Kwadropus Duster Robot
Suction Cups

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The premise

- Octopuses live neutrally buoyant in the water—they don't really sink and they don't really rise up, they can rest in the water without moving up or down. This is similar to how an astronaut floats around in the Neutral Buoyancy Lab when they train for a space walk on the space station. When astronauts are inside the space station in micro-gravity, it is similar to being neutrally buoyant—they don't sink or rise. The air has a lot less mass so it is very difficult to move enough air to 'swim' when on the Space Station.

The Proposal:

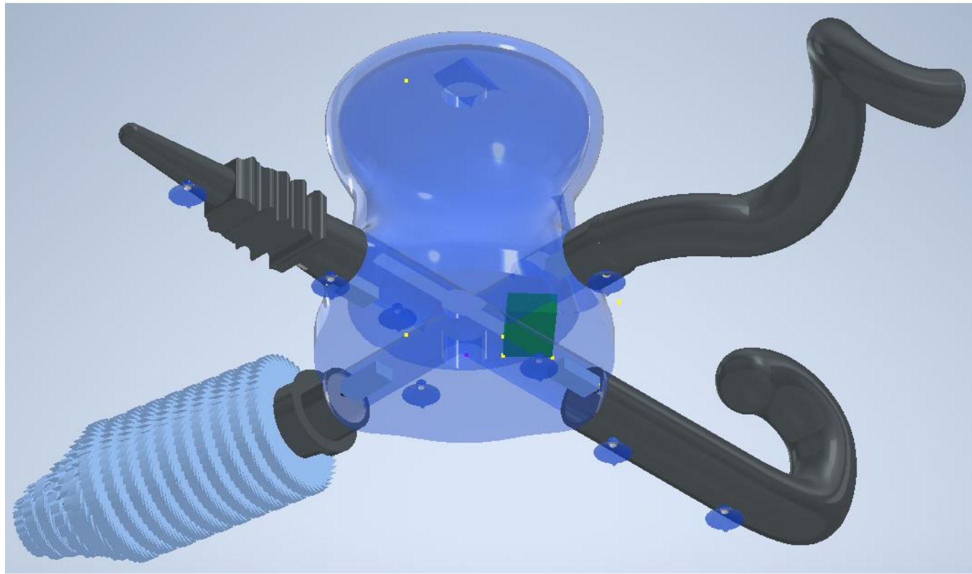
- HUNCH would like to demonstrate the feasibility of an octopus like, soft robot that can crawl around the inside of the Starlab or Axiom Space Stations using flexible arms and suction cups on handrails and flat or curved, smooth surfaces for mobility and uses some kind of duster appendage to remove dust from the walls of the space station. The idea is that it needs to work kind of like a Roomba (but doesn't vacuum up the dirt) for a zero-g environment. An Octopus has 8 arms but HUNCH expects that our dusting robot may only need 4 arms—which makes it more of a Kwadropus. Like an octopus, each of the 3 mobility arms need to be able to act independently to find something to grasp and hold to prevent the Kwadropus from pushing away from the wall. Two suction cups per arm will need to be placed where they will have the most chance of being used. While the 4th arm, a duster arm, is cleaning, at least one of the mobility arms has to be holding the Kwadropus onto a wall or handrail either with a grasping of an object or a suction cup to a surface to keep it from being pushed away from the wall and floating aimlessly. If somehow the Kwadropus does get pushed away from the wall and handrails, the Kwadropus will use some kind of octopus like propulsion to push itself back to the wall.

A Roomba is a small, robotic room sweeper and vacuum cleaner. We are looking for a duster without the vacuum suction.

The Teams

- The **Kwadropus Robot** is divided up into **five different projects** to allow small teams to concentrate on what they are good at and increase each team's chances of success. This is how NASA or any engineering company would develop a new product. Part of each team's responsibility is to be aware of what the other team's requirements are and to stay on their own requirements so everyone continues to work for the same goal and final product.

