NEXT ENGINEERS

ENGINEERING DISCOVERY

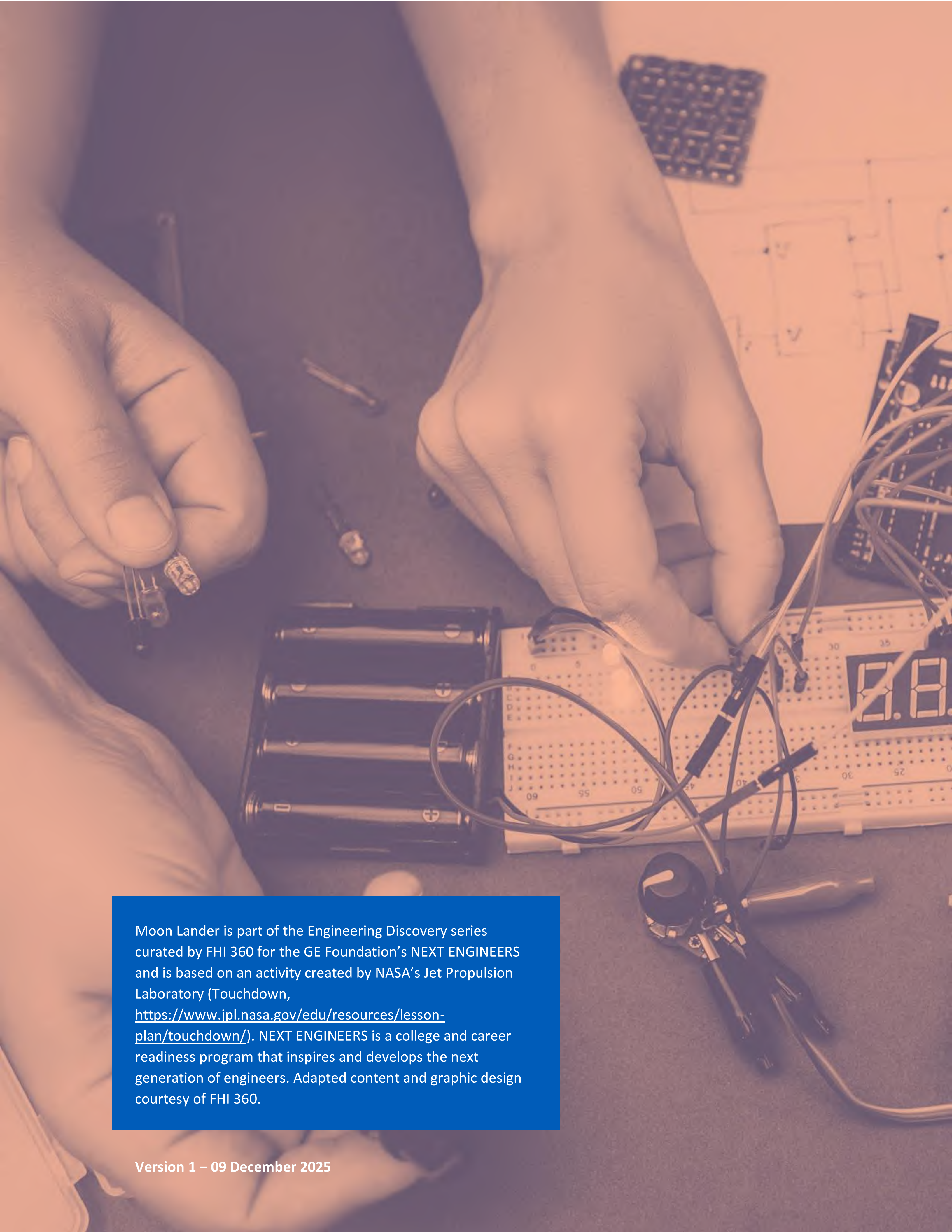
Difficulty Level 1

Moon Lander

Aeronautical Engineering

Mechanical Engineering

NEXT ENGINEERS



Moon Lander is part of the Engineering Discovery series curated by FHI 360 for the GE Foundation's NEXT ENGINEERS and is based on an activity created by NASA's Jet Propulsion Laboratory (Touchdown, https://www.jpl.nasa.gov/edu/resources/lesson-plan/touchdown/). NEXT ENGINEERS is a college and career readiness program that inspires and develops the next generation of engineers. Adapted content and graphic design courtesy of FHI 360.

