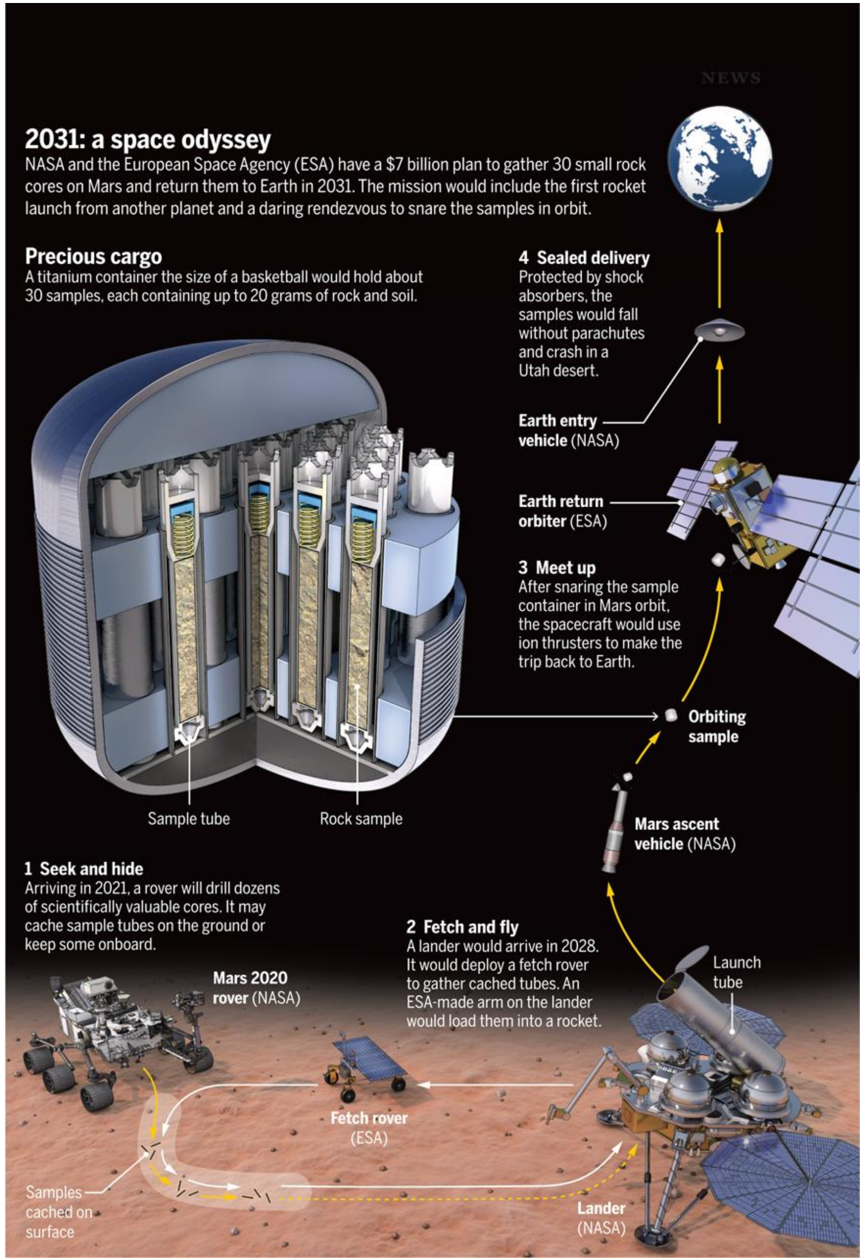
Robotic method to pick up rock core samples on Mars

Problem:

- The Perseverance rover on Mars has taken 43 highly engineered sample tubes that will one day be returned to Earth for testing. At least one of these tubes will hold an air sample of Mars and most of the others will hold soil and rock samples. Perseverance has a coring tool that drills holes in rocks and pulls out a cylinder of rock the size of a piece of chalk. The sample tubes are designed to prevent contamination or loss of air (with the help of a sample holder) when being transported from the surface of Mars, through space, the atmosphere of Earth and the impact on Earth. In the event that something happens to the sample tubes in that long journey from Mars to the lab on Earth (never launches, lost in space, burns up in Earth's atmosphere,...), 10 of the sample tubes are being left on Mars in specific places so they might be retrieved by a later mission so that all of the science is not lost.
- How does NASA plan on retrieving those samples?
- Your mission is to help with this retrieval by making the Sample Retriever (robotic method of picking up the Sample Tubes). Rather than sending a large rover like Perseverance, that would limit the rocket design of getting the sample back to Earth, NASA is using a small more generic robotic rover as the method of holding and transporting your robot. **You are <u>NOT</u> making the rover. Your team is making the robotic Sample Retriever that picks up the samples left on the surface.**

Glenn Johnson is working with the HUNCH Team to make improvements on this project and will be mostly done by August 1st 2026. Changes will be made during the school year as students ask questions and need clarifications.



