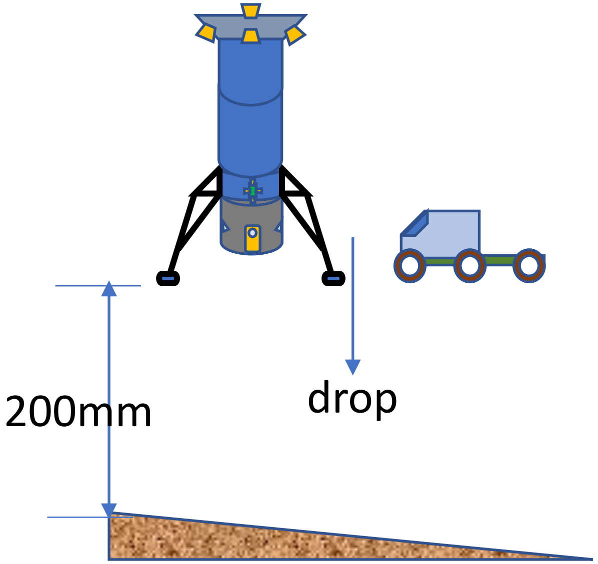
Lunar Landing Legs and Cargo System

The Challenge

The South Pole of the moon is different than the Apollo sites near the equator. Like Apollo, the Artemis Lunar Lander will be landing on a terrain that will have rocks and dust but the Artemis sites will probably have a slope that can make a tipping over a possibility especially a tall rocket. Here is an alternate lander configuration that would allow cargo to be off loaded to the surface quickly with minimal assistance from the astronauts. Although this is an interesting concept there is a lot of work needed to turn it into a good solution. The fuel and oxidizer tank configurations and the engines will be worked by another company but the landing legs and the method of attaching and releasing the payload/supplies needs to be worked out.
For the competition, 3 cans on the top are representing the fuel and oxidizer (top can is empty) with engines of the rocket on top. After landing the tanks would be partially empty but still have fuel for the ascent of the rocket after the payload is delivered. The mass distribution would be different but because of the engines the mass would still be similar to the soup cans. Design your legs to be able to handle these difficulties.



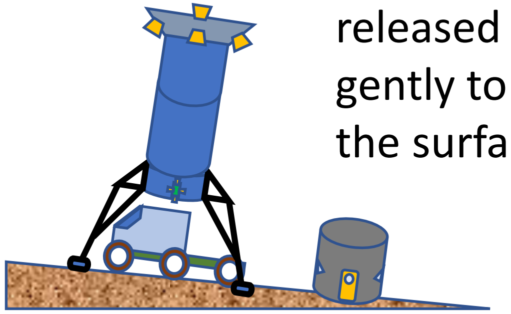
Design, build and test the light weight legs of a lander to fit the rocket body and a payload release system so that the rocket and payload can be dropped 200mm onto a **6 degree** slope without falling over or dropping the payload and then be able to release the payload gently on the surface after landing.

- The body of the rocket is represented as 2 cans of Rotel diced tomatoes --283 g, 101mm tall and 1 can of Bush's Best baked beans—235 g and 75mm tall

2 separate tests

The payload/supplies are represented as

- 1 can of Bush's Best baked beans—235 g and 75mm tall
- And a scaled, 3D printed Lunar Rover



Payload released gently to the surface.

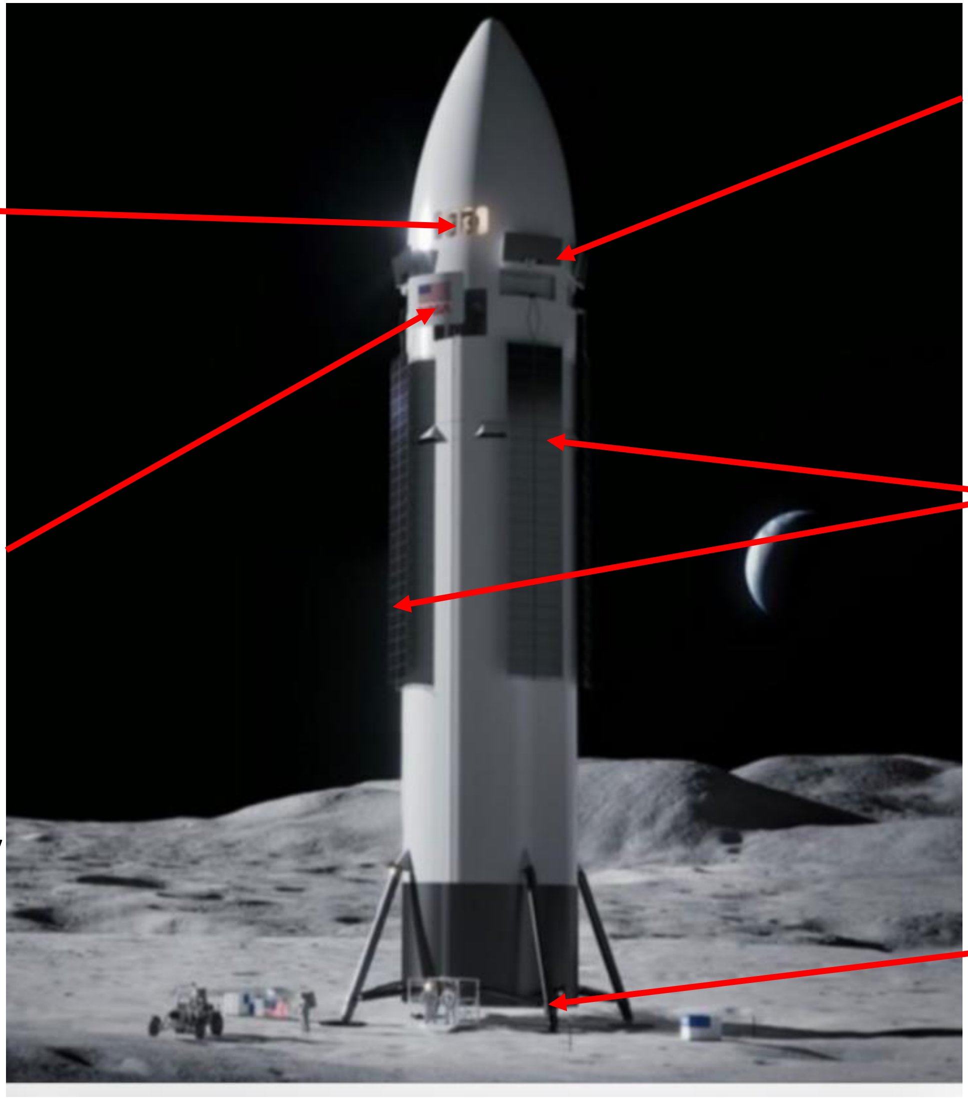
Lunar Lander—Payload and Equipment Delivery

- One of the biggest difficulties with building a lunar base is delivering all of the equipment and materials needed for building and supplying the base. When on earth, there are lots of people, equipment and methods for a supply chain of getting the goods where and when they are needed. On the moon it will be much more difficult since no one else (usually only 2 people at a time on a space walk) is there and every time the astronauts go outside, it can take hours to prepare and it is always difficult to be in a suit that fights your movements from the pressure inside. There is also the potential of your suit getting damaged from micrometeorites or cut from equipment or tools--death is bad.
- It is important for NASA to look for easy ways to supply materials for the moon that don't require a lot of astronaut time. The more robotic the deliveries can be without having to carry supplies off a rocket, the more time the astronauts have to do the real work of assembling the Lunar Base.