  - Mobility Arm Team
    - Develop one robotic arm with minimal amount of rigid parts that can pull itself from one location to another using a handrail or other
    - Can rotate to grasp in multiple directions
  - Suction Cup Team
    - Develop a suction cup that can conform itself to a smooth but rounded surface and suction onto it. This could be size related—small suction cups can attach to smaller curves, big suction cups can only attach to fairly flat surfaces.
  - Propulsion Team
    - Develop a propulsion that simulates how an octopus uses a directional jet of water to move itself if it can't grab or grip the wall or handrail.
  - Duster Arm Team
    - Develop a flexible and moving dusting arm that will be able to remove and absorb dust as the robot moves around the module walls without liberating dust into the surrounding volume. (slow may be important)
  - Control Team
    - Develop a method of hive programing similar to an octopus where each arm is able to control itself autonomously—looking for a grip-- but still takes commands from the central brain to clean the room in a random fashion or if the robot is floating away from the wall



- No team should try to do a whole robot—each of these projects requires deeper thinking and prototyping. Two or more teams can put their projects together to help demonstrate how things fit together but that does not mean they will be selected together.
- Because this is the first attempt at this kind of motion, none of these have to act fast. This robot could take an hour to move a few inches. We need to see what kind of motion is possible

General ideas updated to answer several good questions

Nobody has done this before so we are exploring something new.

- As of now, we are attempting to demonstrate the technology and the techniques of how this can be done as individual parts. I'm not too worried about the size of your demonstration as long as your prototype can fit on a table top and show how it works. Once we have terrific ideas from each of the teams, then we will look at how to incorporate all of the ideas into a functional robot.
- The only team that needs to have motors at this point in the development is the control team. If you are able to show your mobility arm or duster arm works by pulling strings or use a syringe to push air in and out of it, that works for me. Later on we can see what kind of motor is needed to pull the string or pump to suck out the air. If you can activate your suction cup with a couple of strings and/or a syringe that will show the idea—motors are ok but not needed.
- This robot will eventually operate on batteries similar to a Roomba. We would aim at it being able to operate for 1 to 2 hours on its own before it has to recharge.
- Expect that the internal temperature of the space stations will be around 71 degrees F.
- It needs to be soft so that it doesn't damage hardware as it moves around. Also since we are aiming at many different space stations, soft robotics may allow for more diversity of movement in a generic environment.
- It is early to know what size the kwadropus duster will be in the end but I think we should aim for a robot that would be around 2 to 2 ½' in diameter and maybe a foot tall.

Starting points but not enough information

How does an elephant trunk work

- https://www.businessinsider.com/elephant-trunk-powerful-nose-sniff-out-bombs-2019-1

Anatomy of the tongue

- https://www.google.com/search?q=how+do+tongues+move&rlz=1C1GCEA_enUS939US939&ei=-6YhZM3SFY7DqtsP5q6lgAY&ved=0ahUKEwiNvMPxp_z9AhWOoWoFHWZXCWAQ4dUDCBA&uact=5&oq=how+do+tongues+move&gs_lcp=Cgxnd3Mtd2l6LXNlcnAQAzIFCAAQgAQyCAgAEBYQHhAPMgYIABAWEB4yCAgAEBYQHhAPMgoIABAWEB4QDxAKMggIABAWEB4QDzIGCAAQFhAeMggIABAWEB4QDzIICAAQFhAeEA86CggAEEcQ1gQQsAM6BwgAEIoFEEM6CAgAEIoFEIYDSgQIQRgAUJsIWP0XYIYbaAFwAXgAgAGHAYgBnAeSAQMwLjiYAQCgAQHIAQjAAQE&sclient=gws-wiz-serp#fpstate=ive&vld=cid:aa384407,vid:lATWhP0wJ5c

Robotic turtle—soft parts

- https://mashable.com/video/mit-robot-sea-turtle

Completely Soft Robot

- https://www.technologyreview.com/2016/12/08/155290/meet-the-worlds-first-completely-soft-robot/

Octopus soft arm

- https://onlinelibrary.wiley.com/doi/full/10.1002/aisy.201900041
- https://www.youtube.com/watch?v=8IXncY4L_nc

Chameleon inspired

- https://www.youtube.com/watch?v=trDz4Ukz_VQ

Langley Soft robotics lab

- https://www.youtube.com/watch?v=VuxnPLU_KEs
- https://www.youtube.com/watch?v=iwQRYzLZvGE

Oregami octopus—You will not be able to use magnets like this one because the changing magnetic field would damage the electrical systems in the space station, but there is some really cool thoughts here

