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CANADARM ROBOT ARM MOBILITY SYSTEM

REFERENCE, USER AND ASSEMBLY MANUAL

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8+

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STEM.ORG AUTHENTICATED™ EDUCATIONAL PRODUCT

DESIGNED BY Dr. Pablo SPACE RESEARCHER

ASSEMBLY VIDEO

Item No. 63800

DESIGNED IN THE USA

This kit will teach you how to assemble and operate a robotic arm, like the one used in Space Shuttle Program.
You will assemble and operate a robotic arm, and try your satellite repair skills in space.

WARNING!
Not to be used by children except under adult supervision.

SAFETY INFORMATION

⚠ WARNING:
CHOKING HAZARD - Small parts.
Not for children under 3 years.

This STEM toy has been designed for children of 8 years of age and older.

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Concept, text and design by: Pablo de León, Kein Design, Martin Demonte and the team of Future Explorers LLC.

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CANADARM ROBOT ARM MOBILITY SYSTEM

REFERENCE, USER AND ASSEMBLY MANUAL

INDEX

Meeting Dr. Pablo

My name is Pablo de León, but I am better known as Dr. Pablo. For the past thirty years, I have been working on what I consider to be the most fascinating topic of all time: human spaceflight. Human spaceflight is the study of how to send humans into space. It involves designing spacecraft, spacesuits, and all of the associated tools, equipment, and systems that astronauts need to explore space. It also includes the exploration of celestial bodies such as the moon and Mars.

Throughout my career, I have primarily focused on designing advanced spacesuits for returning to the moon and starting the human exploration of Mars. I have received several NASA awards, and the American space agency has funded my research to study ways to protect astronauts from the most hostile medium known to humanity, which is space.

I have always been passionate about space exploration, and in this new stage of my life, I want to share this enthusiasm with all of you. Even if you don't plan to become an astronaut, aerospace engineer, or rocket scientist, this knowledge will serve you well in the future.

Through these projects, we will learn and have fun together. We will be putting together experiments, models, and vehicles. My intention is to share my passion for space exploration with all of you.

Now, in a time of diminishing resources on Earth, it is imperative that we find ways to harvest the unlimited potential of energy and resources we have in space, and we need you to make it possible.

Dr. Pablo

DESIGNED BY Dr. Pablo SPACE RESEARCHER

What is a Canadarm?

The Canadarm robotic arm is a manipulation system used in space missions by NASA. It was developed by the Canadian Space Agency (CSA) and private companies, and has been utilized in numerous space missions, including those involving the NASA Space Shuttle and the International Space Station (ISS).

Here, you will learn about the history of the Canadarm robotic system. There is a lot to learn, and it will take some time. However, if you prefer to begin assembling your robotic arm now, that is ok. You can come back to learn more about the history of this amazing machine a little bit later.

You can start the assembly now by turning to page 17 of this manual.

The original Canadarm was specifically designed for use on the Space Shuttle and made its inaugural flight in 1981. It had a length of 15 meters (49 feet) and consisted of several articulated segments that allowed for precise movement. Its primary function was to manipulate payloads, such as satellites, scientific equipment, and other objects, both inside and outside the Shuttle's cargo bay.

Space Shuttle mission STS-2, November 1981, shows the Canadarm being flown in space for the first time. (Photo Credit: NASA)

IFly Deck Canadarm commands. (credit: NASA)

The success of the Canadarm led to the development of the Canadarm 2, an improved and advanced version that has been in use on the International Space Station since 2001. The Canadarm 2 is significantly longer, measuring 17.6 meters (57 feet), and has a higher payload capacity. Unlike its predecessor, the Canadarm 2 is not situated on the Space Shuttle but is instead mounted on the ISS, allowing it to traverse along the structure.

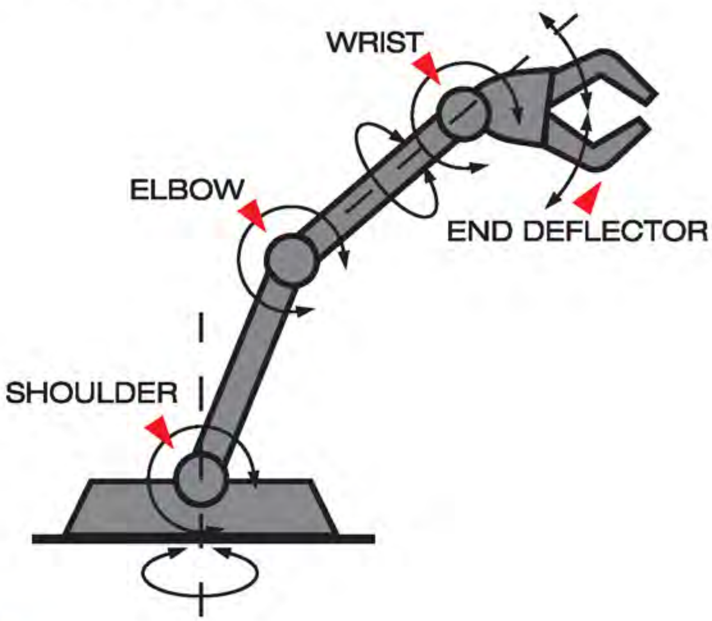
Canadarm 2 on board ISS (credit: NASA)

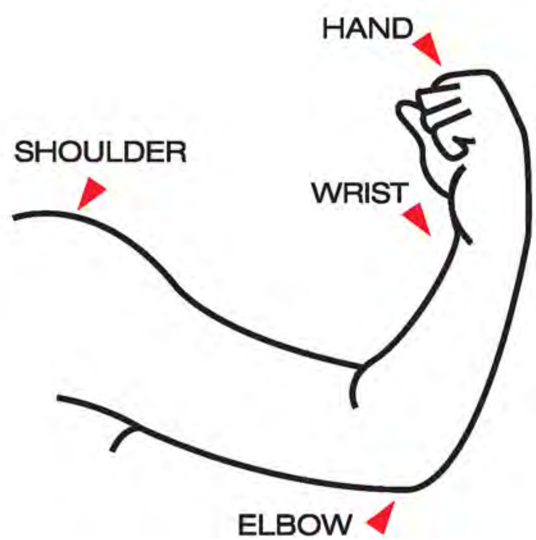
HTV4 (Credit: JAXA NASA)

The Canadarm 2 serves a crucial role in conjunction with Japan's H-II Transfer Vehicle (HTV) and Orbital Sciences Corporation's Cygnus spacecraft, facilitating the capture and docking of uncrewed vehicles to the ISS. Furthermore, the Canadarm 2 features a specialized "hand" known as "Dextre," which is capable of executing delicate and intricate tasks such as maintenance and repairs on the space station.

The Canadarm encompasses several components and functionalities that enable its effective operation in the space environment. Here is a general overview of its functioning:

Design and Structure:
Resembling a human arm, the Canadarm is comprised of articulated segments. These segments are interconnected through rotary joints and incorporate motors and sensors for precise movement and control.
The human arm and the Canadarm are two fundamentally different systems in terms of design, structure, and functionality. Here are some comparisons between the two:





As depicted in the previous drawing, the Canadarm (along with most robotic arms) is designed to resemble a human arm. It consists of a shoulder, elbow, wrist, and an "end effector" that functions as a hand. Our own Canadarm will be built following the same general design.

Structure and Reach:
The human arm comprises bones, muscles, tendons, and joints, constrained by human anatomy. In contrast, the Canadarm is a robotic arm specifically crafted for use in space. It consists of several articulated segments that allow it to reach and manipulate objects in the space environment.
For its articulations, the Canadarm utilizes electric step motors controlled by a computer, which receives instructions from astronauts aboard the Space Shuttle.

Strength and Precision:
The human arm possesses substantial strength and gripping ability, while the Canadarm is designed to handle objects in space and microgravity, where weightlessness prevails.
The Canadarm exhibits high precision and executes smooth movements controlled by astronauts.
Although the human arm can perform rapid actions, such as during a tennis match, the Canadarm's movements are comparatively slower but extremely precise.

Photo by Frank Caldeiro

Many years ago, a NASA astronaut showed me how to control the Canadarm.
In the photograph, I am seen in the cockpit of the Space Shuttle Simulator at NASA's Johnson Space Center in Houston, learning how to operate the Canadarm.
The black joystick in the upper right corner is the control mechanism used by astronauts to direct its movements, while they monitor its operation through TV monitors and the top window.

At that time (1997), I also had the opportunity to learn about the Space Shuttle and practice landings in their flight simulator. As part of the kit, I received a large poster of the Space Shuttle with the Canadarm installed.

Photo by Frank Caldeiro

Specific Functionalities:
The human arm is indispensable for everyday activities and tasks, whereas the Canadarm is specifically engineered for space-related assignments such as spacecraft assembly, payload manipulation, and astronaut assistance.

Some movements of the Canadarm may resemble those of the human arm, albeit with variations due to the robotic nature of the Canadarm and the conditions it operates in space. Here are a few examples:

Flexion and Extension:
Both the human arm and the Canadarm are capable of flexion and extension movements, bending or stretching the arm in specific directions.
However, the human arm accomplishes this movement through joints and muscles, while the Canadarm employs articulated segments controlled by step motors.

Rotation:
Both the human arm and the Canadarm can perform rotation movements, revolving the arm around its axis. The human arm achieves this through shoulder and elbow joints, while the Canadarm can rotate its articulated segments to alter the arm's orientation.

Grasping and Gripping:
Although the Canadarm does not possess the same grasping and gripping capability as the human arm, it can utilize special mechanisms at its end, such as end effectors, resembling human hands. These mechanisms allow it to grip objects using pincers or docking mechanisms.

While there are similarities in some basic movements, it is important to note that the Canadarm is specifically designed to operate in space and perform specific tasks within that environment. It does not possess the flexibility and adaptability of the human arm.

How is our Canadarm different from the real one?

As previously discussed, the Canadarm employs electrical impulses and step motors for movement. However, our model of the robotic arm will utilize hydraulic technology, meaning it will be powered by water, but it will mimic the movements of the Canadarm.

There are several reasons why we don't use hydraulics in robotic arms in space. The use of hydraulic pistons in space presents various challenges and limitations due to the unique and extreme conditions of the space environment. Here are some issues associated with using hydraulic pistons in space:

Fluidity and Fluid Leaks: Hydraulic pistons rely on fluids, such as hydraulic oil, to generate force and movement. However, in orbit, the weightless and vacuum conditions can hinder the proper flow of hydraulic fluids. The absence of gravity affects fluid distribution and circulation, leading to problems with fluidity and potential leaks.

Temperature Sensitivity: Space experiences significant temperature variations, ranging from intense solar radiation to extreme cold in deep space. Hydraulic pistons are sensitive to temperature fluctuations and may encounter operational issues or failures when exposed to extreme thermal conditions. The expansion and contraction of hydraulic fluids and mechanical components can affect the accuracy and reliability of the pistons.

Canadarm during testing (Credit: Canadian Space Agency)

Maintenance and Lubrication:
Hydraulic systems require regular maintenance, including monitoring and fluid replacement, as well as lubrication of moving components. Conducting these maintenance tasks in the space environment can be challenging and expensive. Additionally, the absence of gravity hampers the uniform distribution of lubricant, resulting in issues of inadequate or excessive lubrication.

Weight and Space:
Hydraulic systems, including pistons and hydraulic pumps, tend to be relatively heavy and occupy a significant amount of space. In space missions, where weight and space are limited and valuable, utilizing hydraulic pistons can be inefficient and reduce payload capacity.

While hydraulic pistons are widely used in terrestrial applications due to their efficiency and force generation capabilities, they pose challenges in the space environment due to the absence of gravity, concerns about fluidity, temperature sensitivity, maintenance difficulties, and their impact on weight and available space. Consequently, alternative systems such as electric actuators are preferred in space as they may be better suited to specific space conditions and requirements.

Therefore, since we will be testing our Canadarm here on Earth, we have decided to make it hydraulic, as it will be easier for you to assemble.

Canadarm end effector (credit NASA)

Ground Control:
The Canadarm can be operated by astronauts aboard the space station as well as from the ground control center. Operators at the ground control center utilize remote control systems and video cameras to guide the Canadarm in its movements and specific tasks.

Canadian Space Agency astronaut Chris Hadfield pilots Canadarm during Mission STS-74. (Credit: NASA)

Functions and Applications:
The Canadarm serves various functions and applications in space. It is employed for spacecraft docking, satellite deployment and repair, equipment and payload movement, visual inspections, and more. Its capability to handle both heavy and delicate objects has proven crucial in numerous space missions.
The Canadarm has been an indispensable component in space exploration, serving as a valuable tool for assembling and maintaining space stations, as well as supporting various space missions.

Development of the Canadarm:
The Canadarm was developed by the Canadian Space Agency (CSA) in collaboration with the Canadian engineering company Spar Aerospace. The initial concept for the Canadarm emerged in the late 1960s when Canada began exploring the possibility of creating a robotic system to assist in the construction and maintenance of space stations.
After several years of development and testing, the first Canadarm was delivered to NASA in 1981. It was utilized on NASA's space shuttle missions for several decades and proved to be an invaluable tool for space exploration.