This is the latest public description of the Space X Human Landing System (HLS)

Crew Cabin—high up (dangerous when leaving, hard to see landing site), next to engines (loud)

Cable driven hoist/elevator—heavy, dangerous, limits size of cargo to the hatch and hoist size, increases work time. It could take hours to remove equipment depending on how it is packed, get it to the ground and out of the way before launch.



Positioned engines up high to minimize dusting—good idea!!

Moveable solar panels—good idea!!

Wider landing gear—good idea!! wider would be better for a very tall rocket

Earth based cargo delivery

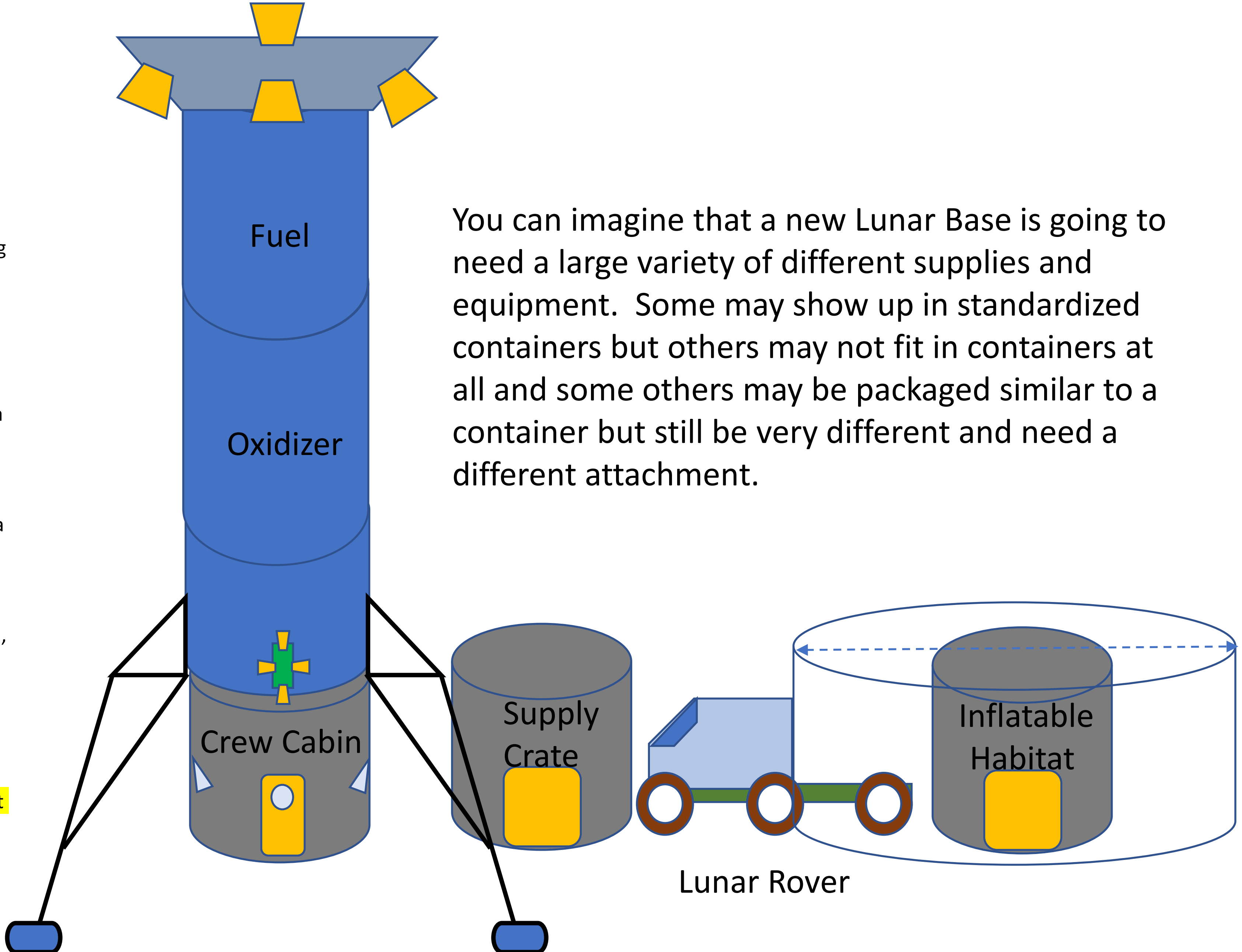
- The objective is to unload the payload as quickly as we can with as little work from the astronauts and leaving as few spare parts behind as possible.
- Helicopters and Quadcopters have been delivering payloads positioned under the belly of the vehicle for a long time. Could a rocket deliver payloads in a similar fashion?
- Design a cargo system that fits underneath the rocket's fuel and oxidizer tanks in between the landing gear.
- The rocket's engines have to be on top not below.
- Because this will be coming from Lunar orbit, the payload cannot dangle from the rocket but must be attached tight against the hull of the rocket
- Needs to be low precision so it can be attached easily but high strength so it doesn't release on a rough landing.
- Could the payload be raised and lowered with
    - Levers
    - Cables
    - Move the landing gear up and down
- Does it grip the payload only from the edges (like how you might grip a soup can) or are there attachment points in the middle? Is it possible or necessary to have both?
- How might you account for payloads that don't require the cylindrical shell? -- like sending just the rover or metal making equipment for the moon?

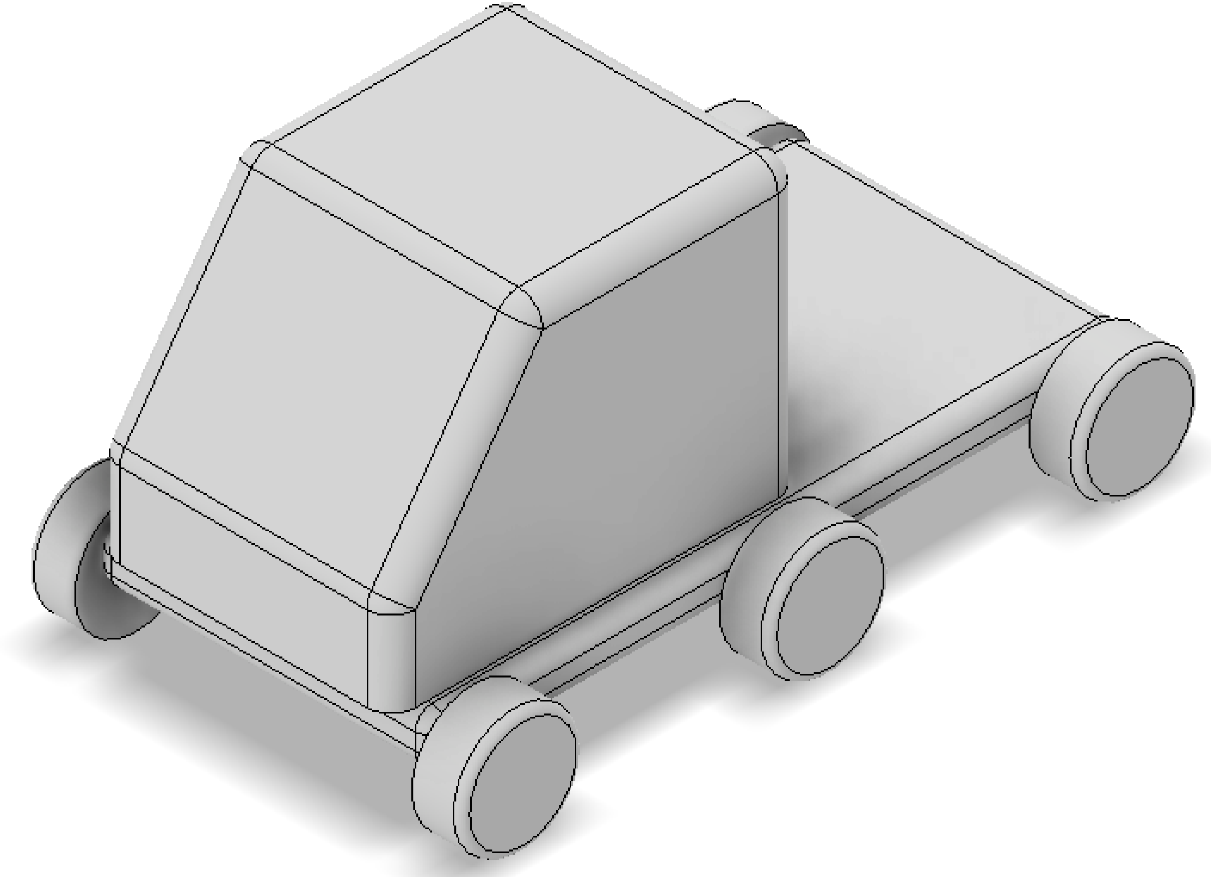
- Here is an alternate lander configuration that would allow cargo to be off loaded to the surface quickly with minimal assistance from the astronauts. Although this is an interesting concept there is a lot of work needed to turn it into a good solution. The fuel and oxidizer tank configurations and the engines will be worked by another company but the landing legs and the method of attaching and releasing the payload/supplies needs to be worked out.