Version 1 – 09 December 2025

Moon Lander

HANDS-ON ACTIVITY

Time	Ages	Cost	Group size (teams)	Activity type
45 minutes	8 - 15	Medium	3 - 4 students	Hands-on Activity
Engineering Areas				
• Mechanical Engineering		• Aeronautical Engineering		

Activity Description

Landing on moons and other planets is a tricky challenge, especially when there are astronauts involved. Part of the solution is to design spacecraft with special shock absorbing systems that can absorb and dissipate as much of the energy of impact as possible. Sometimes these systems are structural where certain parts of the landing system are designed to bend, compress or stretch. Other times mechanisms like springs, dampers, and crushable materials are used.

In this challenge, students will get to design their own lander to protect two marshmallow "astronauts" by ensuring that they remain safely inside their cockpit when the lander is dropped. The aim is to achieve a successful landing from the greatest drop height possible.

About the Engineering Design Challenge

In this challenge, teams design, build, and test a shock-absorbing lander to protect two marshmallow "astronauts" as they land after being dropped from the greatest height possible.

Success Criteria

- The marshmallow "astronauts" must remain safely in the lander cockpit upon impact.
- Teams should drop their lander from the greatest height possible.
- Teams may cut, bend, twist, poke, or fold any of their materials.

Constraints

- Teams may only use the materials provided but they don't have to use all of them.
- Teams must place the cup on the cardboard platform, right side up to form the cockpit in which the "astronauts" will sit.
- The "astronauts" must remain free to move around inside the cockpit i.e., they may not be tied, glued, or wedged into the cup.
- Teams may not cover the top of the cup.

STUDENT DISCOVERIES

Students will:

- Know more about engineering and engineering careers
- Learn the about the Engineering Design Process
- Participate in a team-based learning experience
- Learn about how to absorb and dissipate the forces experienced on impact.
- Have fun experiencing engineering

Materials

Students will need blank paper and pens/pencils to draw their designs.

The following materials will be required **per team** for this activity:

- 1 plastic cup (about 350 ml (12 oz))
- 1 cardboard rectangle (10 cm x 13 cm (4 in x 5 in))
- 3 rubber bands
- 3 index cards (8 cm x 13 cm (3 in x 5 in))
- 8 drinking straws
- 2 marshmallows (the astronauts)
- 10 mini marshmallows
- 1 m (40 in) of tape
- Scissors
- 1 copy of the **Engineering Design Process Summary** (below)
- 1 copy of the **Student Handout** (below)

The following additional materials will be required for **testing** the landers:

- A measuring tape

Facilitation Principles

Working with Youth: Facilitation Tips (https://www.nextengineers.org/resource/working-youth-facilitation-tips) is a handy summary of the key facilitation principles that volunteers need to keep in mind when demonstrating any activity with students.

Facilitator Preparation

1. Read the step-by-step instructions.
2. Collect the materials and place each team's materials in separate bags for easy distribution.
3. Practice doing the activity yourself to identify where students may struggle.
4. Plan when and how any volunteers will share their story and career journey in a relevant and personal way. Try to integrate these stories into the demonstration as much as possible. Volunteers may find the following resources useful:
    a. ***I'm an Engineer! Storytelling Worksheet*** (https://www.nextengineers.org/resource/im-engineer-storytelling-worksheet)
    b. ***I Work with Great Engineers! Storytelling Worksheet*** (https://www.nextengineers.org/resource/i-work-great-engineers-storytelling-worksheet)
5. Practice asking and answering questions students may ask. See ***Frequently Asked Student Questions*** (https://www.nextengineers.org/resource/frequently-asked-student-questions).
6. Print out copies of the **Student Handout** for each group.
7. Prepare the room and set out the materials before the activity begins.

EXTENSION

One of the ways in which to extend this challenge is to require teams to also build as efficiently as possible by imposing a cost on each material and/or requiring them to purchase from a central store with a budget.