Timeline of Notable Missions:

STS-2 (November 1981): The Canadarm made its debut in space during this mission of the space shuttle Columbia. It was employed to deploy and retrieve a solar test platform.

Canadarm STS-2 (Credit: Canadian Space Agency)

STS-7 (June 1983): On this mission of the space shuttle Challenger, the Canadarm was utilized to deploy and retrieve the first Canadian communication satellite, Anik C2.

STS-7 (Credit: NASA)

STS-41G (October 1984): During this mission of the space shuttle Challenger, the Canadarm was employed to deploy and retrieve the Earth Radiation Budget Satellite (ERBS), a communications satellite.

STS-41G (Credit: NASA)

STS-61 (December 1993): The Canadarm was utilized during this mission of the space shuttle Endeavour for the first servicing and repair mission of the Hubble Space Telescope.

Astronaut F. Story Musgrave, anchored on the end of the Remote Manipulator System (RMS) arm, prepares to be elevated to the top of the towering Hubble Space Telescope (HST) to install protective covers on magnetometers. Astronaut Jeffrey A. Hoffman (bottom of frame) assisted Musgrave with final servicing tasks on the telescope, wrapping up five days of extravehicular activities (EVA).

STS-61 (Credit: NASA)

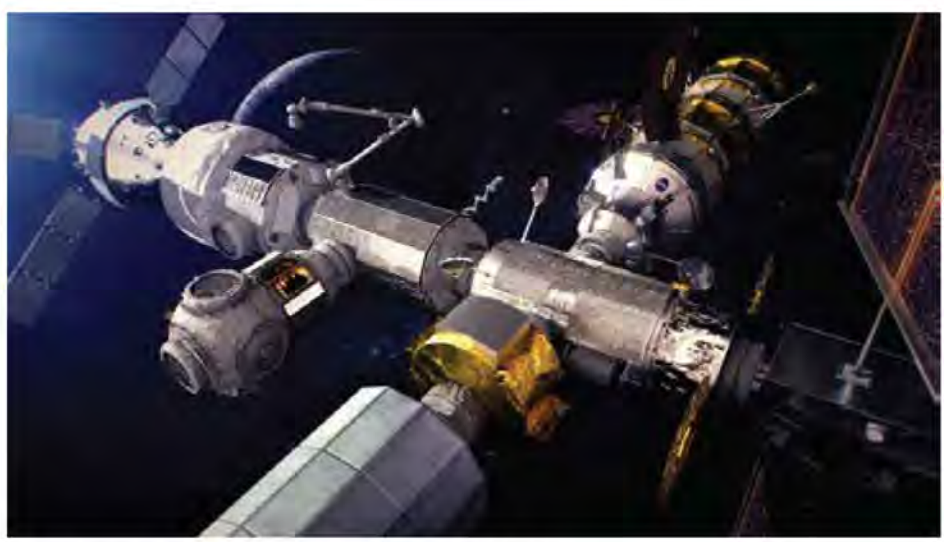
International Space Station (ISS) Assembly Flights:
The Canadarm has been utilized in multiple ISS assembly missions to aid in the construction and placement of modules and equipment.

It's important to note that the Canadarm has evolved over time, giving rise to later versions such as the Canadarm 2, which as discussed previously, is currently in use on the International Space Station.

Canadarm 2 ISS (Credit NASA)

Please note that this is just a selection of missions in which the Canadarm has participated, and there have been more missions over the years.

Regarding the Gateway, the Canadarm 3 will play a crucial role in station operations. The Gateway is expected to be a small space station around the Moon, designed to facilitate lunar exploration and serve as a starting point for crewed missions to the lunar surface.



Canadarm 3 Gateway (Rendition. credits CSA NASA)

The Canadarm 3 of the Gateway will be utilized for various purposes, including:

Assembly and maintenance: It will assist in the construction and assembly of the station, connecting necessary modules and components. It will also be instrumental in equipment and system maintenance and repair.

Canadarm 3 Gateway (Rendition. credits CSA NASA)

Cargo handling: The robotic arm will capture and release spacecraft and payloads arriving at the Gateway. It will be capable of docking with unmanned cargo vehicles and transferring them to the station.

Extravehicular support: During spacewalks, the Canadarm 3 will assist astronauts by providing a stable and secure anchor point, enabling easier movement and work.

Deployment of scientific instruments: The robotic arm will deploy and position scientific instruments in lunar orbit for research and data collection purposes.

Additionally, the Canadarm 3 will be an integral part of the Lunar Gateway Logistics Vehicle, which will transport payloads and supplies from the orbital station to the lunar surface.

In summary, the Canadarm 3 will play a crucial role in Gateway operations by facilitating assembly, maintenance, cargo handling, as well as providing support for spacewalks and the deployment of scientific instruments. Its versatility and manipulation capabilities will be of great value for lunar exploration missions.

This is a photo of myself with the Space Shuttle Atlantis, showing a portion of the Canadarm, at the Kennedy Space Center in Florida (2023).

Therefore, as part of today's project, we will build a working Canadarm robotic arm. After we build it, we will perform some testing to see how it works. We will then report our results, just as any test engineer or scientist would.

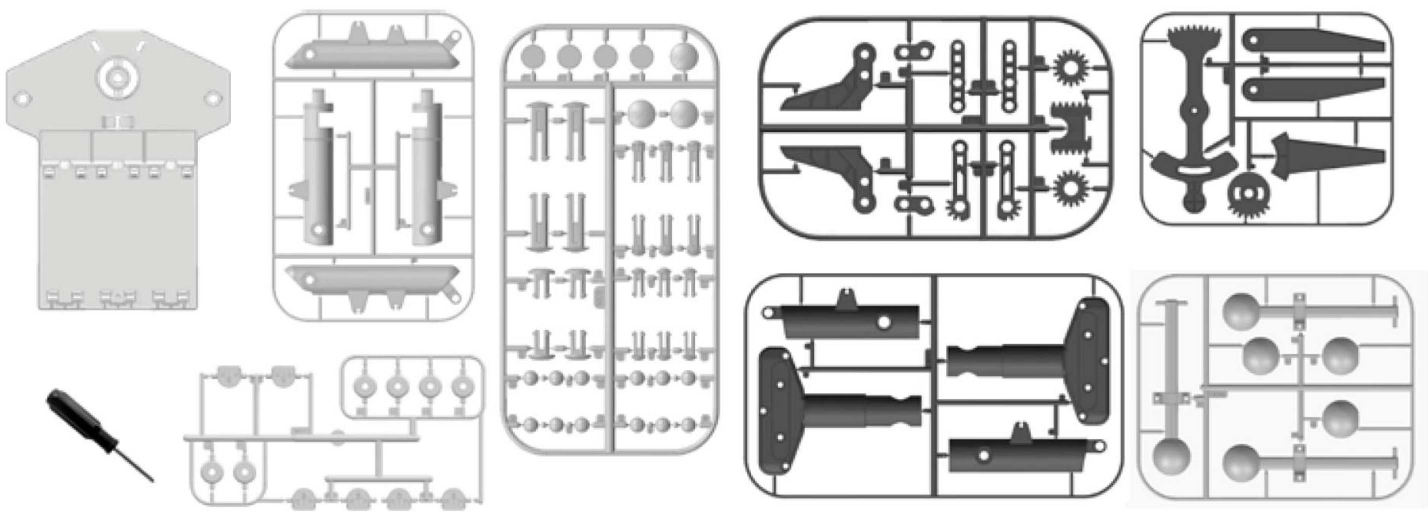
CANADARM ROBOT ARM MOBILITY SYSTEM

STEP BY STEP BUILDING GUIDE

Now that we have acquired sufficient knowledge about the Canadarm, let's commence our project. Together, let's construct our Canadarm robotic system!

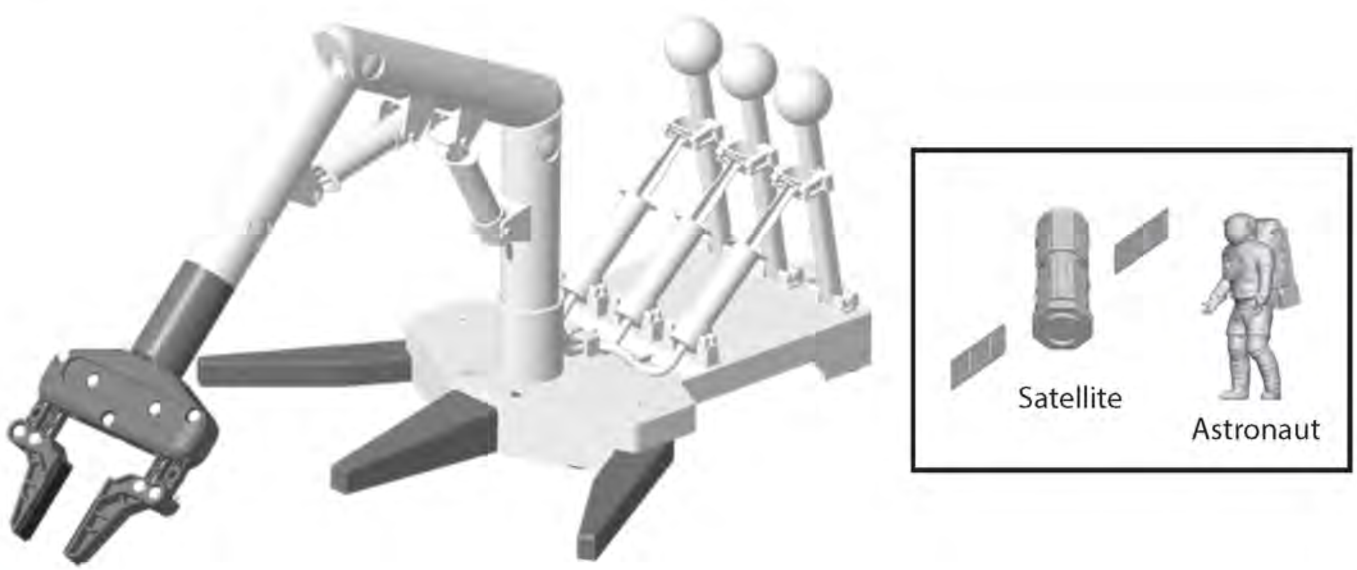
Our initial task is to locate and identify all the components of our robotic arm. Thoroughly inspect each plastic bag and find the part numbers to ensure that you have all the necessary pieces. Our artists have made an effort to make each figure self-explanatory, but I will also provide some guidance here to ensure your comprehension of each step.

Inside the box, you will find a collection of parts depicted in the figure below:

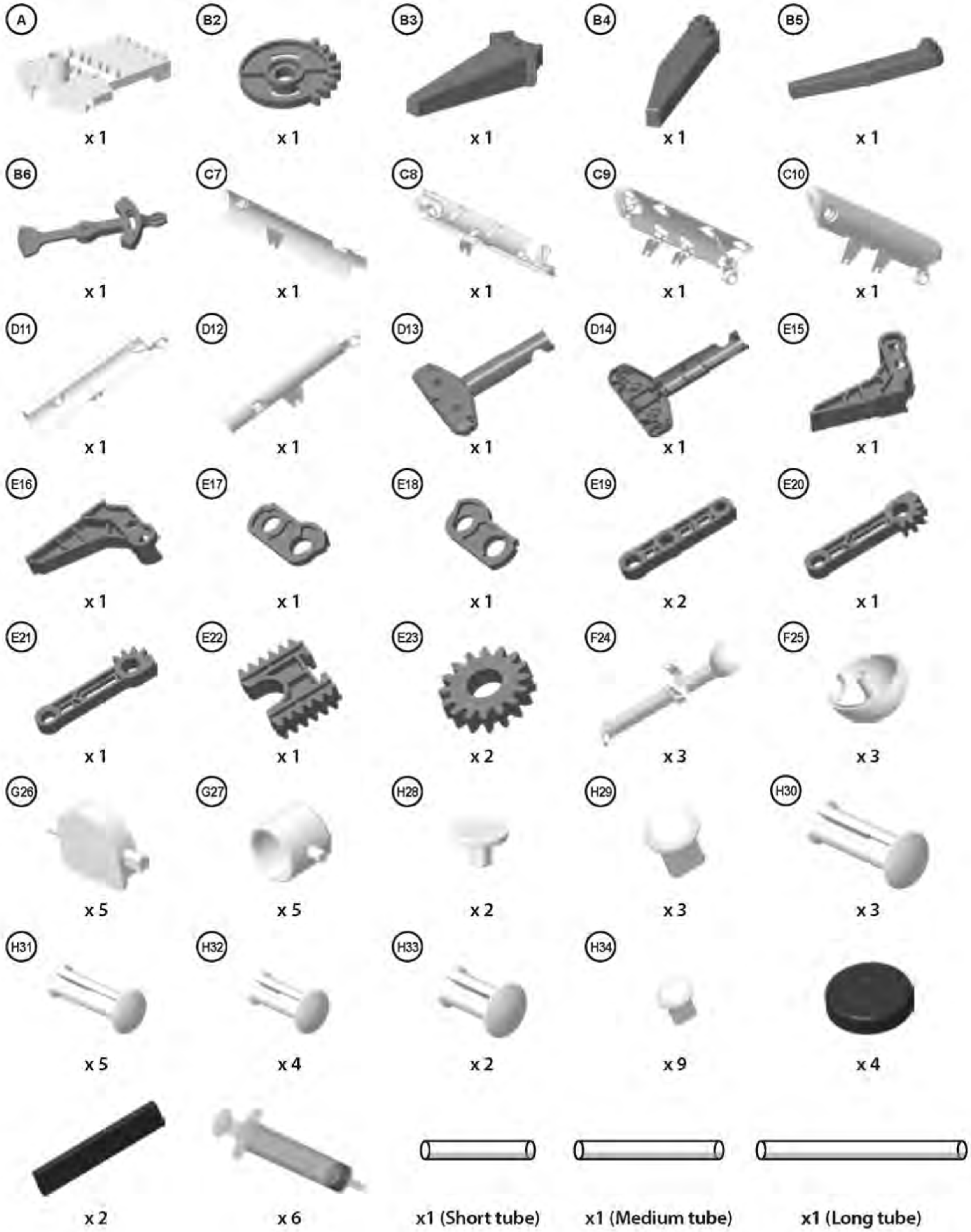


1. The diagram in the previous page presents an exploded view of all the various components. It may appear overwhelming, but fret not, we will proceed step by step to assemble our robotic arm.

