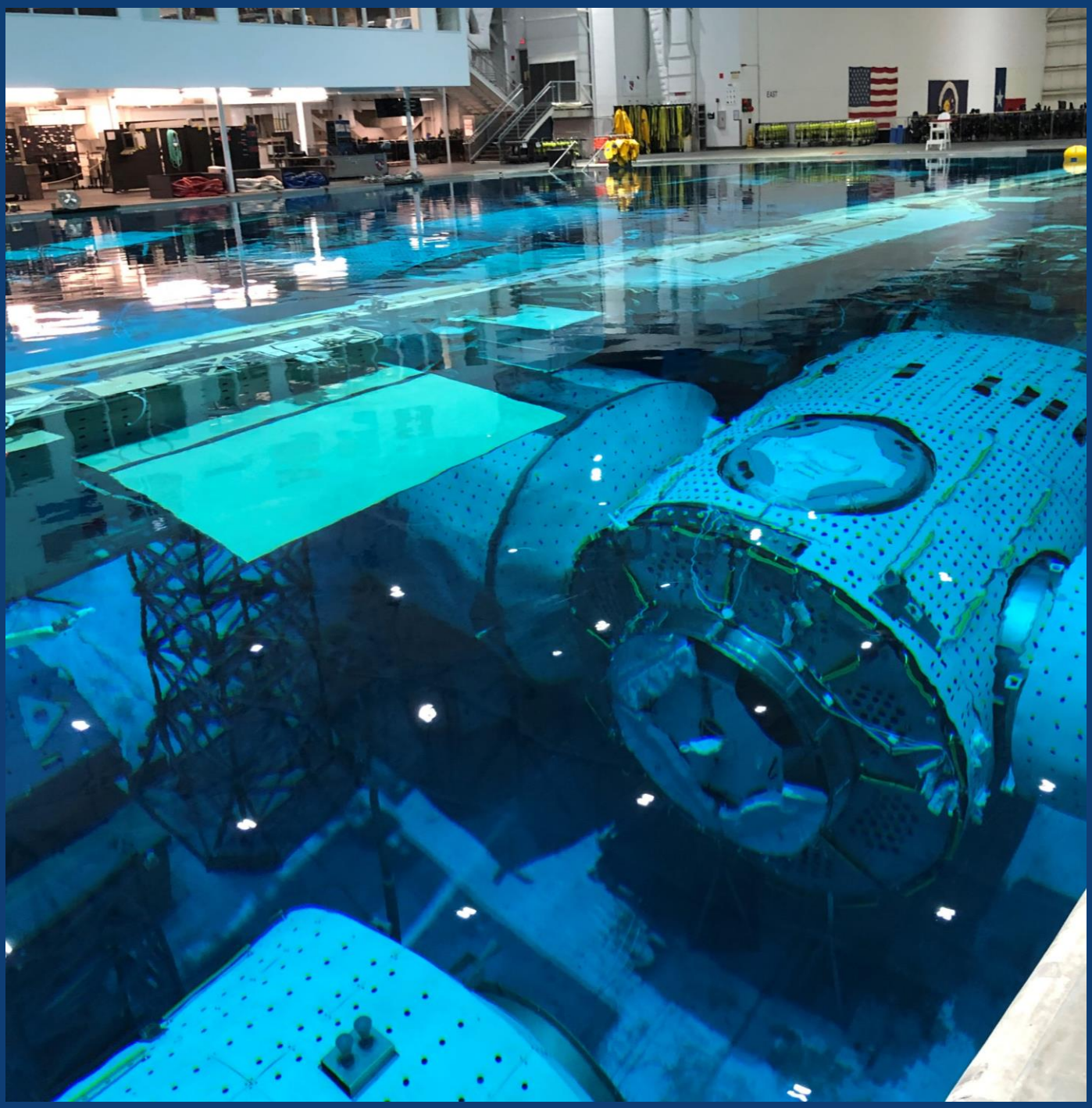
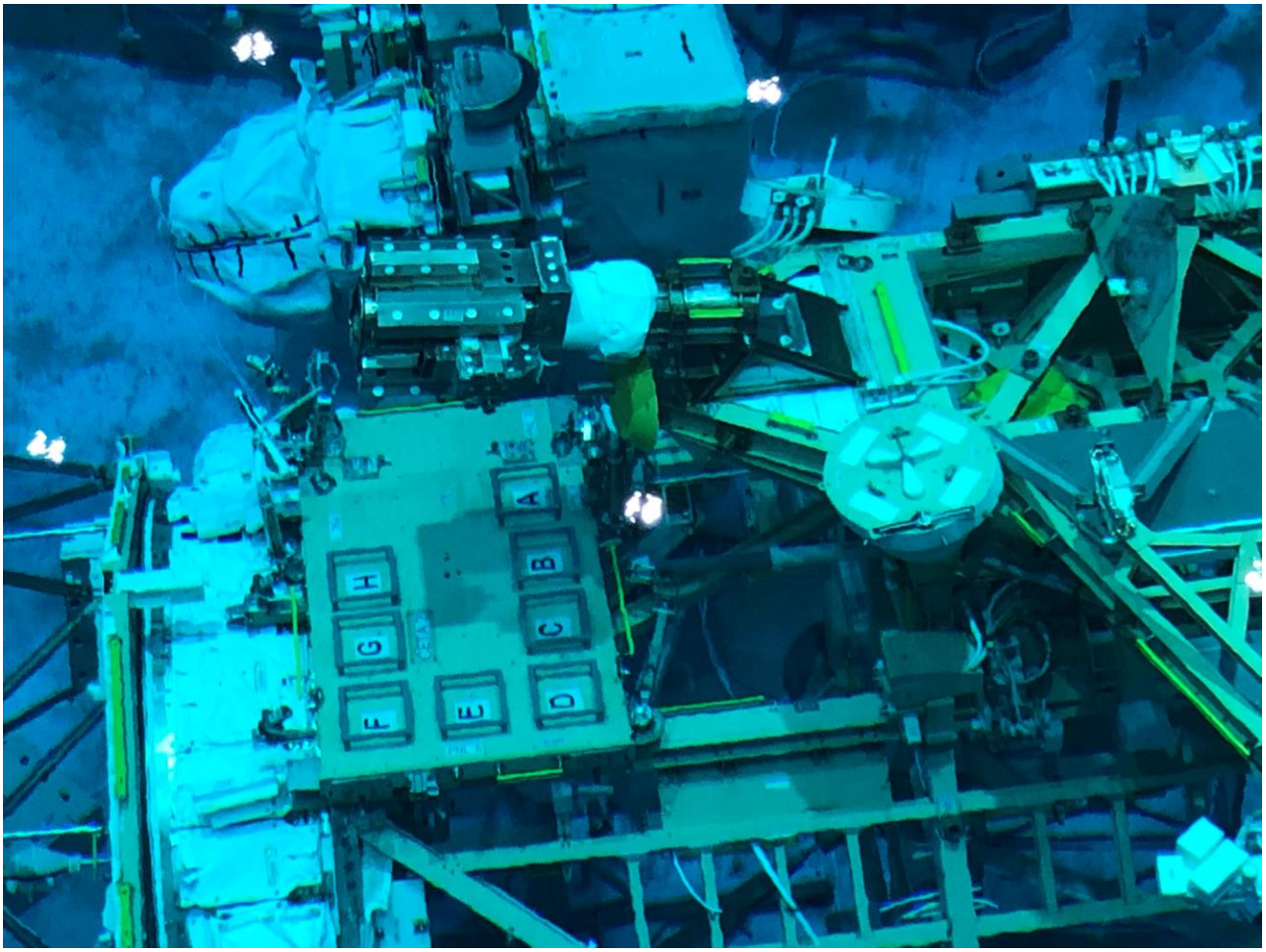