The challenge:

- Design and build minimal weight but sturdy landing legs and a payload system that will hold the payload when the rocket body is dropped from 8" off the ground to a 6 degree slope without tipping over and release the payload once the rocket is stable.
- Minimize the weight of your landing legs—anyone could put a bowl underneath a rocket and call it good but it would obviously be too heavy to fly it that way. Try to cut down on the weight to support your rocket as best as you can.
- Once in space the landing gear does not need to be retractable. Since there isn't any air that would cause friction, the landing gear doesn't affect flight either on orbit or between the lunar surface and orbit. Make your landing gear fixed if you like or only deployable.
- There is no maximum weight limit for the legs or the payload release system but the intent is that you are trying to have reasonably small legs and a reasonably small release system.
- The release system does not have to be fully automated but it helps if astronauts have less to do.

You can imagine that a new Lunar Base is going to need a large variety of different supplies and equipment. Some may show up in standardized containers but others may not fit in containers at all and some others may be packaged similar to a container but still be very different and need a different attachment.

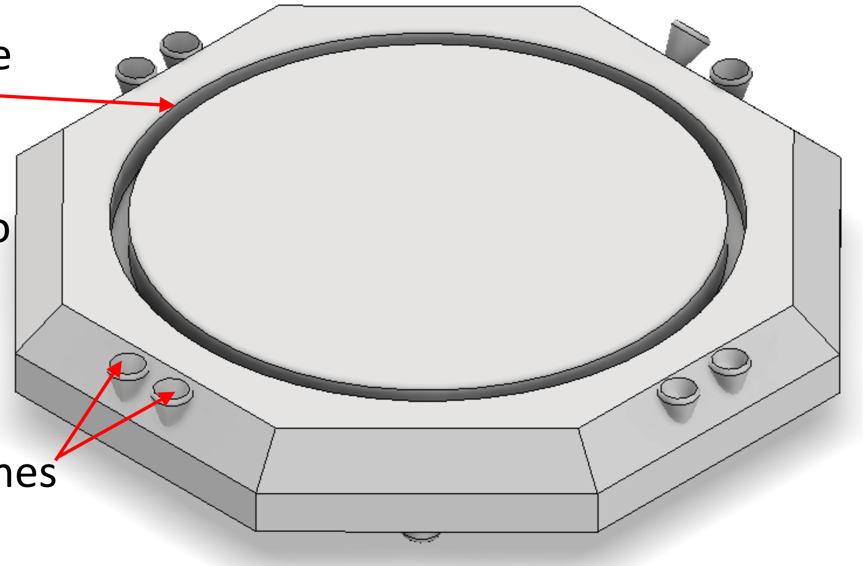


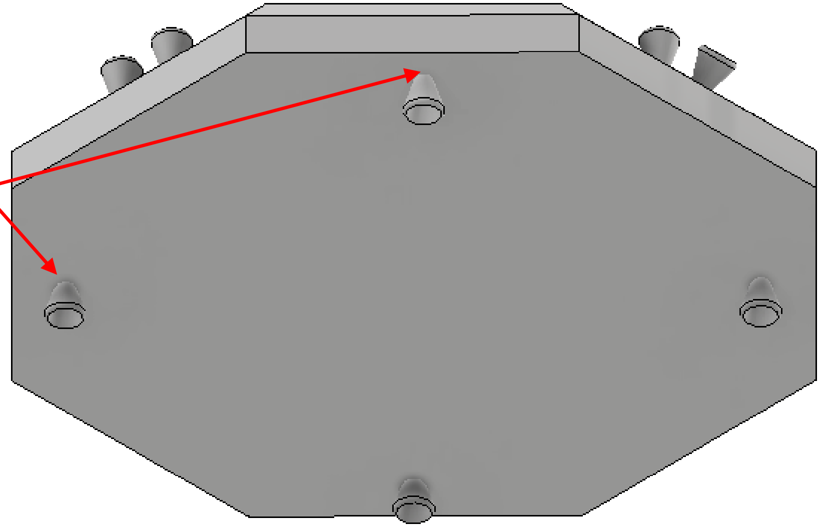


You may add attachment points for rocket.

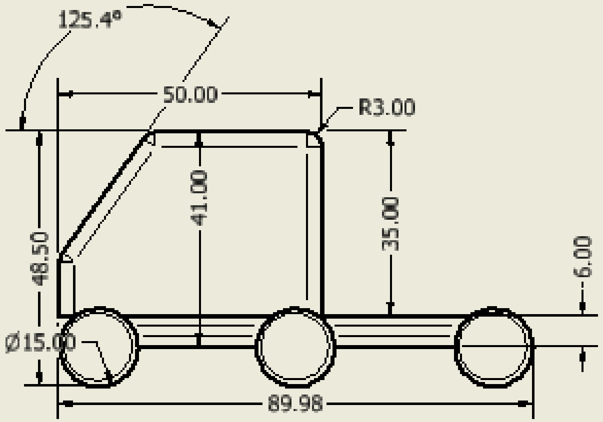
Print out these 2 models at 100% infill out of PLA. The rover is one of your two payloads (the other is the can of beans). The rocket engine block goes on top of your rocket and keeps everyone's mass distribution the same. The things that will change will be your team's landing legs and how they attach the two different payloads to the bottom of the rocket.

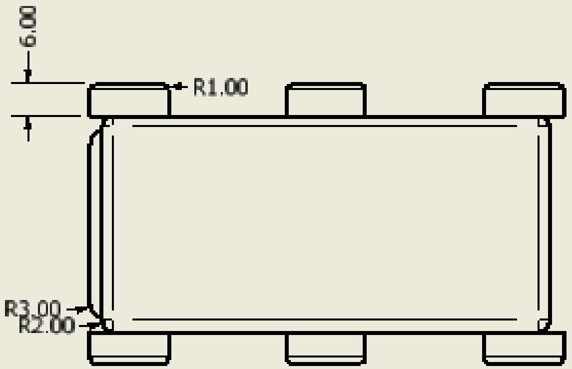
This is a simplified rocket engine block where each of the landing thrusters can pivot with its adjacent back up engine. During landing, 4 variable thrust engines would be firing at the same time and pivoting to keep the landing straight.