KEY WORDS

- Cantilever
- Center of gravity
- Constraints
- Criteria
- Damper
- Engineering Design Process (EDP)
- Engineering Habits of Mind (EHM)
- Engineers
- Iteration
- Pliable
- Prototype
- Tripod

Step-by-Step Instructions

Time	Instructions	Materials
5 min	**Welcome & Introductions** • Welcome students to the activity and briefly introduce yourself. • Have any volunteers introduce themselves. As appropriate, have any volunteers share their stories and career journeys with the group.	
5 min	**Pre-Challenge Exploration** • Ask the group if anyone knows when astronauts first landed on the moon. • Say that it was 11 July 1969 and at that time very little was known about what the moon's surface was actually like. • Explain that whenever we send spacecraft to the moon (or other planets like Mars) it is very important that they land gently without injuring the astronauts or damaging the spacecraft or instruments. • Often, this involves slowing the spacecraft down from speeds of up to 29,000 km/h (18,000 mph) as well as using shock absorbers. • Ask for a volunteer to stand on a chair and then jump to the ground. As they do, ask the rest of the group to watch and then describe what this student does. • Explain, that whenever we jump down from something like a step or chair, we bend our back and knees to help absorb some of the energy or shock of landing. Hence the term shock absorber. • Show the group an index card folded into a concertina and how such a structure can also act as a shock absorber. • Explain that soft materials (like mini marshmallows) or flexible or pliable structures (like an index card concertina spring) can be effective shock absorbers.	Activity Background

TIPS FOR WORKING WITH STUDENTS

- **Be prepared** by practicing the activity beforehand. Being prepared is the best start to leading confidently and having fun.
- **Facilitate like an engineer** by reflecting during and after each session. What worked? What could be improved? How could you do things differently next time?
- **Teamwork is critical** in engineering so encourage it among students. Make sure no one dominates and everyone gets to play.
- **Give one instruction at a time** to keep a large group on task and doing what you need them to do.
- **Give regular time updates** to keep students on track.

5 min	**Challenge Overview**
	• Explain that students are going to work as teams of engineers to design a shock absorbing lander to protect two marshmallow "astronauts" as they land on the moon.
	• Show the group the materials that each team will get.
	• Explain that the two "astronauts" must remain safely inside the cockpit upon landing, that the lander that achieves a successful landing from the greatest height will be the winner and that teams may cut, bend, twist, poke, or fold any of their materials. These are the success criteria.
	• Explain the constraints:
	  ○ Teams may only use the materials provided.
	  ○ Teams must place the cup on the cardboard platform, right side up to form the cockpit where the "astronauts" will sit.
	  ○ The "astronauts" must remain free to move around inside the cockpit i.e., they may not be tied, glued, or wedged onto the bottom of the cup.
	  ○ Teams may not cover the top of the cup.
	• Note that the two key design considerations teams should think about are how to create a shock absorbing mechanism and how to keep their lander from tipping over during flight.
	• Tell students that they will have 25 minutes to design and test their landers. Within this time, each team will get two official test opportunities to record their greatest successful drop height.
	• If necessary, briefly describe the engineering design process that teams will follow using the **Engineering Design Process Summary** (below).
	• Divide the group into teams of three or four and provide each team with its equipment and materials.
		Building Materials
		
		Engineering Design Process Summary
		
		Student Handout

25 min	**Engineering Design Challenge**
	• Have students work through the **Student Handout**.
	• As teams work, circulate around the room encouraging teams and answering any questions they might have.
	• As teams work on their designs have them consider the following questions:
	  ○ Should their lander be symmetrical?
	  ○ Should it be tall or short?
	  ○ How many shock absorbers will it have?
	  ○ How will these be made and how will they work?
		Student Handout

TIPS FOR MAKING CONNECTIONS

1. **Give constructive feedback** to help students grow and improve.
2. **Ask open-ended questions** to better understand what and how students are thinking.
3. **Be respectful** by listening actively and responding openly and authentically. Give students your undivided attention and the respect you want them to give you.
4. **Be honest** about what you know. Say if you don't know something. Encourage students to keep trying by sharing some of your own failures and the lessons you learned.

	○ Where will they be located? ○ How will they be attached? • Make sure that after about 15 minutes each team has done the first of their official tests. • If a team's lander keeps tipping over, suggest that they adjust the position of the cockpit of their shock absorbers to balance the weight better and get the lander's center of gravity closer to its middle. If a team's lander bounces on impact, suggest that they change the number, size, and position of the shock absorbers or find other ways to absorb more of the impact energy. • Encourage teams to continue testing, refining and improving their designs to achieve the highest successful drop height possible before they return for their second formal test. • Remind groups that any failures they encounter are simply an opportunity to learn and improve.	
5 min	**Reflection and Closing** • If possible, give teams a few minutes to discuss the reflection questions in the **Student Handout**. • After this bring students back together to discuss their experience of the activity, including challenges they had and one thing they learned.	Student Worksheet

FACILITATION TIP

To help you manage the official test process, allow teams to conduct an official test with any of the activity facilitators or volunteers. Just make sure that the drop height of each successful landing is recorded for each team. If there is a whiteboard available, it is a good idea to record successful drop heights here so that all teams know the latest height to beat.