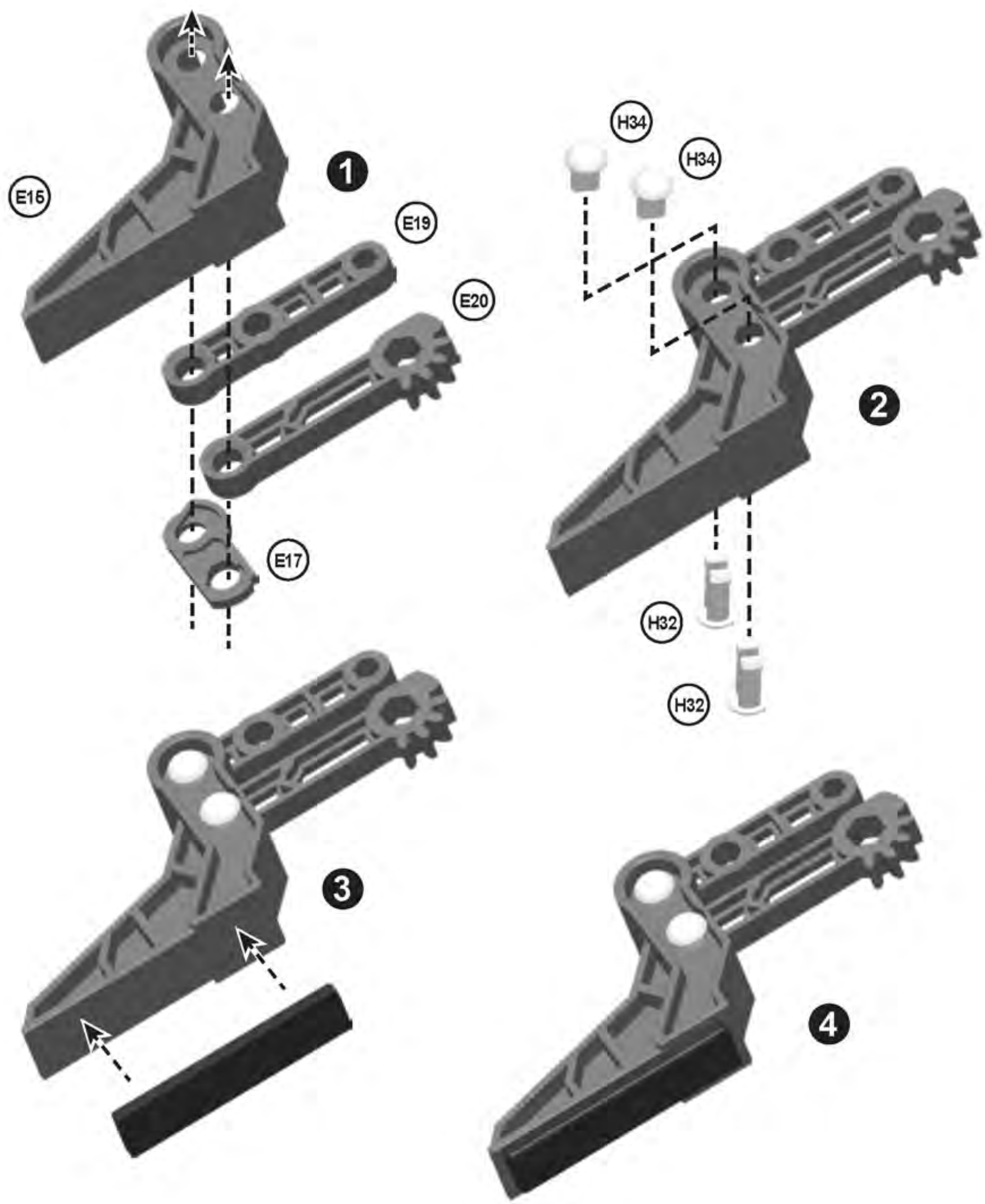
2. This is how our Canadarm robotic arm will appear once it is completed. On the right side, we have a number of levers that will control the arm's movements, including the "end effector." Our kit also includes an astronaut and a satellite, both of which we will be able to grasp with our robotic arm.



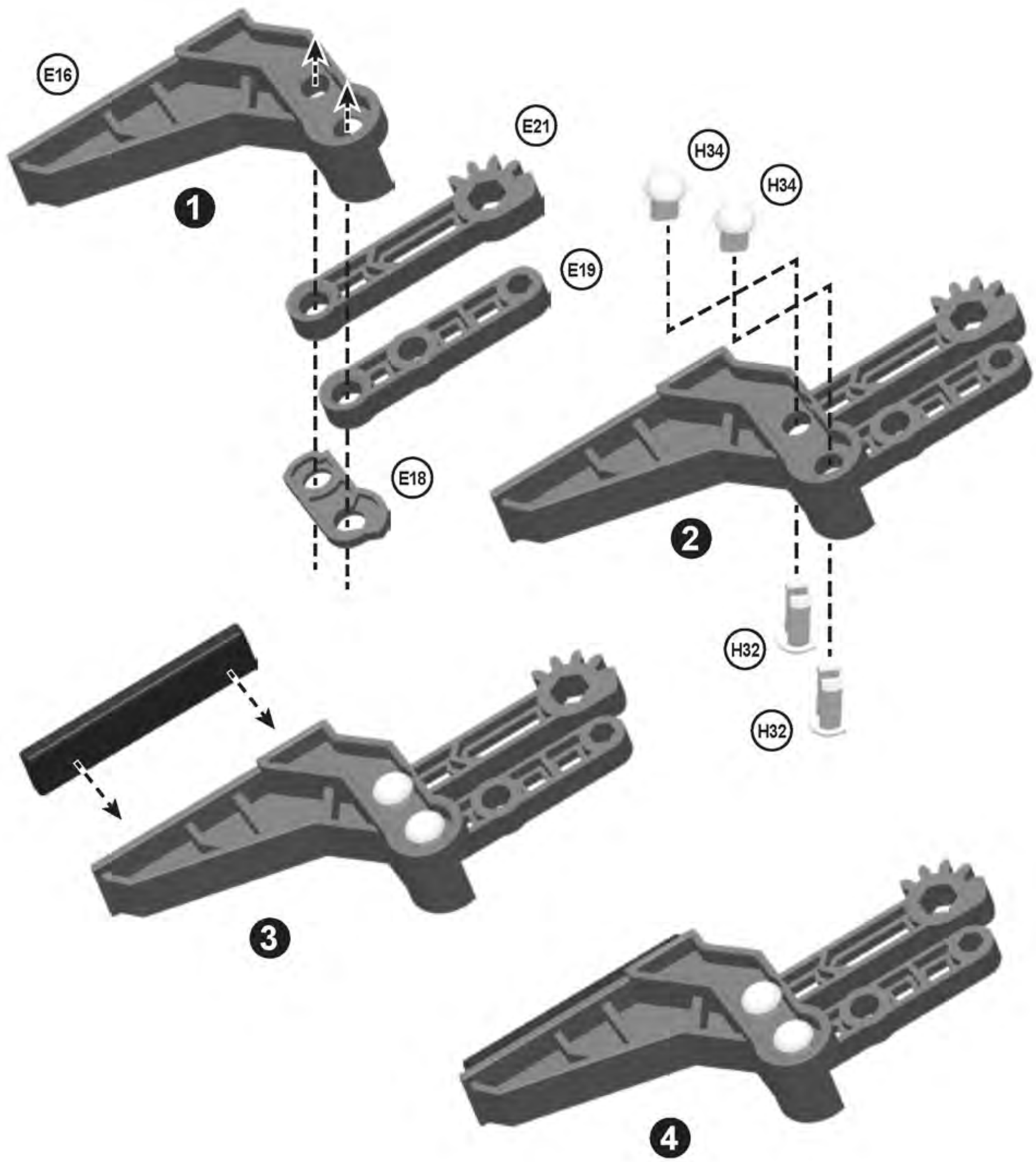
3. The following is a list of parts, accompanied by the quantity of each piece we possess. Carefully detach them from the plastic base. The number after the "x" signifies the quantity we have for each part. The identification of each part is inside the corresponding circle. These part numbers are crucial for the correct assembly of our robotic arm.



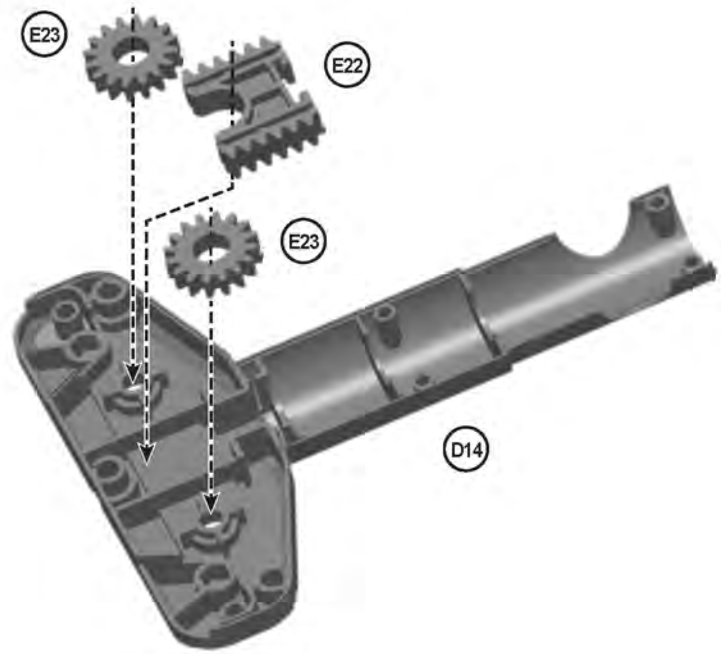
4. First, we will assemble our "end effector," which is the term used in robotics for our robotic hand. This component allows us to grip various elements of our robot. Locate the numbered parts mentioned below and follow the assembly instructions provided in the drawings. The H plastic pegs will serve as "bolts" to hold the parts together.

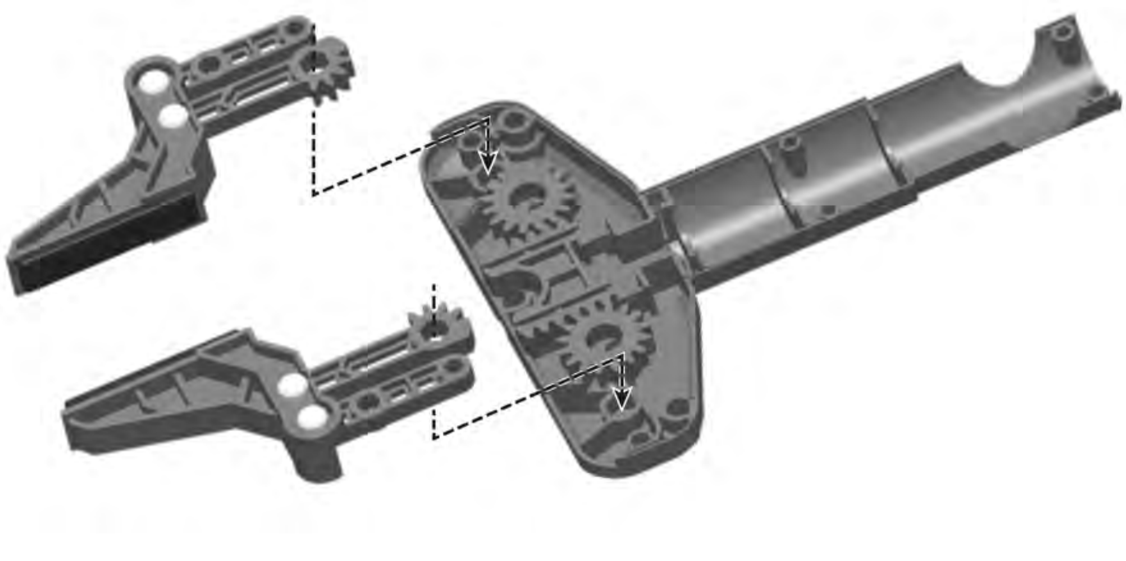


5. Now, proceed to assemble the other side of the "end effector" following the same steps as you did for the previous side.