Objective:

Design, build and test a robotic mechanism that will mount on a Generic Mars Rover and pick up 2 Sample Tubes someplace within a 30cm diameter circle and place them into the Launch Container attached to the Generic Mars Rover.

Bigger picture:

- The Launch Container will be on the back of a small, generic rover. Once full of the core samples, the rover will return to the launch vehicle and back up to the launch vehicle where a separate arm will remove the launch tray and place it on the rocket to be sent to Mars orbit where it will rendezvous with another satellite that will return the samples to Earth.
- You may use the front and/or top of the rover surfaces. The Launch Container where the samples will be placed is on the back of the rover. It is your choice for how you want to use the top and front surfaces but it will be important for NASA to keep the weight down as much as possible. Robot body has the following dimensions
- Rectangular body--13cm x 33cm x 42cm
- with 6 wheels 15cm clearance from the ground
- Side solar panels
- The method of how you pick up the samples is up to the team
- Can be a robotic arm or some kind of scoop

- It would be best if you could make picking up the sample tube fully automated but that is tough because it has to recognize the sample tube and pick it up correctly and deposit it into the sample holder—very difficult.
- I expect most teams will operate their robotic arm remotely. For this to be more realistic, the driver of the arm can not view the robot or the sample directly but only through any cameras on the robot. This remote control should be done wirelessly if possible.

- I suspect that each team will have at least 2 cameras—one on the arm and one watching the arm's position along with the space in front of the rover

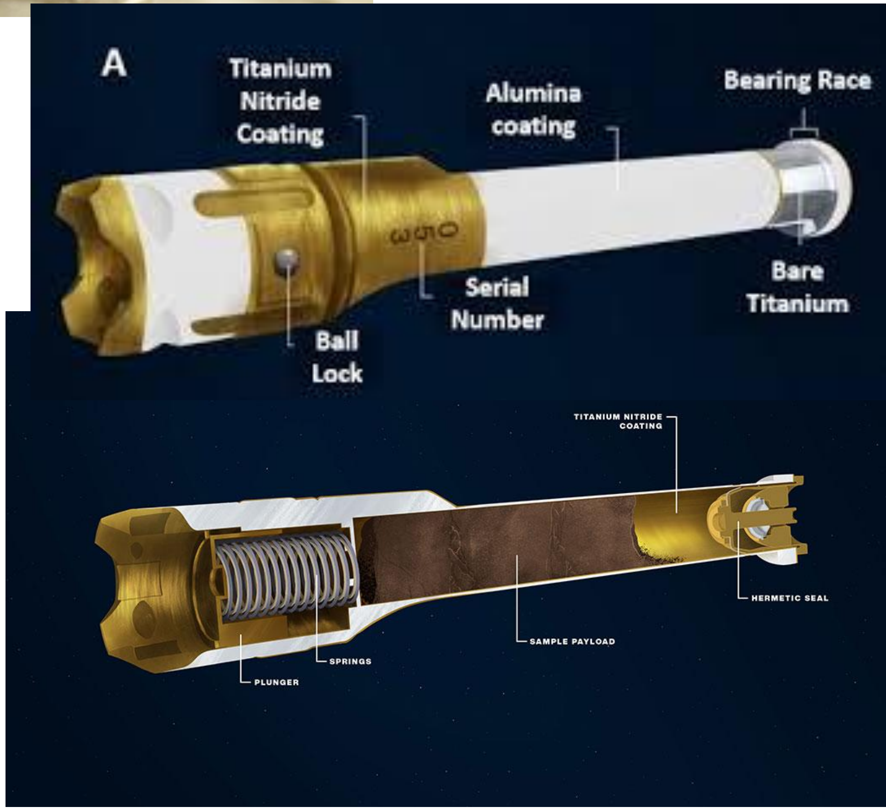
<u>Sample Retriever</u>

- Must be able to pick up one Sample Tube within a 30cm circle from the front of the rover.
- Your Sample Retriever can not weigh more the 2kg not including the battery
- Inside the Sample Tubes, the core samples are the size of a piece of chalk used in a classroom chalk board. 1cm x 8cm
- The samples are contained in titanium Sample Tubes to protect them.
- Deposit into Launch Container
- Make a 3-D printable Launch Container

