Lunar Scooter Wheels

During Apollo, NASA toyed with the idea of sending up some kind of electric motorcycle. For the Artemis program there may also be some interest in a two wheeled vehicle. Mobility of getting on and off the motorcycle and positioning while riding was a significant factor that prevented it from going. The new space suits would make it even more difficult to getting on and off a motorcycle like vehicle. However, standing on a scooter may be easier. A scooter could also fold up and fit on the back of a small rover as an emergency vehicle or could go in places a 4 wheeled vehicle could not. A two wheeled vehicle can avoid holes and rocks easier, going between obstacles, drive on steep angles and be more comfortable in bumpy terrain since the legs could be the shock absorbers instead of a cushioned seat.

The scooter would look similar to the ones pictured here except that there will not be a seat but it may have a small tool box or sample holder. It will be foldable to take up less space on the rover and will need fenders to keep the lunar regolith from kicking up onto the astronaut and equipment. There will also be a head light and maybe other lights to aid in visibility. You are not building or designing the scooter only the wheels—a tough job, especially because of the environment.

Lunar Scooter

- Two wheeled vehicles are easier to maneuver between rocks, around and through craters with an incline.
- A scooter would make a good back up vehicle for a rover breakdown or for getting somewhere the rover can't go.
- A two wheeled vehicle can handle slopes a 4 wheeled vehicle can't without rolling down the slope.
- No need for suspension—it's all in wheels and legs--no seat
- Some flex in the wheels through the spokes
- Will need to be able to handle 100 lbs Earth weight

Parallel wheels vs. Inline

- A Segway style of scooter may have an advantage by way of how the astronaut would stand on the Segway versus how they would stand on an in-line scooter considering the suit mobility.
- An inline scooter could have a safety factor if the battery dies, the astronaut could still push it by foot like a regular scooter but that wouldn't be possible for a Segway style scooter.
- Another potential advantage of an inline scooter is its ability to going between rocks and pot holes. Not as possible with the parallel wheel scooter.
- All of that said, there may not be a solid answer for which style would be chosen to go to the moon. A Segway style of scooter could also be an option for the moon. For simplicity of the project, design these wheels for an inline scooter. The wheels for both would still be very similar and could be used on either.

Requirements for Lunar Scooter Wheels

Problem:

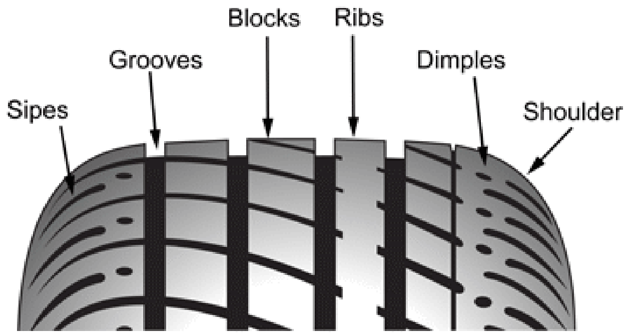
Most of the wheels designed for the moon and Mars are made for robotic rovers that move fairly slow—a few centimeters per second. These wheels will need to move the astronaut at speeds around 1 meter per second. This requires a very different kind of tread.

Objective:

Develop and build the front and rear wheels for a lunar electric scooter:

- Light weight—$1.2 million /pound to deliver materials to the moon
- Should be able to last more than a 300 miles in rough conditions
- Appropriate materials for the lunar environment
- Vacuum
  - Lunar day = 28 days where around 14 is sunlit and around 14 is in the dark
  - Temperature range between +260 in the sun to -280 degrees Fahrenheit in the shade
  - Fine grain, dry, sharp dust
  - Static electricity from the sunlight pushing electrons
  - 1/6th Earth gravity
- No larger than 18 inches diameter
- ½ inch axels
- No wider than 10 inches
- Expect a speed range of 0 to 15 mph in very rough terrain with soft soil, rocks and pot holes.
- Front and rear wheels can be the same or different—be prepared to defend either.
- Is there a reason to have both wheels as drivers or should one drive and the other is free?—why?
- There is value to both narrow and wide tires you are shooting for what works best for this application and environment.
- Shock absorption will be in the wheels (spokes, tread, hub) and the astronaut's legs—no shocks
- On earth, the astronauts + the space suit + the scooter + rock samples will have a weight of around 500 to 600 lbs. On the moon this will be around 83 to 100 lbs. Design your wheels to meet this need.

