# Kwadropus Duster Robot Controls

Glenn Johnson, Don Pettit, Kayden Valverde, Dani Alvarez, Gene Gordon, Kristen Magas

**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.

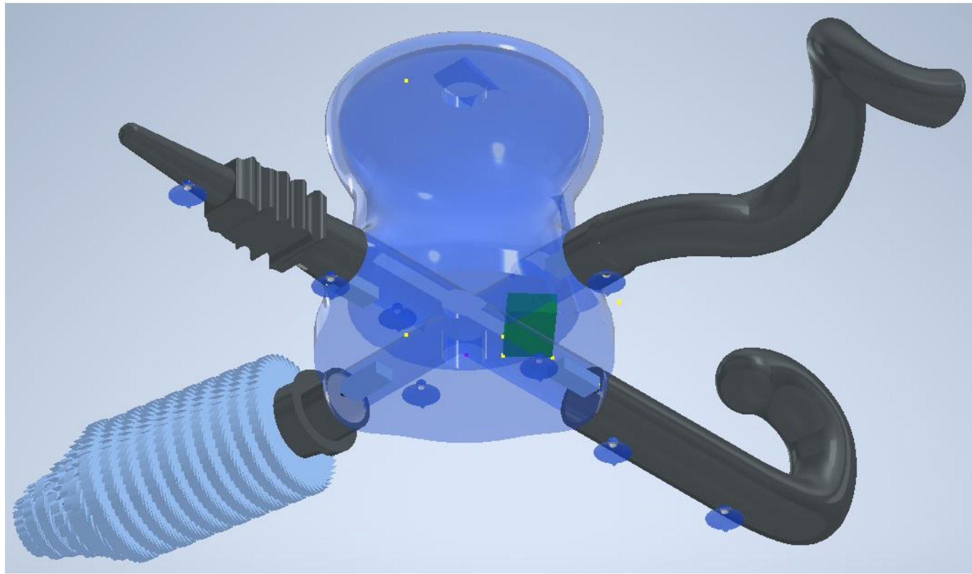
**The Proposal:**

- HUNCH would like to demonstrate the feasibility of an octopus like, soft robot that can crawl around the inside of the Starlab, Axiom, Tiangong, Lunar Gateway, Orbital Reef, Haven-1 or any other 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**

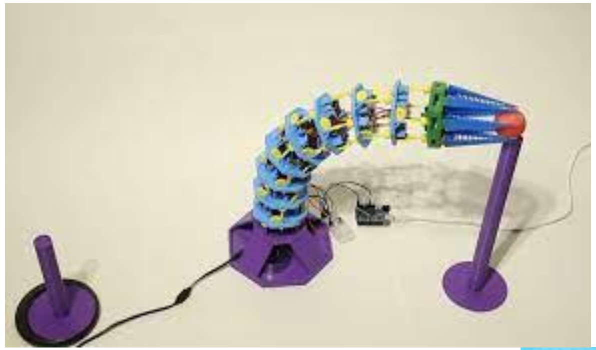
- https://techxplore.com/news/2021-08-omnidirectional-octopus-like-robot-arm-motor.html

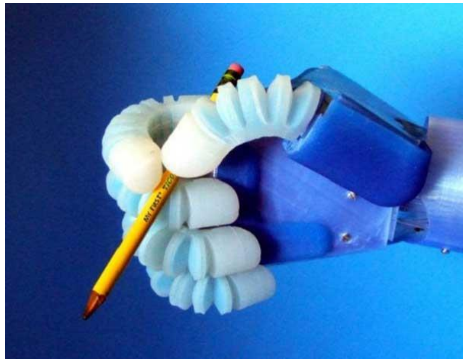
**Tips for making soft robotics components**

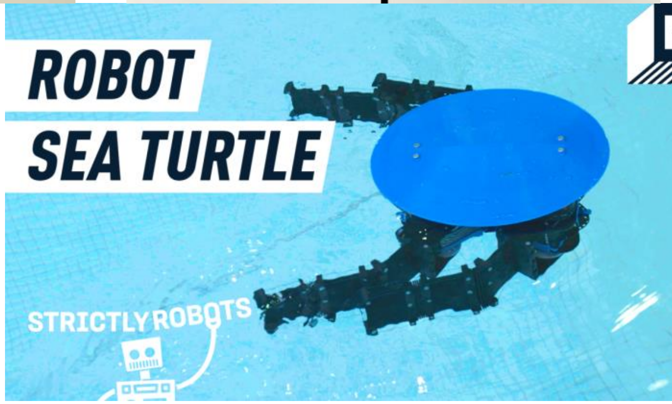
- https://www.youtube.com/watch?v=TyYW9BmMeSs
- https://www.youtube.com/watch?v=GgJt6vIbiso