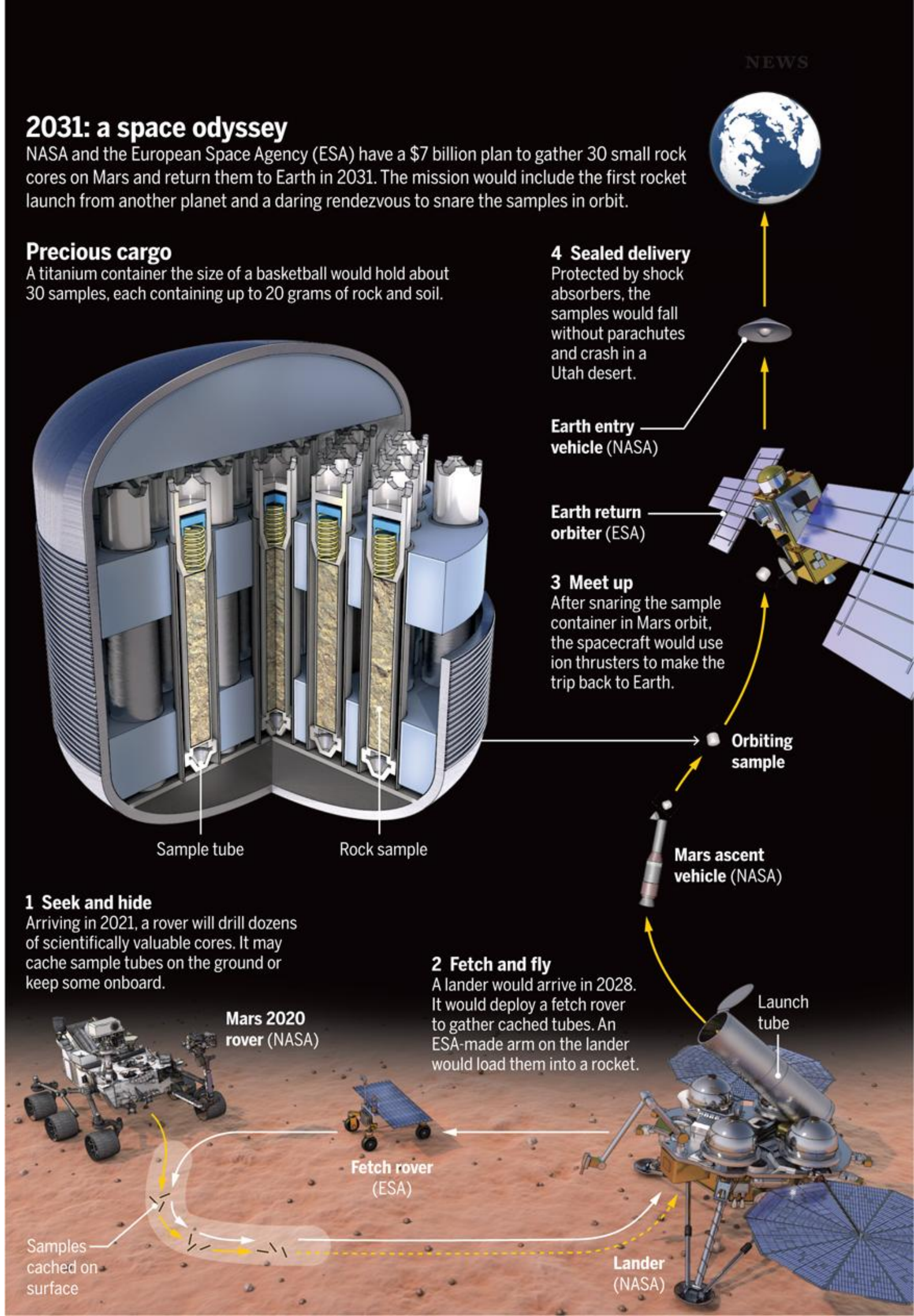
<u>The Test</u>

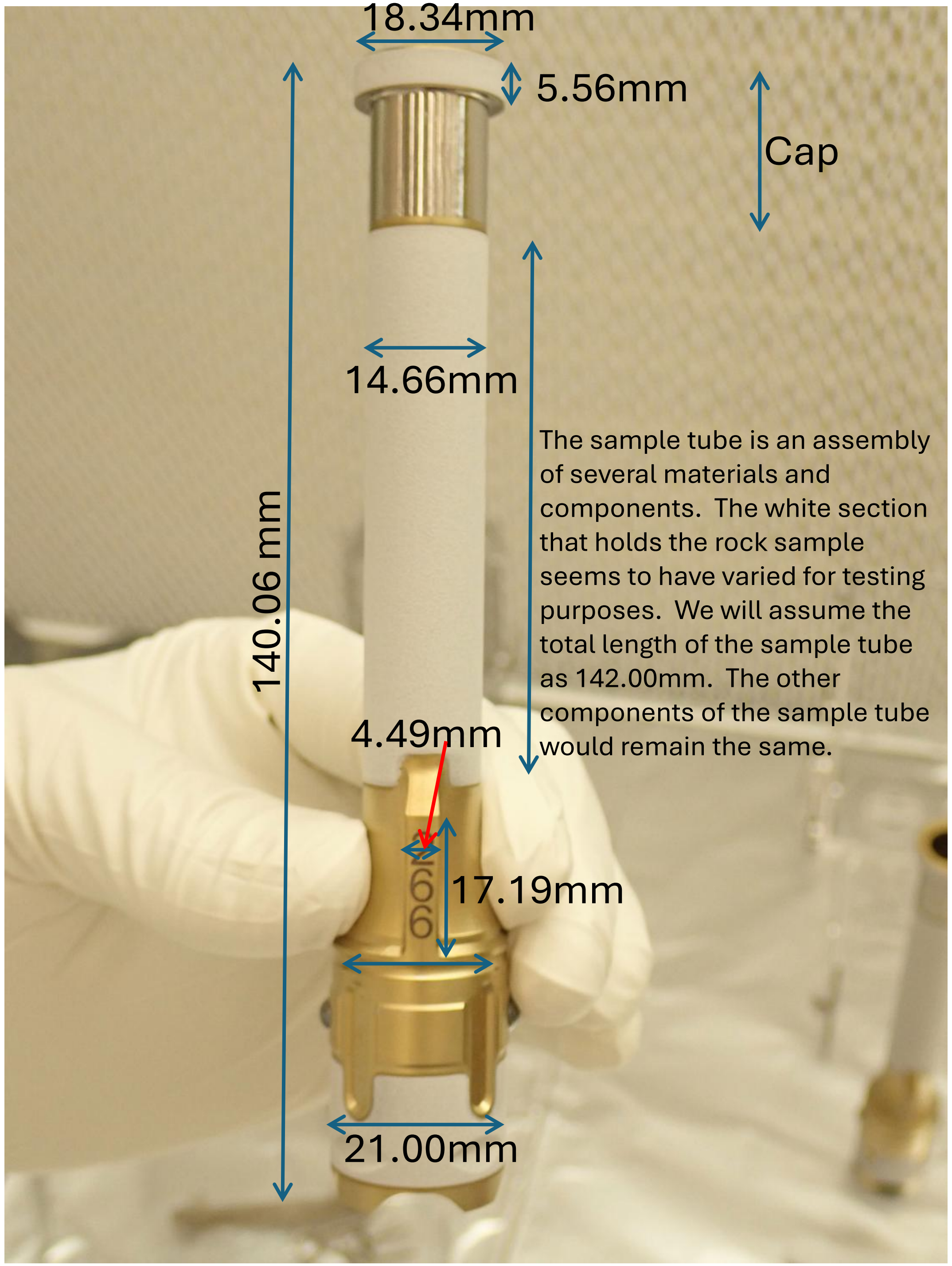
- The demonstration will be done with a 30cm diameter paper plate containing sand and pea gravel covering the paper. The Sample Tube will be dropped randomly onto the plate with the sand and gravel. The team's robot arm driver will pick up the sample tube and place it into the Launch Container at the back of the rover. This must be done using the cameras on the rover and robot arm without directly seeing the robot arm and sample tube or cues from other team members watching (we are simulating this being on Mars). After one sample is deposited into the Launch Container, a second sample tube will be dropped in a different random location on the plate and the robot arm driver (same or different team member) will retrieve the sample tube and place it into the Lauch Container.

Sample Tube



- This is an early description of the mission that NASA hopes will work. We are working on the mission that would happen only if this one goes wrong (and let’s face—this is a hard mission. The primary mission will be to load the sample tubes in the rover into a launch vehicleThere is no guarantee that this will work the first time.



