaged olives moved by any team
3. Task Points = Team score ( $L_t$ ) divided by ( $L_w$ ), times max points or

$$\text{Task Points} = \frac{L_t}{L_w} \times 75 \text{ or } \frac{L_t}{L_w} \times 50$$

<b>Example</b>		
Task Winner Winning Score ( $L_w$ ) = 55	Team 5 Trial 1: 41 olives Trial 2: 45 olives Team Score ( $L_t$ ) = 45	Team 5 Points Middle School Score = (45/55) x 75 = 61.36 pts High School Score = (45/55) x 50 = 40.91 pts



**Assigning Points to Performance - continued**

Dexterity Task – Writing (High School)

1. High School Team Writing Score ( $W_t$ ) = greatest number of correctly written characters completed by team
2. Writing Task winner ( $W_w$ ) = Greatest number of correctly written characters by any team
3. Task Points = Team Writing Score ( $W_t$ ) divided by ( $W_w$ ), times 50 points

$$\text{Task Points} = \frac{W_t}{W_w} \times 50$$

<b>Example</b>		
Task Winner Winning Writing Score ( $W_w$ ) = 30 characters	Team 5 Trial 1: 23 characters Trial 2: 21 characters Team Writing Score ( $W_t$ ) = 23	Team 5 Points High School Score = $(23/30) \times 50 = 38.33$ pts

Total Performance Score:

1. Middle School Performance Score  
= Strength Efficiency + Object Relocation
2. High School Performance Score  
= Strength Efficiency + Object Relocation + Dexterity



**2011-2012 MESA USA  
National Engineering Design Competition  
Prosthetic Arm Challenge - Pilot  
Device Performance  
150 points**

Inspection and Performance Datasheet

MESA Center: \_\_\_\_\_ MESA School: \_\_\_\_\_

Level: MS HS                      Advisor/Teacher: \_\_\_\_\_

Student Team: \_\_\_\_\_

**Inspection**

Device is a trans-radial (below the elbow) prosthetic ..... Y / N  
 Device does not have a mass more than 2 kg..... Y / N  
 Did the team provide an itemized budget with references and documentation..... Y / N  
 Device did not exceed the \$20 pre-tax price limit ..... Y / N

Device Mass (including all parts of all configurations): ..... kg

Device Total Cost: ..... \$

**Performance**

Strength Efficiency Task

Trial 1  
# of Crossings successfully completed: \_\_\_\_\_

Mass of container plus water ( $m_c$ ): \_\_\_\_\_ (g)

Trial Mass ( $T_m$ ): \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ (g)  
crossings                       $m_c$

Mass of device ( $D_m$ ): \_\_\_\_\_ (g)

Strength-to-Mass Ratio =  
 \_\_\_\_\_ (g) / \_\_\_\_\_ (g) = \_\_\_\_\_  
 $T_m$                        $D_m$

Trial 2  
# of Crossings successfully completed: \_\_\_\_\_

Mass of container plus water ( $m_c$ ): \_\_\_\_\_ (g)

Trial Mass ( $T_m$ ): \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ (g)  
crossings                       $m_c$

Mass of device ( $D_m$ ): \_\_\_\_\_ (g)

Strength-to-Mass Ratio =  
 \_\_\_\_\_ (g) / \_\_\_\_\_ (g) = \_\_\_\_\_  
 $T_m$                        $D_m$

Object Relocation Task

Trial 1:  
# of olives successfully moved and placed: \_\_\_\_\_

Trial 2:  
# of olives successfully moved and placed: \_\_\_\_\_

Dexterity Task (high school only)

Trial 1:  
# of characters successfully written: \_\_\_\_\_

Trial 2:  
# of characters successfully written: \_\_\_\_\_

Lead Judge: \_\_\_\_\_

Signature confirms that scores have been accurate recorded by judges



**2011-2012 MESA USA  
National Engineering Design Competition  
Prosthetic Arm Challenge - Pilot  
Itemized Budget Sheet**

**Itemized Budget Sheet**

MESA Center: \_\_\_\_\_

MESA School: \_\_\_\_\_

Level: MS HS

Advisor/Teacher: \_\_\_\_\_

Student Team: \_\_\_\_\_

<b>Part</b>	<b>Unit Dimensions</b>	<b>Retail Price</b>	<b>Price per Unit</b>	<b>Quantity Used</b>	<b>Total Cost</b>	<b>Retail Source</b>
<i>6061 Aluminum flat (example)</i>	<i>1/8" x 1/2" x 24"</i>	<i>\$1.98/flat</i>	<i>\$0.0825/inch</i>	<i>10</i>	<i>\$.0.82</i>	<i>Metalsdepot.com</i>





**2011-2012 MESA USA  
National Engineering Design Competition  
Prosthetic Arm Challenge - Pilot  
Writing Sample**

Font: Arial Black

Font Format: Outline

Font Size: 100

A B C D E  
F G H I J K  
L M N O P  
Q R S T U  
V W X Y Z