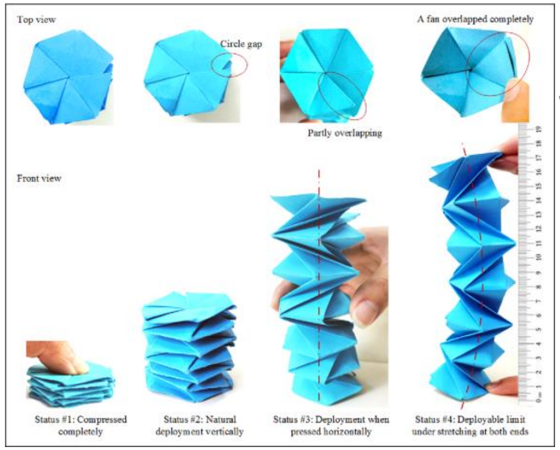
**Other related ideas for soft robotics**

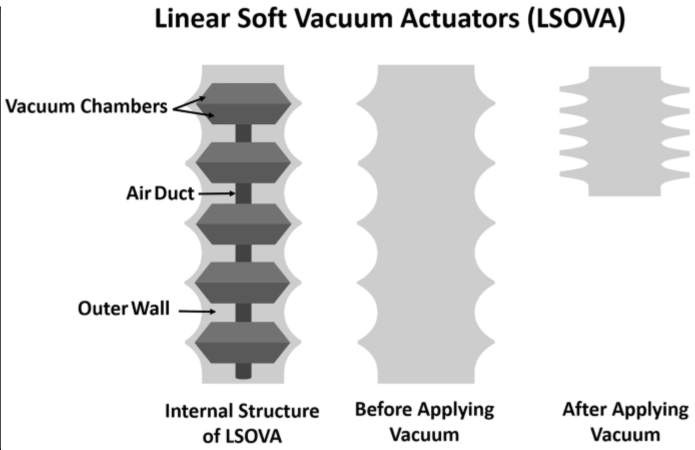
- https://www.universetoday.com/162514/engineers-design-a-robot-that-can-stick-to-crawl-along-and-sail-around-rubble-pile-asteroids/







