MARYLAND

MESA CHALLENGE

LEVEL: Secondary

2023—2024

PLANETARY LANDER

An Expanding Structure Challenge

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

23-03929

Planetary Lander: An Expanding Structure Challenge

Level: Middle and High School

Type of Contest: Team

Composition of Team: Two to four students per team (four team members is strongly encouraged)

Number of Entries: One entry per school

Next Generation Science Standards:

- MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4
- HS-ETS1-2, HS-ETS1-3

Background

How do you think NASA sends something like satellites into space that are too big to fit in the space shuttle? Or how does NASA ensure the Mars Rover lands on the planet successfully?

Engineers solve many kinds of problems. Often they are given very specific design criteria and asked to develop the best solution. Sometimes they can only use certain materials. Sometimes their devices must only use a certain amount of energy. Sometimes their structures must be able to carry a certain amount of weight or be a specific size. Sometimes there is only a small space to fit a large item.

Regardless of the project, engineers are almost always given specifications related to size. For example, the final product might need to fit inside a specific-sized container. Engineers have to think about how to fit all the components required for a project into a small space. Think about all the components that fit inside a computer or how small the battery has to be to fit inside a watch.

Now think about the objects we send to space. For example, solar panels on a spacecraft. The panels must fit into tiny containers when launched from Earth, but need to expand large enough to collect solar energy for the spacecraft when opened in space. The panels also need to be strong so they don't break when opened, since it isn't easy to repair things in space. On top of that, the panels need to be light. The lighter they are, the less energy they need to be launched into space. In other words, engineers are looking for an efficient design. The structure could be a satellite that goes into orbit, or a vehicle that explores the surface of a planet. It may also have to be ejected from a space craft then successfully land on the planet's surface.

Successfully landing a rover on a planetary surface is an important mission for the Johns Hopkins Applied Physics Laboratory's (APL) Space Exploration Sector. APL engineers are working on a new mission with NASA to land a rover on the Moon. The mission, Lunar Vertex, is set to launch in 2024. The rover will study the lunar surface for about 13 Earth days (half of a lunar day). The VIPER lunar rover is also set to launch in late 2023 to search for water on the Moon! Another rover mission APL scientists have helped with is the Perseverance rover exploration on Mars!

Landing on the planet is part of the challenge, getting into space is another challenge. On July 12, 2022, NASA shared the first images of space from the James Webb Space Telescope. The James Webb Space Telescope is the largest optical telescope in space! The images are amazing, but what's more amazing is how they got a telescope the size of a tennis court into space. Here's a hint: It was folded up like origami! Learn more here: How Does The James Webb Space Telescope Work? - Smarter Every Day 262.

Now, it is your turn to build something big that can fit into a small transport tube to then deploy and land successfully on another planetary surface!

Mission

In this MESA challenge, students will use the engineering design process to design to build an expanding structure that allows the astronauts to land successfully on the surface of another world. The main goal of the project is to build the most efficient lander that allows for a successful landing from the highest height possible. The students will use this height and figure out how high the astronauts can drop for a successful landing on the planet (or moon). That is, the final design should be as light as possible while protecting the astronauts while landing. The lander will be made of components that fit entirely inside a transport container of a specified size. The lander will have the capability to be deployed/assembled to span a greater distance than the length of the transport container. When testing the lander, the team will remove the components of their lander from the transport container, assemble the lander, and demonstrate the astronauts are successful when landing from the highest height possible.

Judging Guidelines

The competition will be scored based on the following components: design and construction, presentation/performance demonstration, and electronic poster. The Scoring Sheets at the end of this document provide details about the scoring of each component with the following points for each category (100 points total):

Design and Construction	20 points
Video-Recorded Presentation with Demonstration	60 points
Electronic Poster	20 points
Total Score	100 points

Tiebreaker

In the event of a tie, the following will be used as tiebreakers:

1st — The team with the highest Design and Construction score

2nd — The team with the highest poster score

Safety Note: When testing your Planetary Lander, safety is the top priority. If the recorded test drops are deemed unsafe by the head judge, the team will be disqualified.

All tests drops must follow these rules:

- An adult must be actively watching during testing.
- No rooftop drops are permitted, unless the space is a sanctioned school space.
- No climbing on furniture, chairs, etc., is permitted.
- When using a ladder, there must be a spotter.
- If dropping off of a stairwell, balcony, observation tower, etc., there must be a safety rail. Do not lean over the rail.