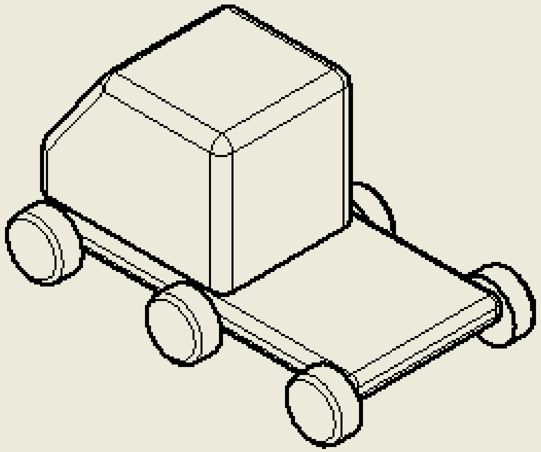


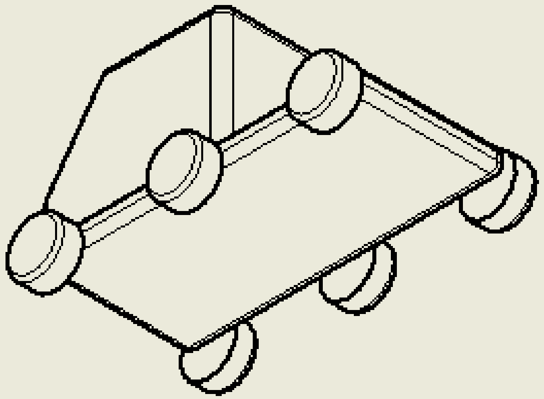


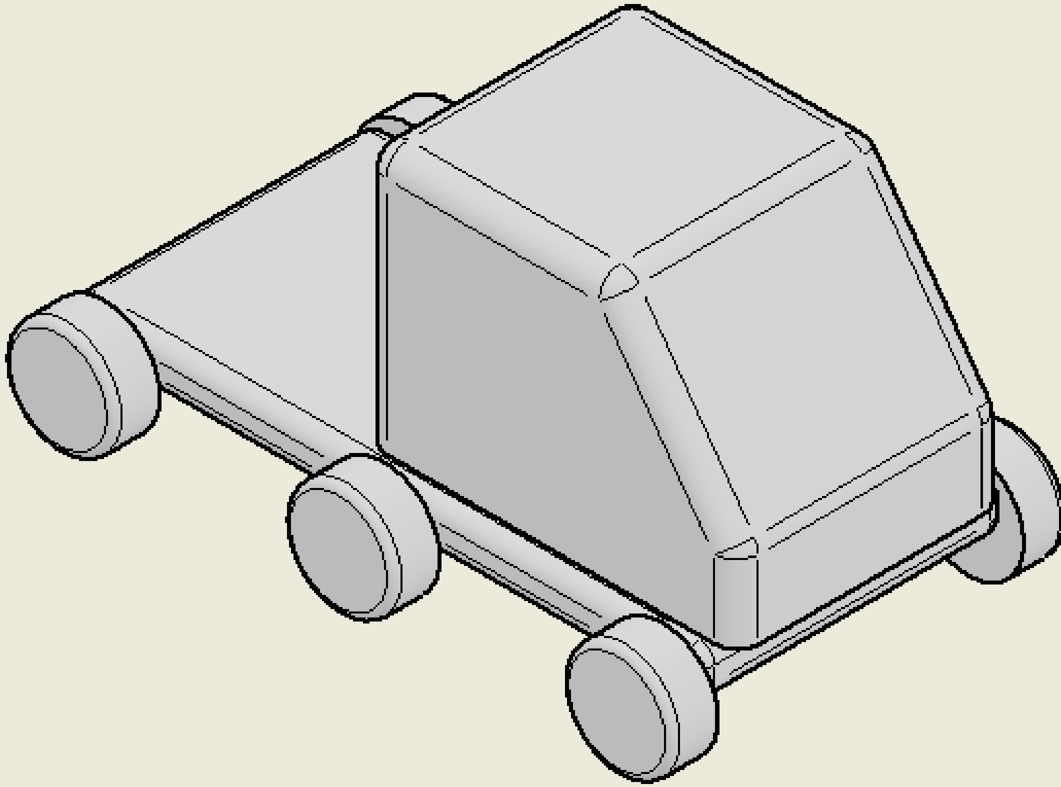
All dimensions in mm



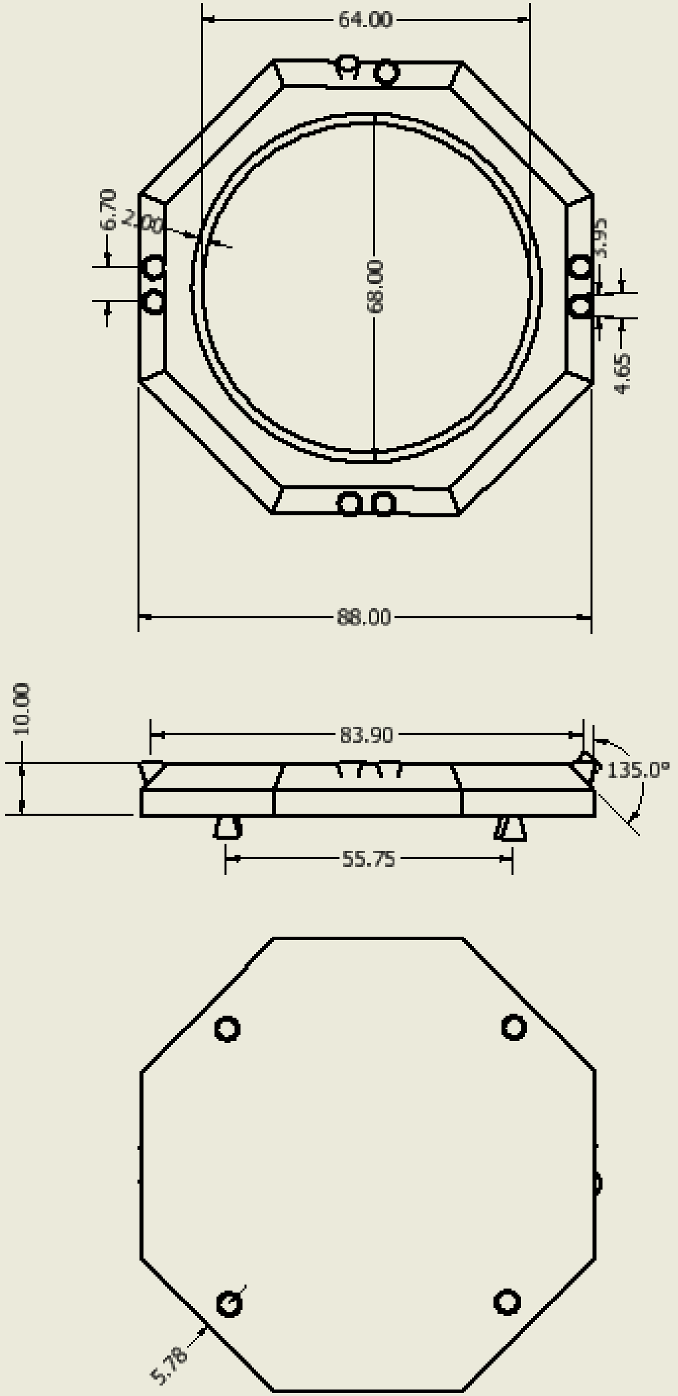


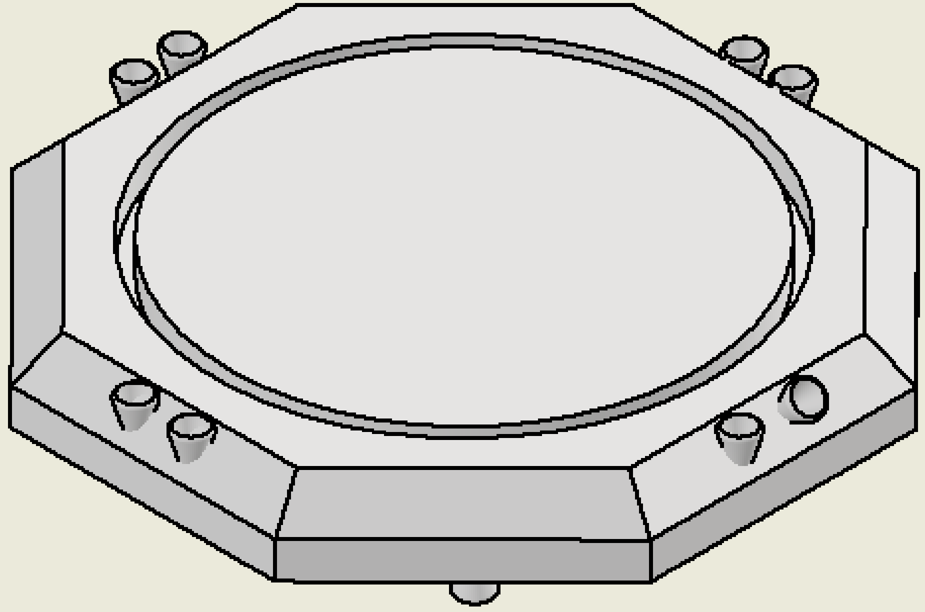






ISO
SCALE 2:1





ISO
SCALE 2 : 1

All dimensions in mm

Use these 4 cans to represent your Lunar lander stack up.

You may remove the paper wraper but you should not puncture the cans that have the “fuel” and “payload”.

Total height is 344.5mm

Empty Diced tomato Can

Fuel and oxidizer used during landing

The first can of diced tomatoes represents the empty fuel tanks from the landing. Should not puncture

Rotel Mexican Style Lime and Cilantro—283g
67 mm Diameter on the top rim of the can x 101mm height

Full Diced tomato Can

Fuel and oxidizer for use at take off

The second diced tomatoes can represents the fuel and oxidizer needed for taking off and getting to lunar orbit. You may attach materials to outside of this can but it needs to stay full of diced tomatoes to represent the weight distribution. No Puncture.

Empty Beans Can

Working space for legs and payload attachment

This beans can should be emptied and used as the attachment for landing legs and the payload attach/release system—holes allowed.

Bush’s Best Original Baked Beans 235 g
67mm diameter on the top rim of the can
75mm height of can

Full Beans Can

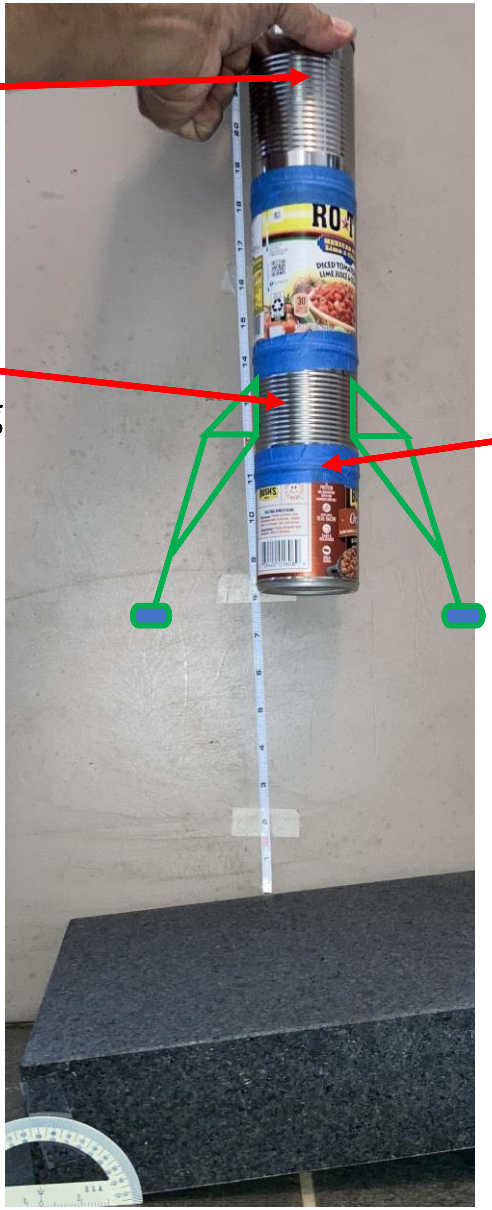
Payload

This beans can represents the payload that we are delivering to the moon. No puncture.