EVA Simulation using ROVs

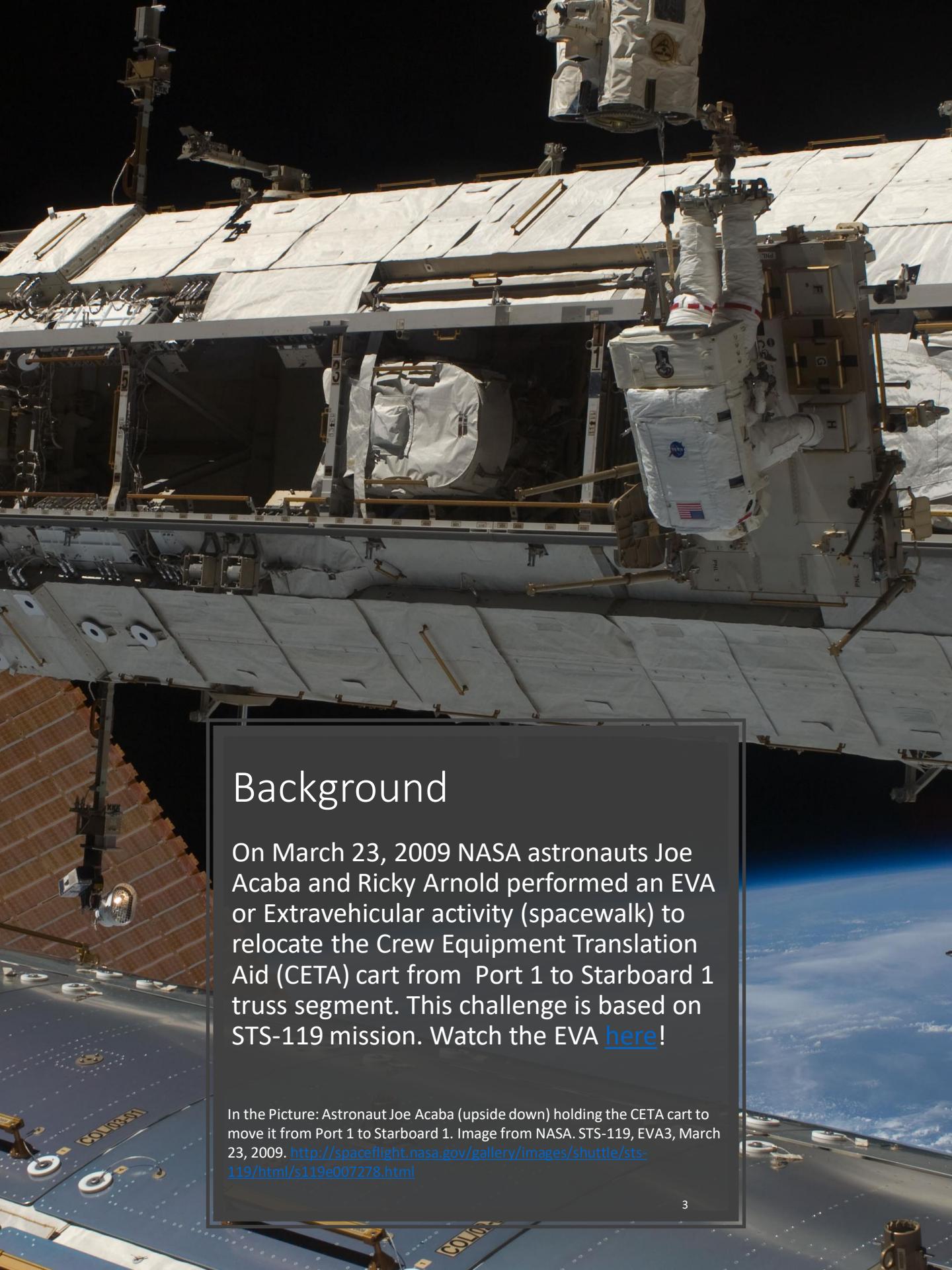
Created by: Aymette Medina

Background

According to NASA, the mission of the Neutral Buoyancy Lab (NBL) is to prepare for space missions involving spacewalks. NASA team members use the NBL to develop flight procedures, verify hardware compatibility, train astronauts and refine spacewalk procedures during flight that are necessary to ensure mission success. Find more information about the NBL https://www.nasa.gov/centers/johnson/pdf/167748main_FS_NBL508c.pdf



Neutral Buoyancy Lab. CETA cart. Image: Aymette Medina.



Background

On March 23, 2009 NASA astronauts Joe Acaba and Ricky Arnold performed an EVA or Extravehicular activity (spacewalk) to relocate the Crew Equipment Translation Aid (CETA) cart from Port 1 to Starboard 1 truss segment. This challenge is based on STS-119 mission. Watch the EVA here!

In the Picture: Astronaut Joe Acaba (upside down) holding the CETA cart to move it from Port 1 to Starboard 1. Image from NASA. STS-119, EVA3, March 23, 2009. http://spaceflight.nasa.gov/gallery/images/shuttle/sts-119/html/s119e007278.html

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The Challenge: EVA simulation using ROVs

- Teams of 2-3 students will design and build a tool to attach to the ROV and complete an EVA (spacewalk) simulated mission.
- Your tool will need to be able to disconnect and connect brakes to move the CETA cart from Port 1 to Starboard 1 on the truss segment.
- EVA must follow this order:
  - Attach a flotation device to the brake in the Starboard 1 (right brake). This will release the brake (the brake will float, so you can do the next step).
  - With the tool attach to the ROV, move the CETA cart from Port 1 to Starboard 1 (move left to right until the end).
  - Removed the seal (pool noodle piece inside the PVC elbow) from the brake in Port 1 to active the mechanism and put the brake (brake will go down).
- Use the Engineering Design Process to design, build, and test your tool and flotation device.
- Complete the Student Activity Worksheet.

Mission Course Assembly – International Space Station Truss Segment

Materials

(1) Corrugated Plastic Sheet 15” x 24”

(2) CPVC ½” elbows

(6) CPVC ½” wing elbows

(4) CPVC ½” tees

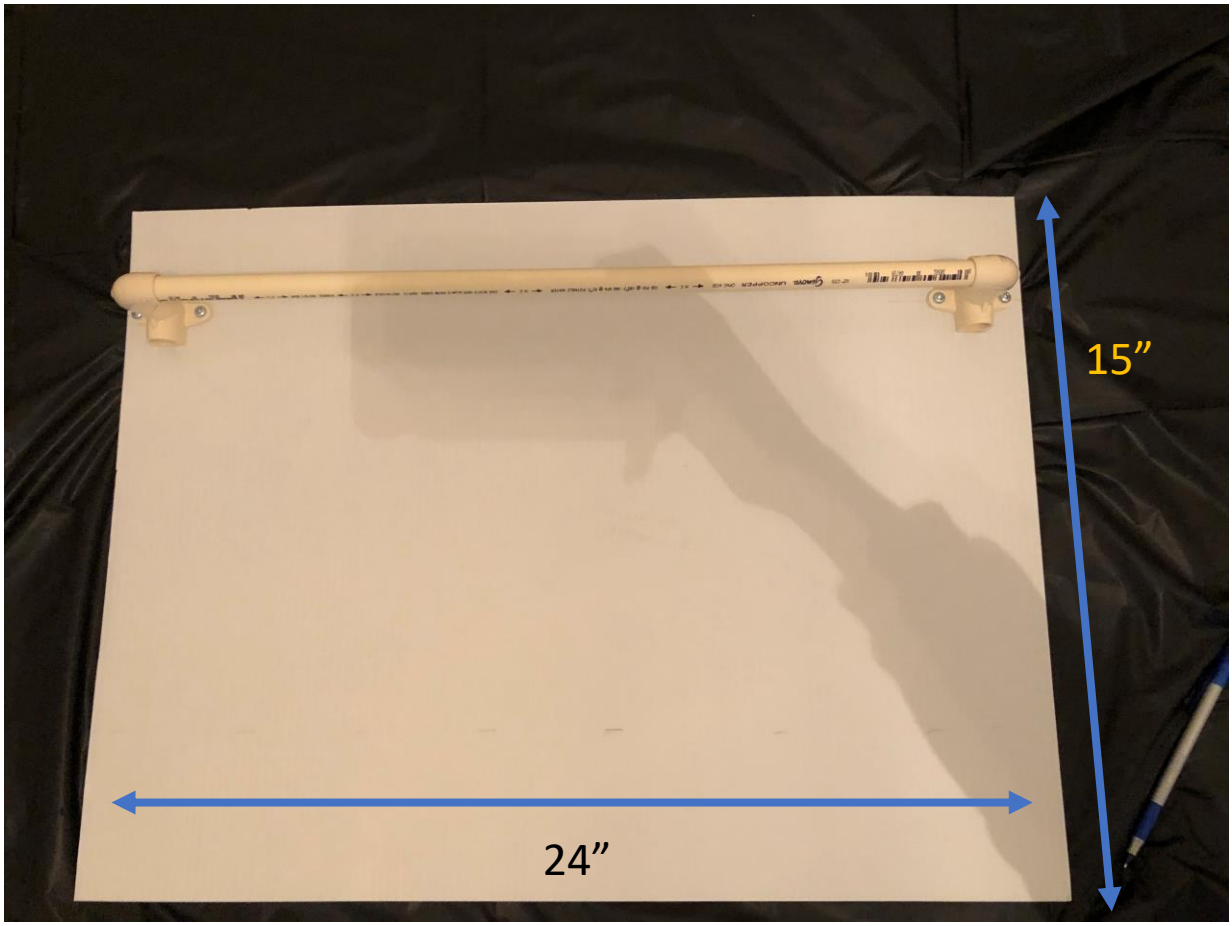
CPVC ½” pipe:

- (2) Pipes of 3 cm (join the elbow to the elbow wing)
- (1) Pipe of 52 cm for the truss segment rail
- (4) Pipes of 4 cm to connect the Tee with the elbow wing
- (2) Pipes of 3 cm to join the tees

