Straw Landing!

Demonstration

Participants will learn about how the surface of the moon is made up of loose rocks, particles, and dust. This demonstration will illustrate how landing on celestial objects, such as the moon, with rockets or explosives, can create regolith patterns.

Number of Participants: 1-5

Audience: Elementary (ages 5-10) and up

Duration: 5-10 mins

Difficulty: Level 1

Materials Required:

- Medium sized container: Plastic bin or cardboard box
- Half a cup of loose play sand
- Half a cup of rice
- A handful of small marshmallows
- A cup of flour
- A tablespoon of brown sugar
- Straws (1 per person)
- A piece of paper (1 per person)

Setup:

1. Mix the sand, rice, marshmallows, flour, and brown sugar into a bin so that there is a thin layer of the mixture
2. Give a straw to each participant
3. Have the students hold the paper with one hand, and the straw in the other. Then have the students blow through the straw onto the paper. The paper will move from the force of the air.
    a. The air directed through the straw at the paper shows the thrust a rocket would produce.
4. Have each participant blow through the straw on the sand, and as the students blow, have the students move closer and closer to the sand
    a. This simulates a rocket landing on the moon or a similar rocky surface

b. Notice how the mixture scatters away and leaves a small crater. Smaller materials will disperse much more than larger materials.

Presenter Brief:

Be familiar with the composition of the moon and how it has a very loose surface made up of regolith. Know that the reason regolith exists is because of all the asteroids that hit the moon and vaporize, breaking the moon's surface and scattering its material around. Also be familiar with the moon landings as well as the problems regolith caused the Apollo missions. The underlying principle underlying lunar landings is conservation of momentum and energy. Slowing down the spacecraft requires the expulsion of propellant which collides into the ground and transfers its energy to the regolith. The inhomogeneity of the propellant expulsion results in the regolith spreading out in uneven patterns known as ejecta.

Vocabulary:

- Regolith: a layer of loose rock, pebbles, material, and dust that cover the surface of the moon
- Asteroid: a small object flying through space orbiting the sun made up from rocks and debris leftover from the creation of the solar system
- Crater: the impact site of an asteroid on the moon (or other astronomical bodies)
- Ejecta: the material thrown out from a crater from an impact

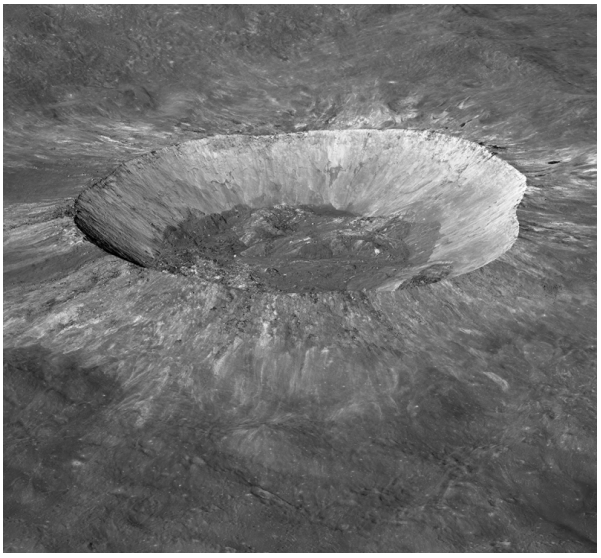
o 

Figure 1: Giordano Bruno Crater on the moon (Source: NASA)

o The white streaks around the edges of the crater are the ejecta

- Rocket: a vehicle propelled by the heating and expansion of gasses
- Plume: the gasses that are expelled from a rocket
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    Image 2: The plume from a Falcon 9 launch (Source johnkrausphotos.com)
- Thrust: the force generated from a rocket nozzle