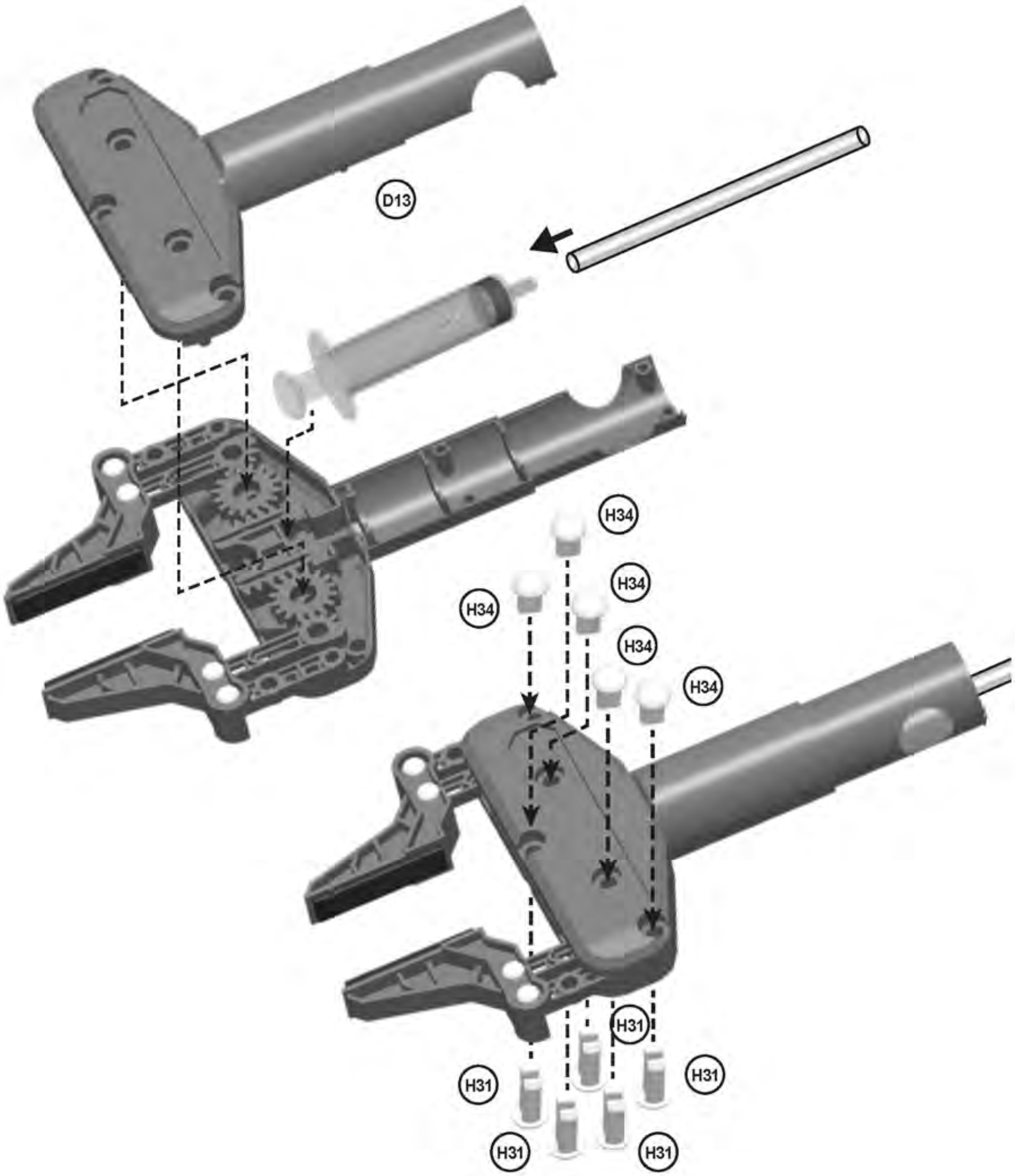
6. Next, we need to assemble the mechanism responsible for opening and closing the end effector. Refer to the graphics below to ensure the proper installation of the plastic gears, as they control the movement of the effector. Pay attention to the position of the E22 piece, as it will be connected to one of our syringes to transmit fluid-based motion.



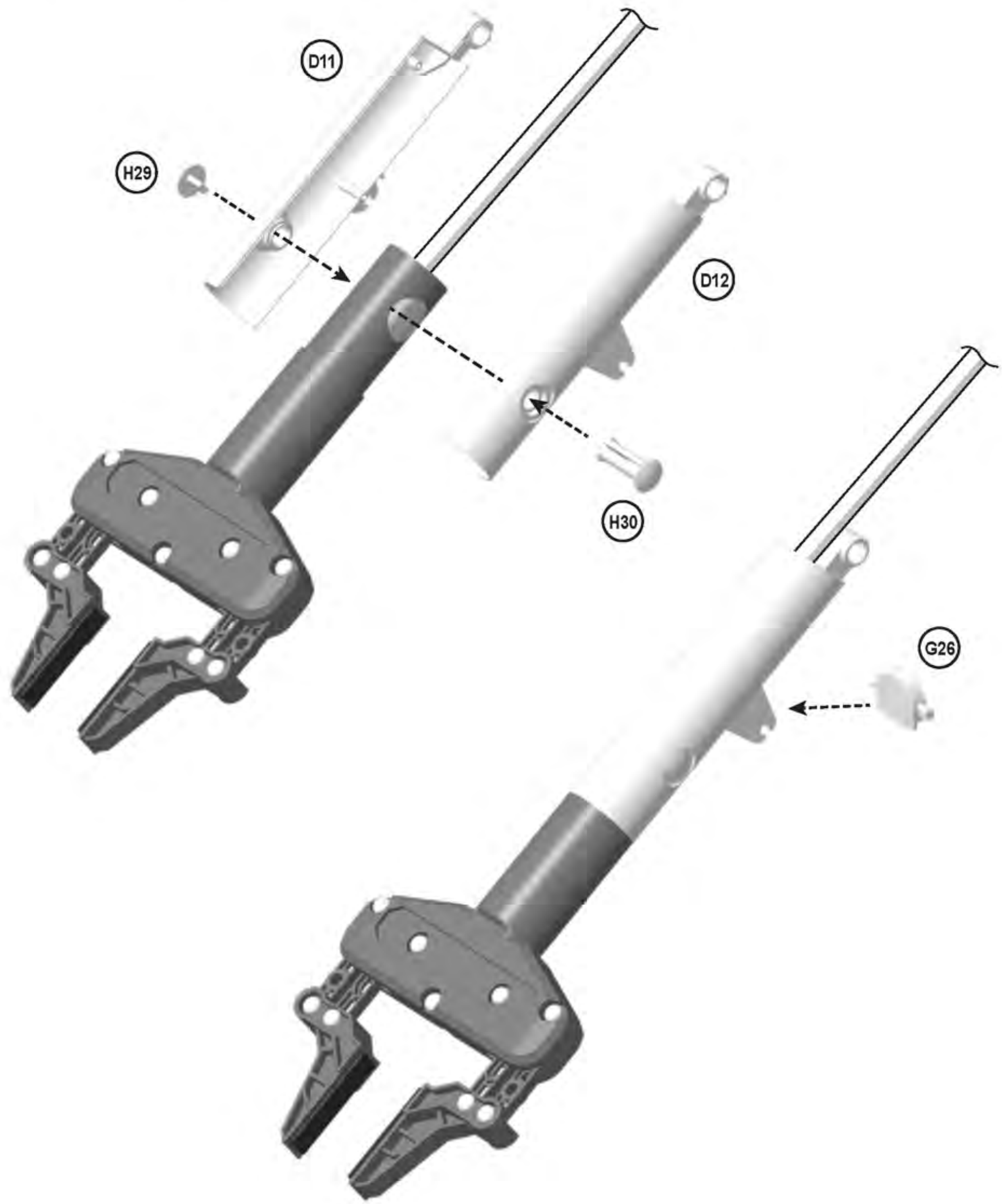


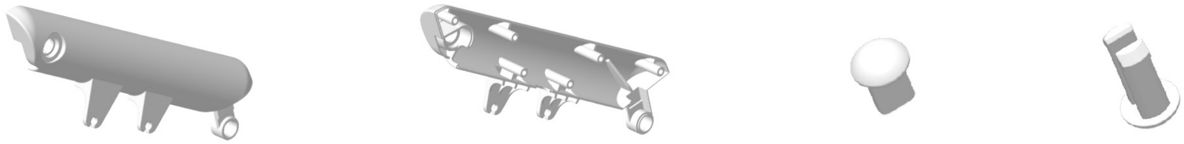
x 1 | x 1 (Long tube) | x 5 | x 5

7. In this step, locate the first syringe and the first plastic transparent long tube. Since this part will be enclosed between D13 and D14, you may want to fill the syringe with about half of its capacity with water. Regular tap water can be used for this task. Afterward, securely connect the long plastic tube and close both halves by using the H "bolts" to hold them together.



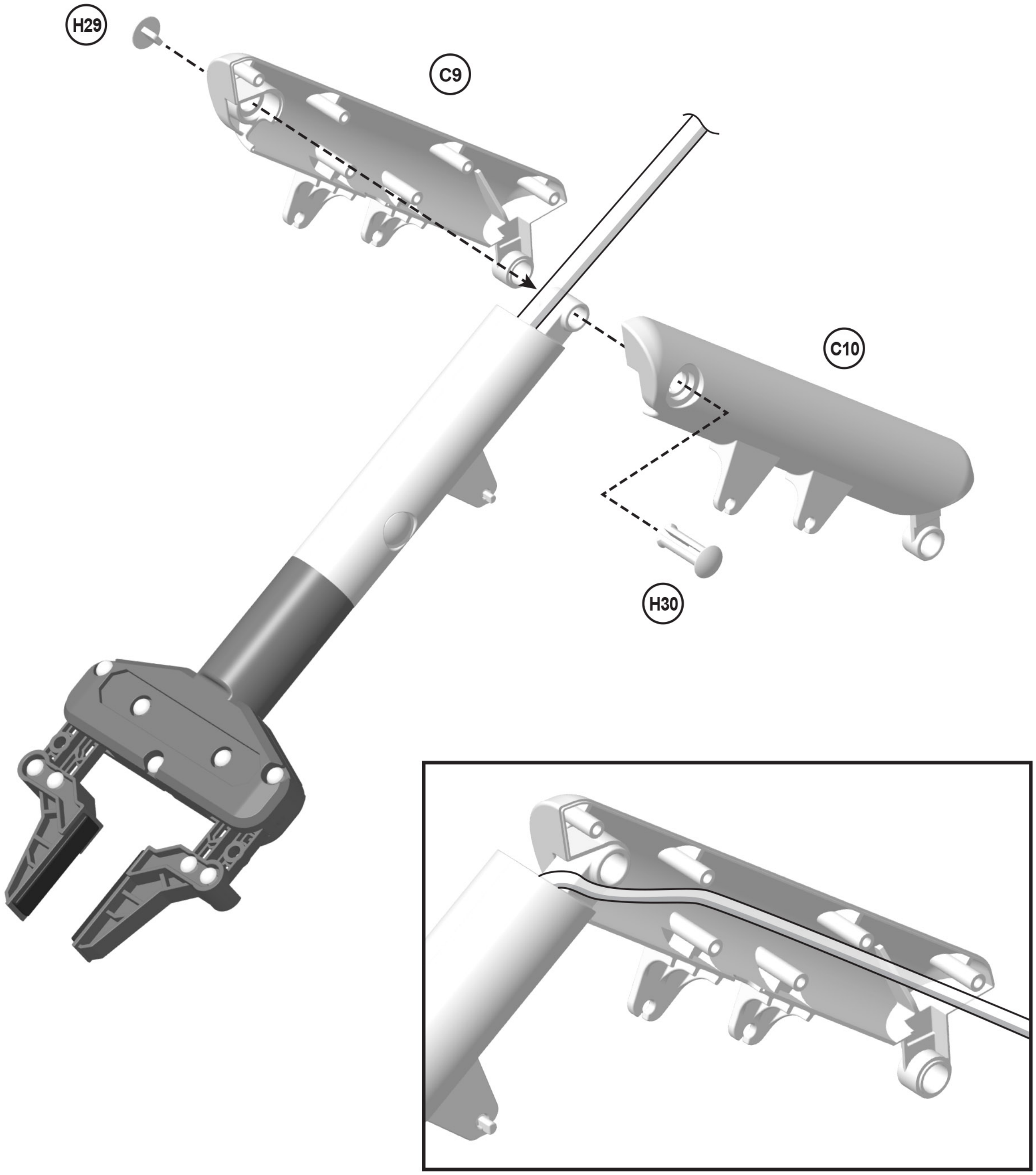
8. Connect the plastic parts (D11 and D12) and secure them as shown below. Ensure that the plastic flexible tube passes through the middle of the arm. Then, connect part G26 as indicated.





x 1 x 1 x 1 x 1

9. Here we will assemble the second joint of our robotic arm. Connect parts C9 and C10, being careful not to press the flexible plastic tube that will carry the fluid to the control section.