(26) Screws 8 x ½ or 8 x ¾

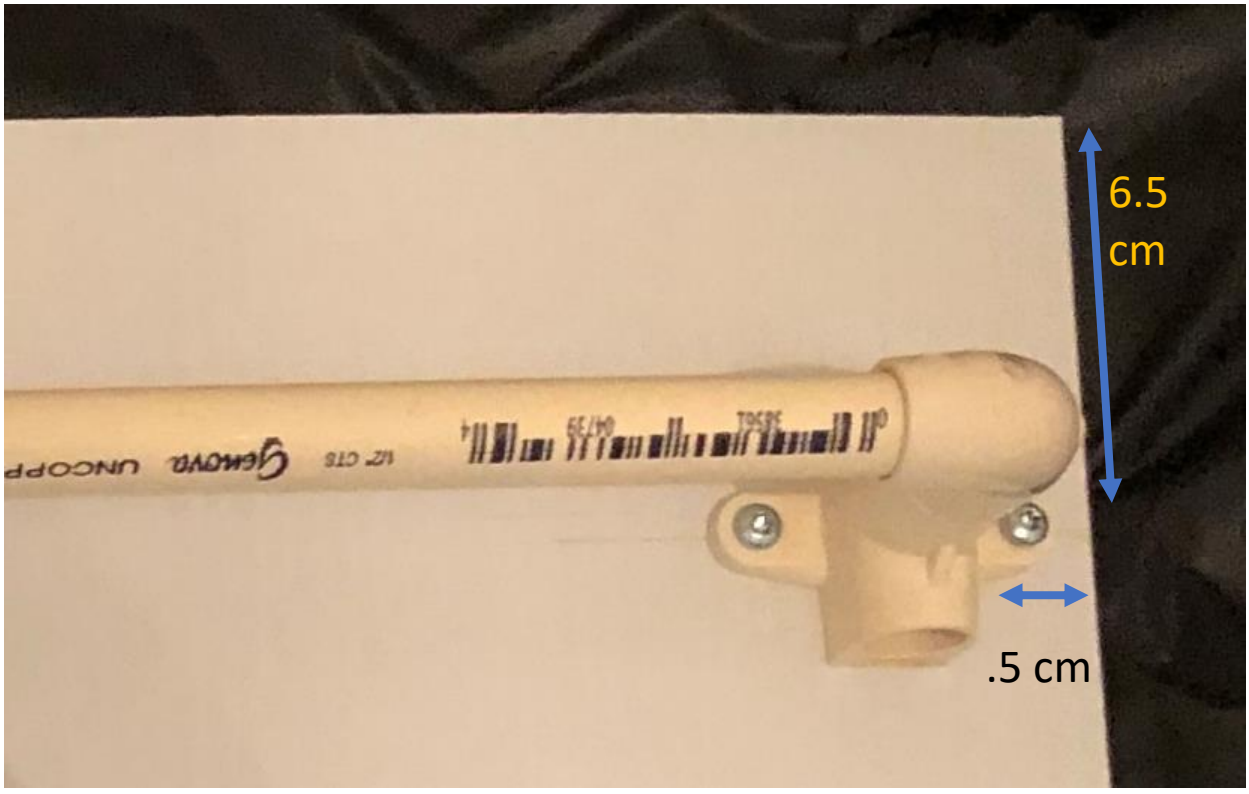
Drill

Mission Course Assembly – International Space Station Truss Segment

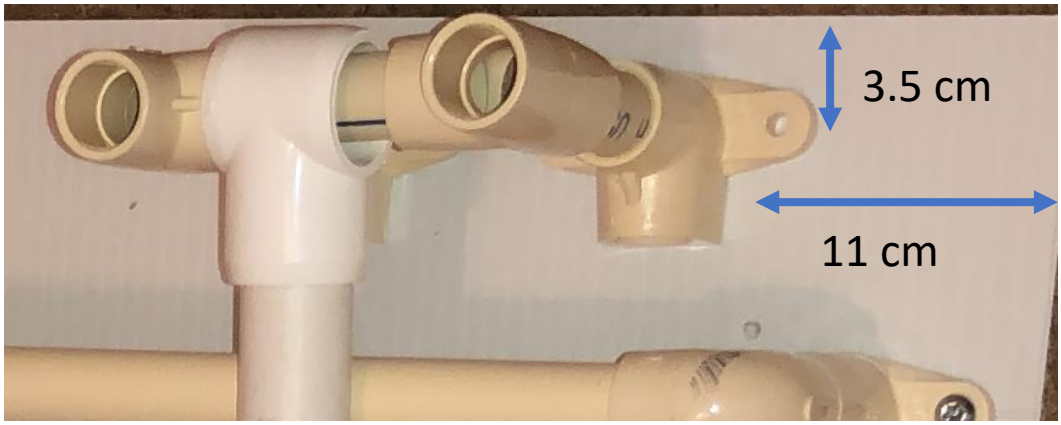


Mission Course Assembly – International Space Station Truss Segment

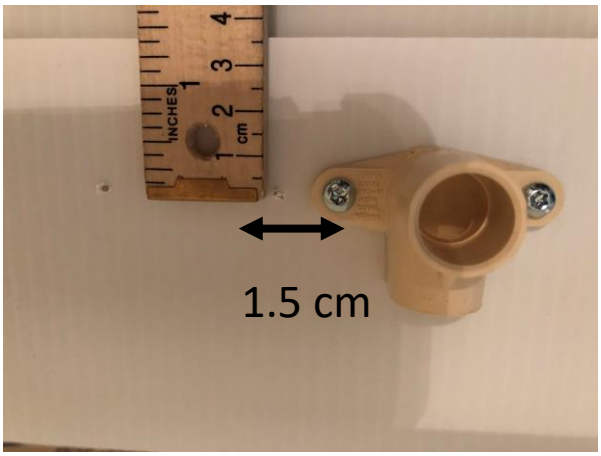
Measure 6.5 cm and .5 cm as shown in the picture. When you have the .5 cm, do a mark with a pencil. Put the elbow wing as in the picture, so you can do a mark in the other side of the elbow wing to drill.
Do the same in the other side. Drill and screw.
Take the 3 cm pipe, attach to the elbow wing and connect an elbow as show in the picture. Do the same in the other side. I recommend drill and screw to secure the elbows to the pipe but is up to you.
Take the 52 cm pipe and attach it to the elbows to complete the rail. I recommend secure the pipe to the elbow with a screw. If you want to do it, drill it now, but don't screw it because you will need to open the pipe later to put the CETA cart inside the rail.



Mission Course Assembly – International Space Station Truss Segment

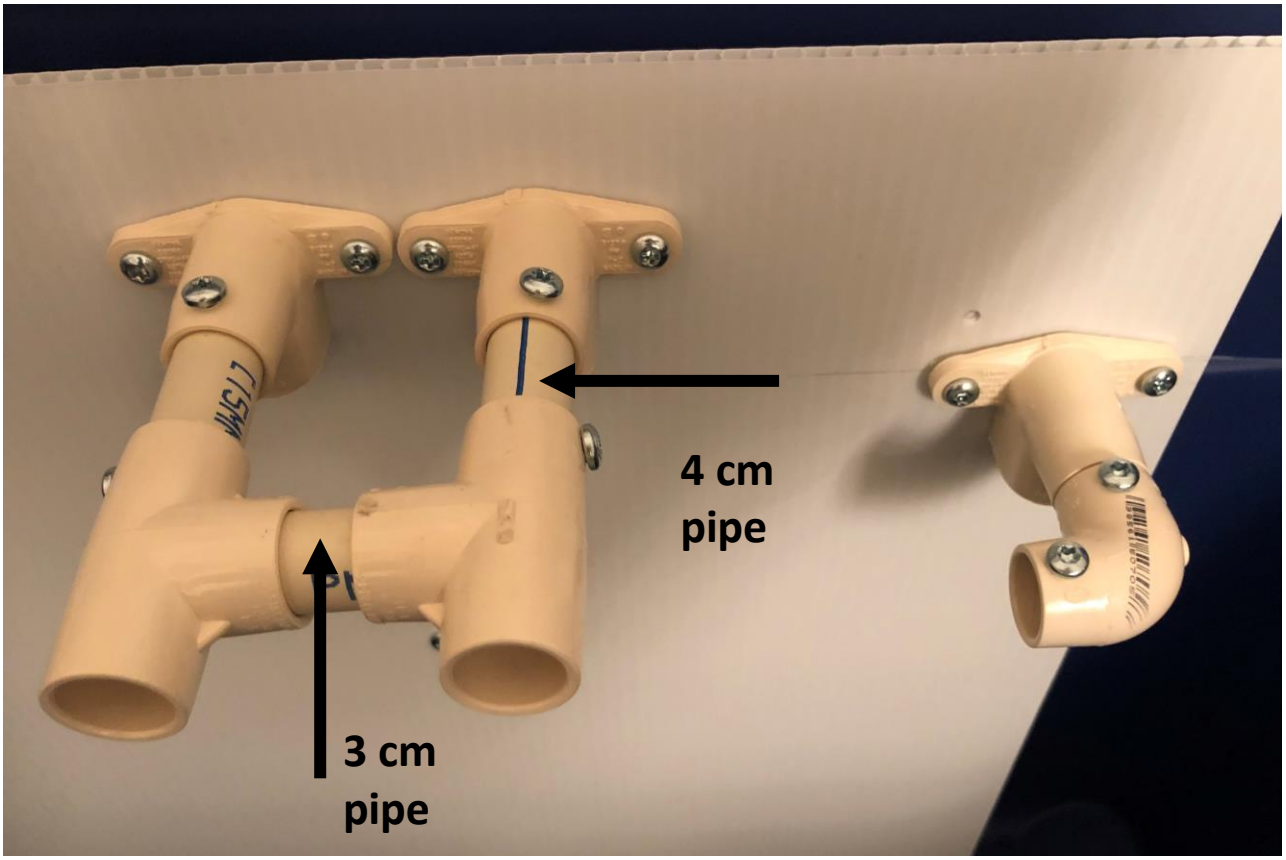


Measure 11 cm and 3.5 cm as shown in the picture. When you have the 3.5 cm, do a mark with a pencil. Put the elbow wing as in the picture, so you can do a mark in the other side of the elbow wing to drill. Drill and screw. Measure 1.5 cm from the screw, do the mark, review that you have 3.5 cm and drill. Put the elbow wing, do the mark, drill and screw.



Do the same in the other side

Mission Course Assembly – International Space Station Truss Segment



Attach the 4 cm pipe to the elbow and connect it to the Tee as shown in the picture. I recommend put some screws to secure the pipes to the elbows and tees. Connect both tees with the 3 cm pipe. I don't recommend put a screw on the 3 cm pipe because the sling tee needs to be loose, so the mechanism can work. Feel free to make this part better and let us know sharing your improvements. Don't forget to do the same in the other side.