Zoom in for measurements

Empty

Can contains your equipment for holding and releasing the payload and legs



Yours won’t be tape because you have to release your payload.

Sloped landing surface

1. Pour 1 inch of wet concrete into a lasagna pan and let it dry with some texture on the top.
2. Next pour 1” of dry concrete onto the top of the now dried concrete.
3. Lift up one side to make a 6 degree slope with the floor. This is your test rig.
4. Place a cover over the lasagna pan when not in use to minimize dust escaping.

I will post a picture of the lasagna pan with concrete soon.

Apollo vs Artemis

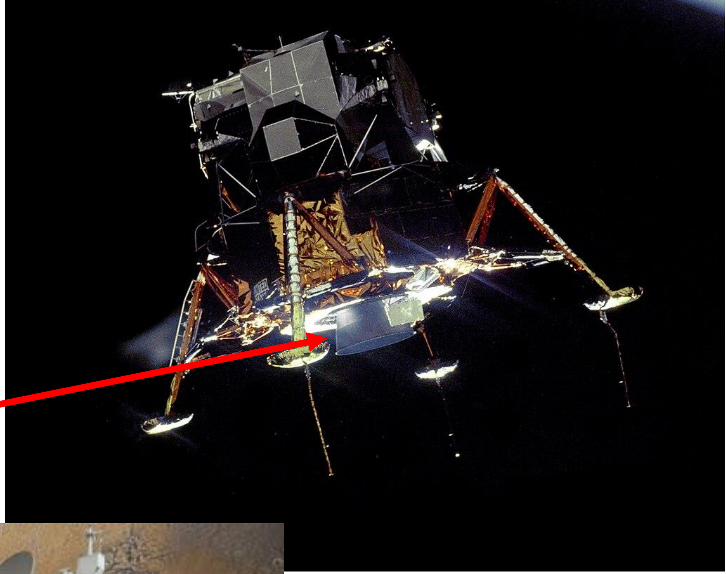
- The lunar lander for the Apollo program had an engine and tanks for landing separate from the engine and tanks for leaving the moon. They didn’t have to worry about restarting the same engine after landing when it could have been damaged by rocks and dust. The Artemis mission can’t leave behind parts of the lander since it is intended to be reusable. This means we need to protect the engines from the dust and debris that might be kicked up when landing. (when the first Space X Starship took off from Boca Chica, some of the engines were damaged from flying rocks and debris from the launch pad)
- Having the engines higher up away from the debris is one way. Is there another way to protect the engines? **Not your concern—someone else will work that problem.**

Ascent of Apollo 17. Leaving descent stage behind.