Tire Knowledge



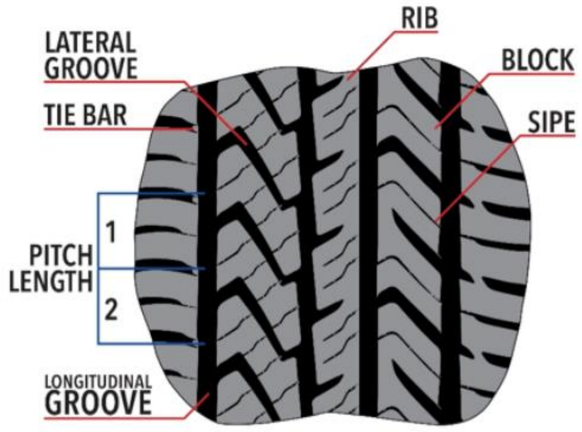
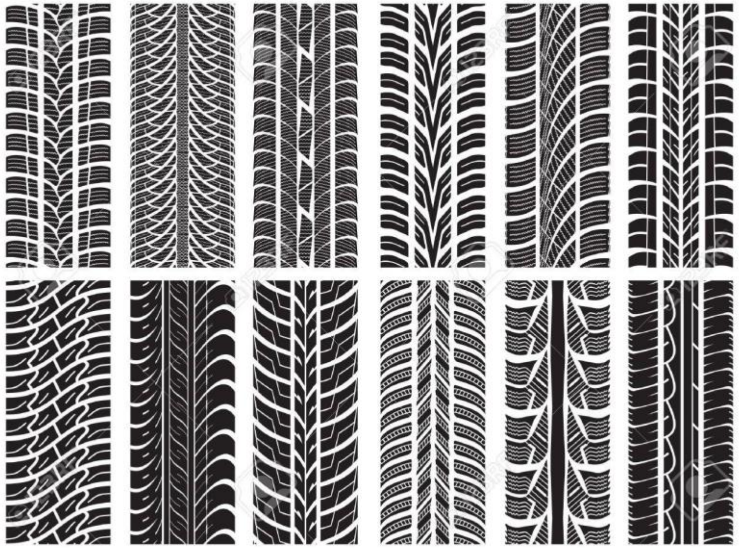


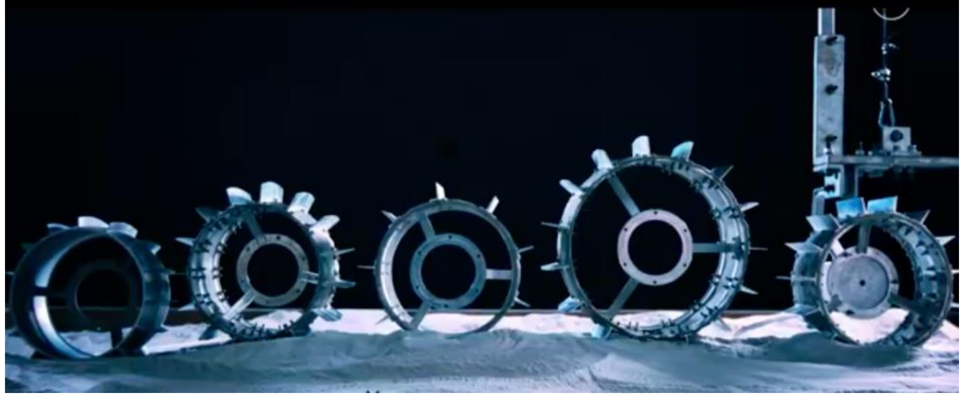
Figure 1: Tread pattern components (Source: Yokohama Tire Corp.)