Continuing Projects

MESA USA recognizes that there is both an interest in and benefit for student teams to continue work on a project started in previous years. However, all projects must be new and original. Teams cannot continue working on a project started in previous years.

Plagiarism Policy

Academic honesty and personal integrity are essential to ensure future success as college students and STEM professionals. As such, the APL STEM Program Management Office expects that the work presented as a part of this challenge will be solely the work of the students. If the work or ideas of someone else are used to further students' work, proper credit must be given to the owner. Failure to do so will be interpreted as an act of plagiarism. If it is determined that a student committed plagiarism, they will be disqualified from the competition and will be ineligible to receive any awards. They may also risk further sanctions from the APL STEM Program Management Office.

MESA USA Code of Sportsmanship

At all times during the course of the competition, MESA students, staff, advisors, and supporting family members should act in a professional and courteous manner.

General Design Requirements and Constraints

Teams must follow these general design requirements:

Planetary Choice: Decide what planet or moon your lander is landing on.

Transport Container: Before being assembled and/or expanded (deployed), all parts of the lander must fit inside the provided transport container at the same time. The transport container is a 20-cm-long tube with an inside diameter of 9.5 cm.

All components of the lander must fit inside the transport container at the same time. No part can protrude from the transport container.

- The lander must be designed in a way that it can be removed from the transport container and assembled in less than 3 minutes.
- When deployed/assembled, the lander must be at least 30 cm in length.

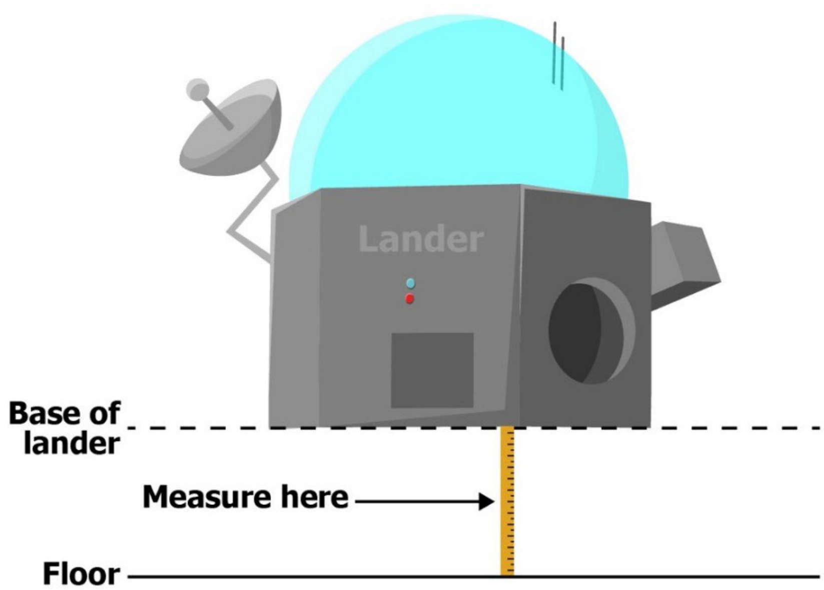
Astronauts: The astronauts will be represented by two ping-pong balls. Each astronaut must have an individual "seat" in the lander represented by a 3-oz cup. They cannot be attached with any adhesive (glue, tape, etc.), they cannot be covered or encapsulated, and the inside of the cups cannot be padded (nothing in the cups besides the balls).

A successful landing is when the lander lands and the astronauts (ping-pong balls) stay in their "seat" (cup).

- Two astronauts (ping-pong balls) must stay in their "seats" for a successful landing on a flat, hard surface. The astronauts can move, and will still be safe, as long as they remain in the "seat."
- Students will use the highest height that had a successful landing on Earth and determine the successful height the astronauts can fall to land successfully on the Moon.

Height: The Planetary Lander must successfully land from at least 2 meters from the base of the lander.

- To measure: The tape measure should stretch from the bottom or base of the lander to the floor (see image below).



Size: When deployed/assembled, the lander must be at least 30 cm at its widest width.

Height Trials: The height can be considered a successful height if the lander successfully lands with the astronauts seated for at least two out of three trials at the same height.

Bonus 10 points

Not all planets and moons have an atmosphere, and some, like the Moon, have a very thin atmosphere. In those cases, a parachute would not help slow down the lander like on Earth, because parachutes need air from the atmosphere to work.