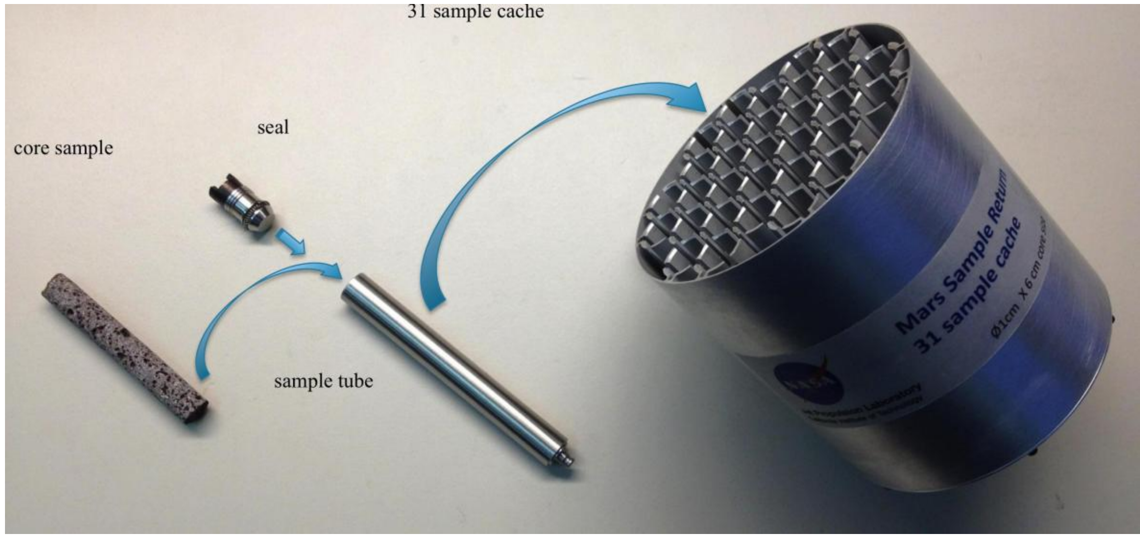


Sample Tube Dimensions

- I have not found exact measurements for the Sample Tubes so I am using this photo and the little data I've found on the internet. I'd like teams to use this information for developing their own sample tubes they can 3D print for your own testing.
- Measurements taken from this photo using 21.0mm diameter as the base measurement.
- These dimensions are the most critical. You are welcome to make other assumptions but make sure these are represented in your 3D print of the Sample Tube.
- The overall length seems to vary in the descriptions available on the internet. I think there were times when they used shorter or longer barrel lengths for testing. For simplicity let's make the **total length 142.0mm**
- Watch for updates on this page as students may help out with data.

Reminds me of Dr. Who's Sonic Screwdriver.

- https://www.nasa.gov/centers-and-facilities/jpl/the-extraordinary-sample-gathering-system-of-nasas-perseverance-mars-rover/
- There are several videos that will play on this site if you let it run

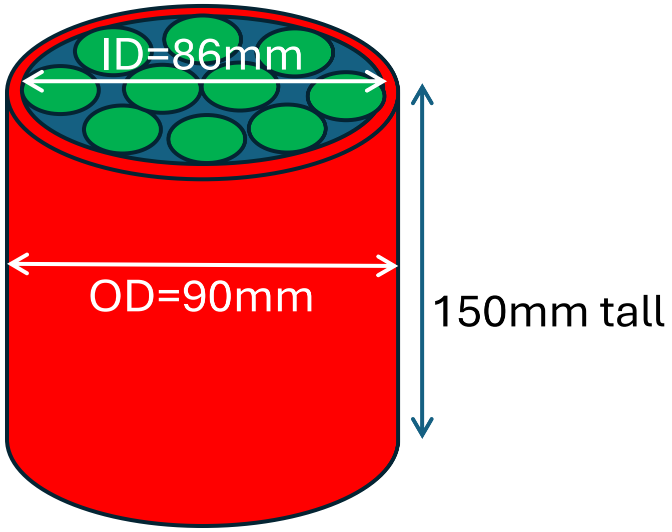


This is the launch Container that will take 31 samples to Earth We will be using a Launch Container for only 10 Sample Tubes