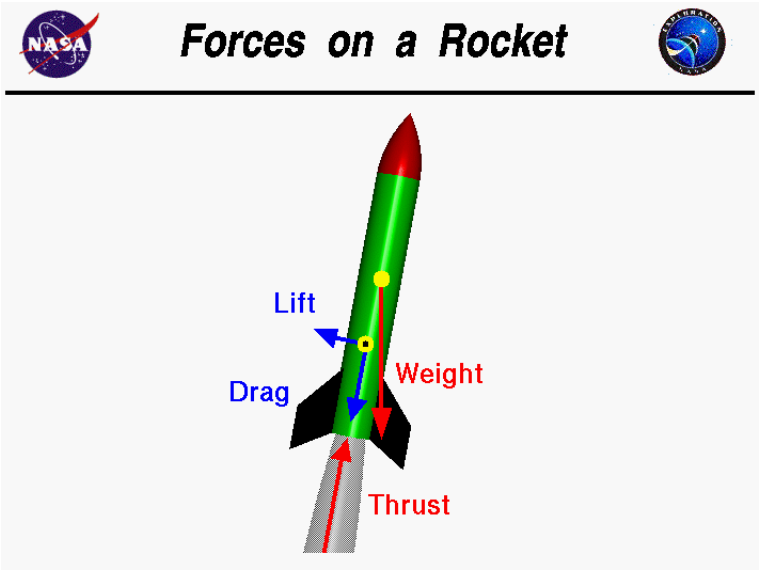

Figure 3: The force diagram of a rocket. Notice how thrust is the upwards force.

Physics & Explanation:

Elementary (ages 5-10):

Start by asking the students what they know about the moon. Students will probably say a variety of things, such as it's up at night, it's bright, etc. You can give them some fun moon facts and correct their common misconceptions (see list at the end of the document). **Ask the students if humans have ever landed on the moon and if they would ever like to go to the moon.** How do the students think people got to the moon? Guide the students to the answer that you need a rocket to get to the moon. This is when you have the students blow on the paper to show that rockets create a push.

Ask the students if they think the surface of the moon is hard and rocky, or if it is sandy and dusty. Make sure the students understand that the surface is sandy and dusty, but underneath the sand it is rocky. A simplified explanation is that the moon is very old, and so it became sandy. **Ask the students to *hypothesize* what would happen if a rocket landed on the moon. What would happen to the dust? Would it stay still?** Have the students run the main experiment with the straws and mixture.

Show the students videos of the moon launches and landing to show the students that this is how it actually works and that they understand how humans landed on the moon. See the linked videos in the additional resources section.

Middle (ages 11-13) and general public:

First should be a simple explanation on how rockets work. **Ask if anyone has an idea on how rockets launch and land**. Explain that using the conservation of momentum, the gas leaving the rocket is going so fast that the rocket (to conserve momentum) gains speed, pushing the rocket up into space. The same concept works in reverse when landing. You can use this time to have the students run the paper and straw portion of the demo.

Ask the students about what they know about the moon and the moon landings. Answers may vary, and correct any misconceptions (see the list at the end of the document). **Ask the students if they think the surface of the moon is hard and rocky, or if it is loose dust and rocks.** Make sure the students understand that the surface is loose dust and rocks, but underneath the regolith the moon is rocky. **Ask the students to *hypothesize* what would happen if a rocket landed on the moon. What would happen to the dust? Would it stay still? How might the salt, rice, sand, etc react? Will the materials behave differently?** Try to encourage some critical thinking using the conservation of momentum. The less massive substrate (salt, sugar) will move further than larger substrate (rice, marshmallows). These represent the difference between the regolith and the rocks on the surface of the moon. Have the students run the main experiment with the straws and sand.

Show the participants videos of the moon launches and landing to show the students that this is how it actually works and that they now know how humans landed on the moon. You can also ask if other bodies in the solar system might have this property (Mars is one example). See the linked videos in the additional resources section.

High School (ages 14+):

First should be a simple explanation on how rockets work. **Ask if anyone has an idea on how rockets launch and land**. Explain that using the conservation of momentum, the gas leaving the rocket is going so fast that the rocket (to conserve momentum) gains speed pushing the rocket up into space. The same concept works in reverse when landing. Also highlight the fact that rocket plumes aren't necessarily homogeneous. Use this time to have the students run the paper and straw portion of the demo.