Mission Course Assembly – Brakes

Materials

(1) PVC ½” elbow

(2) PVC ½” sling tee

(1) PVC ½” tee

PVC ½” pipes (2) of 2.5”

(4) Screws 8 x ½ or 8 x ¾

Drill

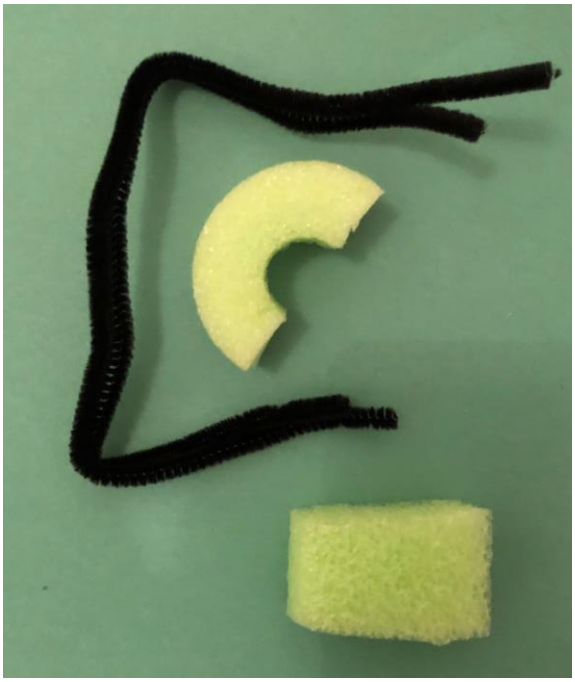
Industrial velcro 4” x 2”

Epoxy

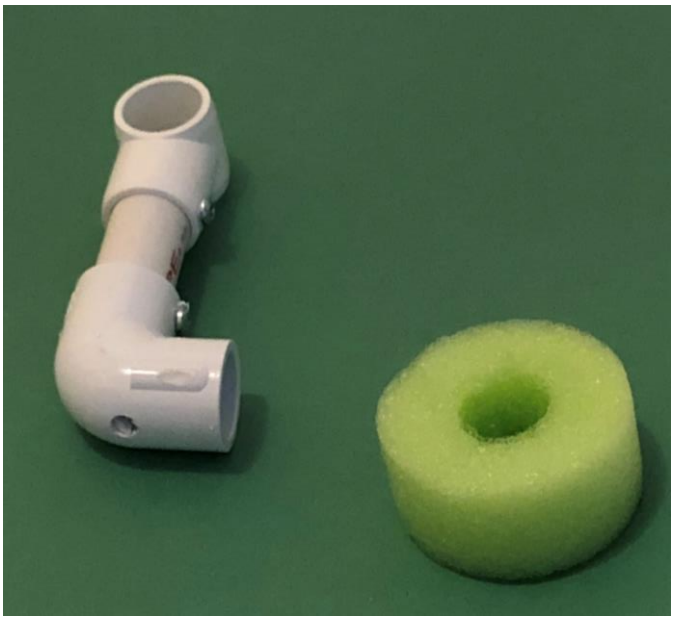
(1) Pool noodle

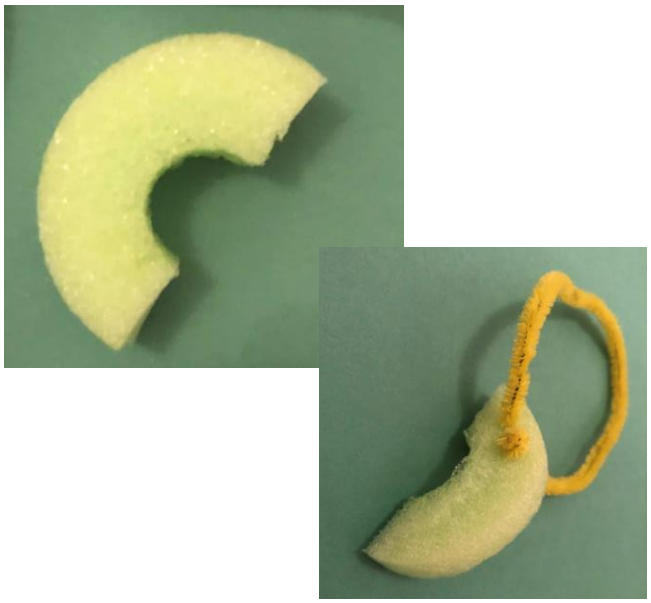
(1) Pipe cleaners

(1) Corrugated plastic 5 cm x 5 cm



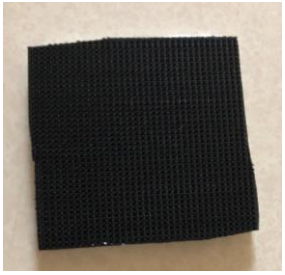
Mission Course Assembly – Brakes





- Take the sling tee, attach the 2.5 cm pipe, and attach the elbow to the pipe. I recommend secure the pieces with screws.
- Take a piece of pool noodle and cut in a half. Measure 1 cm and cut.
- Measure .5 cm and do a hole through the pool noodle and pass the pipe cleaner through it. Secure with a knot at both ends of the pipe cleaner.

Mission Course Assembly – Brakes



- Take the sling tee, attach the 2.5 cm pipe to it, and attach the tee to the pipe. I recommend secured the pieces with screws.
- Cut 5 cm x 5 cm of industrial Velcro and stick it to the corrugated plastic.
- Use the epoxy and glue the corrugated plastic to the PVC tee. I recommend cured the piece for 24-48 hours before used and put a book or something heavy on top. This is up to you.

Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

Materials

Corrugated plastic sheet (31 cm x 39.5 cm)

(36) CPVC ½" elbows (you can substitute the elbows and pipes to do the "squares" with straws and secure it with hot glue, no need for tie wraps or drill)

(32) CPVC ½" pipes of 3 cm

(1) CPVC ½" pipe of 5.5 cm

(1) CPVC ½" pipe of 8 cm

(2) CPVC 1" connector

(32) Tie wraps of 8" and (4) of 4"

(2) Pool noodle of 13 cm x 5 cm

(1) Spray paint (white) (optional)

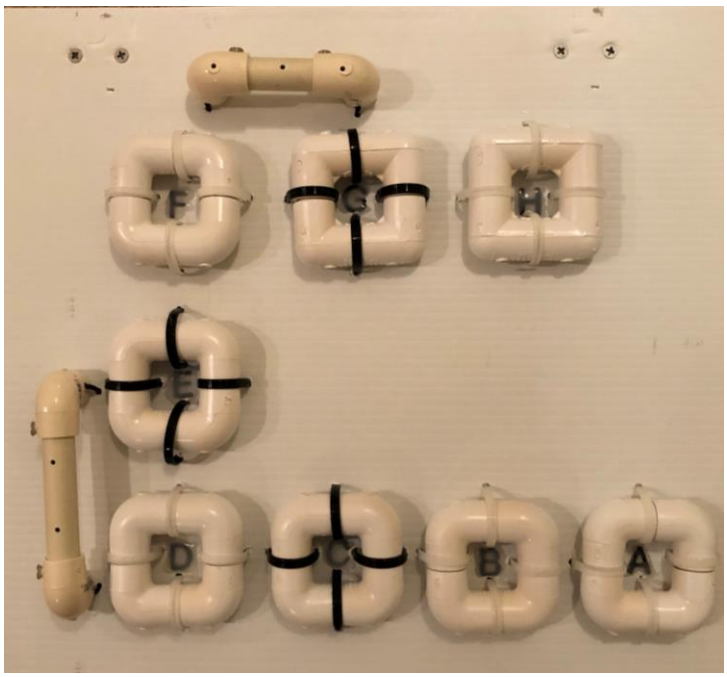
Letters A-H (mine are stickers from Dollar Tree, but you can write it with permanent marker)

Hot glue sticks

Hot glue gun

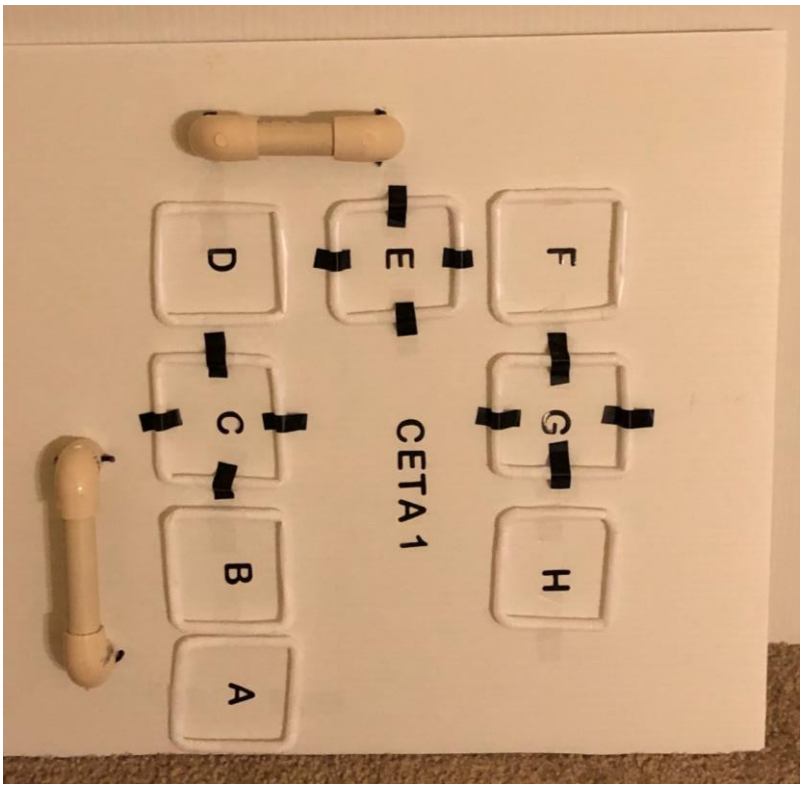
Drill

8 Screws



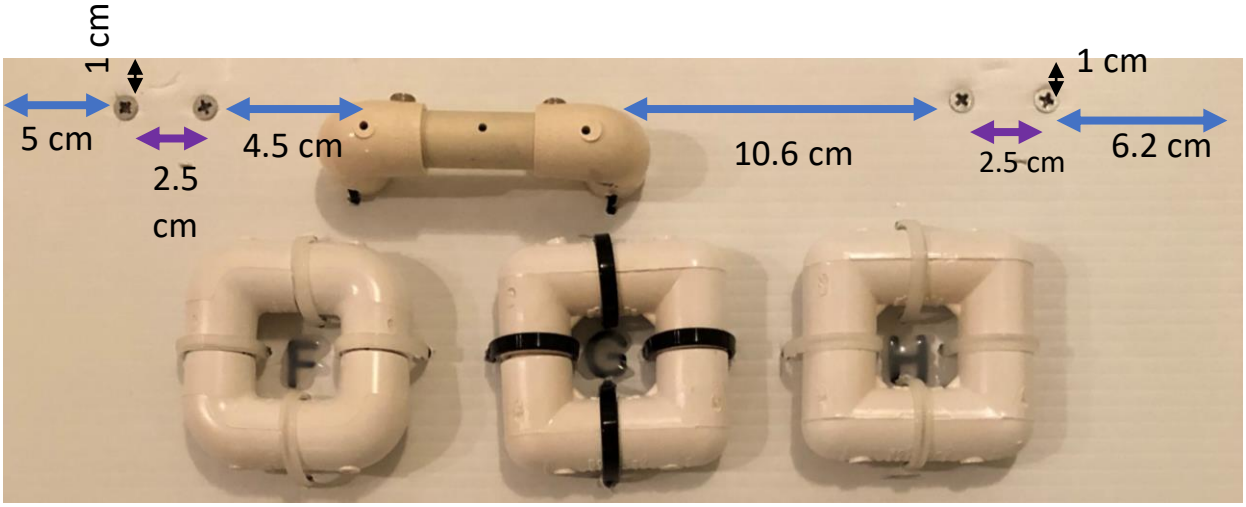
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- Take the elbows (36) and drill a hole. Separate 32 to form the “squares”. If you want to paint the “squares”, I recommend paint the elbows separately before join all the pieces to form the “ squares”.
- Take the 3 cm CPVC pipe and attach it to the elbow until you form a “square”.
- You can substitute the elbows and pipes to do the “squares” with straws and secure it with hot glue, no need for tie wraps or drill. I used electrical tape instead of tie wraps (black) with my first prototype.