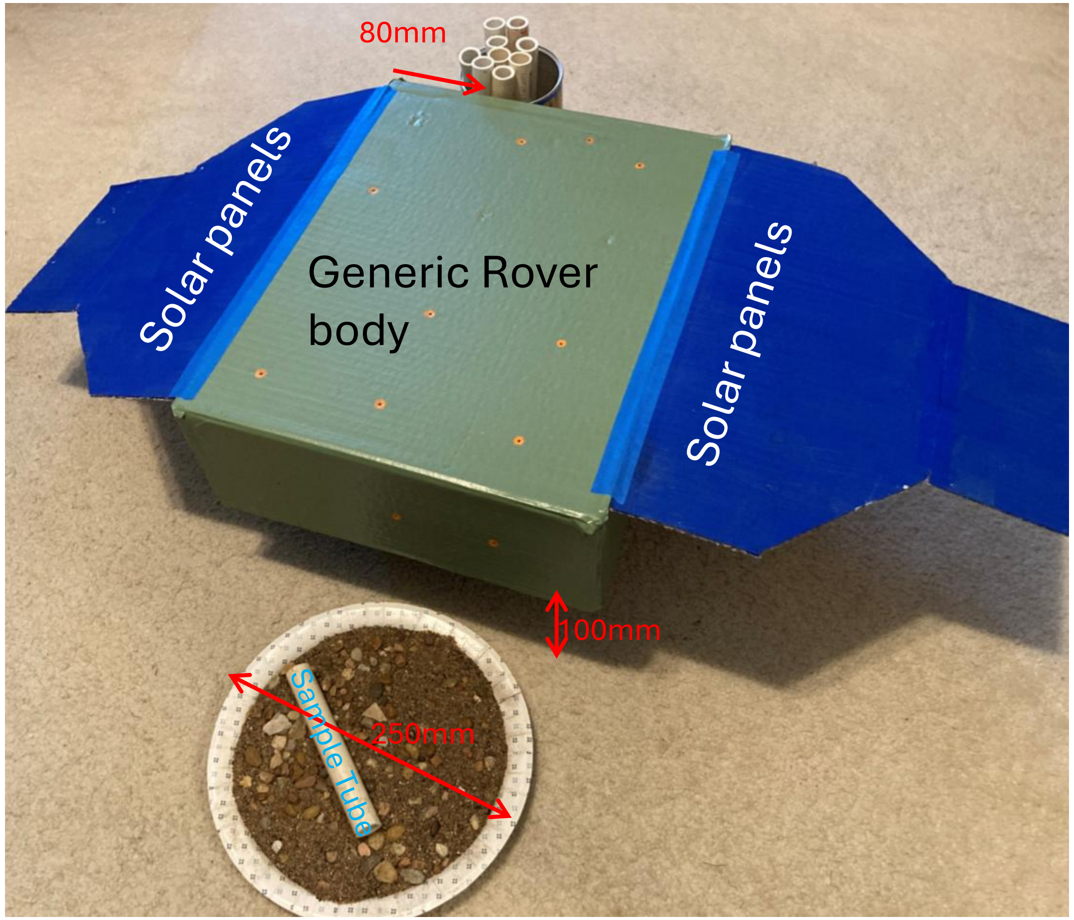
Launch Container

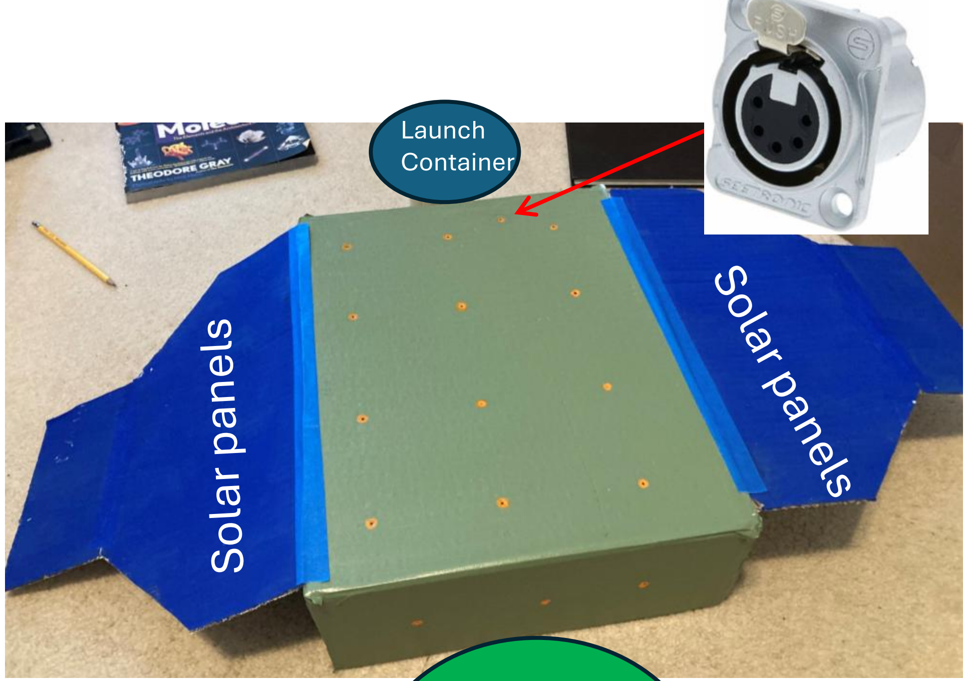
3D print or build a Launch Container with an internal diameter of 86 mm and an outer diameter of 90 mm and 150mm tall. Place holes in the top of it to receive the Sample Tubes (green). There should be about 1-2 mm between each Sample Tube hole. The space between (blue) could be done with a gyroid fill or your choice of other fills. This is intended as cushion for the samples.
Each of the green holes should be 22mm diameter at the top but can be smaller at the bottom to help hold the Sample Tubes.

Flat plate holds it on the bottom with a 4mm ridge
Spring loaded pins hold the top down
Where the top of the Launch Container is even with the top of the rover



I used a cashew can that is 3.75” diameter—too big a diameter, too small in height.