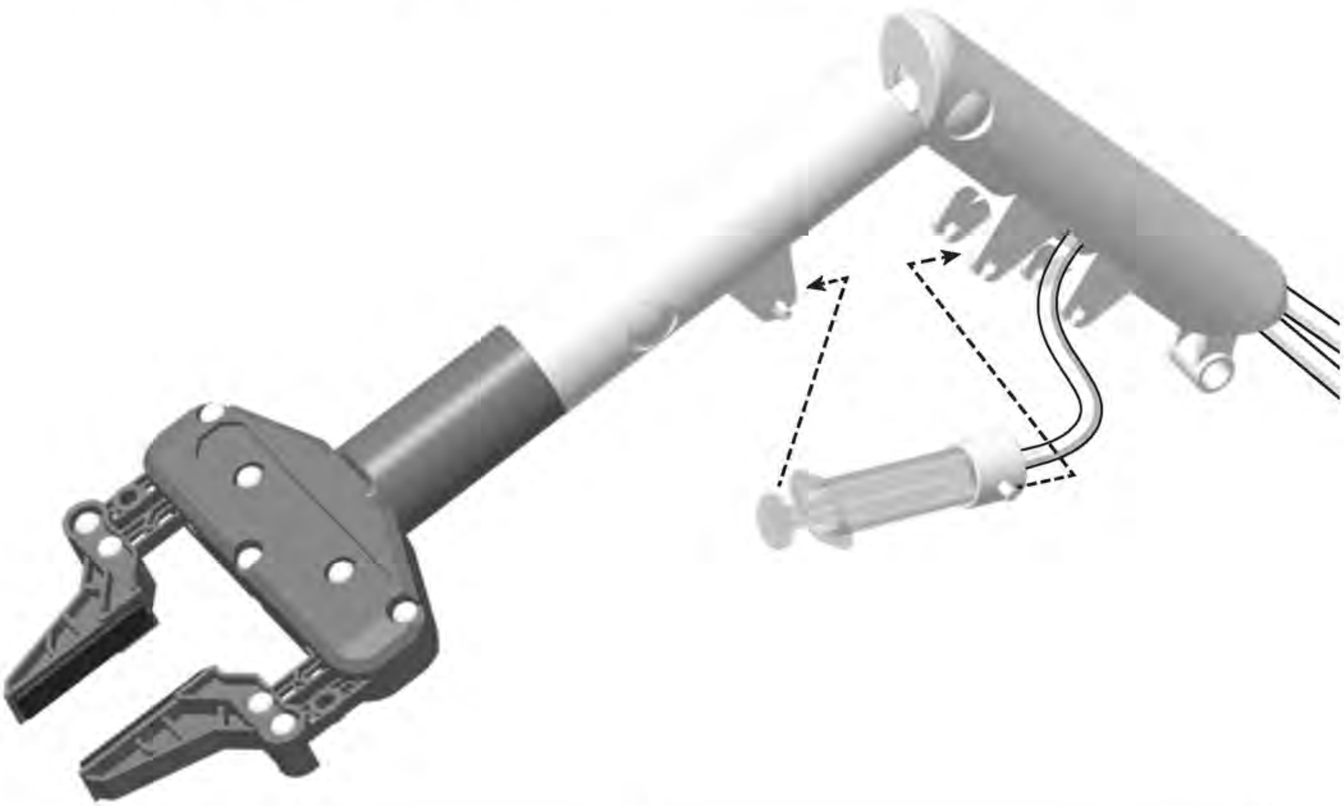


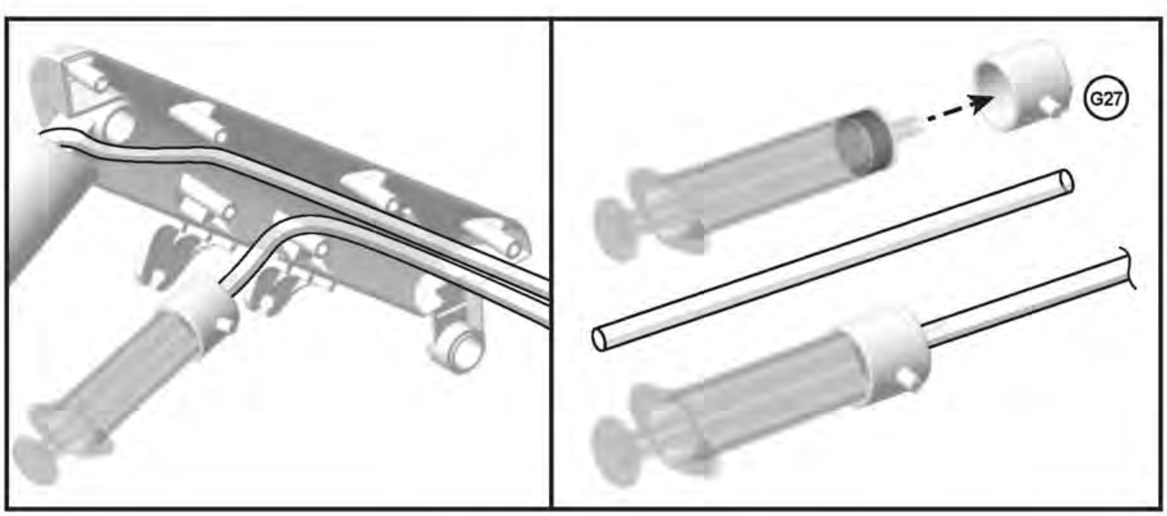
x 1

x 1 (Medium tube)

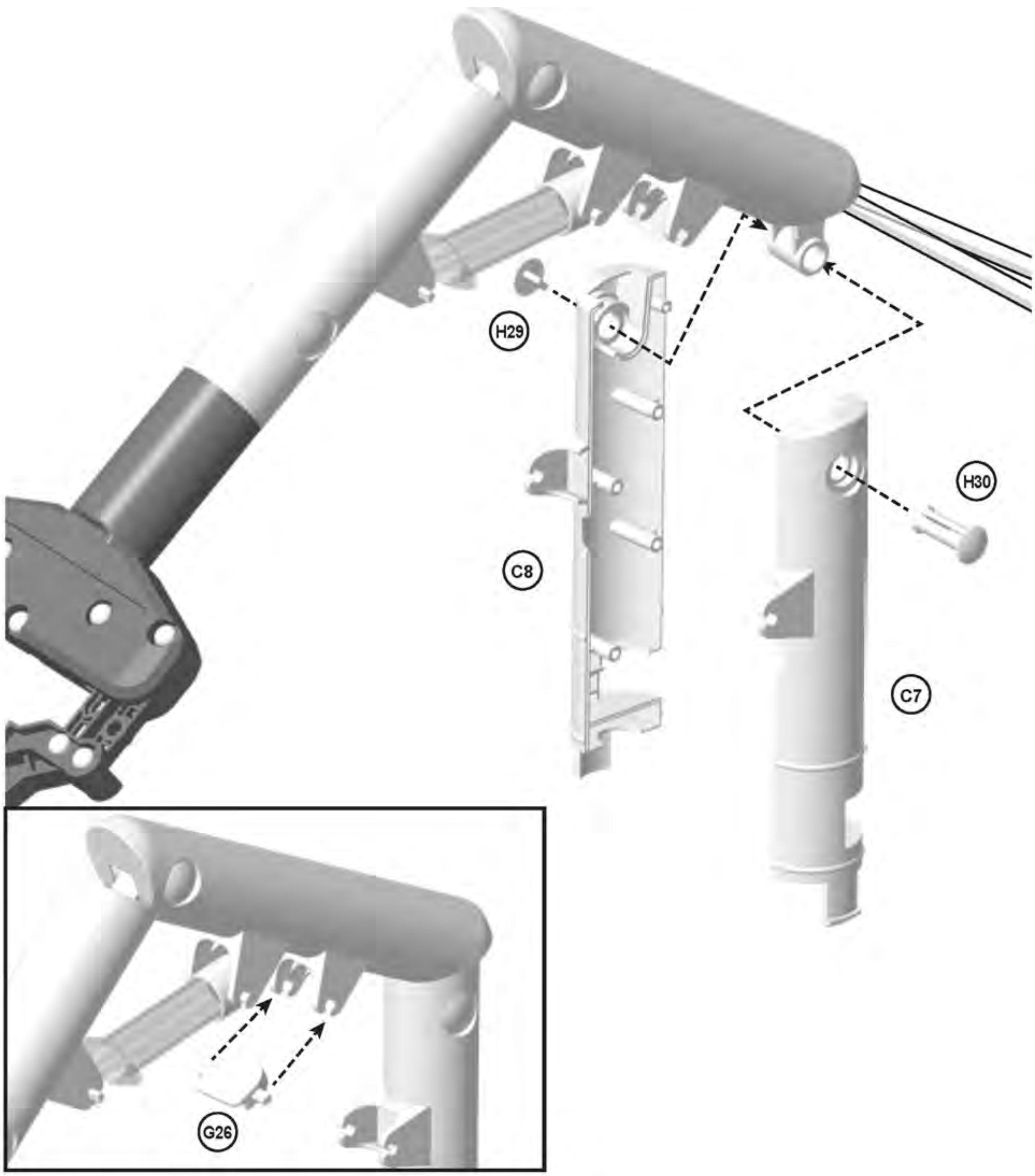
x 1

10. In this step, connect the second syringe. Remember to fill it with approximately half (50%) of its capacity. You may need to adjust the water level later. Once filled, securely connect it to the plastic tube and install it according to the provided drawing, using part G27 as support. Pass the tube between the second portion of the arm as shown in the figure. At this point, you will have two tubes running across the second portion of the arm: one controls the end effector, and the other controls the first articulated joint of the arm.