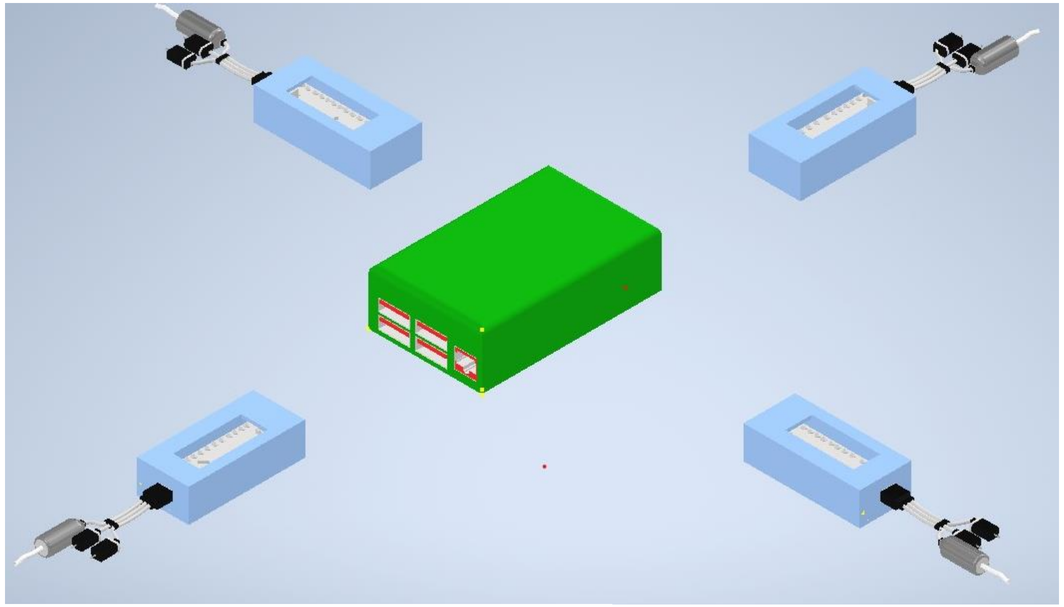



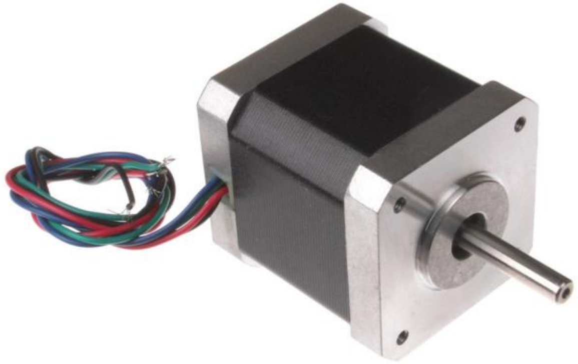



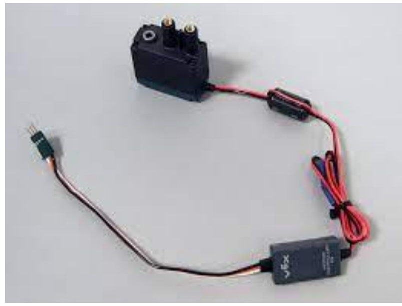
# Control Team

- An octopus has 9 brains. One in each arm and one in it's mantle. This explains why an octopus arm continues to wriggle, respond to food and respond to pain for up to 5 hours after being cut off. Each octopus arm is feeling around for food independent from the other arms and from the central brain. Once the central brain makes a decision for attacking prey, escaping from a predator or other general motions, the arms react as one. Although you can find much more information on this, we should not pretend to think we understand the advantages and disadvantages of this mulit-brain. This robotic experiment may help us understand the octopus better.

- Develop the controls and software needed to drive the 3 mobility arms, the propulsion and the duster arm
- Part of the objective of this project is to explore what kind of value there may be to this kind of separation of brain functions—to simulate some of the octopus functionality. This project will use an Arduino(or similar small processor) to control 3 or more servo motors to actuate an octopus arm and two suckers. The Raspberry Pi (or similar small computer) will give commands to two other servos that will operate an air bag and a directional valve for propelling the octopus short distances with puffs of air.
- To work this project you need to be able to obtain
- This could be done with a variety of controllers-Vex, maybe even Lego robotics—the point is that primary processor needs to be able to run the duster arm, the propulsion and then let the secondary processor hunt around for a grip with the arm and suction cups.
    - Equivalent of an Arduino
    - Equivalent of a raspberry Pi 4
    - 5 servo motors or more
    - 4 micro switches that can be used as contact sensors
    - Able to program in Python or C sharp







The objective right now is not size but functionality. Show me that the secondary controller is able to independently control the arm and then take commands when the primary controller needs to give directions. Later in the development we will try to fit the needed electronics into the package that we want.