Ask the students about what they know about the moon and the moon landings. Answers may vary, and correct any misconceptions (see list at the end of the document). You can encourage discussion about the moon's phases and how the phases work. Talking about lunar and solar eclipses is also relevant to the subject of the moon.

Ask the students if they think the surface of the moon is hard and rocky, or if it is loose dust and rocks. Make sure the students understand that the surface is loose dust and rocks, but underneath the regolith the moon is rocky. Asteroids are constantly colliding into the moon where the asteroids break up and spread a layer of

dust on the surface. **Ask the students to *hypothesize* what would happen if a rocket landed on the moon. What would happen to the dust? Would it stay still? How might the salt, rice, sand, etc react? Will the materials behave differently?** Try to encourage some critical thinking using the conservation of momentum. The less massive substrate (salt, sugar) will move further than larger substrate (rice, marshmallows). These represent the difference between the regolith and the rocks on the surface of the moon. Have the students run the main experiment with the straws and sand. How might landing on an asteroid be different from landing on the moon or Mars? Observe the pattern of the ejecta and notice how it spreads out in a somewhat random pattern.

Show the participants videos of the moon launches and landing to show the students that this is how it actually works and that they now know how humans landed on the moon. Ask if other bodies in the solar system might have this property (Mars is one example). Ask if regolith is a problem for humans, and possible solutions to those problems. See the linked videos in the additional resources section.

Additional Resources:

- Common Misconceptions
    - Myth: the moon is only out during the night
        - Fact: the moon can appear during any time of the day. It depends on when in its orbit it is. A full moon only appears at night.
    - Myth: the moon landing was faked.
        - Fact: it was, in fact, not faked. It would have cost more to try to fake the moon landing realistically than to actually go to the moon at the time.
    - Myth: the moon is made of cheese
        - Fact: as much as that would be fun, the moon is sadly not made of cheese. Rather it is made of rocks and metals. Many of the rocks humans have found on the moon are like Earth rocks.
- Moon Fun Facts

    - A current popular theory for how the moon was created is during the early solar system, a mars sized object came and collided with Earth, throwing a chunk of rock into orbit around Earth which became the moon
    - It takes light 1.3 seconds to get from the Earth to the Moon!
    - The moon is tidally locked, meaning one side always faces the Earth. This is the result of more mass being pulled to one side over time, slowing the rotation of the moon down to its orbital period.
    - The moon isn't uniformly dense. In fact, the side facing the Earth has more mass than the far side of the moon.
    - 7 separate countries/agencies have landed something on the moon. The United States, the Soviet Union, China, Japan, Luxemburg, the EU, and India.
    - Without the moon, the climate on Earth would be a lot less stable. Life may not even be able to survive! The moon acts as a "stabilizer" for Earth's wobble.

- Apollo 11 launch and landing: https://www.youtube.com/watch?v=nOcDftgR5UQ&ab_channel=NASA
- Apollo 17 lifting off the surface of the moon (the regolith scatter can be seen) https://www.youtube.com/watch?v=9HQfauGJaTs&ab_channel=SmithsonianNationalAirandSpaceMuseum
- Building a lunar base out of regolith on the moon: https://www.youtube.com/watch?v=j0TPJQSmAHU&ab_channel=VergeScienceVergeScienceVerified

References:

1. How many countries have been to the moon?: https://starlust.org/countries-that-have-been-to-the-moon/

2. What is Lunar Regolith?: https://www.universetoday.com/20360/lunar-regolith/#:~:text=The%20surface%20of%20the%20Moon,a%20sea%20of%20lunar%20soil.
3. Four Forces on a Rocket: https://www.grc.nasa.gov/www/k-12/rocket/rktfor.html
4. Article on Lunar Regolith from NASA: https://curator.jsc.nasa.gov/lunar/letss/regolith.pdf