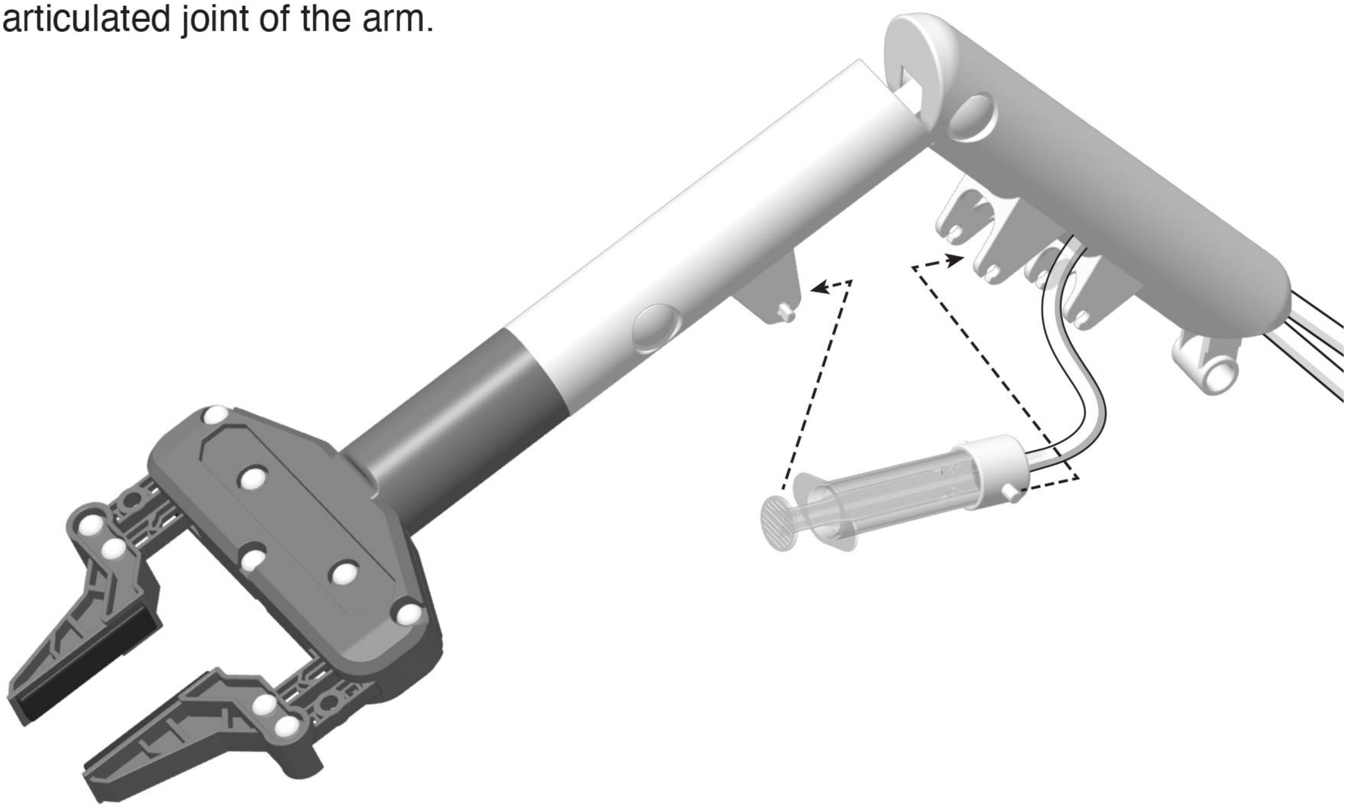


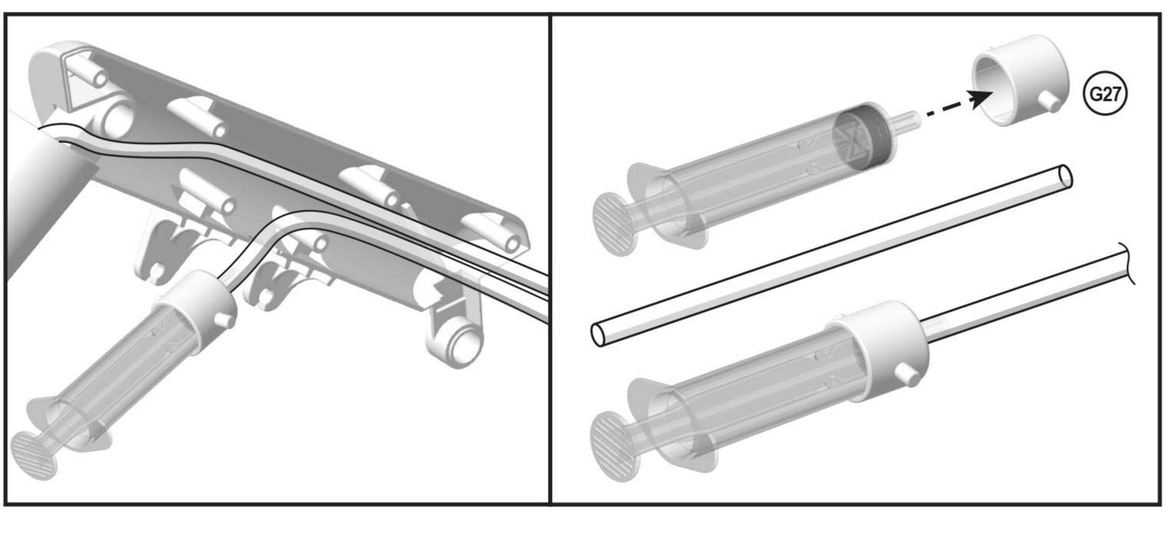


11. Let's proceed to assemble the second articulated joint of the arm. For this task, find parts C8 and C7. Do not close them yet, as you need to thread the tube through them. Also, locate part G26 and secure it, as it will serve as support for our third syringe.



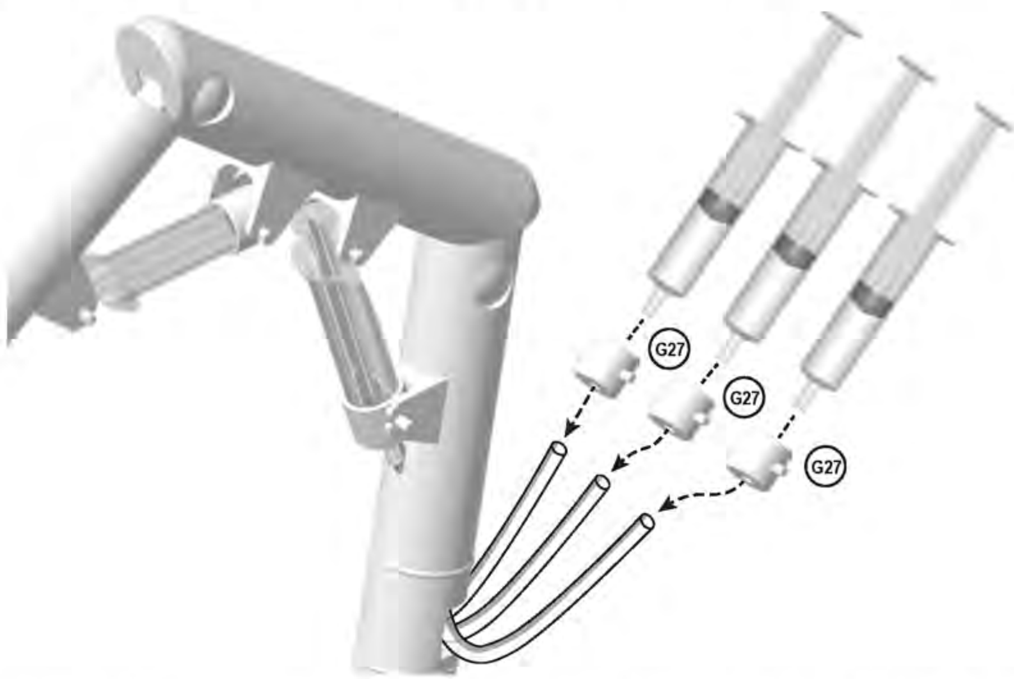
10. In this step, connect the second syringe. Remember to fill it with approximately half (50%) of its capacity. You may need to adjust the water level later.
Once filled, securely connect it to the plastic tube and install it according to the provided drawing, using part G27 as support. Once the syringe is properly installed, pass the tube between the second portion of the arm as shown in the figure. Connect parts C9 and C10, being careful not to press the flexible plastic tube that will carry the fluid to the control section. Close it with the securing pegs as shown below. At this point, you will have two tubes running across the second portion of the arm: one controls the end effector, and the other controls the first articulated joint of the arm.





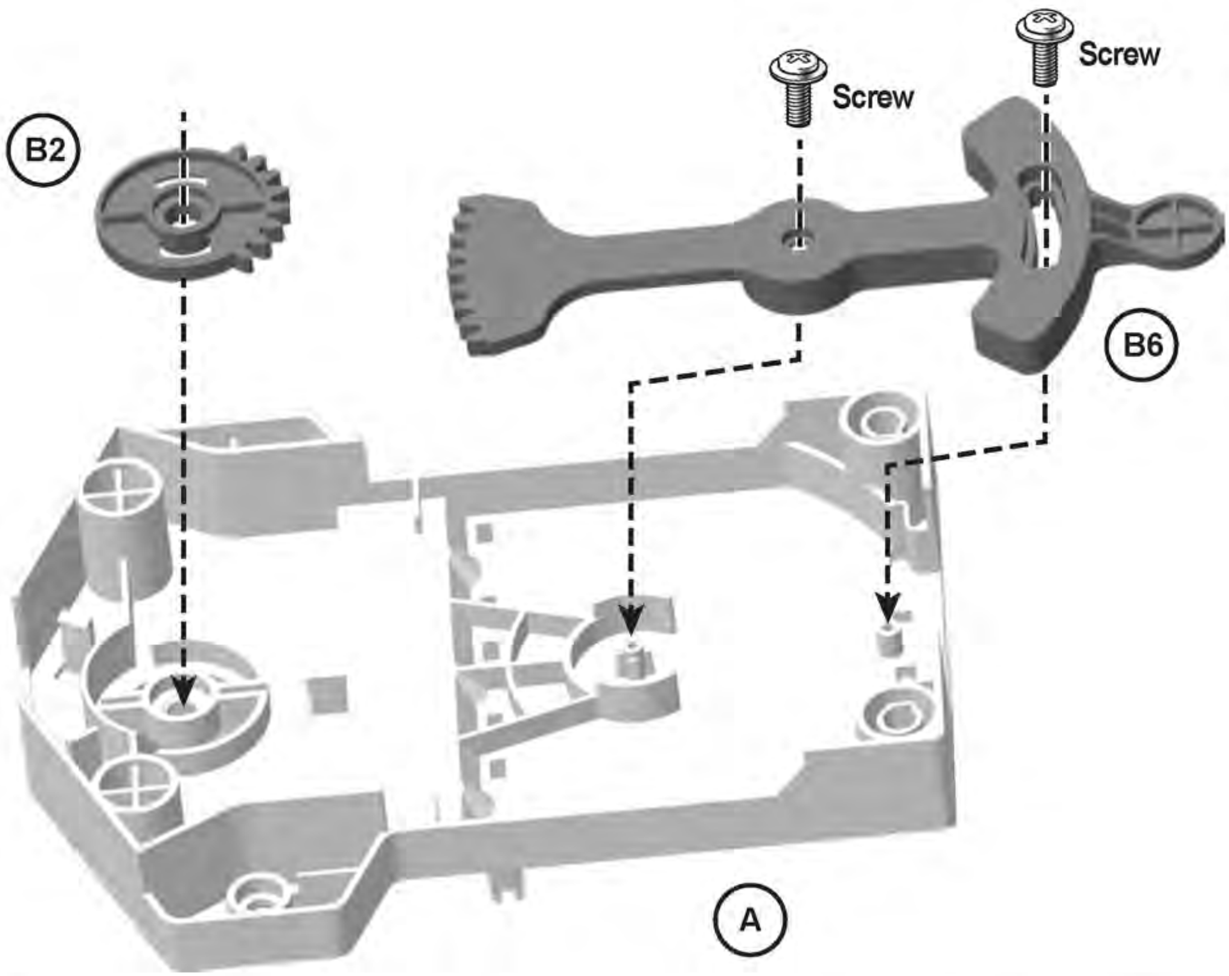
x 3 **x 3**

13. Now, it's time to connect the other end of the syringes. I also recommend filling them halfway with water. Before connecting them on the other side, ensure that all the air inside the plastic tubes is replaced with water, eliminating any air bubbles from the system. Once all the air is removed, press the syringes into the tubes, placing the plastic supports (G27) between the syringes and tubes.

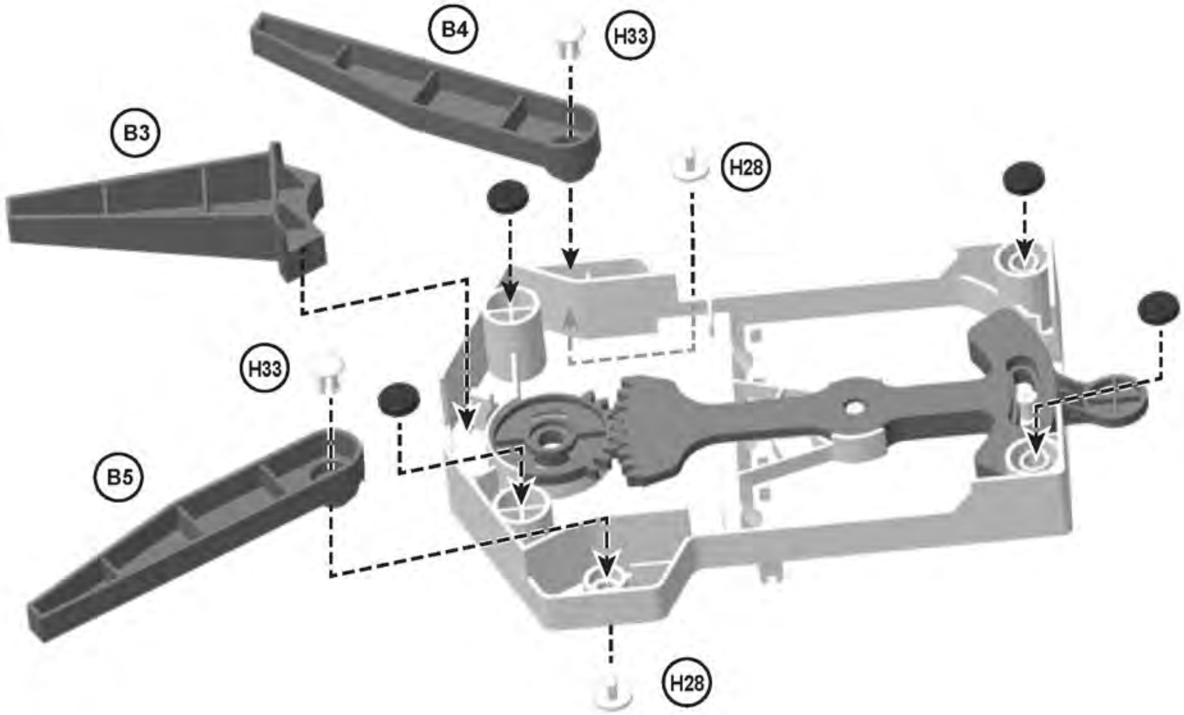


14. After removing all the air from the system, press the syringes into the tubes while placing the plastic supports (G27) between the syringes and tubes. Our robotic arm is starting to take shape!