# Octopus brain

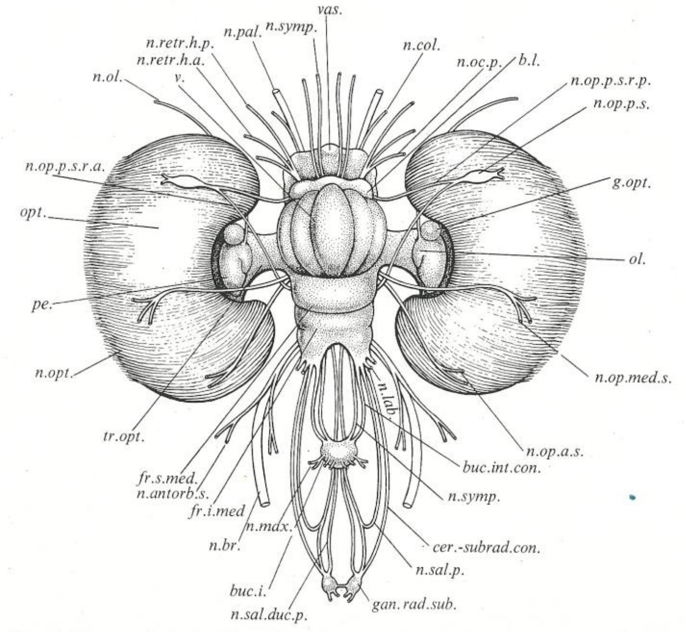