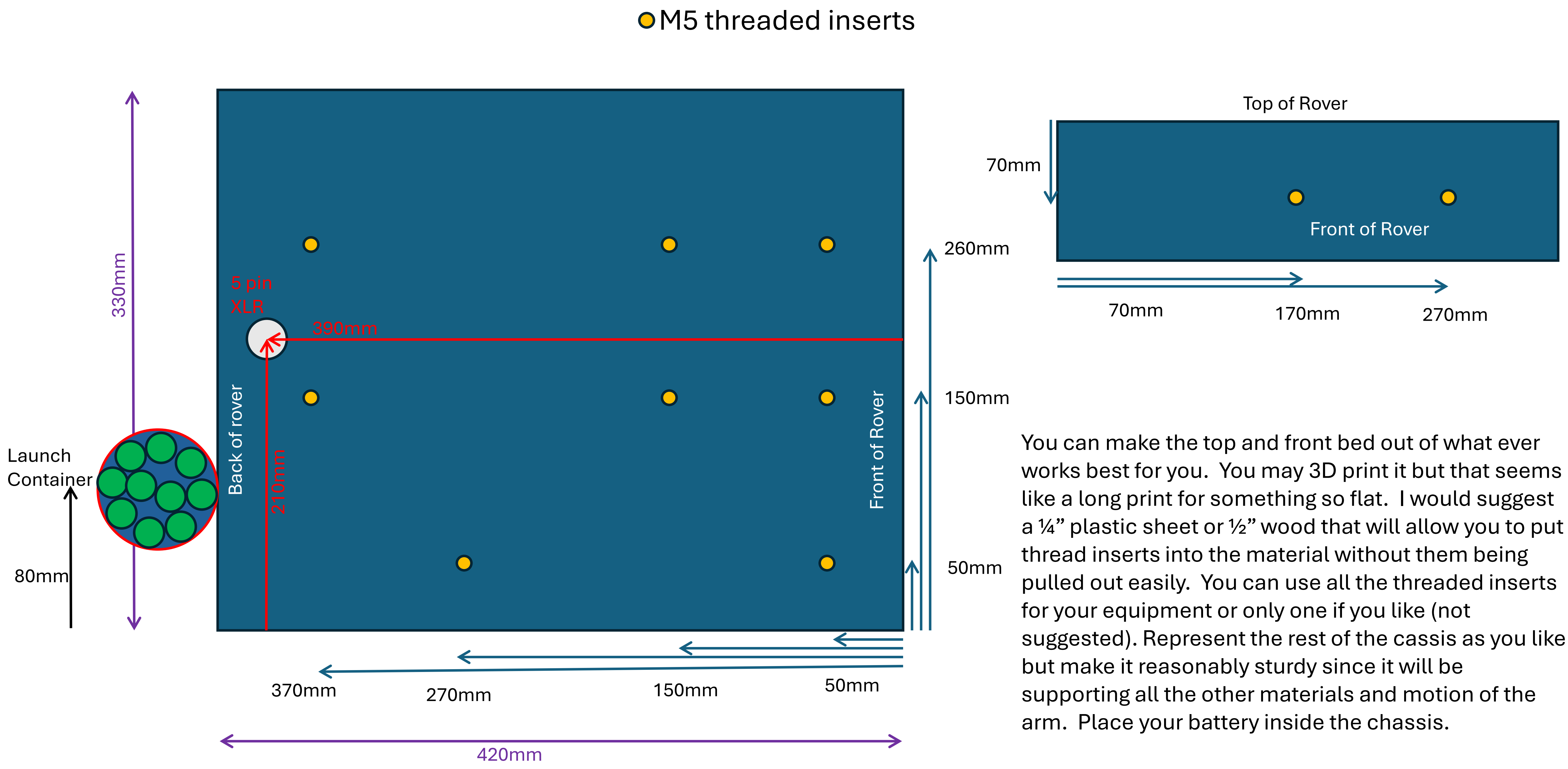


This is a cardboard model of the rover's deck and solar panels. 13cm x 33cm x 42cm. There are (8) M5 nuts in the top and (2)on the front of the deck to allow attaching your equipment to. There is a 5 pin XLR connector (this style, brand is not important—around $5- $10) on the top back portion of the deck for you to connect for power and data.
The Launch Container will be attached to the opposite side of the rover. Enlarging this photo will give you locations for the attachment points.
Your team can make this out of wood or plastic for attaching your Sample Retriever to. Place your batteries inside and connect your Sample Retriever to the 5pin XLR