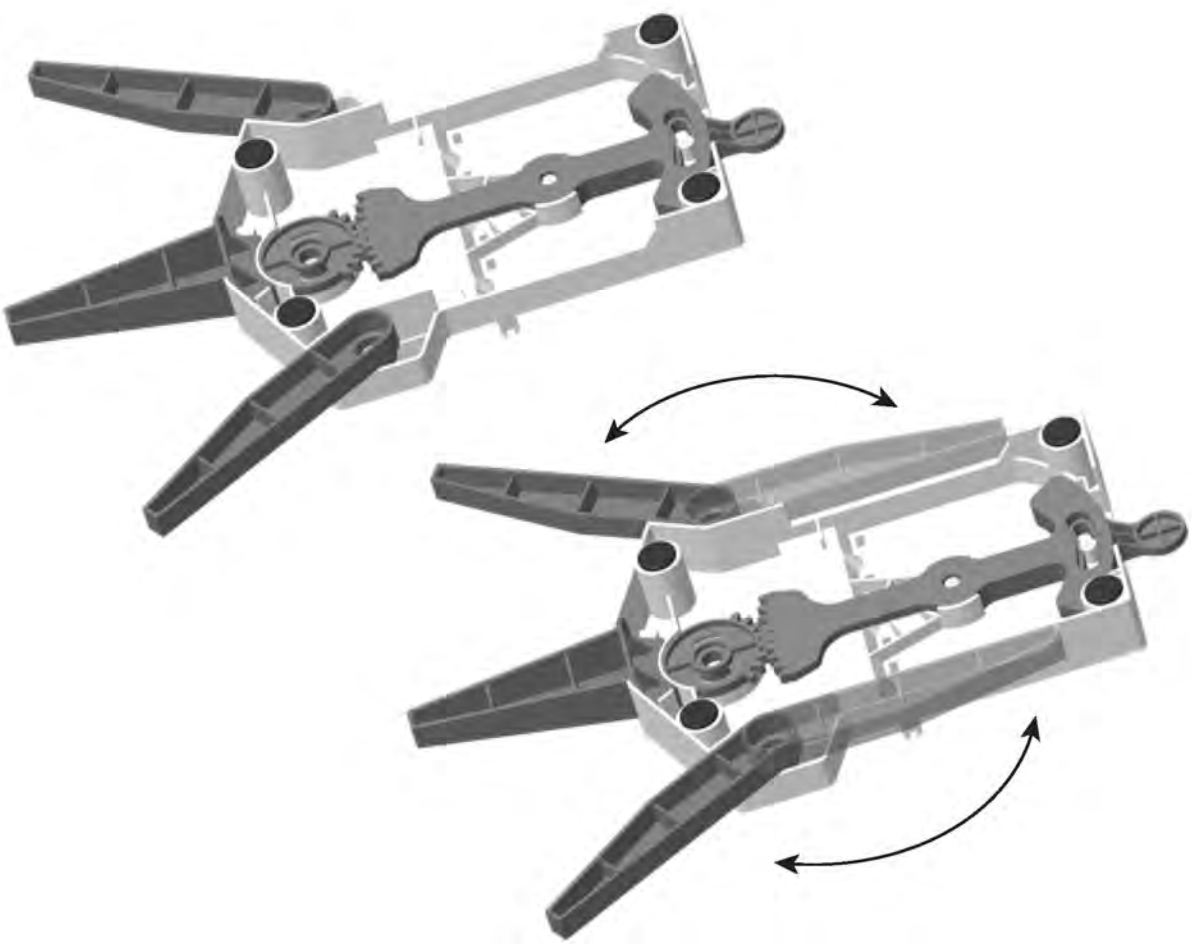
15. Now, it's time to assemble the base and control station for our Canadarm. Start by identifying the base A, and the moving parts B2 and B6, along with the two provided screws. Use the provided screwdriver to secure them in place. Remember not to tighten them excessively, as they need to move sideways. Test their movement to ensure they function properly.



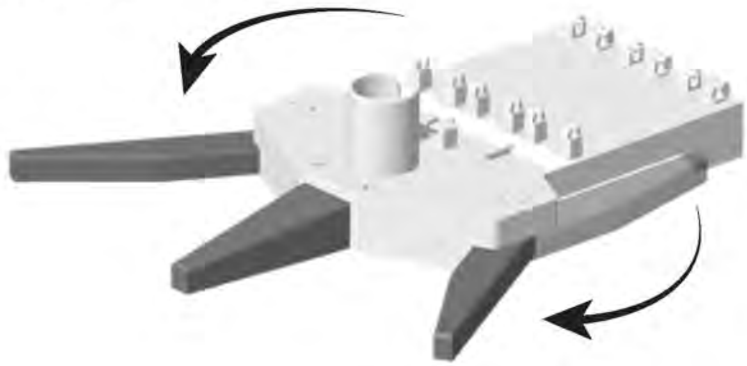
16. Moving on, let's assemble the legs of our base. Locate B3, B4, and B5, and install them as shown. Secure all the depicted elements in place and use the plastic pegs as described. Additionally, attach four rubber non-sliding pegs.



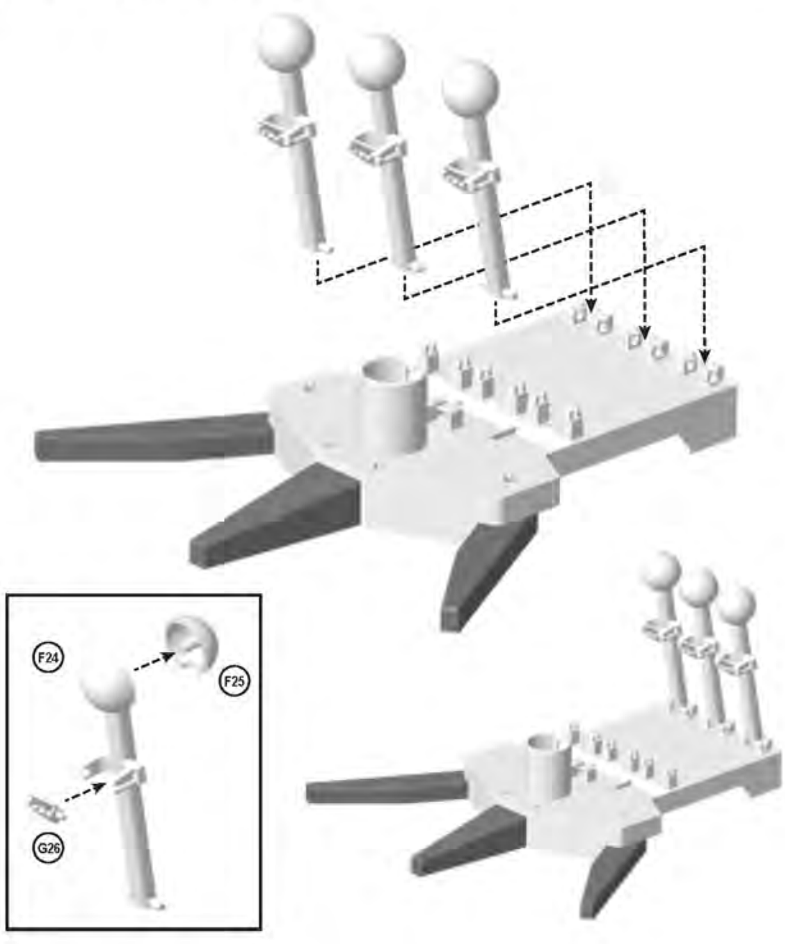
17. Verify that the side support legs can open and close to the sides of the base, as demonstrated below.



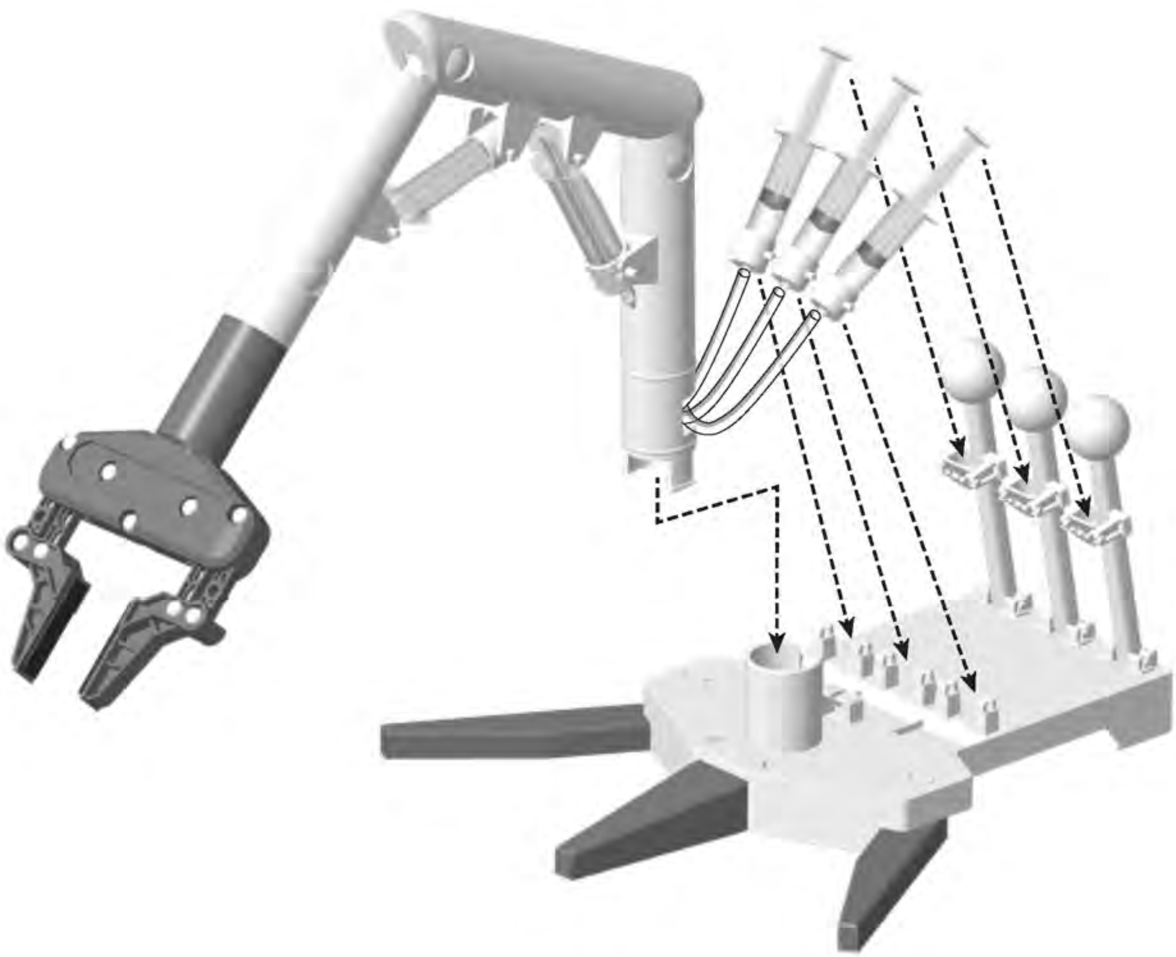
18. Now, turn the base around. This is where you will secure your Canadarm and assemble the controls.

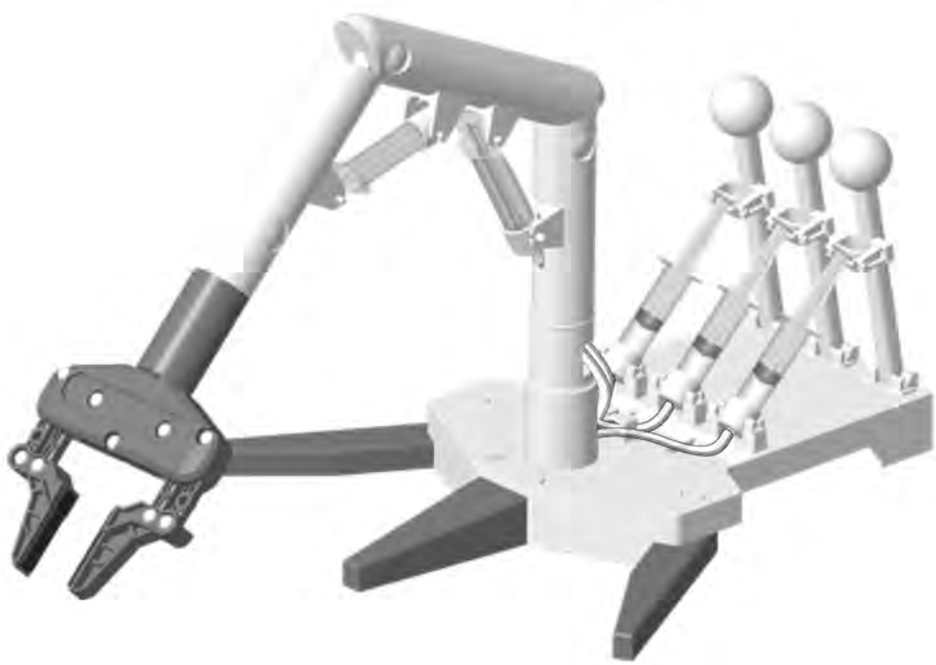


19. The next step is to assemble the levers that will manually control your robotic arm. Connect each lever carefully to part G26, and then secure each lever to the base following the figure below.