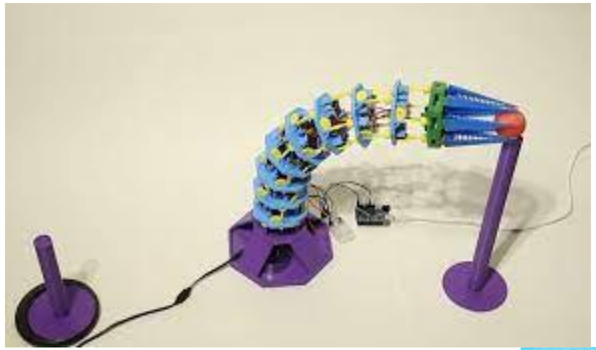
- https://techxplore.com/news/2021-08-omnidirectional-octopus-like-robot-arm-motor.html

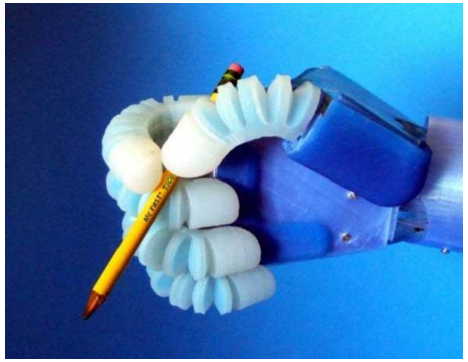
Tips for making soft robotics components

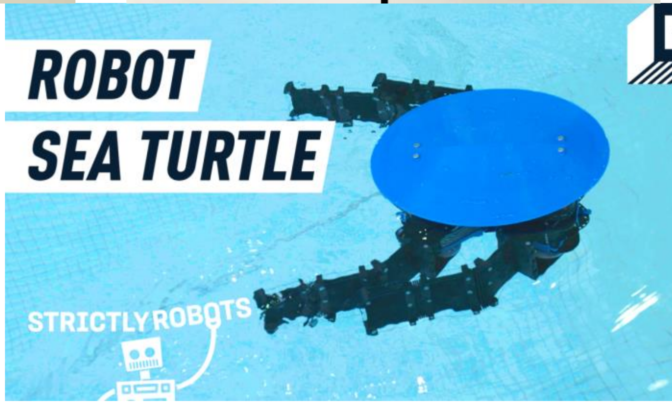
- https://www.youtube.com/watch?v=TyYW9BmMeSs
- https://www.youtube.com/watch?v=GgJt6vIbiso

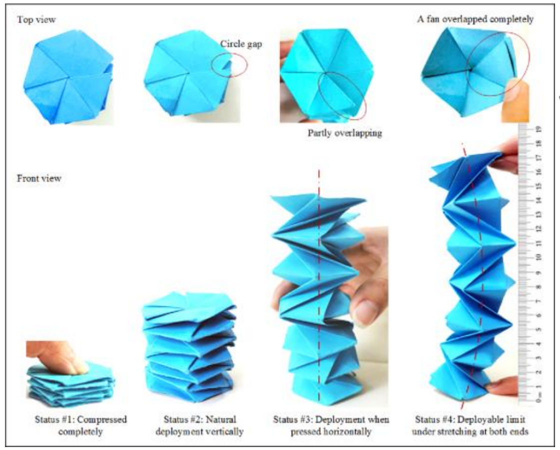
Other related ideas for soft robotics

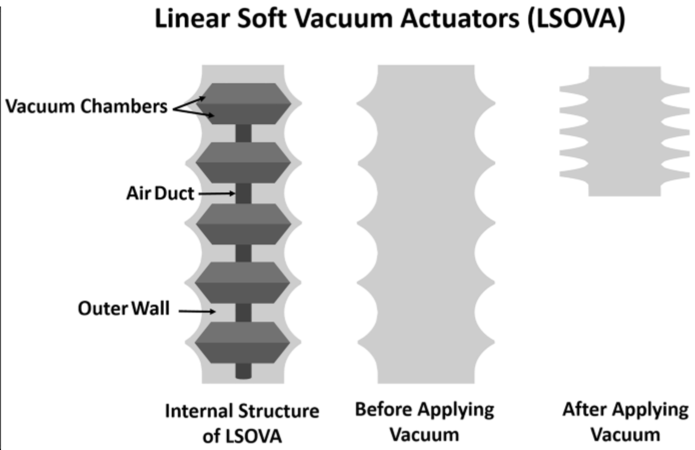
- https://www.universetoday.com/162514/engineers-design-a-robot-that-can-stick-to-crawl-along-and-sail-around-rubble-pile-asteroids/