Bonus Challenge—Create a Planetary Lander that DOES NOT use a parachute for a successful landing.

Materials

Materials: Teams are welcome to use any suitable materials or tools to construct and assemble the Planetary Lander. Competition scoring is based on the device being made of more than 50% recycled and/or repurposed materials (not a kit). Keep in mind that you are building a structure that is as light as possible, while still successfully landing with the astronauts safely in their "seats."

Some material ideas: grocery bags, toothpicks, paper, rubber bands, cardboard, aluminum foil, popsicle sticks, and repurposed packing materials.

Provided Materials: Teams will be provided one transport tube, two ping-pong balls (astronauts), two 3-oz cups (seats), one roll of tape, pipe cleaners, and straws. The rest of the materials are up to the team.

REQUIRED: The provided transport tube, two ping-pong balls, and two 3-oz cups "seat" are required.

Creativity: We encourage teams to be creative! Here are some suggestions, but you are free to add your own creative ideas, as long as they don't restrict the mission of the Planetary Lander: create a team or mission logo or flag, color your Planetary Lander, and/or draw a face on each astronaut.

Note: The team will need to supply a scale, which is not included in the kit.

Testing the Lander

Teams must follow the procedure below to test their Planetary Lander:

1. The team will have up to 3 minutes and 0 seconds to remove all parts of their structure from the transport tube, assemble the structure, and prepare to launch.

   Note: The structure must start in the transport tube, so judges can see that it fits completely in the tube.

2. Students must demonstrate three drop trials on video from their highest height. At least two of the three drops from the test height must be successful to be scored.

   Use the Planetary Lander Height Trials Chart in Appendix A to document each version of your lander prototypes and your height trials.

3. Weigh the Lander and calculate the acceleration using the formula in the "Planetary Lander Calculations" section of this document.

Safety Note: When testing your Planetary Lander, safety is the top priority. If the recorded test drops are deemed unsafe by the head judge, the team will be disqualified.

All tests drops must follow these rules:

- An adult must be actively watching during testing.
- No rooftop drops are permitted, unless the space is a sanctioned school space.
- No climbing on furniture, chairs, etc., is permitted.
- When using a ladder, there must be a spotter.
- If dropping off of a stairwell, balcony, observation tower, etc., there must be a safety rail. Do not lean over the rail.

Planetary Lander Calculations

When a rocket is launched carrying the Planetary Lander, there are two forces at work. The force of *thrust* from the rocket boosters moves the rocket upward, and the force of *gravity* acts in the opposite direction on the mass (rocket). When the thrust from the rocket boosters is greater than the mass of the rocket and force of gravity, the rocket can lift off!

In this challenge, you will use the weight of your lander and the rocket for "M" (mass) and the provided force for "F" to calculate "A" (acceleration).

Using Newton's Second Law of Motion (F = MA), solve for acceleration (A = F/M).

Reminder: 1 newton (N) = 1 kg · m/s^2, and the gravity on Earth is 9.8 m/s^2.

For the purpose of this example, force = 10 N and the rocket = 1 kg.

The following table shows example acceleration calculations for two teams:

	Team A	**Team B**
Force (N)	10 N	10 N
Mass of Lander + Rocket (kg)	1.13 kg	1.10 kg
Acceleration (m/s)	10N ÷ 1.13 kg = **8.85 m/s**	10N ÷ 1.10 kg = **9.09 m/s**

Think about how acceleration affects efficiency. Team A will accelerate slower. Why? (An efficient lander = less energy used)

Now that the Planetary Lander is in space, let's calculate the equivalent successful height to drop onto the planetary surface of choice using the successful height you discovered on Earth.

Using this equation: $U = m \cdot g \cdot h$

(U = potential energy, m = mass, g = gravity, h = height)

Solve for h on the planetary surface.