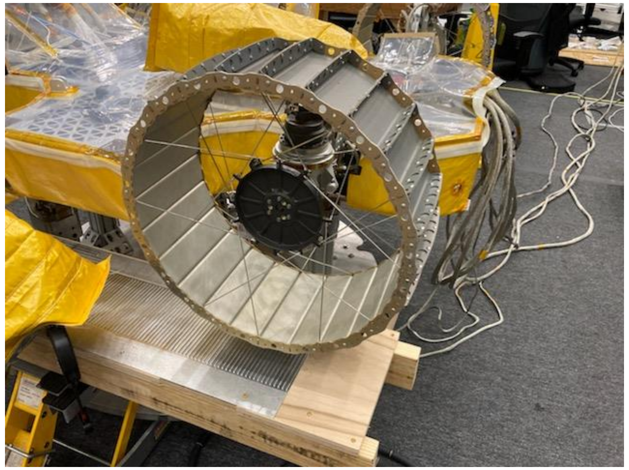
There is a lot of technology that goes into tires and wheels. The size and shape of the block, sipe, lateral and longitudinal grooves are all chosen for specific purposes on a tire, either for grip on different surfaces or durability over time or maybe keeping the tire quiet among other things. Although these pictures are about rubber tires, the terminology is applicable to the wheels you will be designing and building. Study up on different types of tires and how they are used. Don't be afraid to go into a tire shop and ask questions and tell them about your project. Driving in dry sand is a challenge that both motorcycles and 4WD vehicles like to work.

Grousers—the paddles that stick up out of the tire or tread

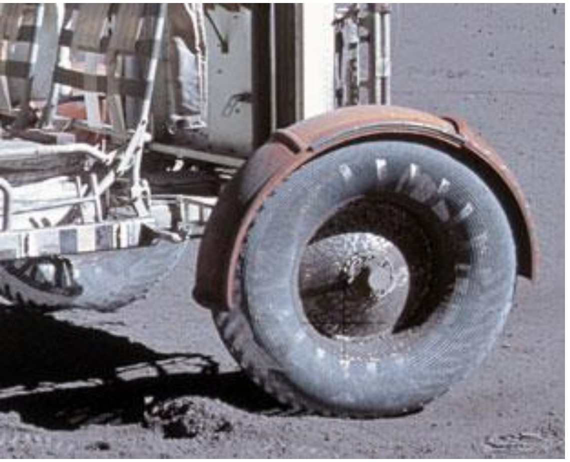
Check out videos on 4WD on sand and loose dirt.
Tires for sand?
https://www.youtube.com/watch?v=HyPRBoo0nCQ
Desert and beach sand driving
https://www.youtube.com/watch?v=snQdgMpAKfU



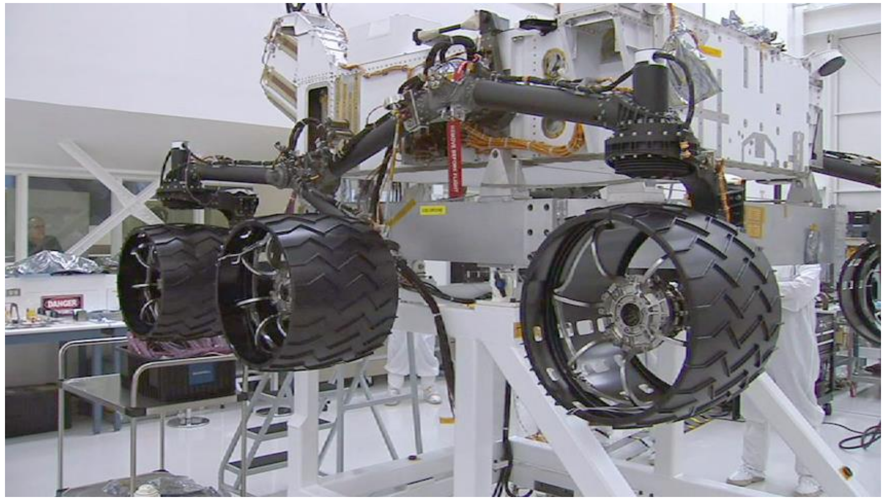
Grousers are the paddle like structures on the wheels. The size of the grousers can determine how much sand they kick up how steep of hills they can climb and how much the wheel digs into the soil. The shape can also determine how well it can steer.