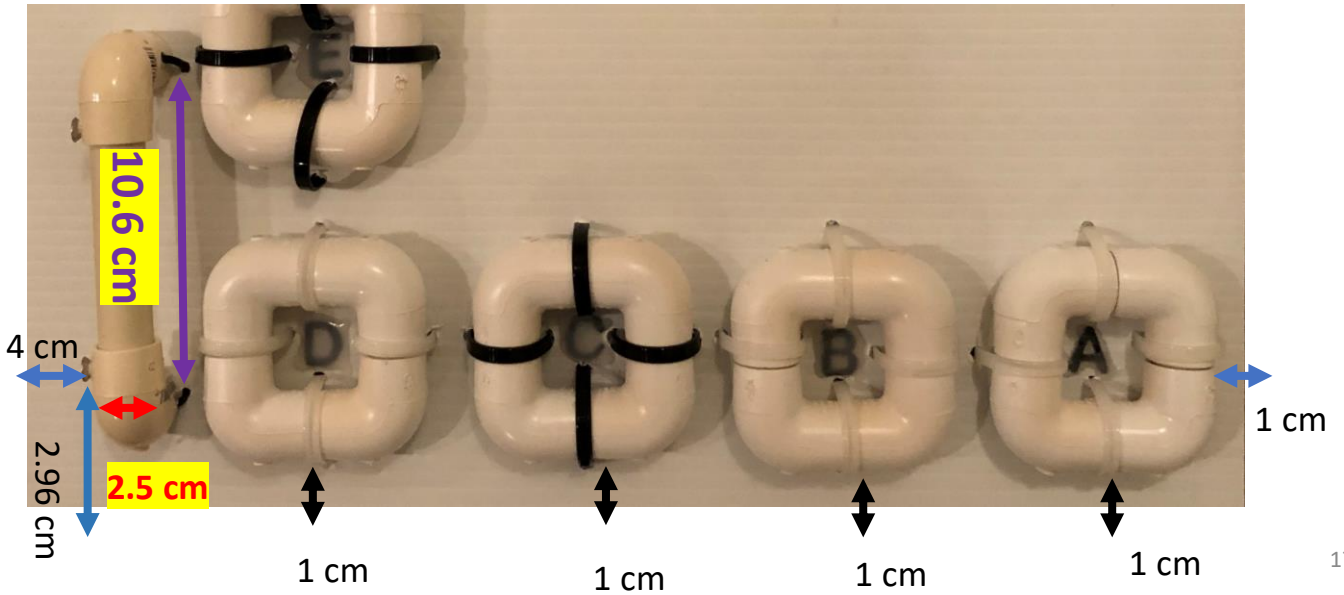
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- Take 2 elbows and drill a hole through it to pass a tie wrap later, as shown in the picture.
- Take the 5.5 cm CPVC pipe and drill a hole in the middle. Attach the elbows at the ends of the pipe and drill a hole to screw as shown in the picture. (Top handle)
- From left, measure 5 cm and 1 cm as shown in the picture. Draw a mark. Measure 2.5 cm and draw a second mark. These two marks are your guide to drill and attach the CPVC connector. You can drill the holes now or later, is up to you. Measure 4.5 cm and draw a mark. After you drill this, you are going to be passing a 4'' tie wrap to attach the elbow and secure the handle.
- From right, measure 6.2 cm and 1 cm as shown in the picture. Draw a mark. Measure 2.5 cm and draw a second mark. These two marks are your guide to drill and attach the 2nd CPVC connector. You can drill the holes now or later, is up to you. Measure 10.6 cm and draw a mark. After you drill this, you are going to be passing a 4'' tie wrap to attach the other elbow and secure the handle.



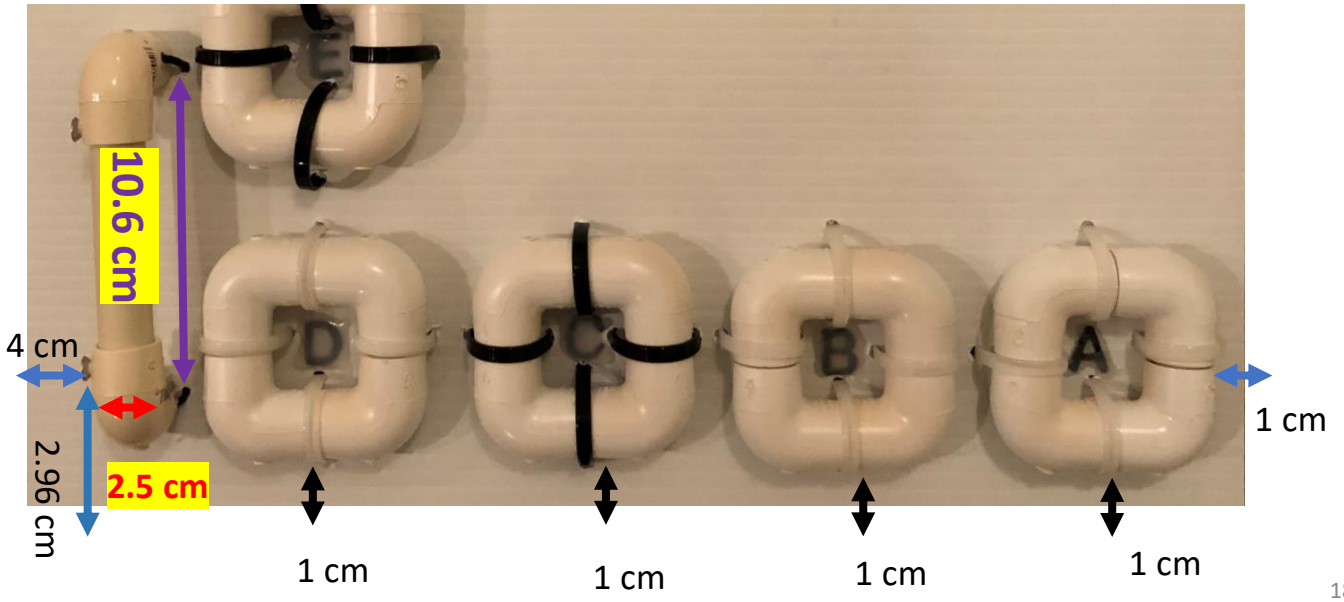
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- As you did before, take 2 elbows and drill a hole through it to pass a tie wrap later, as shown in the picture.
- Take the 8 cm CPVC pipe and drill a hole in the middle. Attach the elbows at the ends of the pipe and drill a hole to screw as shown in the picture. (Side handle)
- From left, measure 4 cm and 2.96 cm as shown in the picture. Draw a mark. Measure 2.5 cm and draw a second mark. These two marks are your guide to drill and pass a 4” tie wrap to hold the elbow of the handle. Measure 10.6 cm (down to up from the mark) and draw a mark. Measure 2.5 cm and draw a second mark. After you drill this, you are going to be passing a 4’’ tie wrap to attach the other elbow and secure the handle. It should be 10.6 cm from one tie wrap to the other, as shown in the picture.



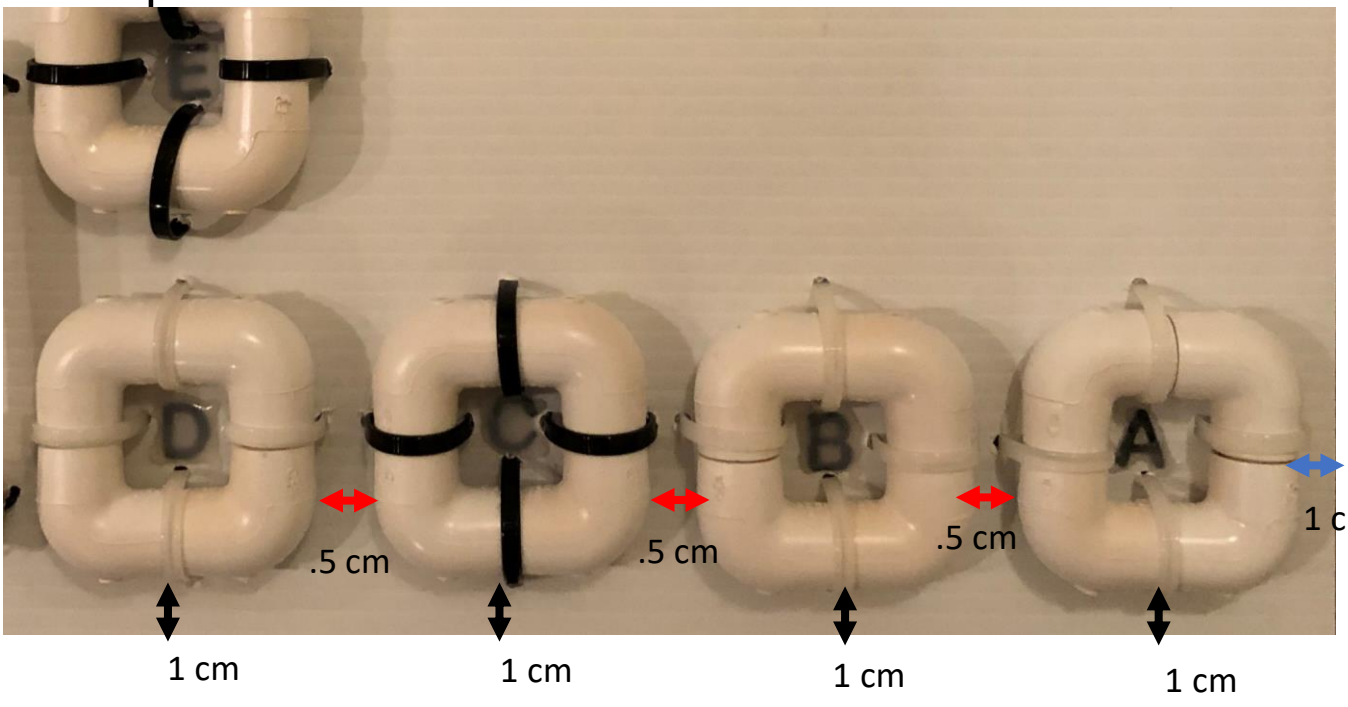
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- From right, to deal with “square” A, measure 1 cm and 1 cm as shown in the picture. Draw the marks and drill. Take the “square” and placed it, so you can draw a point inside the “square” to drill later and pass a tie wrap. I can’t tell the measure because depending on the brand and type of CPVC elbows the measures might vary. If you take a good look on the CETA cart complete picture, you can see that “squares” G and H are bigger than the others.
- If you draw the points inside the “square”, drill the holes. Take a tie wrap and pass through the hole on the bottom. Now that you have the square “kind of secure”, flip the “square” and write or stick letter A.