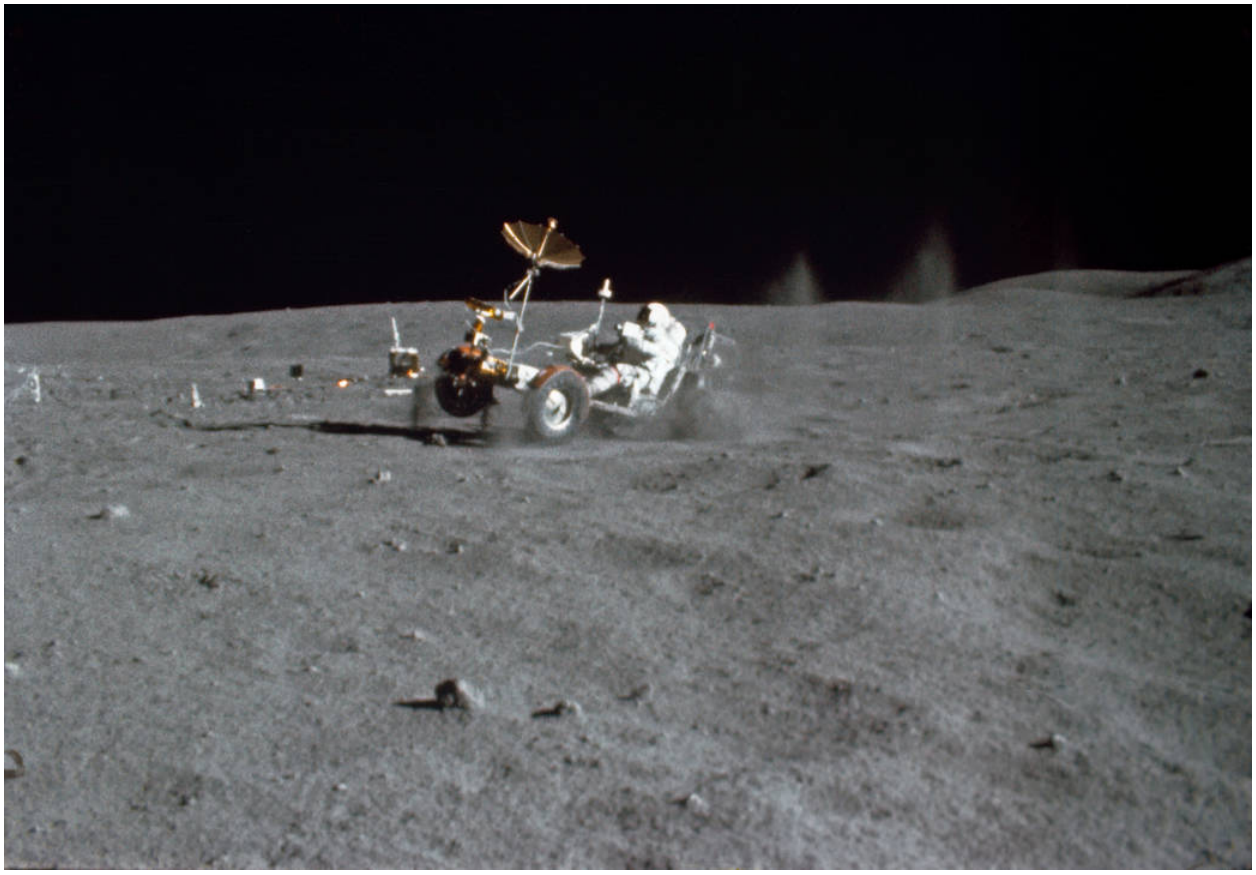

Figure 4: John Young racing on the moon. You can see the lunar dust (regolith) flying up behind him. (Source: NASA)