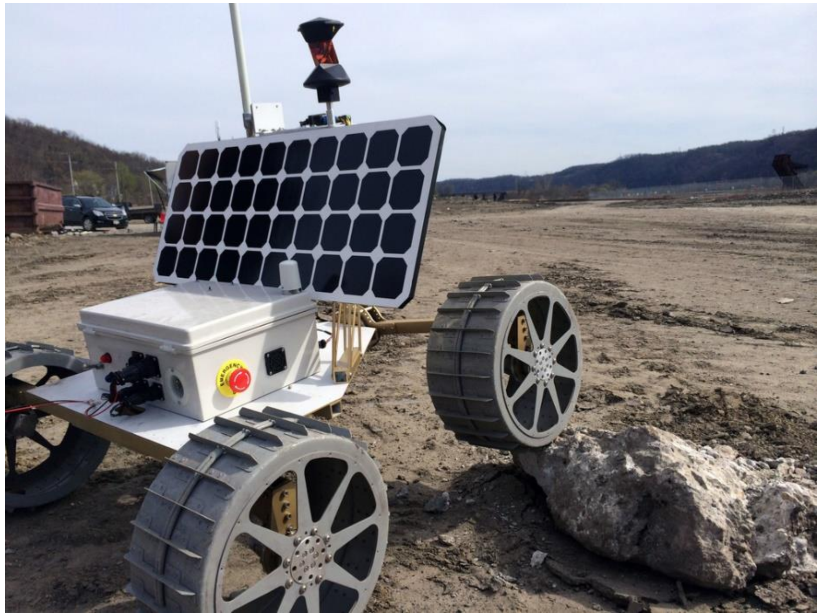
New wheels being tested for the VIPER lunar rover being built at Johnson Space Center.



Apollo Lunar Rover—these wheels were intended to ride mostly on top of the regolith without digging down and were the only off world wheels intended for higher speeds—about 10 to 15 mph.



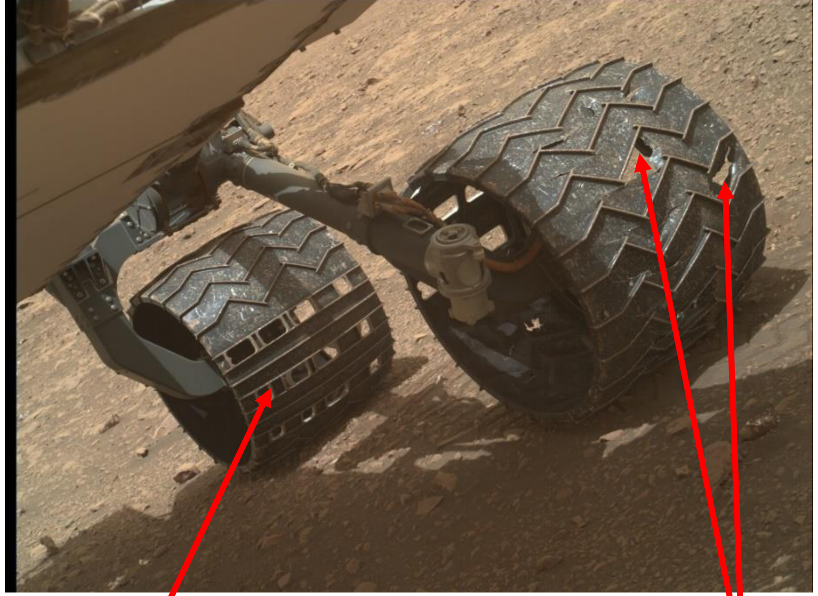
Curiosity rover that is currently on Mars. The aluminum spokes are intended to be somewhat flexible and absorb some of the vibrations as it drives over rocks and other hard surfaces.



Hopeful Lunar Rover

Not Pneumatic

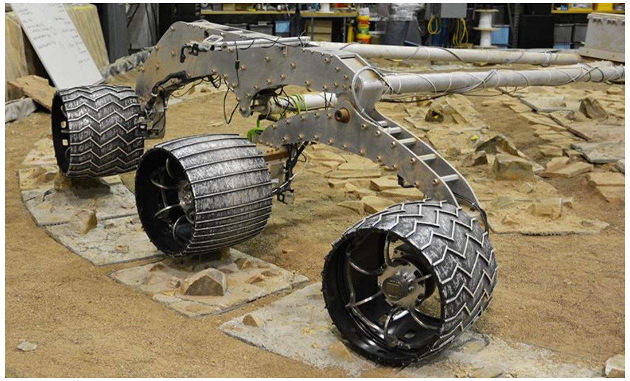
- The Curiosity wheels that are on Mars have had difficulties with dents, cracks and holes. Some of this is due to the shape of the treads as well as the rocky surface but this is over several years of driving.
- There are different treads for different purposes. Some treads are for driving traction and other treads for being pulled--tires for freeway driving, mud tires for trucks, slicks for race cars, tractor tires, trailer tires. Some tires are better for side loads like taking sharper turns or going diagonally up a hill side.