Extension

This activity can be extended in the following ways:

- Require teams to protect three or more marshmallow "astronauts".
- Impose a minimum drop height.
- Add a budget constraint to require teams to consider cost-efficiency in their design as well. Have them purchase the materials from a central store with a fixed budget.

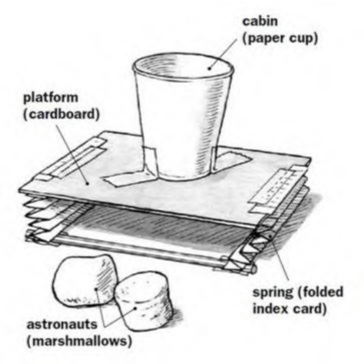
Key Words

- **Cantilever:** a rigid structure, like as a beam or slab, anchored at only one end while the opposite end remains unsupported and extends horizontally.
- **Center of gravity:** The single point where an object's entire weight seems to act, or the balance point where it would rest if unsupported.
- **Damper:** A device that dissipates the energy from an oscillating system, causing its vibrations to decrease over time.
- **Pliable:** The property of a substance that allows it to bend, fold, or twist easily without breaking or cracking.
- **Tripod:** A three-legged stand used to support and stabilize equipment and structures.

- **Constraints:** Limitations of materials, time, budget, size of team, etc.
- **Criteria:** Conditions that the design must satisfy to be considered successful.
- **Engineering Design Process (EDP):** The iterative process of researching, designing, prototyping, and testing engineers use to solve problems and design solutions.
- **Engineering Habits of Mind (EHM):** Six unique ways that engineers think.
- **Engineers:** Inventors and problem-solvers of the world. Twenty-five major specialties are recognized in engineering (have a look at the infographic at https://tryengineering.org/wp-content/uploads/18-EA-381-InfographicEngineering_R2-6.pdf).
- **Iteration:** The process of repeated design, testing, and redesign.
- **Prototype:** A working model of the solution to be tested.

Activity Background

Landing manned or unmanned spacecraft on other moons and planets is hard. Landers like the Apollo Lunar Lander perform slow and controlled "soft landings". This helps ensure that any astronauts are not harmed and that the lander itself or any scientific equipment onboard is not damaged.



A possible Moon Lander design by NASA is used under fair use https://www.jpl.nasa.gov/edu/resources/lesson-plan/touchdown/

Spacecraft travel at enormous speeds but then need to slow right down to be able to land safely. Braking from 29,000 km/h (18,000 mph) to just 3,6 km/h (2.2 mph) is no mean feat and requires special decent engines.

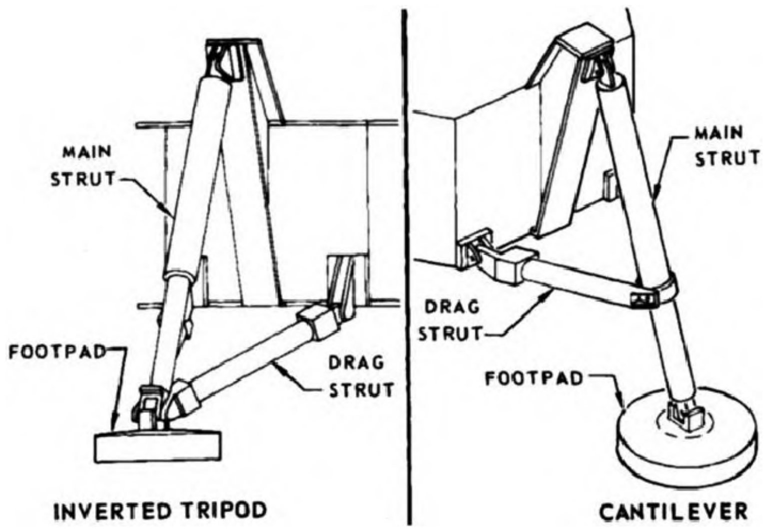
Then even at low landing speeds, it is necessary for the lander to employ mechanisms able to absorb and dissipate as much of the energy of the landing as possible. These mechanisms can be of various types:

- **Crushable materials**: Structures like aluminium honeycombs in footpads or other structural elements absorb energy through irreversible deformation and crushing. This is a lightweight and effective technique but can only be used once. This kind of mechanism was used in the Surveyor landers.
- **Telescopic dampers**: These are fluid or gas-filled cylinders that provide damping. They are often used for individual equipment or as primary landing struts. Their stiffness can be adjusted for different conditions.
- **Spring-dampers:** These combine springs to store elastic energy and dampers for energy dissipation.
- **Magnetorheological (MR) Fluid Dampers**: These are a promising new kind of semi-active damper. The dampers are filled with a fluid containing micron-sized ferrous particles. Ordinarily this is a low viscosity fluid. However, in the presence of a magnetic field (generated by passing a current through a coil), the ferrous particles align into chain-like structures and greatly increase the viscosity of the fluid. The greater the current, the stronger the field, the higher the viscosity.

The structure of the lander's legs can also offer shock absorption. There are two basic designs:

- **Cantilever Legs**: This is a very simple design that involves a primary strut connected to the lander with a fixed secondary strut. On impact, the primary strut experiences a bending load.
- **Inverted Tripod Legs**: This is a common design. Several struts (usually three) all join together at a footpad. All struts experience compressive forces on impact.

The differences between these are illustrated below.



Inverted Tripod and Cantilever Leg Configurations by Marc Briere is used under fair use.
https://www.researchgate.net/figure/nverted-Tripod-and-Cantilever-Leg-Configurations-4_fig7_232382018

Finally, some lunar landers incorporate footpads. These can help protect the main shock absorbing structures by dissipating energy as well. Sometimes they include crushable honeycombs.

While sophisticated systems like MR fluid dampers are obviously not possible, teams can experiment with different spring or material damper systems as well as leg structures like those described above, possibly even including tiny marshmallow footpads.

Additional Resources

- ***Moon landing***
  https://en.wikipedia.org/wiki/Moon_landing#Human_Moon_landings_(1969–1972)
- ***Apollo Lunar Module***
  https://en.wikipedia.org/wiki/Apollo_Lunar_Module
- ***The Surveyor Shock Absorber***
  https://ntrs.nasa.gov/api/citations/19690002490/downloads/19690002490.pdf
- ***Moon lander structural design using Truss Me!*** (6:31)
  https://www.youtube.com/watch?v=ZGrQHq6cjdI

References

This activity is based on **Touchdown** originally created by NASA's **Jet Propulsion Laboratory** and available at: https://www.jpl.nasa.gov/edu/resources/lesson-plan/touchdown/.

Visit the **JPL Education website** (https://www.jpl.nasa.gov/edu/) for a host of other great engineering activities and resources.

Jet Propulsion Laboratory
California Institute of Technology

Lądownik księżycowy

MATERIAŁY DLA UCZNIÓW

Zaprojektujcie i zbudujcie lądownik, który ochroni dwóch „astronautów” z pianek podczas zrzutu z jak największej wysokości.

1 ZIDENTYFIKUJ I ZDEFINIUJ PROBLEM

Kryteria sukcesu

- Po uderzeniu o podłoże „astronauci” z pianek muszą pozostać bezpiecznie w kokpicie lądownika.
- Waszym celem jest wykonanie udanego lądowania po zrzucie z jak największej wysokości.
- Możecie ciąć, zginać, skręcać, nakłuwać i składać wszystkie otrzymane materiały.

Ograniczenia

- Możecie korzystać wyłącznie z materiałów przygotowanych do tego zadania.
- Kubek należy umieścić na tekturowej podstawie, otworem do góry, tak aby pełnił rolę kokpitu, w którym będą siedzieć „astronauci”.
- „Astronauci” muszą mieć możliwość swobodnego poruszania się wewnątrz kokpitu: nie wolno ich przywiązywać, przyklejać ani unieruchamiać w kubku.

2 ZBIERZ INFORMACJE

Materiały

- plastikowy kubek i tekturowy prostokąt,
- 2 pianki (astronauci),
- 3 gumki recepturki i karty indeksowe,
- 8 słomek do napojów i 10 mini pianek,
- 1 m taśmy klejącej oraz nożyczki.