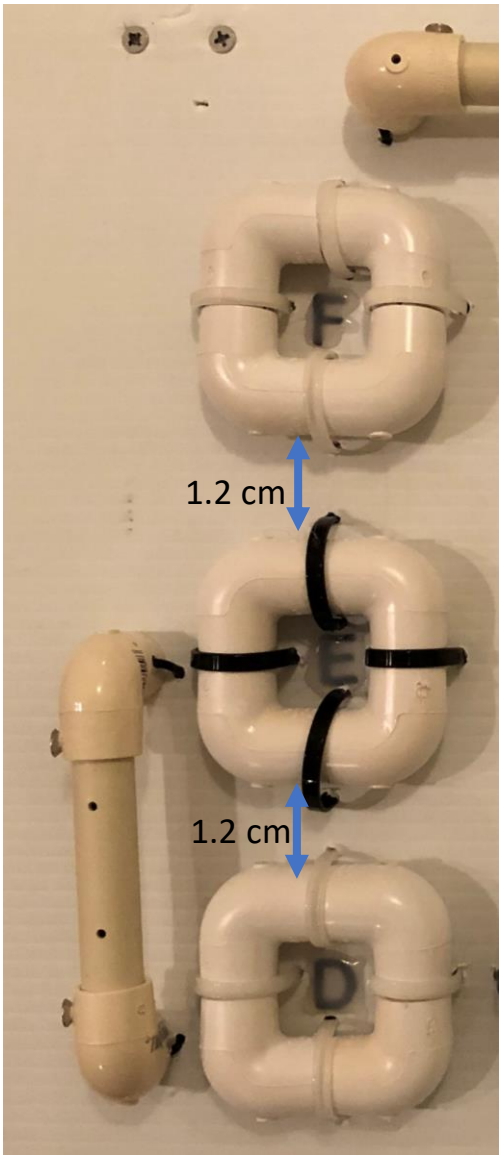
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- Put the “square” in the original position and draw the points to mark where the others tie wraps should go. It is up to you if you want to drill, pass the tie wraps and finish with “square” A, or mark the rest of the letters and drill later.
- Between “squares” A and B should be .5 cm of distance as shown in the picture.
- Repeat the same for “squares” B, C, and D. Finish the process and secured all the “squares” with tie wraps.



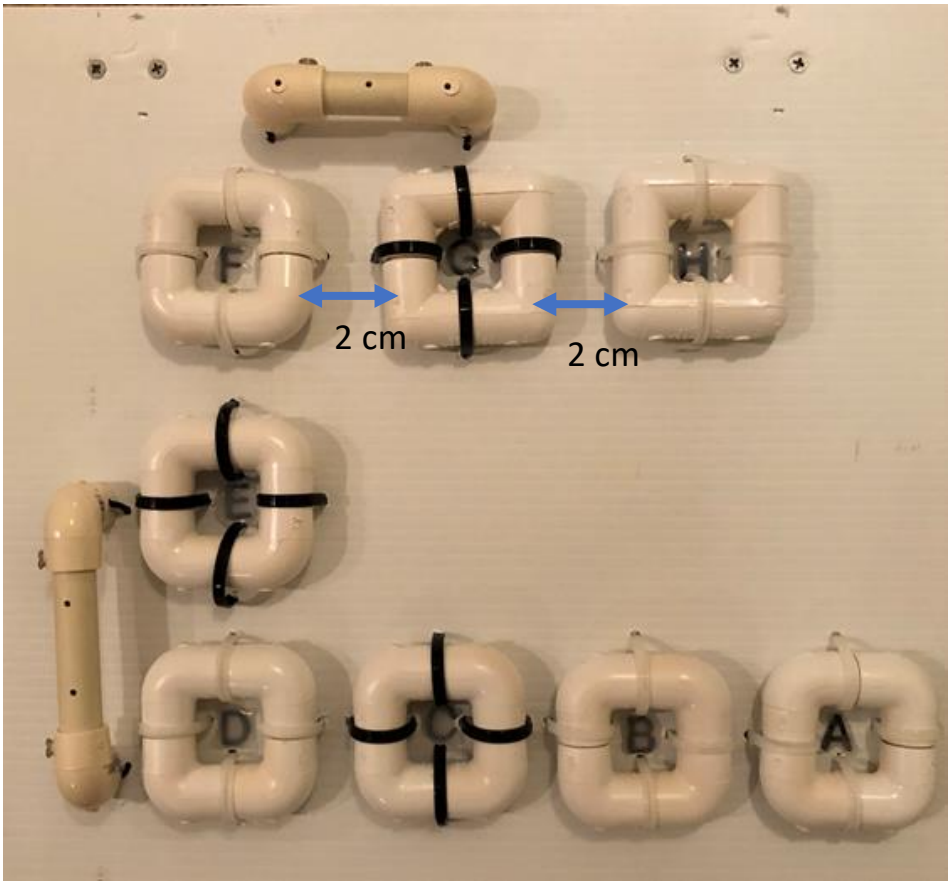
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- From the tie wrap of “square” D, measure 1.2 cm up, as shown in the picture. Draw a mark, drill and pass a tie wrap. Once you have the “square” “kind of secure”, flip it to write or stick letter E. Flip it back to the original position and draw the points to mark where the others tie wraps should go.
- Secure the “square” E and then proceed to do the same with “square” F.



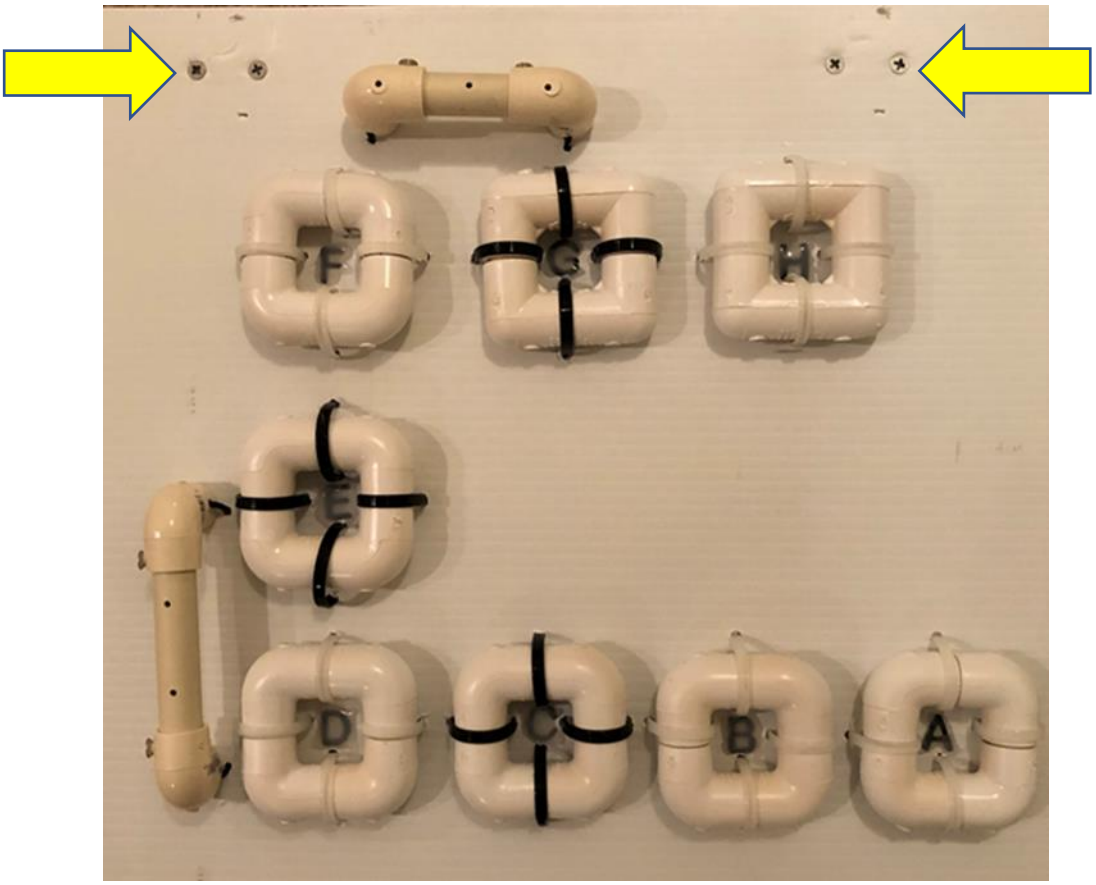
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- From the tie wrap of “square” F, measure 2 cm to the right, as shown in the picture. Draw a mark, drill and pass a tie wrap. Once you have the “square” “kind of secure”, flip it to write or stick letter G. Flip it back to the original position and draw the points to mark where the others tie wraps should go.
- Secure the “square” G and then proceed to do the same with “square” H.