Hint: *This is a two-part equation. You also need to find the gravity (also known as gravitational acceleration) at the surface of your planetary surface of choice.*

Electronic Poster

Each team must create an electronic poster. We recommend using Microsoft PowerPoint. All information must be contained on **one single slide** that has been resized to 36 inches × 24 inches (width × height). The electronic poster must contain the following information:

1. **School Name**
2. **MESA School Coordinator(s)/Adviser(s)**
3. **Team Members and Their Roles** (two to four members per team)
4. **MESA Logo**—Include the APL MD MESA logo, no smaller than 3 inches × 3 inches.
5. **Engineering Design Process**—The team should describe the process they used to design and engineer the Planetary Lander, including the following:
    - How the design was tested and selected (including trial charts and sketches and/or pictures of the original design)
    - Improvements or changes that were made to the design and why
    - A complete (but brief) description of some of the problems the team encountered in designing the Planetary Lander and how they resolved those problems
6. **Planetary Lander Calculations**—The team must show the acceleration calculations for the trials they completed.
7. **Bibliography**—List at least six resources used for this challenge. Include books and websites. Reference citations must be formatted according to the American Psychological Association (APA) style for reference citations.[1]

Electronic Poster Submission Instructions

1. Complete an electronic poster. We recommend using PowerPoint.
2. Save the poster as a PDF file, using the following format for the file name: **School name_Planetary Lander_poster**
3. Submit the PDF file as instructed **no later than 11:59 p.m. on the specified due date**.

Presentation with Demonstration Requirements (Video Submission)

The team must deliver a video-recorded presentation that describes their design process and the final design of their Planetary Lander. The presentation, including the demonstration, can be a maximum of

[1] Available at: https://apastyle.apa.org/style-grammar-guidelines/references.

10 minutes and 0 seconds in duration. Teams should use appropriate visual aids to support the presentation. Creativity is encouraged. Each team must address the following during the presentation:

Introduction of Team Members/Description of Roles

Background Information

- What planetary surface is your lander landing on?
- What background research did the team do for this challenge?
- What did the team have to know for the Planetary Lander to land from the highest height possible?

Engineering Design Process

- How did the team go about designing their Planetary Lander?
- How did the team test the design of the lander?
- What improvements or changes did the team make to the design during the development process? In other words, describe the iterations of the design.
- What are the key elements of the final design?
- What obstacles did the team face while working on this project? How did the team overcome those obstacles?

Demonstration

- Does the team's final design meet all design requirements and constraints?
  - The video must clearly show that the lander completely fit inside the transport tube before assembly.
- Can the team's lander be completely removed and assembled in the allotted time?
  - The video must show the team removing all parts of their lander from the transport tube and the assembling of the lander.
  - The team must show that the Planetary Lander meets the assembled size requirement.
  - This process must be completed in less than 3 minutes.
  - This portion of the video must be unedited and at normal speed, so judges can confirm that the entire process from start to finish was completed in the allotted time.
  - Place the final lander on a scale and show the reading to verify the weight.

Evaluation of the Lander

- Does the team's lander land the astronauts successfully from at least 2 meters?
- Planetary Lander calculations:
  - The video must show how the team did the calculations and talk about the factors that may have affected acceleration and their drop height.
- Note: The more detailed step-by-step calculation will be shown on the poster.

- What part(s) worked well?
- What could have worked better?

Lessons Learned/Next Steps

- What did the team learn while working on this project?
- What are the next steps for the project? How could the team's lander be improved (i.e., what would your team do if you had more time/resources)?

Video-Recorded Presentation Submission Instructions

1. Upload the video to YouTube as an unlisted video.
2. Create a document containing the school name, team member names, MESA School Coordinator name(s), and a link to the video on YouTube. Please only list two to four members per team.
3. Save the document as a PDF file, using the following format for the file name: **School name_Planetary Lander_demo**.
4. Submit the document as instructed **no later than 11:59 p.m. on the specified due date**.

Note about Videos:

Remember to watch the video and make sure all of the required elements are included and easily seen or heard. For example, viewers can't read a ruler, so say the length as you show the measurement.

If the judges can't clearly observe something that is scored, you will not get points for that item.

Note about the 2023–2024 Competition:

Projects submitted to each Regional Competition will be scored ahead of time, and winners will be announced during the in-person showcase and awards ceremony. All files must be submitted no later than 11:59 p.m. on the due date specified by the MESA Regional Coordinator.

The teams that win the Regional Competition will progress to the 2024 Statewide MESA Competition. The Statewide MESA Competition will also be judged in advance, and an in-person MESA Day showcase and awards ceremony will take place in May on the campus of the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland.