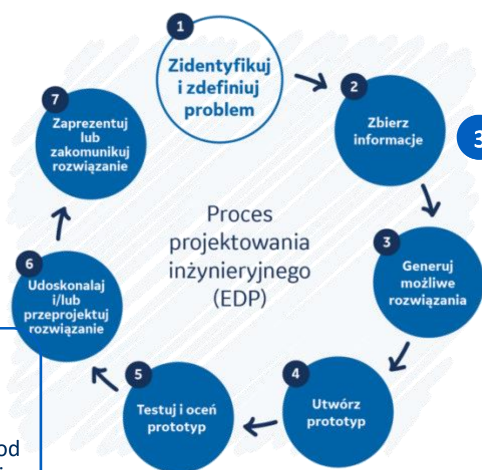
W ciągu 25 minut musicie wykonać 2 próby i uzyskać udane lądowanie po zrzucie z jak największej wysokości.

? Zastanówcie się

- Co może sprawić, że Wasi astronauci wypadną z kokpitu?

7 ZAPREZENTUJ LUB ZAKOMUNIKUJ ROZWIĄZANIE

W ciągu 25 minut musisz przeprowadzić co najmniej jedną próbę, aby pokazać, jak dobrze działa Twój lądownik. Wygrywa zespół, którego lądownik wykona udane lądowanie po zrzucie z największej wysokości!



3 GENERUJ MOŻLIWE ROZWIĄZANIA

Przyjrzyjcie się dostępnym materiałom i zastanówcie się, jak możecie ich użyć do zbudowania swojego lądownika. Narysujcie teraz kilka swoich pomysłów.

? Zastanówcie się

- Czy na Ziemi jest powietrze? Jak obecność powietrza wpłynie na Wasz projekt?
- Jak możecie zmienić kształt niektórych materiałów, aby zmienić ich właściwości?
- Jak duży i wytrzymały powinien być Wasz lądownik?
- Czy powinien być wysoki czy niski?
- Czy musi być symetryczny? Dlaczego tak lub dlaczego nie?
- Czy zbudujecie amortyzatory? Jeśli tak, to jak je wykonacie, ile ich będzie i gdzie je zamocujecie?
- Jak możecie sprawić, aby Wasz lądownik był stabilny zarówno podczas lotu, jak i w chwili lądowania, tak aby pianki nie wypadły z kokpitu?

6 5 TESTUJ, OCEŃ I PRZEPROJEKTUJ SWÓJ PROTOTYP

Zanim przystąpicie do prób, wykonajcie jak najwięcej własnych testów. Rozpocznijcie testy od mniejszych wysokości i stopniowo wprowadzajcie niewielkie poprawki do swojej konstrukcji.

? Zastanówcie się

- Co zaobserwowaliście podczas testu?
- Jak zachowywał się Wasz lądownik podczas spadania i po uderzeniu o podłoże? Czy przewrócił się? Czy odbił się od podłoża? Co możecie zrobić, aby się nie przewracał ani nie odbijał?
- Czy Wasz lądownik uszkodził się podczas lądowania?
- Jakie zmiany możecie wprowadzić, aby poprawić jego działanie?
- Jakich materiałów jeszcze nie wykorzystaliście? W jaki sposób możecie je wykorzystać?

4 UTWÓRZ PROTOTYP

Teraz czas zbudować Wasz lądownik.

Testujcie go jak najwcześniej i jak najczęściej. Dobrym pomysłem jest wypróbowanie wielu różnych rozwiązań i sposobów działania, aby przekonać się, które z nich sprawdzają się najlepiej. Pamiętajcie, niepowodzenia są naturalną i ważną częścią procesu

D Y S K U S J A I R E F L E K S J A W Z E S P O L E

1. Czy udało Wam się zbudować lądownik, który ochronił „astronautów”? Dzięki jakim elementom Wasz lądownik odniósł sukces?
2. Czym Wasz końcowy projekt różnił się od pierwszego pomysłu? Czego nauczyliście się podczas testowania?
3. Z którego elementu swojego lądownika jesteście najbardziej dumni lub który uważacie za najbardziej oryginalny?
4. Czym zwycięski projekt różnił się od Twojego (jeśli oczywiście nie udało Wam się wygrać)?
5. Gdybyście mogli dodać do swojego lądownika jeszcze jeden materiał, co by to było? Dlaczego?
6. Czy uważasz, że wykonywanie tego ćwiczenia w zespole było bardziej satysfakcjonujące, czy wolałbyś/wolałabyś pracować nad nim sam/a? Dlaczego?
7. Czego dowiedzieliście się o inżynierii?
8. Jak myślicie, jaki związek to ćwiczenie ma z karierą inżynierską?