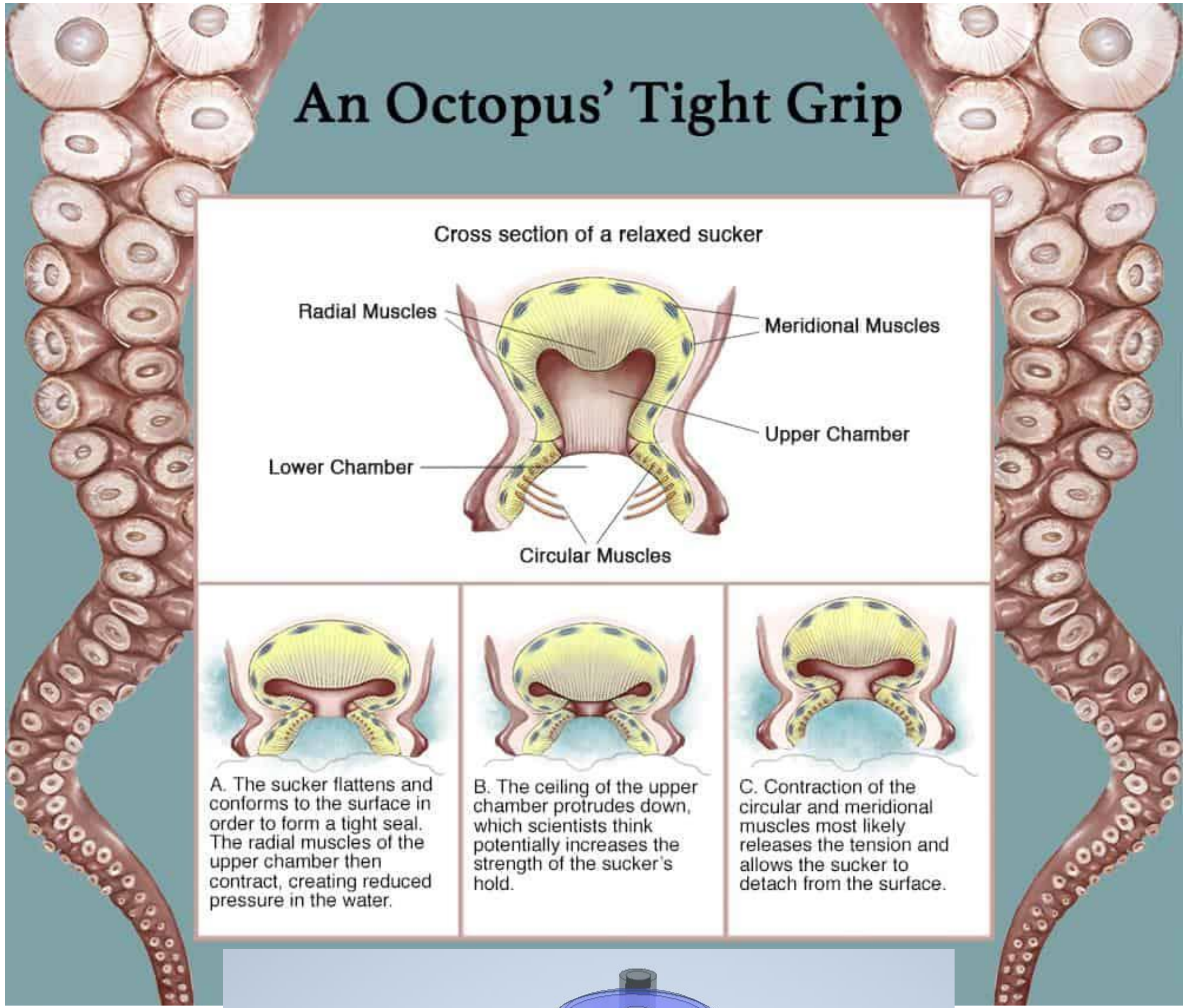


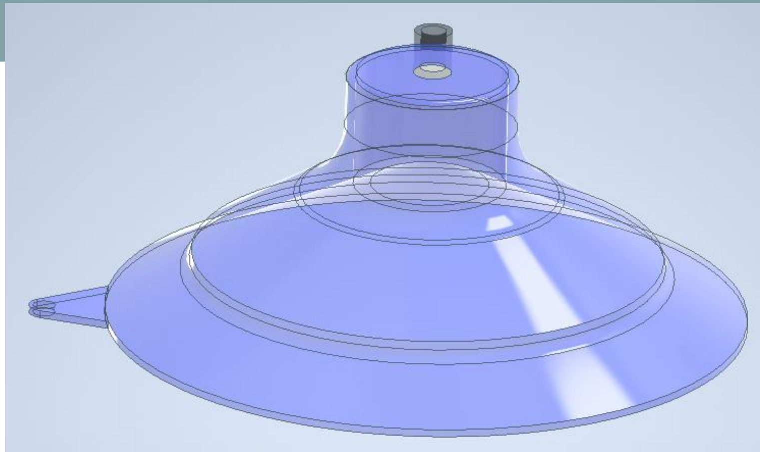




Suction Cup Team

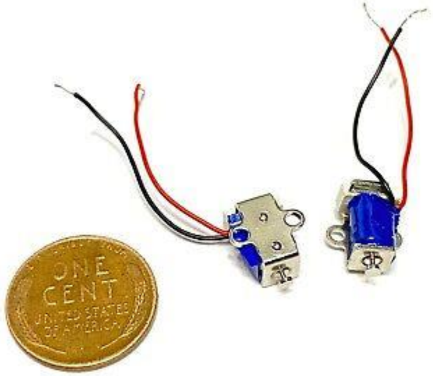
- An octopus can have over 200 suckers on an arm depending on the type of octopus. Each sucker has muscles that allow it to bend and flex to attach to fish, rocks and other food and objects. Each suction cup acts like a finger and can taste what it is touching. Each one also has a hole in the center that allows it to pull in water so it can suck onto objects.   This makes octopus suckers and arms pretty complex.
- On our robot, each arm will have two suction cups. Each Suction cup needs to be able to act independently. Each suction cup should be able to change Shape to allow it to **grab onto a smooth curved surface and release**. The more it can change shape the more it can grab on to.
- https://www.facebook.com/montereybayaquarium/videos/octopus-101-suckers/2162314327347174/
- https://www.google.com/search?rlz=1C1GCEA_enUS939US939&q=How+do+octopus+suction+cups+work&sa=X&ved=2ahUKEwifl-Ck9_r_AhW4GjQIHTigDYIQ1QJ6BAguEAE&biw=1536&bih=722&dpr=1.25#fpstate=ive&vld=cid:43cc694c,vid:XXMxihOh8ps
- This suction cup could be driven mechanically or pneumatically or electromagnetically—I'm open to other ideas too. The point is that they need to be able to grip and then release without pushing the robot away from the wall