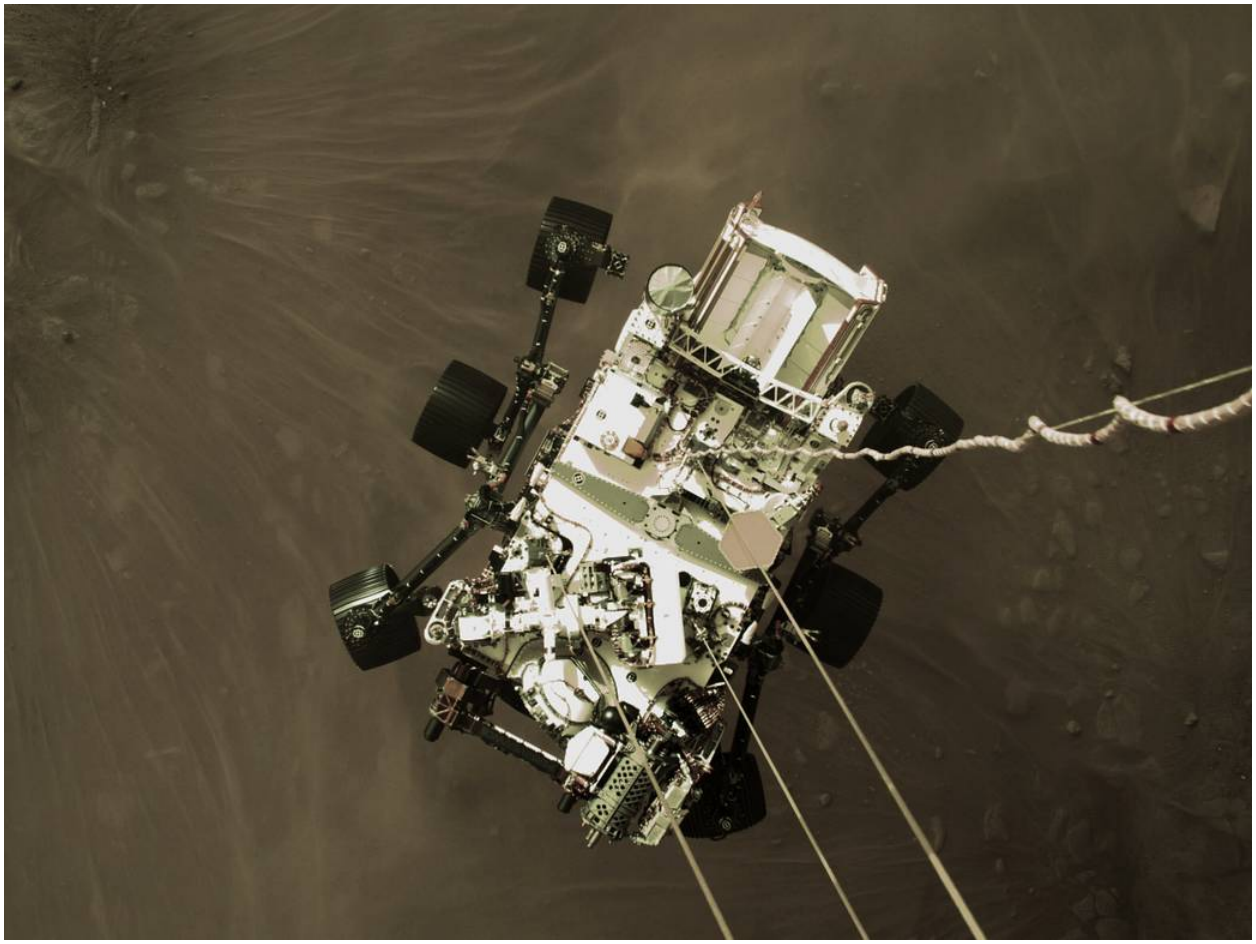

Image 4: the Perseverance Rover landing on Mars. You can see how the regolith on Mars is being blown away by the engines. (Source: NASA)