W D O M U

Kiedy wrócisz dziś do domu, opowiedz swojej rodzinie o lądowniku księżycowym, który zbudowałeś/zbudowałaś. Opisz i wyjaśnij, jak wyglądał proces projektowania i testowania różnych pomysłów oraz w jaki sposób zdecydowałeś/zdecydowałaś się na najlepsze rozwiązanie.

Wyjaśnij, dzięki czemu Twój lądownik zachował stabilność podczas opadania i w jaki sposób pochłonął siłę uderzenia przy lądowaniu, aby „astronauci” pozostali bezpieczni w kokpicie.

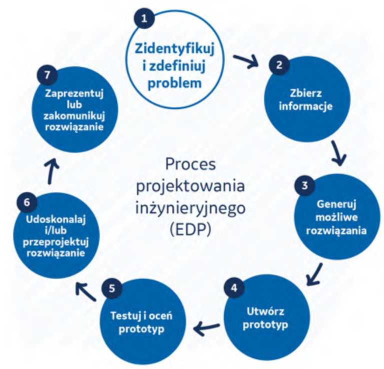
Opowiedz również, jak współpracowaliście w zespole podczas projektowania, budowy i testowania lądownika oraz czego nauczyłeś/nauczyłaś się o pracy zespołowej i procesie inżynierskim.

Powiedz, co najbardziej podobało Ci się w tym zadaniu, co podobało Ci się mniej oraz co zmieniłbyś/zmieniłabyś lub dodałbyś/dodałabyś do zadania, aby było jeszcze ciekawsze. Jeśli chcesz, możesz także omówić z rodziną niektóre pytania do dalszej refleksji.

Proces projektowania inżynieryjnego

MATERIAŁY DLA UCZNIÓW

Proces projektowania inżynieryjnego (EDP[1]) to kluczowy proces, który stosują inżynierowie rozwiązując problemy i projektując rozwiązania.



1. Zidentyfikuj i zdefiniuj problem

Inżynierowie zaczynają od zadawania wielu pytań. Jaki problem trzeba rozwiązać? Kogo to problem? Co chcemy osiągnąć? Jakie są wymagania projektu? Jakie są ograniczenia? Jaki jest cel? Dzięki temu procesowi inżynierowie zaczynają identyfikować **kryteria** (warunki, jakie rozwiązanie musi spełniać, aby można je było uznać za skuteczne) i **ograniczenia** (granice, w ramach których muszą projektować).

2. Zbierz informacje

Inżynierowie dogłębnie analizują problem, zbierając **informacje i dane** na jego temat i na temat wszelkich istniejących rozwiązań, które można by zastosować. Aby wesprzeć badania, rozmawiają z ludźmi z wielu różnych środowisk i dziedzin.

3. Generuj możliwe rozwiązania

Teraz zaczyna się prawdziwa zabawa! Inżynierowie rozpoczynają **burzę mózgów** i opracowują jak najwięcej rozwiązań, niekiedy bardzo szalonych. To czas śmiałych pomysłów i odroczonych osądów. Ważne jest, aby rozwijać pomysły innych, jednocześnie skupiając się na sednie problemu i pamiętając o kryteriach i ograniczeniach. Na przykład, czy jeśli jest określony budżet, to czy potencjalne rozwiązanie da się opracować w ramach tego budżetu?

4. Utwórz prototyp

Inżynierowie wybierają jedno lub więcej najbardziej obiecujących rozwiązań do **prototypowania**. Prototyp to działający model, który należy poddać próbie.

5. Testuj i oceń prototyp

Większość prototypów **zawodzi**, ale to dobrze. Podpowiada inżynierom, na jakich pomysłach powinni się skupić. Inżynierowie muszą również zdecydować, czy projekt rzeczywiście rozwiązuje pierwotny problem.

6. Udoskonalaj i/lub przeprojektuj rozwiązanie

Po zdobyciu wiedzy w wyniku testów inżynierowie **projektują na nowo i ponownie testują** dopóty, dopóki nie znajdą optymalnego rozwiązania – takiego, które równoważy kryteria i ograniczenia.

7. Zaprezentuj lub zakomunikuj rozwiązanie

W końcu inżynierowie dochodzą do punktu, w którym są zadowoleni ze swojego rozwiązania. Nie musi być ono idealne, ale powinno „**zadowalać**" – spełniać kryteria w ramach ograniczeń. Inżynierowie następnie dzielą się swoimi rozwiązaniami z innymi.