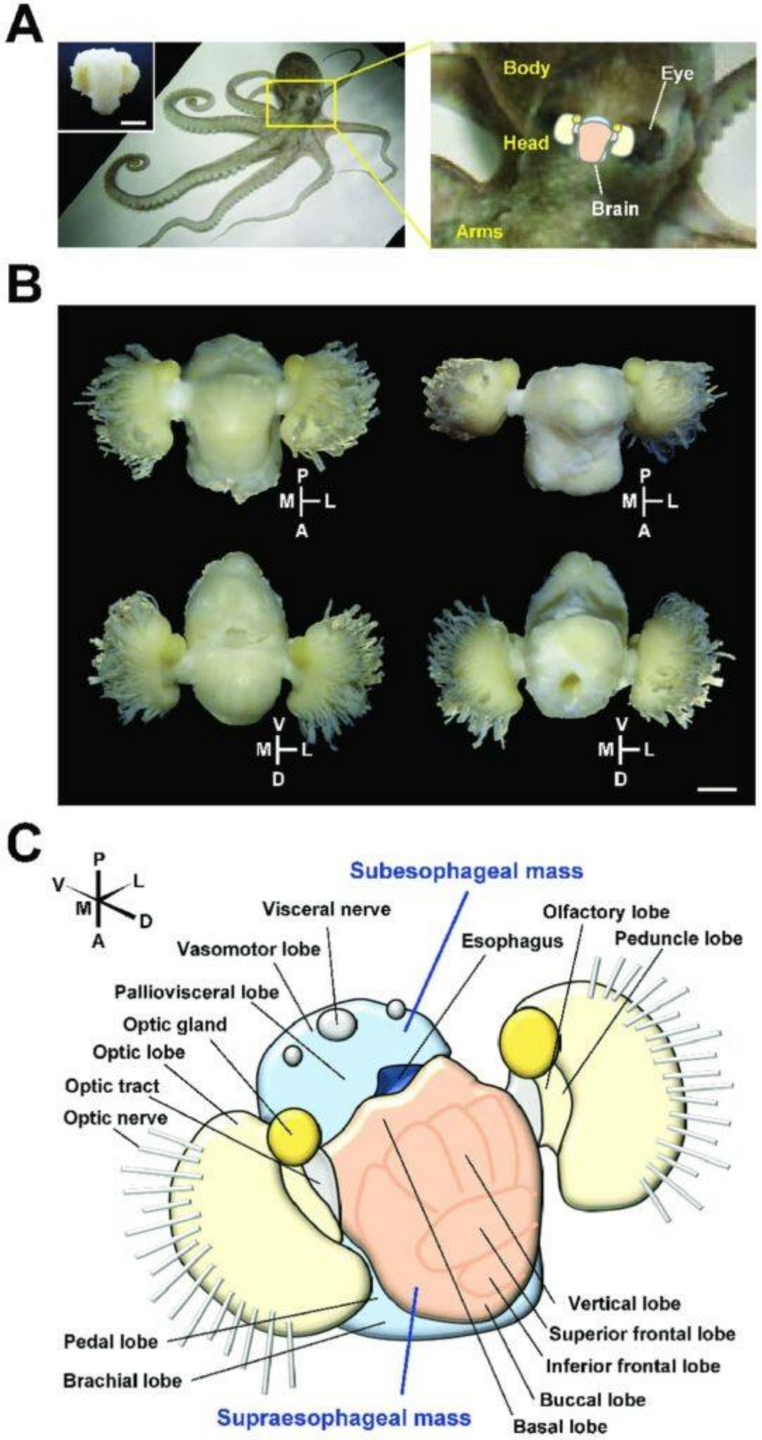
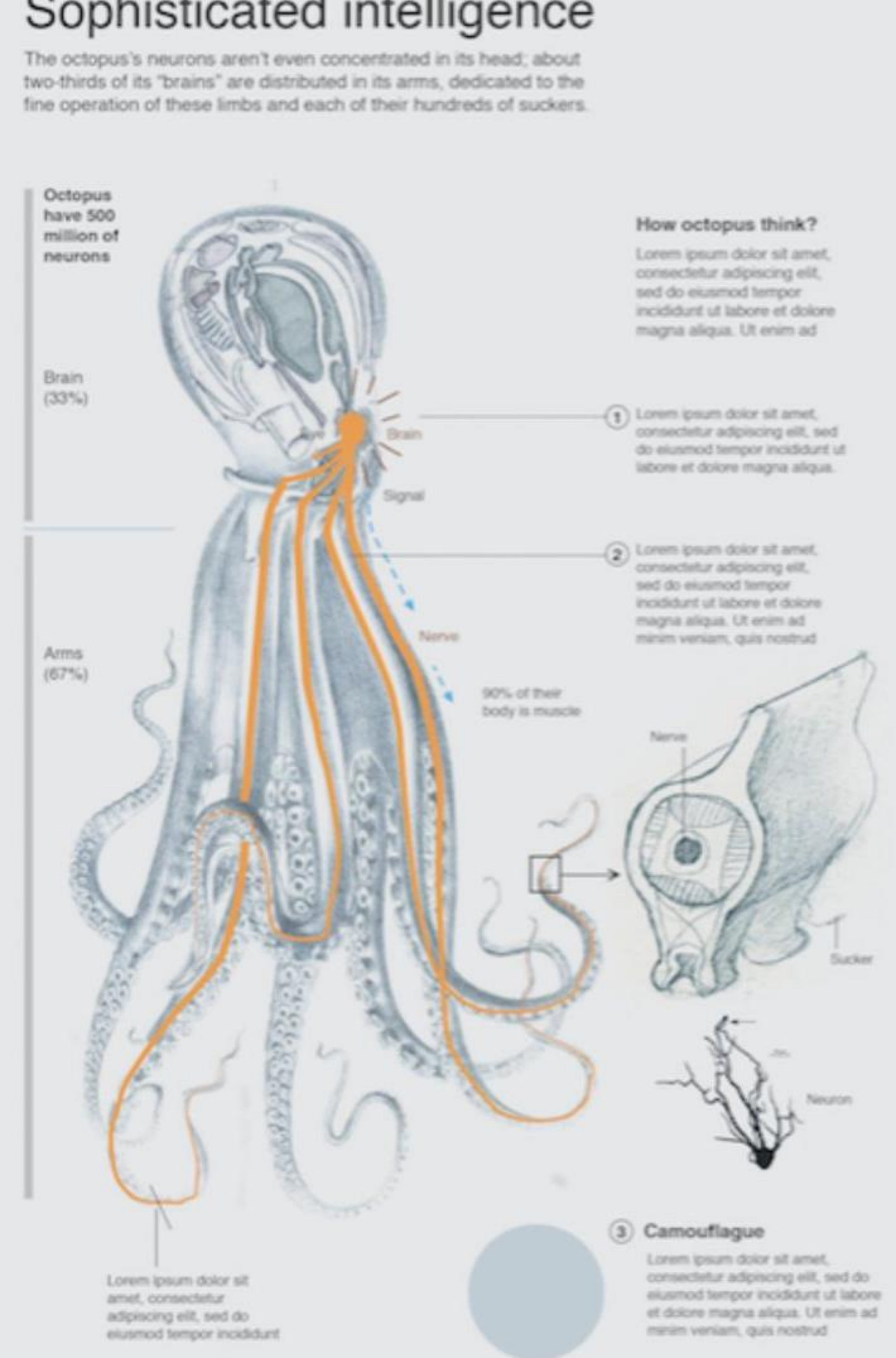