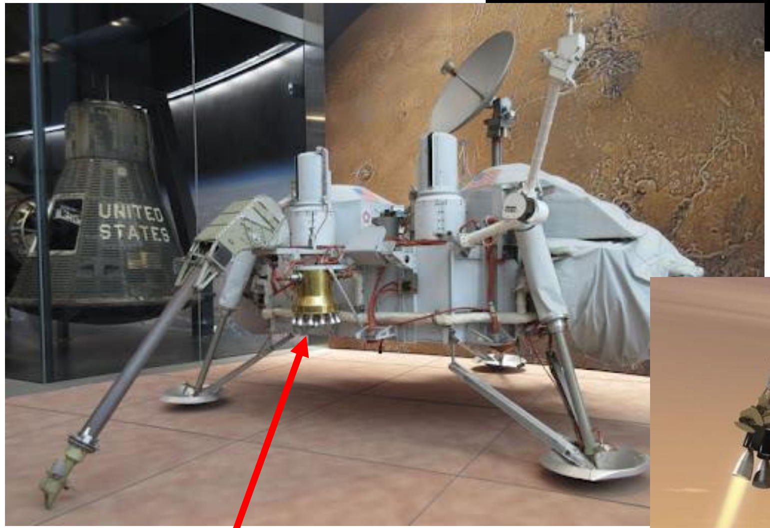
Engines on Space X Starship 1 damaged due to launch pad debris

Landing with multiple engines

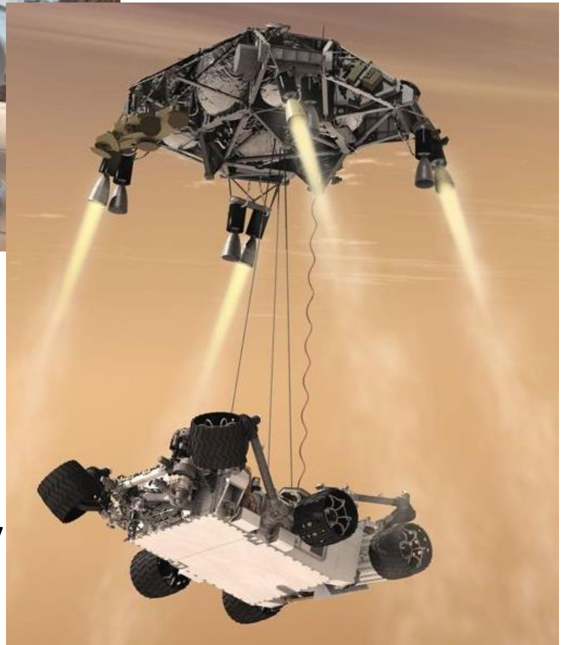
- For landers, its much easier to have one engine or a small cluster of engines located under the center of mass and then gimble the engine(s) to keep the lander strait. The difficulty is that the engine(s) kick up a lot of dust when landing in a dusty area—that dust and rocks can damage the engine if it has to restart. It also means that the payload is above the engine and a method for getting it to the ground is needed. The Apollo astronauts had to climb down a ladder to walk on the moon. What would it be like to bring down big equipment, like a bulldozer for working the lunar surface?
- Another option is to have multiple engines higher up on the lander to minimize the amount of dust and rocks kicked up and to protect the engines. This also allows for the payload to be closer to the ground. The difficulty with multiple engines is that the thrust of each engine needs to very well controlled to keep the lander stable. Fortunately, this is not a new problem and has been solved by at least 4 Mars landers.



Apollo's Single landing engine



One of 3 landing engines for Viking 1 and 2



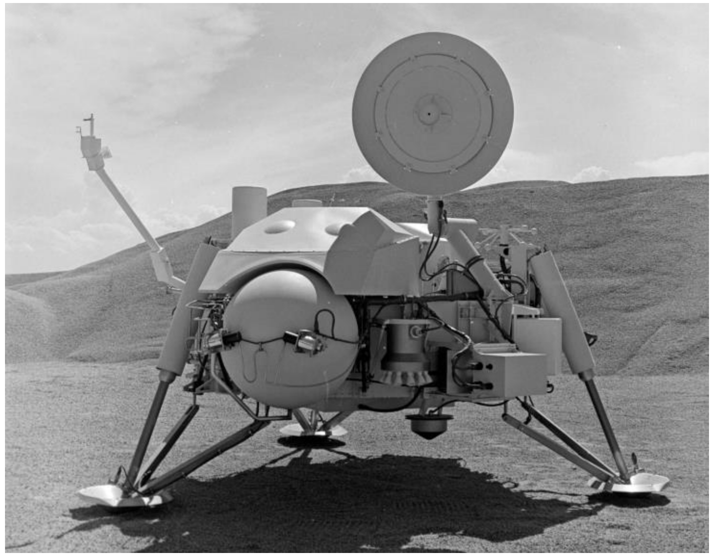
Redundant engines for the SkyCrane for landing Curiosity and Perseverance

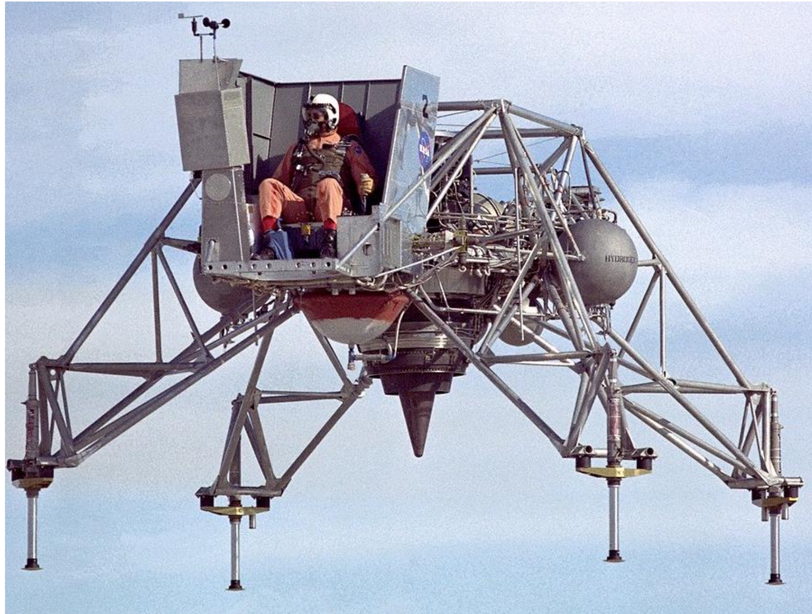
Folding of legs?

- The Lunar Lander will have to be launched from Earth to orbit and the landing legs will probably have to be folded up some how so it all fits in the fairing of the rocket. **That is not part of the project right now.** I would rather you concentrate on how to make the legs and the payload release system work for the primary task—landing on the moon.