Holes in wheel that is Morse Code that spells out “JPL” as the rover drives through the dirt.

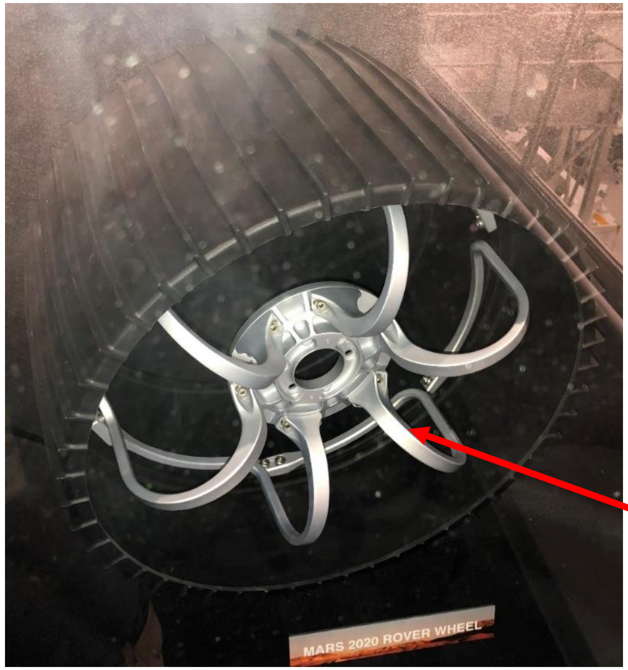
Damage to wheel

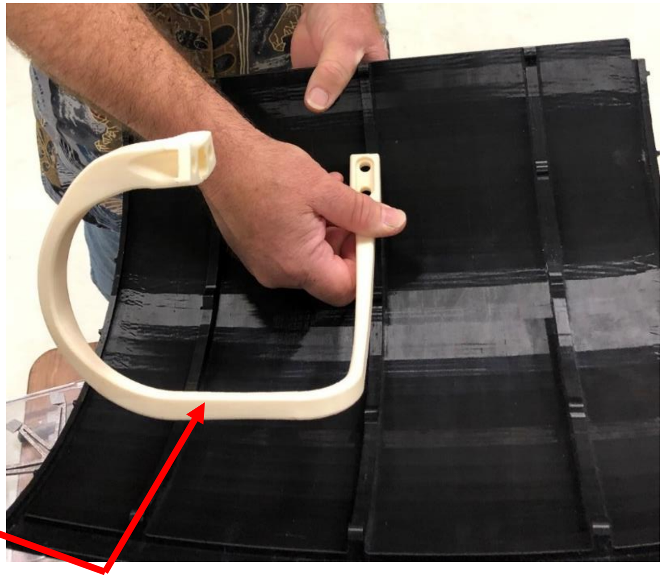
All six wheels on Curiosity are drivers and can steer.



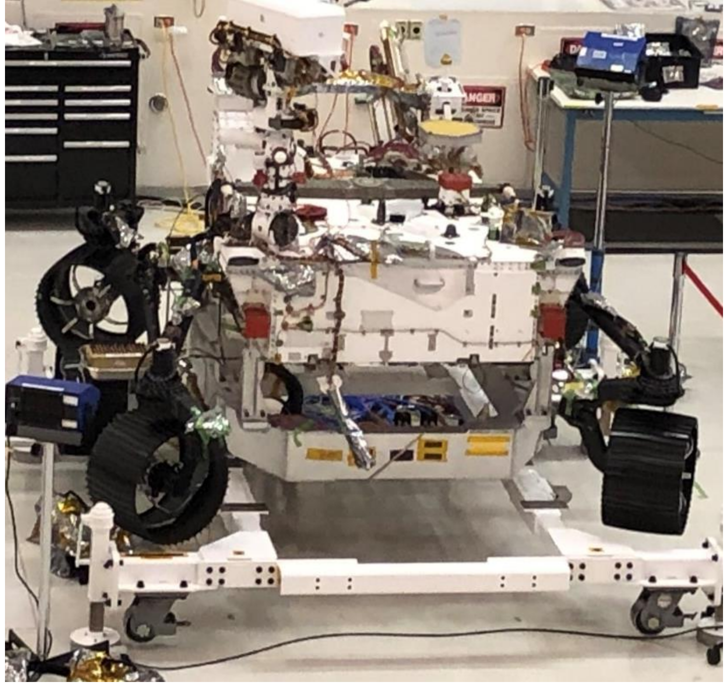
Testing different wheels for Mars at JPL