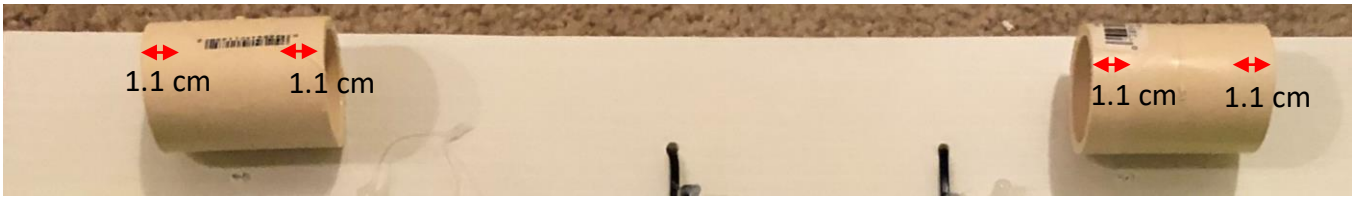
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- Do you remember the 2 pair of holes at the top of the CETA cart? If you drilled the holes, you are ready for the trick, if you didn't please do it now.



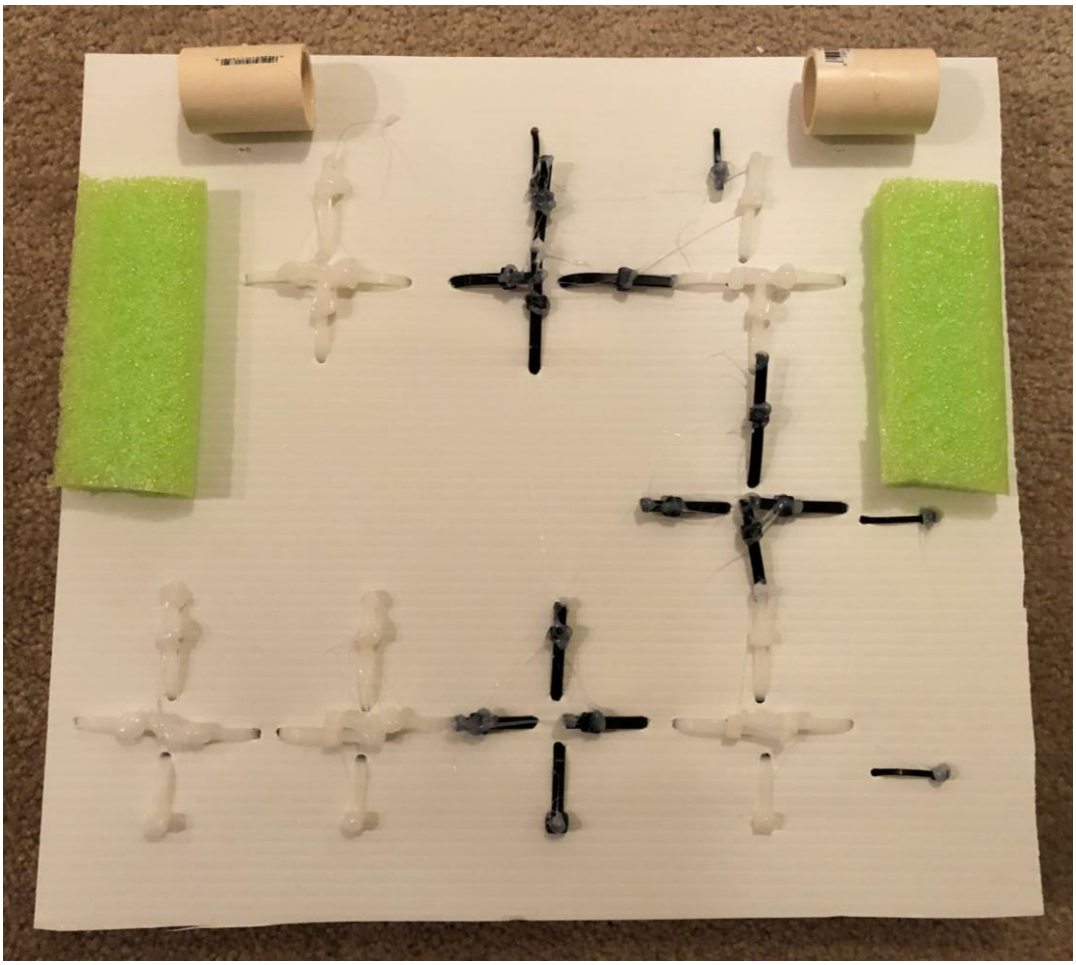
Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- You can take the CPVC connector and measure 1.1 cm from each ends to the center, do the marks and drill the holes, or…
- Do the trick taping the connector 1 cm from the border and with a marker, pass the marks to drill the holes. Is up to you.
- Once you drill it, secure with the screws.



Mission Course Assembly – Crew and Equipment Translation Aid (CETA) Cart

- Cut all the tie wraps (excess). If your students are like mine (they are natural helpers), add hot glue to the sharp areas to avoid cuts. Looks like a mess, but safety first.
- Cut 2 pieces of pool noodles (4” x 2”) and attach the noodles on the back with hot glue or epoxy.



Mission Course Assembly – Test tank

Materials

1 Storage tote 45 gal. (I recommend the blue wheeled one because is strong and easy to carry).

4 corrugated plastic sheet (22” x 2”)

6 pieces of industrial Velcro (4” x 2”)

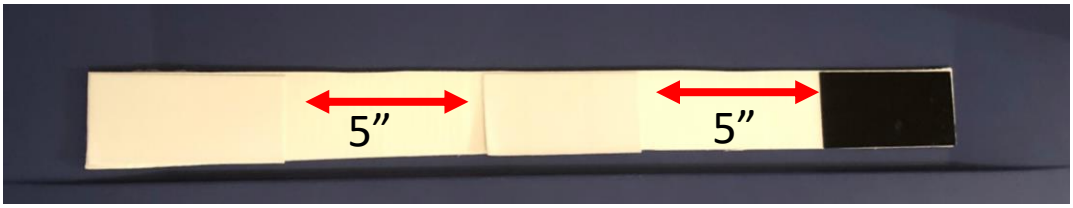
Epoxy

(4) Screws with nuts

Tape

Mission Course Assembly – Test tank

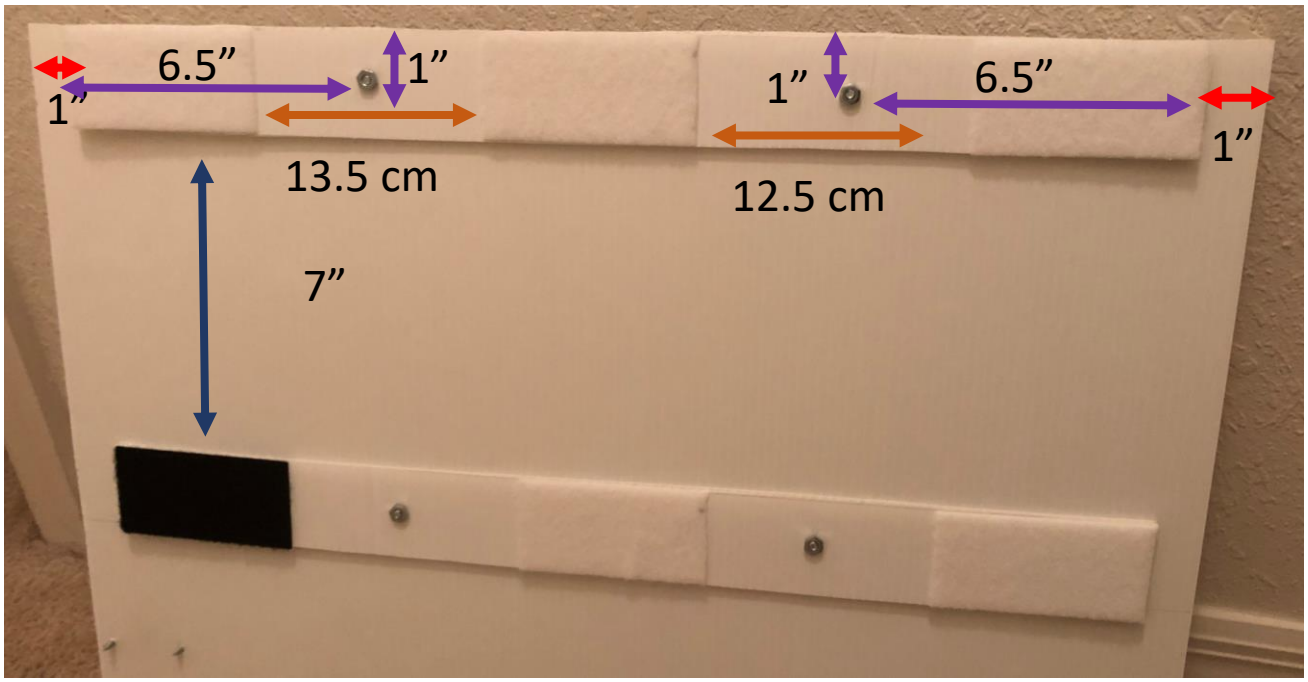
- Select which one you are going to use first (hook or woven) because it must be the same part in the corrugated plastic sheet. Take the corrugated plastic sheet and stick 2 pieces of Velcro at each ends. Measure 5” from the end of one Velcro and stick the other (middle).