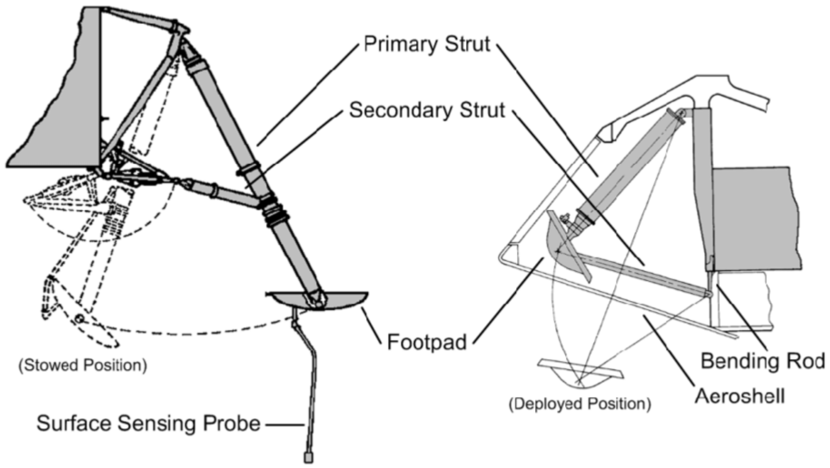
Examples of Landing Legs

- How many legs would you use?
  - 3 easy to level
  - 4 more stable-account for unlevel ground
  - 5 where at least 3 touch – many office chairs have 5 feet for stability
  - 6 legs to spread weight around more
- Do you need shock absorbers
- What kind of shock absorbers would you want?
- What should the foot pads look like?

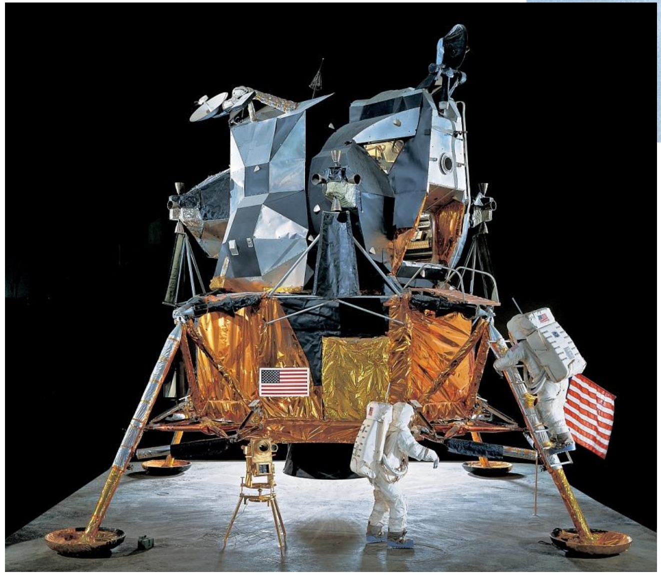




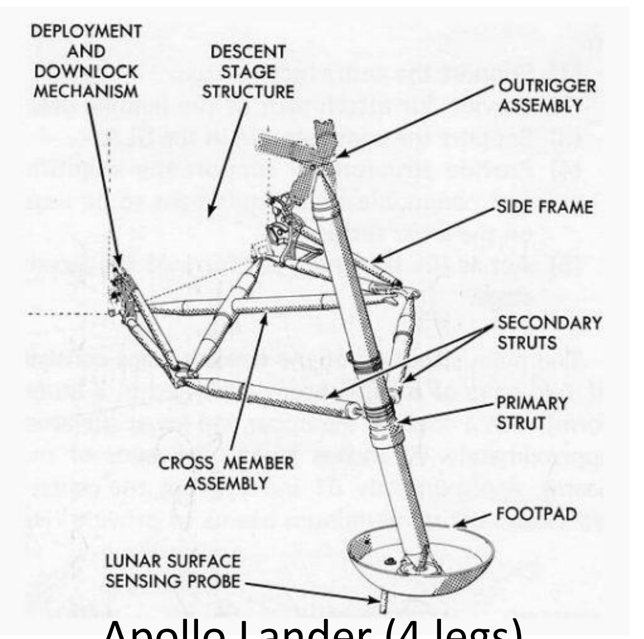
Lunar Lander Trainer (flying bedstead)



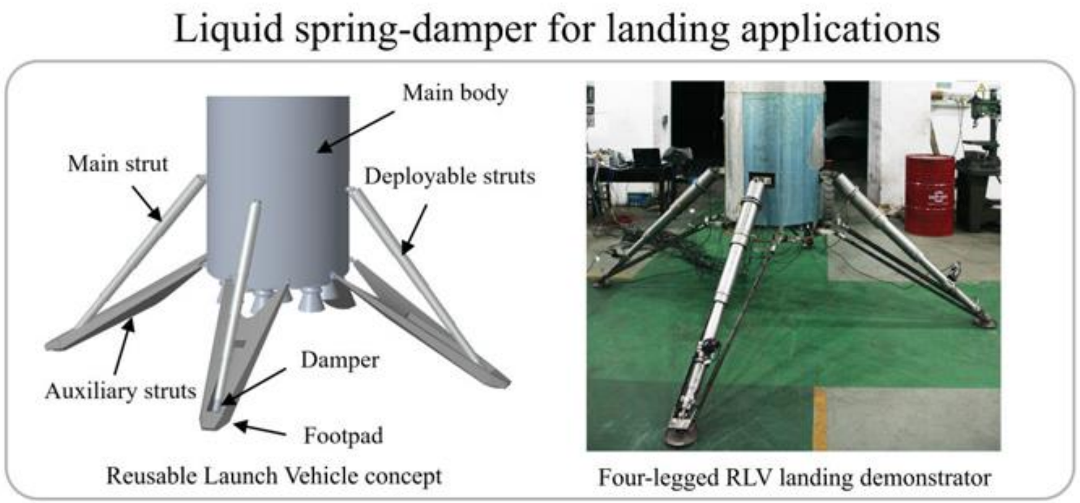
Viking Lander (3 legs)

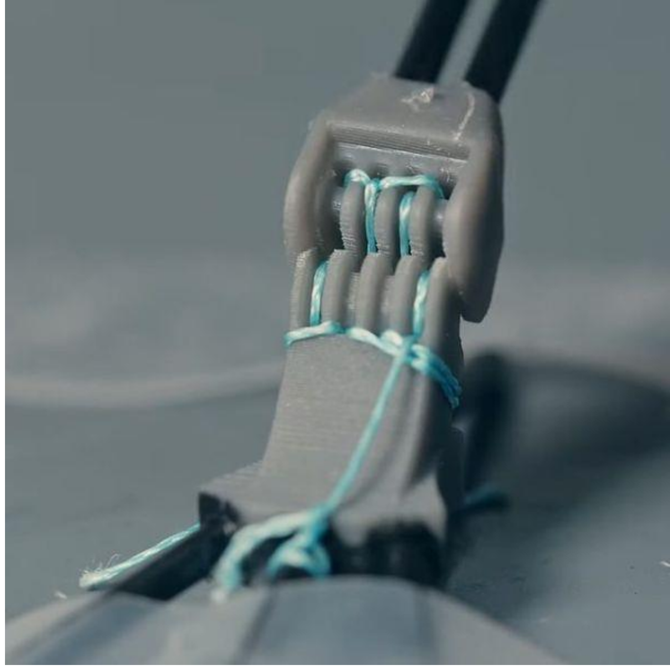


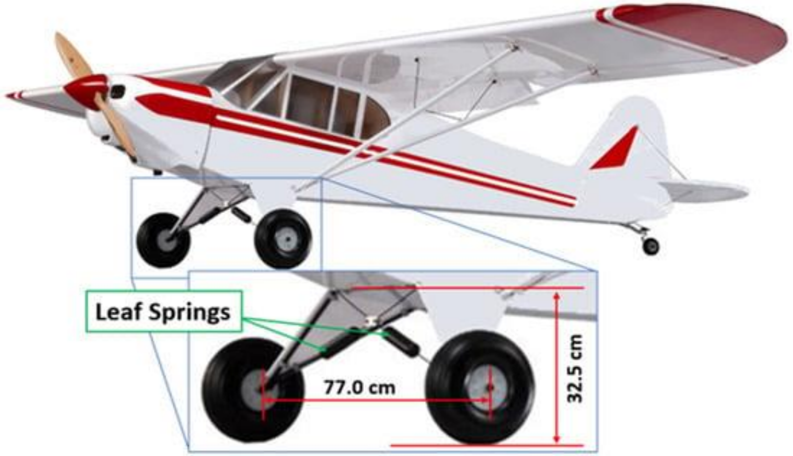
The Apollo legs had an internal crush zone to absorb shock at landing. They only had to land the Lunar Module one time.