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[1] Źródło https://www.teachengineering.org/design/designprocess

Moon Lander Volunteer Guide

This guide highlights some important information, questions, and principles to help you support teams in this challenge. Start by watching a video that explains some of the *Principles for Supporting Young Engineers* (9:40) and then *An Introduction to the Design Challenges* (6:08). You can also read about some general *facilitation tips* about working with youth.

The design challenge

In this challenge, teams design, build, and test a shock-absorbing lander to protect two marshmallow "astronauts" as they land after being dropped from the greatest height possible.

- Success criteria
  - The marshmallow "astronauts" must remain safely in the lander cockpit upon impact.
  - Teams should attempt a successful landing from the greatest height possible.
  - Teams may cut, bend, twist, poke, or fold any of their materials.
- Constraints
  - Teams may only use the materials provided but they don't have to use all of them.
  - Teams must place the cup on the cardboard platform, right side up to form the cockpit in which the "astronauts" will sit.
  - The "astronauts" must remain free to move around inside the cockpit i.e., they may not be tied, glued, or wedged into the cup.
  - Teams may not cover the top of the cup.

Possible design solutions

This challenge is about impulse and the forces experienced by an object during a collision due to changes in momentum. When a cup containing marshmallows is dropped and hits the ground, the upward force applied by the ground to change the momentum of the cup to zero is transferred to the marshmallows which tend to fly out of the cup. In addition, the cup invariably also bounces and tips over, spilling the marshmallows.

Therefore, in designing their lander, teams should be encouraged to explore two approaches to protect their marshmallow "astronauts" and keep then safely inside the lander:

1. Find ways to reduce the impulse of the collision by extending its time (and thus reducing its force) by designing some sort of shock-absorbing system.
2. Find ways to keep their cup from rolling when falling through the air and/or bouncing and toppling over when it lands.

FACILITATION NOTE

While there is no atmosphere on the moon, there is one on Earth and many teams are likely to find that their landers roll and pitch during descent causing their marshmallows to fall out even before impact. Be on hand to assist teams with this by helping them to think about the weight distribution of their lander and also ways to change it that minimise this action.

Key design questions

As teams get started, it will be very tempting for them to jump straight into building. However, encourage them to slow down and to share, discuss, and draw their designs on paper first. The more ideas, the better—and crazy ideas are welcome! Explain that sketches are a great way to test out different designs quickly and cheaply, and to share their ideas with each other.

Here are some questions you can ask teams to help them think through their designs.

- What are you trying to accomplish with your design?
- Is there air here on earth? How will this effect your design?
- What materials do you have and what are the properties of each one? How might each material assist you in your design? How can you change the shape of these materials to change their properties?
- How big will your lander be? How strong should your lander be, and how can you make it stronger?
- Does your lander have to be symmetrical? Why or why not?
- Should your lander be tall or short?
- Will you make shock absorbers? If so, how will you make them, how many will you make and where will you attach them?
- How can you keep your lander stable during flight and on impact, so the astronauts don't fall out?

Key testing questions

As teams build, encourage them to test early and often to make sure that each part of their lander works as intended. Remind teams that failure is an essential part of engineering so any failures they experience need to be seen as opportunities to learn and improve. As teams test, encourage them to start low but then to test their lander with higher and higher drops.

In some cases, you may need to suggest that teams try a completely new design. In this case, spend some time with them to help them think through what an alternative design might look like.

Here are some other questions you can ask while teams test and iterate:

- What did you observe during the test?
- How did your lander behave as it fell and when it hit the ground? Did it tip over? Did it bounce? What can you do to keep it from tipping over or bouncing?
- Have you been able to reduce the force of impact on the "astronauts"?
- Did your lander get damaged on impact?
- What changes can you make to improve the performance of your lander?
- What materials have you not used yet? How might you use these materials?

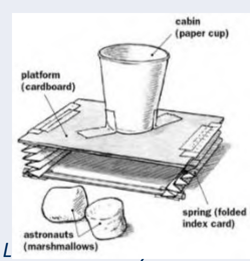
FACILITATION NOTE

Strongly encourage teams to draw their design ideas on paper in as much detail as possible before they start building anything. Failing 'on paper' is much faster and cheaper than failing while constructing something.

If possible, explain why engineers draw sketches of their designs before they build by relating your own experience.

FACILITATION NOTE

An internet search for "lunar lander design ideas" returns many different design ideas that you could suggest to teams. Here is one from NASA's JPL.



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