25 cm
Pick up
zone

- The rover will be dire d team but drives to the location autonomously. The sample retriever your team designs will need to identify the e ground and be able to pick it up and place it in the Launch Container without dust and gravel
- The rover will place the ever within a 30 cm diameter circle of the sample tube. Your team's retriever will need to identify the Sample Tube, pick it up and deposit it into the Launch Container without dust and gravel (don't clog the other sample spots)
- You must be able to pick up 2 **randomly placed** Sample Tubes in the pick up zone and place them into the Launch Container. Being specific about which location in the Launch Container you place it in is even better.
- The terrain on Mars will contain gravel and sand. This means our test ground for your robot will also contain gravel and sand within the 250mm circle.
- The bottom of the rover is 100mm off the ground for driving clearance and does not go any lower. Your Sample Retriever needs to be able to reach down and pick up the Sample Tube
- The Launch Container is 80mm from the right side and the bottom of the container is even with the bottom of the Rover. This puts the top of the Lunch Container 20mm above the surface of the top of the Rover

Generic Rover Dimensions



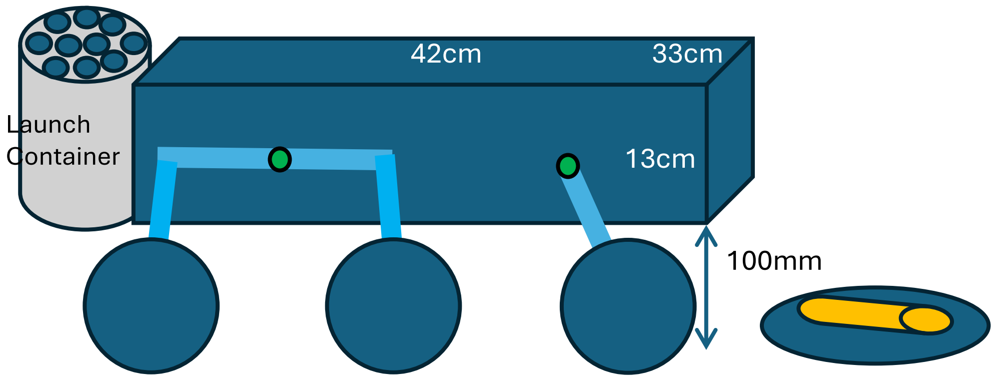
You can make the top and front bed out of what ever works best for you. You may 3D print it but that seems like a long print for something so flat. I would suggest a ¼" plastic sheet or ½" wood that will allow you to put thread inserts into the material without them being pulled out easily. You can use all the threaded inserts for your equipment or only one if you like (not suggested). Represent the rest of the cassis as you like but make it reasonably sturdy since it will be supporting all the other materials and motion of the arm. Place your battery inside the chassis.

Electronics

- Computer
  - Raspberry Pi?
  - Arduino?
  - Other?
- WiFi? Blutooth?
  - How much bandwidth do have for transmitting back?
- Controls?
  - Autonomous?
  - Game controller?
  - Something else that already exists?
  - Specialized?
- How many cameras do you need
  - Can you do it with one or do you need 2 or 3?
  - What kind of camera do you need?
  - How much do your camera(s) weigh
  - Where should it (they) be placed for the best view?
- How many motors do you need to operate your arm?
  - Since you don’t have to worry about the weight of your battery, the main weight constraint will be your motors
  - This doesn’t have to move fast—geared motors with significant torque
  - Could you save motor weight and power by using cables instead of multiple motors?
  - Hydraulics are great on Earth but the temperatures on Mars are cold and a leak of fluid would be unacceptable since it could contaminate a sample or an area.

Notice that this rover is smaller than the Curiosity and Perseverance rovers. This is due to the size of the lander needing to account for the mass of the Launch system that will take the samples from the surface to Mars orbit.

Dimensions of Launch Container
what kind of camera(s) do you need?
How many camera(s) do you need?
How will you locate the sample tube in the pick-up zone?
How will you deposit the sample tube into the Launch Container?
How will you designate where in the launch container it will go?



Things you should study.
Where did they get the rocks?
Why are they searching there?
What kind of rocks are they sampling
Why are those rocks important?
What do we hope to find out with these rocks?

Testing



Fill the plate with sand and dribble a handful of pea sized gravel on top.

These are 3 examples of randomly dropped tubes that a robot should be able to pick up.

This is an example of a sample tube that should be re-dropped since it is not fully supported by the plate.

Fingers, 3 loop lasso, scoop

The samples tubes are made mostly of titanium and aluminum so you should not expect that magnets could be used to pick up the sample tubes.

Keep it simple.

Canada Arm for the Space Shuttle and the ISS

The Canada Arm used on the Space Shuttle and the International Space Station uses 3 cable snares that move to open and close the center triangle as well as pull it closer. This works really well for things sticking up but not as good for things laying down.
https://www.youtube.com/watch?v=TquM-5sXvXs

The Canada Arm on the ISS also has the capability to connect power and data to what it grabs onto.
https://www.youtube.com/watch?v=5r5xkUVJ96E