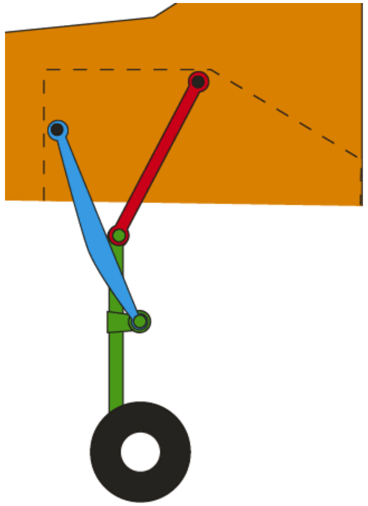
Apollo Lander (4 legs)



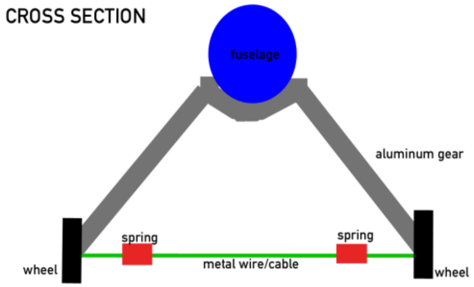




Rolling contact joint is like how your knee works.
https://www.youtube.com/watch?v=TQiLLcumqDw

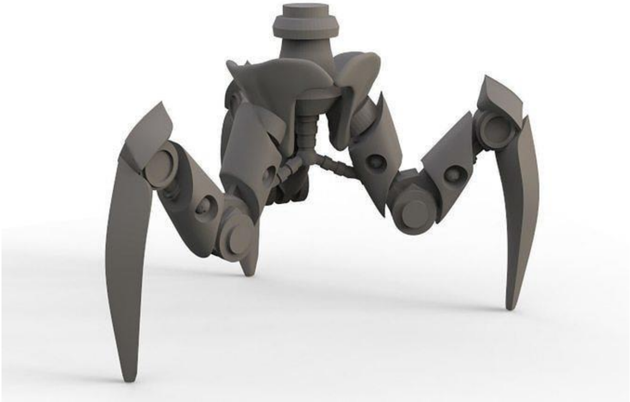


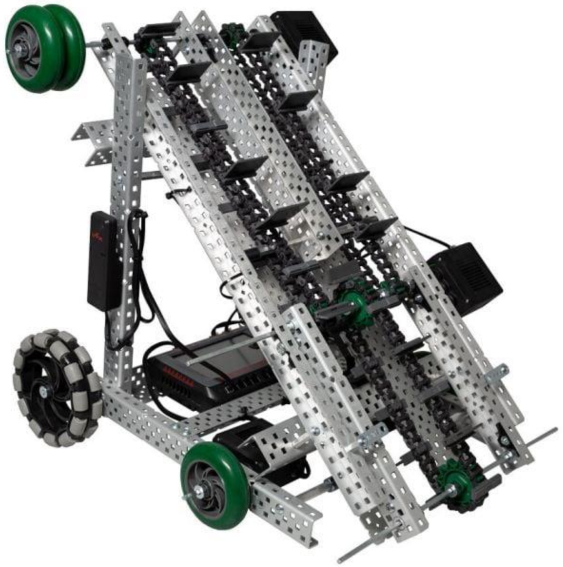
RC Shock absorbers



https://www.mcmaster.com/products/springs/springs-2~/

What do you make the legs out of—metal, 3D print, combination?





Payload clearance

- Your lander will have to have some amount of clearance between the ground and the payload. I would expect it to be somewhere between 2 and 3 cm
- How do you want to lower the payload to the ground once the lander is safe on the ground? You can’t just drop it, there is sensitive equipment onboard.
- Should the payload come down:
  - by a cable lowering the payload?
  - some kind of hydraulic system lowering it slowly?
  - could the legs retract and lower the whole Lander?

Payload Release system

Because this is in space, dangling the payload from underneath the rocket won't be an option. The payload will need to be attached firmly to the rocket. You may suggest a system that uses something on the can or on the rim of the can.

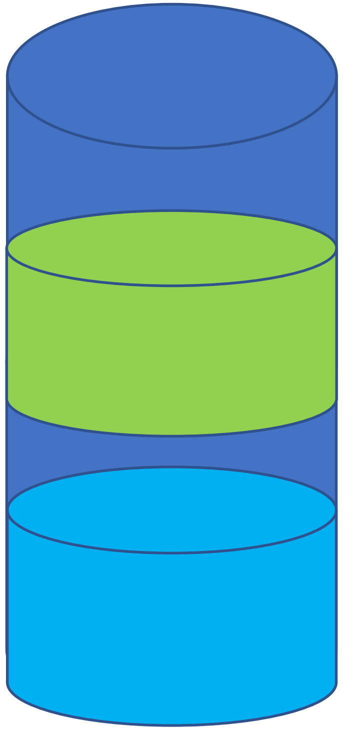
Lots of quadcopters fly with a payload dangling from a cable. That's ok when they are flying around a sandwich or some trinkets from Amazon. NASA is going to want a solid landing before they release a multi million-dollar payload onto the moon. The drop needs to be fairly soft so equipment isn't damaged.

A cautionary tale about skycranes.

https://www.google.com/search?q=simulating+nasa+skycrane+with+quadcopter&sca_esv=d254fc4124ffde86&rlz=1C1GCEA_enUS1104US1104&biw=1920&bih=945&tbm=vid&ei=TopoZpi9K_eT0PEP0sSA2Ag&ved=0ahUKEwiYnJ7DitSGAxX3CTQIHVIiAIsQ4dUDCA0&uact=5&oq=simulating+nasa+skycrane+with+quadcopter&gs_lp=Eg1nd3Mtd2l6LXZpZGVvIihzaW11bGF0aW5nIG5hc2Egc2t5Y3JhbmUgd2l0aCBxdWFkY29wdGVyMgUQIRigAUjdNVCOH1i-MnAAeACQAQCYAYoBoAGGC6oBBDAuMTG4AQPIAQD4AQGYAgugAp8LwgIFECEYnwXCAgUQIRirApgDAIgGAZIHBDAuMTGgB_gw&sclient=gws-wiz-video#fpstate=ive&vld=cid:93b44c86,vid:6KsFICAE1vE,st:0

A little background information.

If the fuel and oxidizer are stacked on top of each other, the center of mass will be higher at touch down. By having the fuel in multiple containers surrounding the oxidizer tank, the center of mass will be lower at touch down. For you, this doesn't matter since you are making only the legs and payload system—not the engines or fuel tanks.



Fuel level at touchdown

Center of Mass

Difference

Center of Mass

Oxidizer at touchdown