Mars Rover wheels



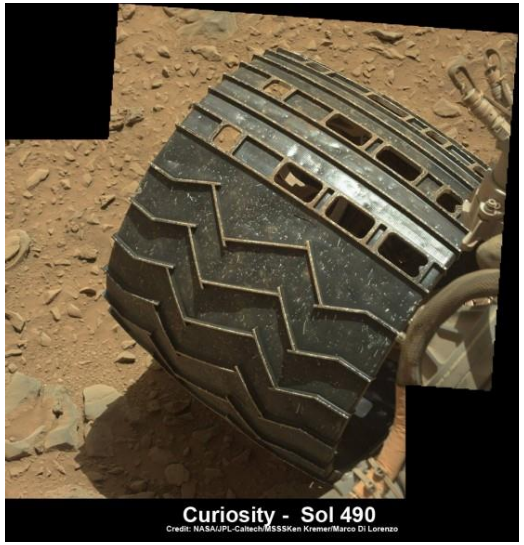


Notice the length and shape of the spokes— allows some flexibility



Mars 2020 Rover being assembled at JPL. The tread on the wheels is more ‘wavey’ than angular on the Curiosity Rover.

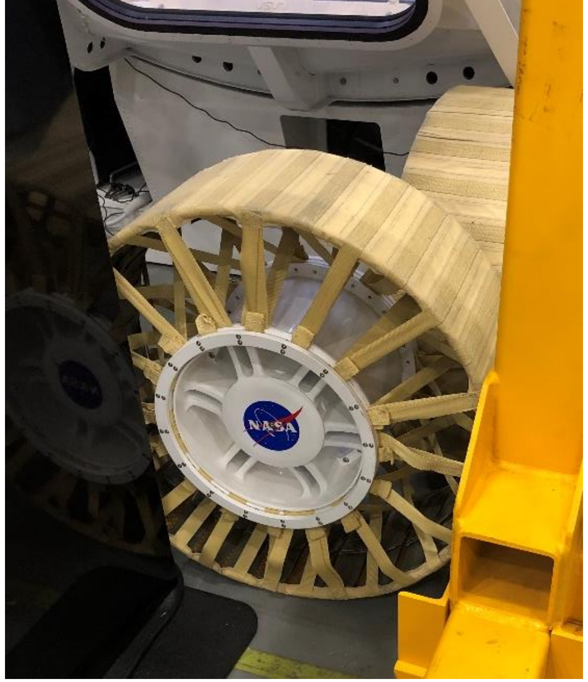
Pneumatic tires (air filled) act as shock absorbers and help even out some of the minor bumps. Rigid wheels are much more bumpy to ride on. Pneumatic rubber tires can not handle the temperature differences on the moon without cracking in the cold and the air would expand and contract as it heats and cools. The wheels on the Curiosity and the new Mars Rover are rigid aluminum and will stay round, the shape and length of the spokes for the rover act as the shock absorbers for the vehicle. Both the Curiosity rover and the new Mars Rover use similar spokes but the aluminum wheels have a different tread to minimize wear on the wheels.



Curiosity Rover wheel on Mars. The angles were determined to cause stress in the aluminum.

Rover wheel that was tested in the JSC Mars yard.

Most of the NASA robotic wheels are designed for going slow speeds (like 1 or 2 mph or less) and won't throw up much dust because of speed. Your design for the scooter will be going considerably faster and will need to think about the dust being kicked up. The people designing the scooter will need to consider fenders that prevent dust from kicking up on the astronaut and the scooter but it may also be valuable to provide traction by riding on top without throwing dirt.



This is a wheel that was proposed and tested on a rover. It is composed of an aluminum hub and a rim that are connected by Kevlar straps. You can see that the straps are tight on the top and loose at the bottom of the wheel. The weight of the rover is hanging from the straps. Although rigid spokes do hold some weight, all wheels function the same—the weight of the vehicle hangs from the spokes. Flexible spokes do not take as much side load, important while turning.