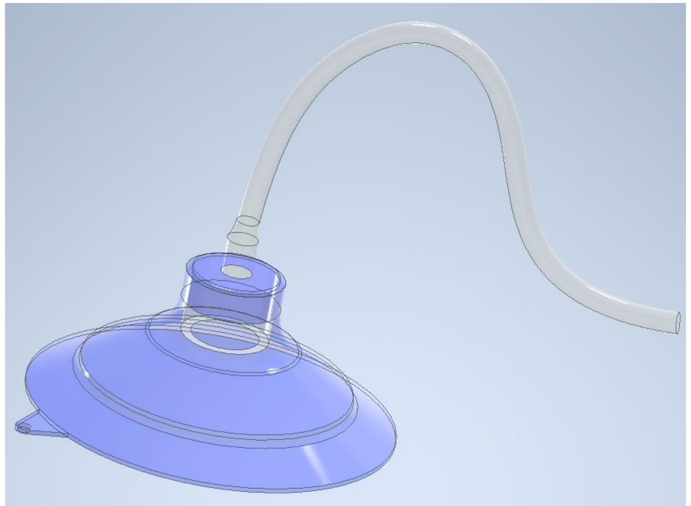


Mechanical activation could be activated with a servo motor

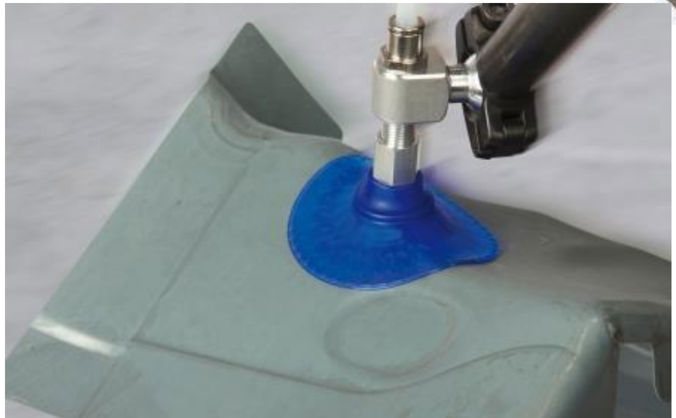
The robot will need to be able to attach its suction cups without pushing on the surface other wise it will push itself away from the wall because of the lack of gravity.



Small Solenoid suction cups (use electromagnets to activate the suction cup)



Pneumatic activation



Needs to be able to attach to curved smooth surfaces. Smaller suction cups can attach to curvier surfaces.

Air pumps for pressure and vacuum are nice but not necessary.

Although air compressors can deliver a lot of air, they are not necessary for developing soft robotics where you are dealing with relatively small volumes. Compressed air and vacuum can be done with small and large syringes.

Suction cups can be actuated by removing air, mechanically pulling up on the diaphragm, pulling up with a solenoid

Check this out!!!! This is really exciting. Notice how the suction cups are used.
https://www.msn.com/en-us/money/other/raw-video-squishy-robotic-worm-slithers-inside-aircraft-engines-for-maintenance/vi-AA1hedfC?ocid=socialshare

Important questions

How important is it for the suction cup to actually be a suction cup, as opposed to some other soft gripping technology?
Great question!!
Suction cups are the obvious choice when emulating an octopus and they don't leave a residue unlike tapes and adhesives. There are mechanical and pneumatic methods of manipulating them. They may not have a curved shape but could be a fairly flat, flexible material that can adhere without
Gecko tape is another material that may be of value to examine and emulates the bottom of the gecko lizard's feet. Real gecko tape uses microscopic filaments and Van der Waal forces to adhere to relatively smooth surfaces and release when pulled at a specific angle—no adhesive. This is a great option if you can get some. Unfortunately there are several brands of tape that say "gecko" in the title but are really just an adhesive—be careful. Real gecko type tape can be expensive but it is getting to be more available.
If you have other ideas, send me an email.
Please give guidance around allowed use of magnetism.
Most of the materials on the ISS are aluminum, stainless steel, plastics, cloth—non-magnetic materials. I expect that the new space stations will probably use similar materials—not much steel. NASA tries to avoid using magnets most of the time to avoid damaging computers or disrupting other electrical components. There are a few magnets on the ISS—most are very weak or kept away from electrical equipment.
Are potential residues or surface marking allowed?
We definitely want to avoid residues as that would be against the cleaning the duster is doing and could cause dust to collect on the residue.
We don't want to scratch the surfaces if we can help it. If we need to come up with some kind of patterns or markings to help guide the robot, I'm open to the idea.

Testing

- Your suction cup should be able to touch a smooth surface and be able to attach and hold with some amount of force but not require much force to attach. It also needs to be able to release quickly and easily without requiring a lot of force.

Try this

- Place a new, flat sheet of paper on a smooth, clean surface. Make a little finger handle with some tape in the middle of the paper. If you lift up on the paper from the corner, it comes up easily. If you pull it up from the center handle slowly, it picks up pretty easily but you can feel a little tug at the beginning of the pull. If you pull it up from the center quickly, you can almost rip the paper. You have turned your piece of paper into a suction cup.
    - If you pull it up slowly, why does it release?
    - What material could you use instead that would make it better?
    - Why isn't there any suction when you pull it from the corner?
    - Would it be better if there was something to make it rigid in one location and more flexible in another part?
    - Does it need to be 8 ½" x 11" to work or could it be done smaller?
    - How might you do this robotically instead of with your hand?
    - What if your smooth surface is curved? How much curve could it handle? Will it still work upside down or without gravity?

Finger handle made of tape