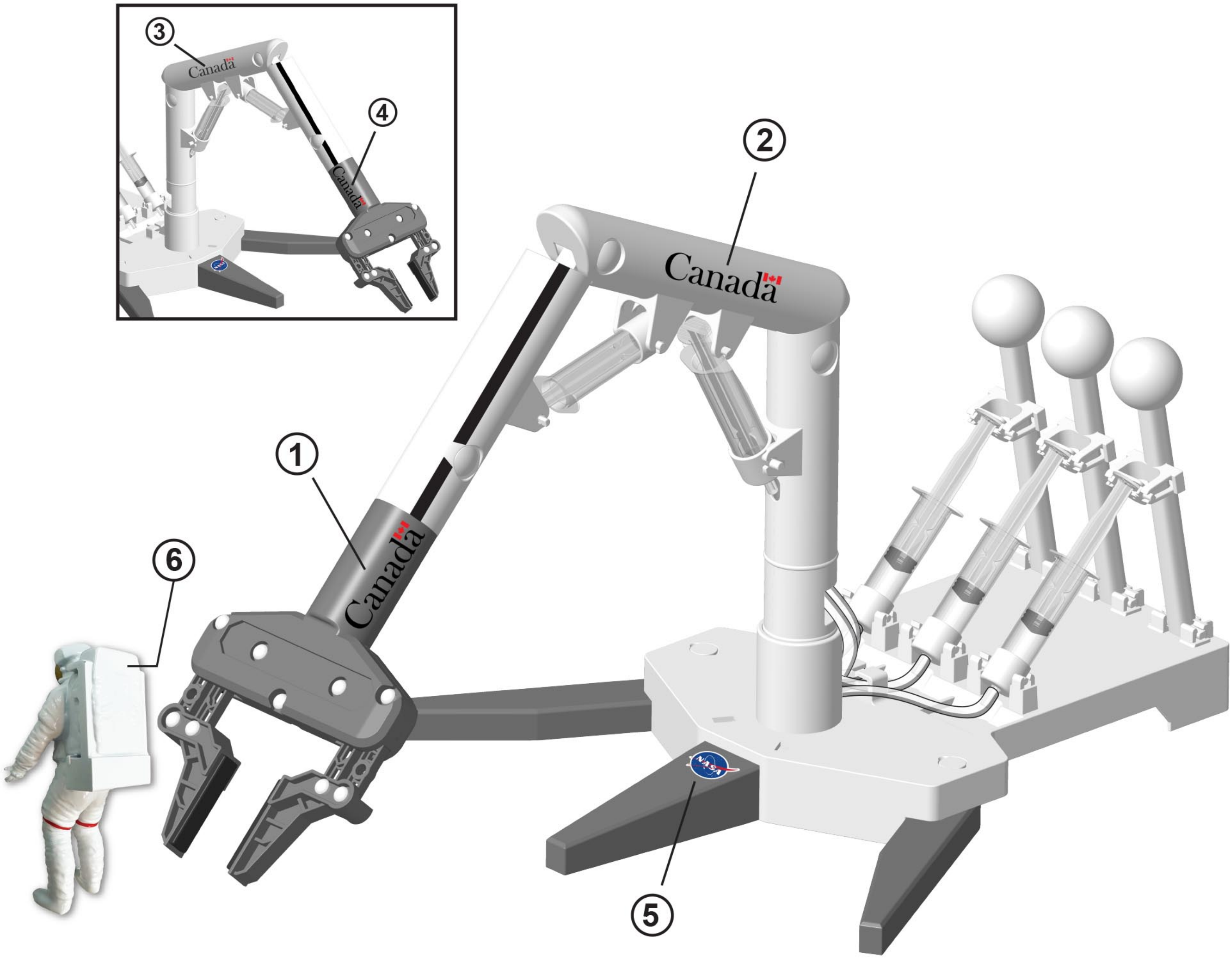


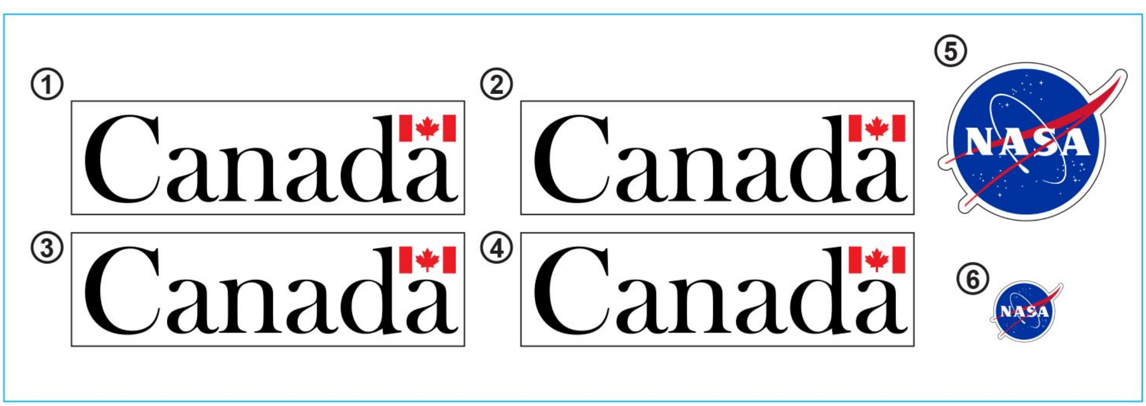
20. We're almost there. Connect the arm to the base using the cylindrical vertical section. Ensure that it securely "clicks" into place on the base. Then, attach the three syringes to the top and bottom securing supports on the base. Check that the plastic tubes are installed as shown in the second figure below.





21. Now, it's time to affix our stickers! Since the Canadarm is, well..., Canadian-made, we want to proudly display its logo, as well as the NASA logo, on the base.

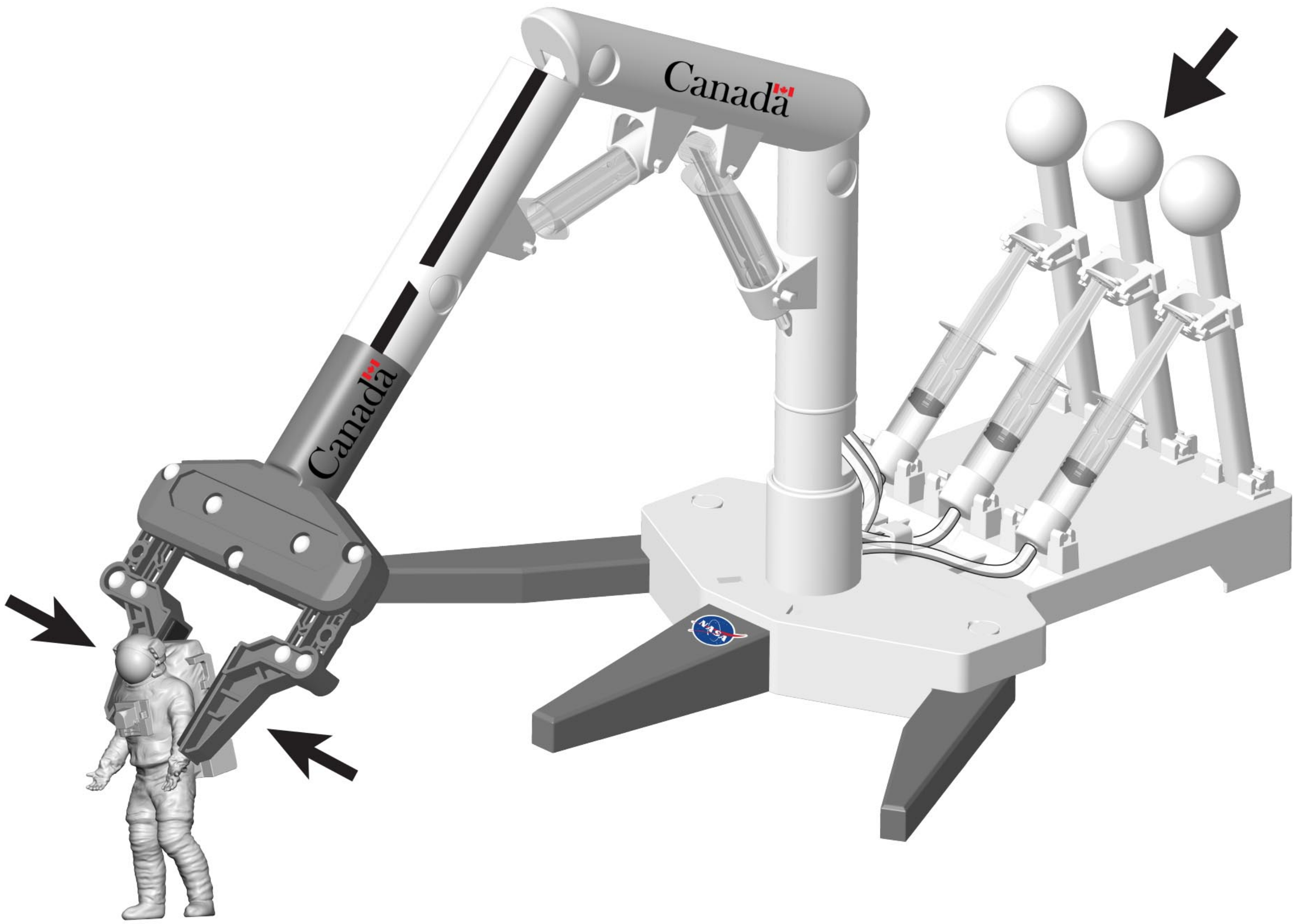


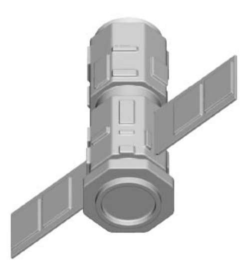


STICKERS

22. Carefully and slowly move the levers now to observe how our Canadarm moves! Check each joint individually and take note of any abnormal movement in each axis. You can test different amounts of water if the arm doesn't reach its full range of motion.

23. If all the joints move smoothly, and the "end effector" opens and closes properly, it's time to start grabbing objects! You can try with our astronaut, or the satellite included in your kit (remember to assemble its solar panels first).

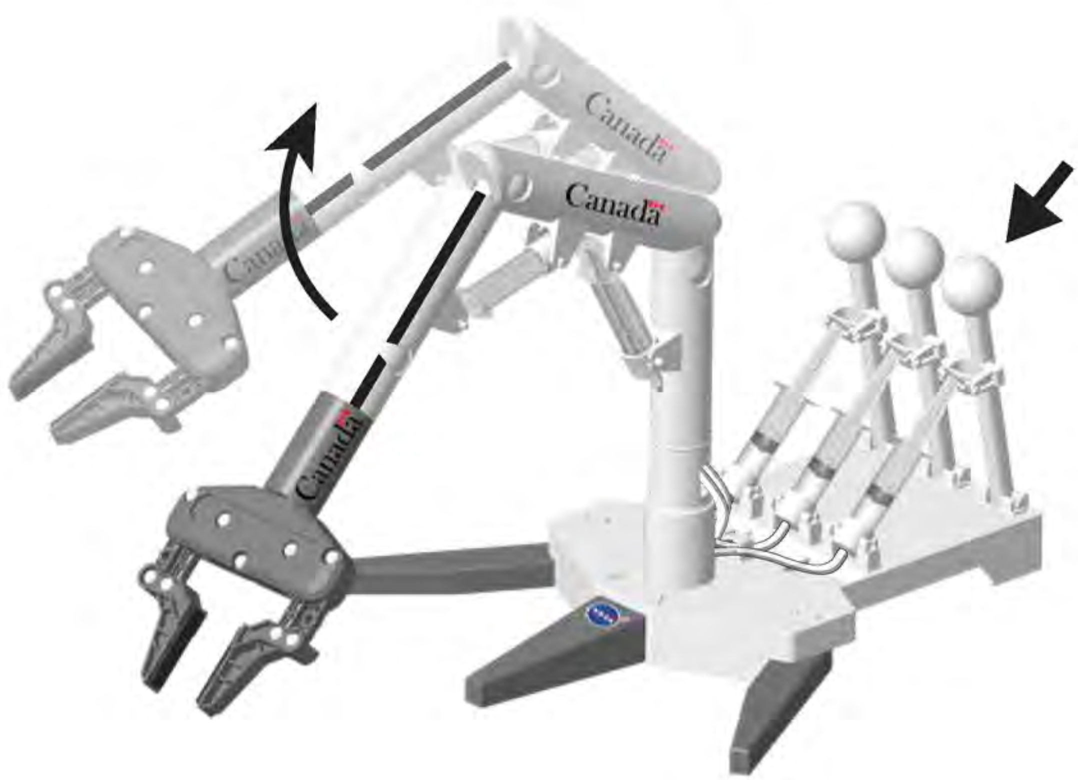




Satellite

Astronaut

24. Now, you can place your Canadarm on top of the Space Shuttle poster, just like the real Canadarm, and experiment with different movements. For example, try maneuvering a satellite from inside the Shuttle and placing it in space using only the levers. How precise are your movements when amplified by the hydraulic system? What are the weight limits for objects? Be cautious not to grab your own fingers (or anyone else's) while operating the robotic arm.



Space Shuttle poster (included)

I hope you enjoyed learning about the history of the Canadarm, building your robotic arm, and testing its capabilities. There's much more to learn in the amazing field of space exploration!

For more space educational toys, please visit our website at **www.futureexplorers.us**

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