- Do the same with the others three sheets. At the end you must have 2 corrugated plastic sheets with 3 pieces of Velcro all with hook sides, and 2 corrugated plastic sheets with 3 pieces of Velcro all with woven sides. They need to connect to join the Truss segment to the box, review first!

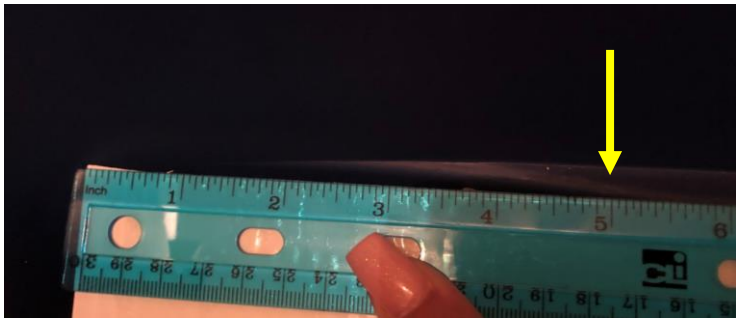
Mission Course Assembly – Test tank

- Locate the truss segment (base). Flip the truss because we are going to work in the back. Measure 1” from each side and placed the corrugated plastic sheet at the bottom. With tape secure the corrugated plastic sheet with Velcro to the base.
- Left to right, from the border of the Velcro to the right measure 6.5” and 1” as shown in the picture. Draw a mark. Do the same in the other side (right to left).
- Drill a hole that pass through both corrugated plastic sheets (the one with Velcro and the base).
- Locate two screws with nuts and from the side with the truss to this side (back), attach the screws and secure with the nuts as shown in the picture.
- Measure 7” from the border, tape the other sheet with Velcro and repeat the same steps.



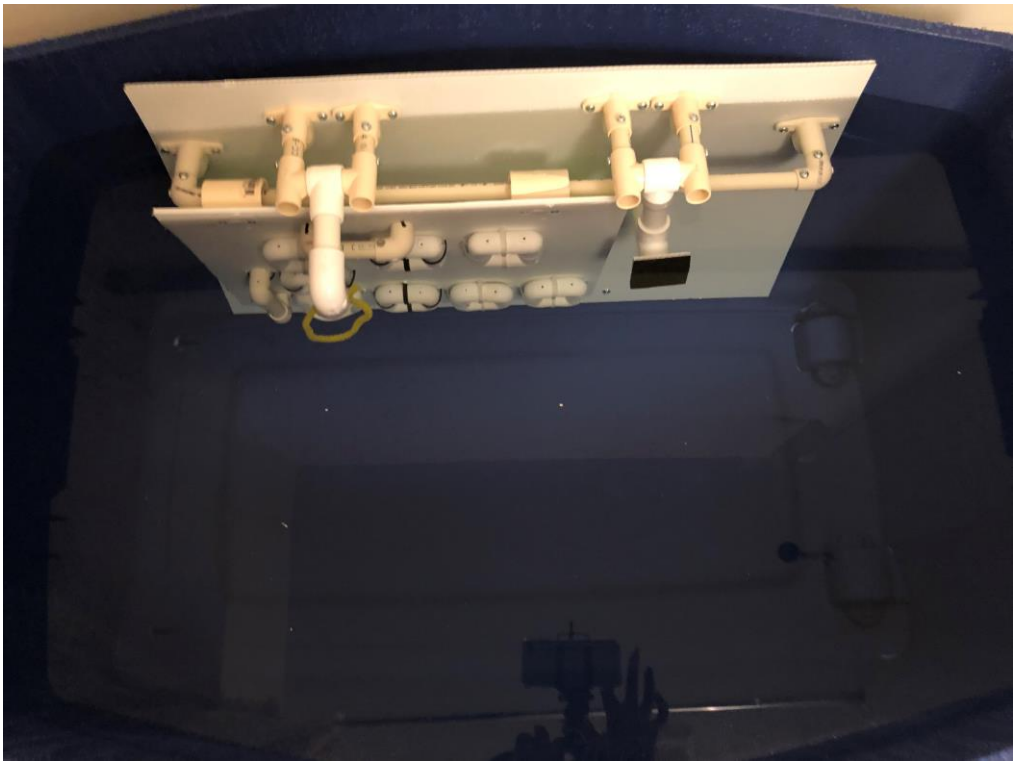
Mission Course Assembly – Test tank

- Locate the storage tote. Inside the box you are going to notice that there is a part that is like “going out”.
- Under that part, take a measure of 5” (both ends) and mark.
- With the epoxy, glue the corrugated plastic sheet to the box. Do the same at the bottom of the box with the other sheet.
- I recommend put books or something heavy to make pressure and cured for 48-72 hours before fill with water.



Mission Course Assembly – Assembly the CETA cart and brakes on the truss.

- Open the pipe, pass the connectors through the pipe, and secure the pipe to the elbows with screws.
- Open the middle part connecting both tees on the brake. Attach brakes and close (don’t use screws or mechanisms will not work).
- Left brake is the one with the elbow at the end (Port1). Put the pool noodle piece inside the elbow with the loop facing down for removal.
- Right brake is the one with the Tee and the Velcro piece (Starboard1). Students need to design, build, and test a flotation device to release the brake.



Grade Level: **6-8th**

EVA simulation using ROVs

Suggested Time: **60 minutes**
10 minutes – Introduction
30 minutes - Design & Build
15 minutes – Test
5 minutes – Discussion

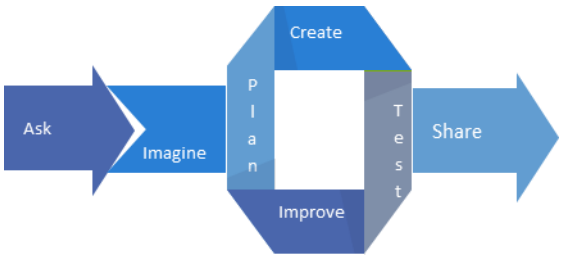
Challenge: Teams of 2-3 students will design and build a tool to attach to an ROV and complete a mission. Your tool will need to be able to disconnect and connect brakes to move the CETA cart from Port1 to Starboard1 on the truss segment.

Objectives:
Following this activity, students will be able to:
- Demonstrate the Engineering Design Process.
- Justify how Remote Operated Vehicles (ROVs) work and where they are used.
- Explain how the Neutral Buoyancy Lab (NBL) functions.
- Evaluate the functionality of the design with regards to the mission.

Materials:
- ❑ Safety glasses
- ❑ Vise
- ❑ Pipe cutter
- ❑ PVC pipe ½”
- ❑ PVC fittings ½”
- ❑ Scissors
- ❑ Duct tape
- ❑ Students Activity Worksheet
- ❑ Pencil

Next Generation Science Standards (NGSS):

MS-ETS1-4 - Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.



NASA Connection:
The mission of the Neutral Buoyancy Lab (NBL) is to prepare for space missions involving spacewalks. NASA team members use the NBL to develop flight procedures, verify hardware compatibility, train astronauts and refine spacewalk procedures during flight that are necessary to ensure mission success.

On March 23, 2009 NASA astronauts Joe Acaba and Ricky Arnold performed an EVA to relocate the Crew Equipment Translation Aid (CETA) cart from Port 1 to Starboard 1 truss segment. This challenge is based on STS-119 mission. Find more information about the NBL
https://www.nasa.gov/centers/johnson/pdf/167748main_FS_NBL508c.pdf

Procedure:
1. Discuss the Engineering Design Process.
2. Put students into groups of 2-3.
3. Introduce the challenge.
4. Show students the available materials to build their tool.
5. Explain the Student Activity Worksheet to the students, emphasizing the importance of gaining teacher approval, or “certification” .
6. Allow students to work in their teams to complete through the Create step on the Student Activity Worksheet.
7. After 30 minutes, bring the students back together to discuss testing guidelines.
8. The teachers will facilitate the testing process. Record each team’s results.
9. Allow time for students to complete the remainder of the Student Activity Worksheet.
10. Bring the students back together to discuss the successful components of each team design, as well as any improvements that could be made.
11. Optional Extension: *If time allows, have each team refine their design for another iteration of the tool.*

STUDENT ACTIVITY WORKSHEET

Directions: ***For each step in the Engineering Design Process, complete the required task to get approval from the teacher to move on to the next step.***

Ask: What problem will you be solving in your Engineering Design Challenge today?

_____
_____
_____
_____

Teacher Initials: _____

Imagine: Think on some ideas about how your tool should look like. Select the best among them.

_____
_____
_____

Teacher Initials: _____

Plan: Draw a little sketch of your tool. Make a list of the materials you will need to gather to construct your tool. Take this list to your teacher for approval before gathering the materials to build your tool.

Materials:

_____
_____
_____

Teacher Initials: _____

Create: Build. Describe how do you build your tool. Write the steps in order. Take your tool to your teacher for your final approval before testing.

_____
_____
_____
_____
_____
_____
_____
_____
_____

Teacher Initials: _____

Test: With your teacher's permission, test your tool in the test tank. Was your tool successful? Why or why not?

_____
_____
_____
_____
_____
_____

Mission Completed: Yes____ No____

Improve: What changes could you make to your tool design to improve it?

_____
_____
_____
_____
_____
_____

Share: During the group discussion, share your test results and improvements with the class.

References

ISSmania2 Channel. (March 23, 2009). *STS-119 EVA#3: 3rd Spacewalk.* Youtube. https://www.youtube.com/watch?v=i4S9gRDTxCY

NASA. (2020). Sonny Carter Training Facility: The Neutral Buoyancy Laboratory. Retrieve from: https://www.nasa.gov/audience/foreducators/spacesuits/facts/index.html

NASA STEM Engagement. (2020). NASA STEM Engagement Goals, Objectives and Design Principles. Retrieve from: https://www.nasa.gov/stem/partnerships/stem-engagement-objectives.html

Oceaneering. (2020). Neutral Buoyancy Lab (NBL) NASA Facility available for industry use. Retrieve from: https://www.oceaneering.com/datasheets/OSS-NBL.pdf