Earlier version
of wheels

This is a test digging vehicle being made by the Swamp Works team at Kennedy Space Center. The sheet metal wheels were designed by the Swamp Works team but built by HUNCH students at Eau Gallie High School—Aircraft Maintenance with instructor Mr. Bill McInnish. They are 17" diameter x about 6" wide. The size of the grousers on the wheels can be very specific for the soil type. Too big and the wheels could dig itself in too much, too small and it may not have the grip to go up the hills. The grousers are also rounded some to allow for better steering.

As the drums on the front and back of the vehicle come down to the surface, they spin and dig up regolith. When they rotate the opposite direction, the regolith empties out of the drum. The rover's job would to go pick up regolith from a distance away and bring it back to where it is needed. The smaller version of this that will go to the moon is expected to travel a longer distance in its 11 day mission of testing than the Curiosity rover has done over several years on Mars.

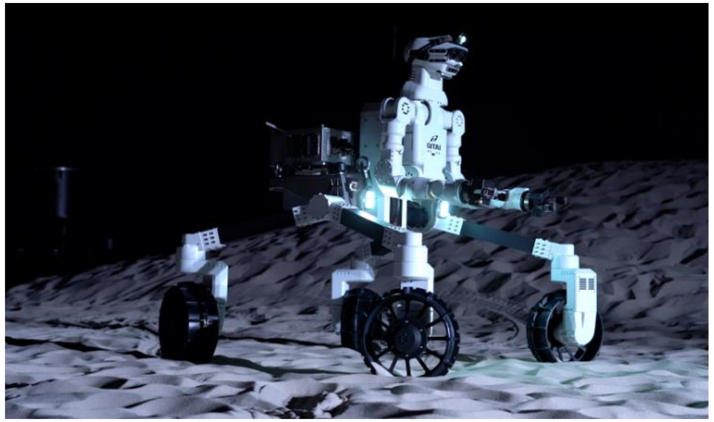
Different tread for different purposes

Aircraft tires have tread for keeping the plane going straight for landing

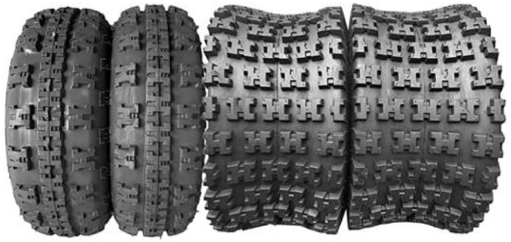
This tractor is rear wheel drive and has front tires specific for steering. Steering traction and pushing traction?

Traction in sand

GITAI Lunar Robot moving in a simulated Lunar environment. I'm not sure how fast it is actually traveling. Notice how deep the wheels go down in the sand as it goes up the hill. https://www.youtube.com/watch?v=mZcwuypT6rU



Balloon tires are more flexible and less rigid so they flatten out on top of the sand to keep the wheels on top without digging in as much.



Different size grousers.

Testing

- It will be important to test your wheels in dry, powdery conditions. Do some research on the many types of lunar soil simulants that NASA and other researchers are using. The objective is to test your wheels in something similar to what it will be driven in, not to spend the most money on dirt.
- Anytime you are working with these dry, small particulate kinds of dirt, it will be important to wear a dust mask to keep from inhaling the particles. Some can be more hazardous than others.
- Play sand from Home Depot or Lowes is probably too large grained and rounded.
- A loam sand might be better since the grain size is smaller and it will flow and move against each other differently than the play sand. If you have some diatomaceous earth (like for a pool filter) that may be helpful also since the particle size is very tiny and the particles cling together more (skeletons of microscopic organisms). Maybe a mix.
- Bags of dry cement mix also have some similarities since the particulate is very small and they are broken crystals and don't have rounded shapes. You don't want to inhale these particles since they react with the moisture of your nose and lungs and make concrete.
- Since the moon is only 1/6th Earth's gravity, the regolith doesn't compact the same as soil does on Earth. This means that the soil may be much looser and easier for the wheels to dig themselves into a hole. Because the particles are much more jagged, they can cling and stick to each other. These sound like contradictions but this shows some of the difficulties researchers are having to model the Lunar soil on Earth for engineering testing.
- I don't know how any of these react to static electricity.