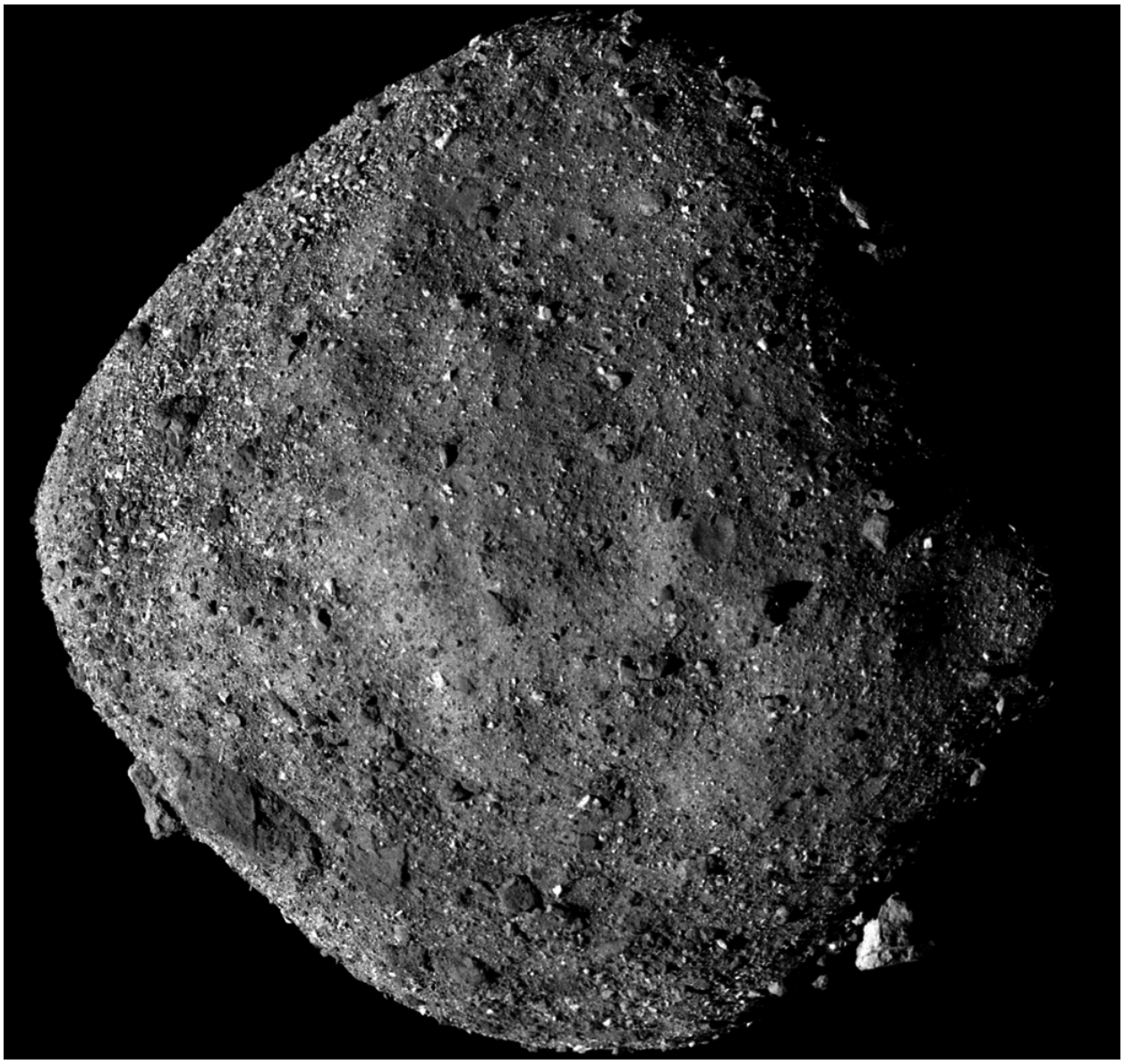

Image 5: This is the asteroid Bennu, the target of the OSIRIS-REx mission. As you can see, the asteroid is made up of a lot of small rocks and is “very loose”. Landing on this would see a lot of regolith thrown around. (Source: NASA)