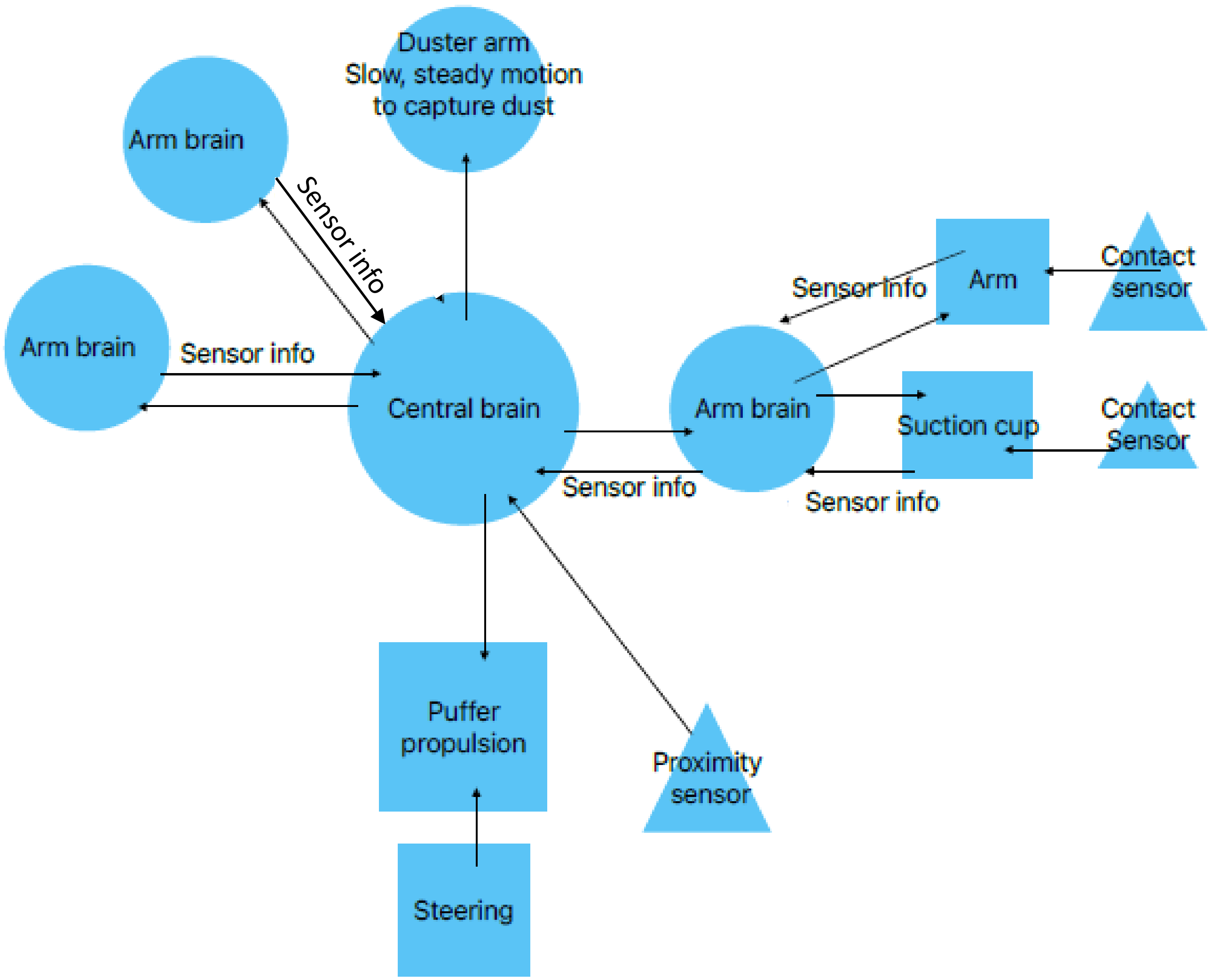

FIG. 1.6. Diagrammatic drawing of central nervous system of *Octopus* as seen from above (modified from Young 1964*b*).



# Control logic

- The last team is the control team Their job is to figure out how to get all of the parts to work together. The overall design is to work similar to a Roomba by picking up dust like a dust mop and randomly move about a module and pick up dust from the walls using handrails and smooth surfaces to get around. An octopus has nine brains. Each arm has an independent brain that controls the arm. When there is a need to have all of the arms working together, the central brain takes over and determines the need for each arm. On this kwadropus each arm needs to be able to search independently for a grip on the wall so each arm will have some autonomy. However if the robot fails to grab onto a handrail or suction cup onto the surface, it will start to float away from the wall and the central brain needs to take control, get the robot back to the wall and direct the overall movement to accomplish the cleaning of the module



# Some questions answered

Are you looking for a distributed control system? (Logic processing located in each arm and some supervisory processor monitoring them and providing inputs when needed)
Yes. The intention is that each mobility arm is looking for a good place to grab onto so the robot is able to dust that area without being pushed away from wall. The central brain would then be in control of running the duster arm and the propulsion system if the Kwadropus starts floating away from the wall.

Would you like a comparison of performance between centralized control and distributed control?
I think it could be done with a centralize control but I'm more interested in distributed control because the octopus has evolved to be an intelligent, strong predator partly because of its distributed brain functions. I think there could be some valuable lessons to learn from having the arms having some of their own autonomy.

Do you care about a User Interface?
I expect that the first unit that is produced, it would need to have a user interface so that corrections can be made and we can monitor the code while operating but eventually I would like it to be as autonomous as the Roomba.

Do you care about the physical demonstration unit?
I don't care what your demonstration unit looks like. I'd like the computing systems to be minimalistic as possible to getting the job done but don't under sell your needs. I'm also hoping you can use materials your school already has for your demonstration unit so you don't have to purchase lots of equipment.

Required planning documents? Program organization and flow diagrams, Instrument Tag lists, Wiring diagrams, Pseudocode
I will be conferring with computer science teachers and programmers that can answer this better and I will get back to you on this.