Appendix A. Planetary Lander Height Trials Chart

Prototype #______________

Test Height	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5

Improvement Notes:

Scoring Sheet
Planetary Lander: An Expanding Structure Challenge (Elementary)

School Name: ______________________ **Judge:** ______________________

Performance Area	Level of Mastery (Select One)					
Electronic Poster and Design and Construction	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Electronic Poster						
General Poster requirements—Contains all required information and is of high quality.	(0)	(1)	(2)	(3)	(4)	____/4
Engineering Design Process—The team described how they worked though the engineering design process and showed evidence (see requirements on page 7 of challenge document).	(0)	(1)	(2)	(3)	(4)	____/4
Trials—The team shows documentation of height trials.	(0)	(1)	(2)	(3)	(4)	____/4
Calculations—The team showed their calculations and explained the results.	(0)	(1)	(2)	(3)	(4)	____/4
Sources—The display board includes at least six cited sources used to assist the team in solving the stated problem (formatted using APA style for reference citations).	(0)	(1)	(2)	(3)	(4)	____/4
Penalties?						
Format – 10-point deduction if the electronic poster is not formatted correctly (i.e., one single slide that is 36 inches × 24 inches)					Points deducted: ____	
					Electronic Poster Section Total:	____/*20*

Performance Area	Level of Mastery (Select One)					
Electronic Poster and Design and Construction	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Design and Construction						
Description of how the team went about designing and testing their Planetary Lander.	(0)	(1)	(2)	(3)	(4)	____/4
Team describes the key elements for a successful landing.	(0)	(1)	(2)	(3)	(4)	____/4
Materials—at least 50% of the materials used were recycled or repurposed. The team explains the materials used.	(0)	(1)	(2)	(3)	(4)	____/4
Description of changes the team made to the design during the development process and description of the key elements of the final design.	(0)	(1)	(2)	(3)	(4)	____/4
Discussion of obstacles the team faced during the project and how they overcame those obstacles.	(0)	(1)	(2)	(3)	(4)	____/4
BONUS: No parachute design with successful landing – 10 bonus points (landing must be successful to earn points)					**Bonus Points: ______**	
Design and Construction Section Total: ____/20						

Scoring Sheet
Planetary Lander: An Expanding Structure Challenge (Elementary)

School Name: ______________________ **Judge:** ______________________

Performance Area	Level of Mastery (Select One)					
Video-Recorded Presentation with Demonstration	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Background Information						
Description of background research the team did related to this challenge and had to know to be successful at building the Planetary Lander. What did the team have to know for the Planetary Lander to land from the highest successful test height?	(0)	(1)	(2)	(3)	(4)	____/4
Demonstration						
The video clearly shows the lander completely fits inside the transport container.	(0)	(1)	(2)	(3)	(4)	____/4
The video clearly shows the team spent no more than 3 minutes removing the lander from the transport tube and assembling it.	(0)	(1)	(2)	(3)	(4)	____/4
The video clearly shows the team conducting at least three test drops, including the highest successful height trial which is at least 2 meters high. **(2× points)**	(0)	(2)	(4)	(6)	(8)	____/8
Evaluation of Final Design						
Description of how well the team's solution works, overall.	(0)	(1)	(2)	(3)	(4)	____/4
Planetary Lander calculations—The team explains how they calculated the successful drop height on the world they chose.	(0)	(1)	(2)	(3)	(4)	____/4
Description of the aspects of the final design that worked well and what could have worked better.	(0)	(1)	(2)	(3)	(4)	____/4

Performance Area	Level of Mastery (Select One)					
Video-Recorded Presentation with Demonstration	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Lessons Learned/Next Steps						
Discussion of what the team learned while working on this project.	(0)	(1)	(2)	(3)	(4)	____ **/4**
Description of what next steps for this project would be (i.e., what the team would do if they had more time/resources).	(0)	(1)	(2)	(3)	(4)	____ **/4**
Overall Quality of the Presentation						
The presentation includes effective and creative use of props, visual aids, sound effects, video editing, etc.	(0)	(1)	(2)	(3)	(4)	____ **/4**
The presentation demonstrates the team's deep understanding and knowledge of concepts related to the challenge.	(0)	(1)	(2)	(3)	(4)	____ **/4**
All team members participate appropriately in the presentation.	(0)	(1)	(2)	(3)	(4)	____ **/4**
The team showed creativity in the project. Examples, not limited to a "mission" logo, flag, colors, etc.	(0)	(1)	(2)	(3)	(4)	____ **/4**
Overall, the team delivered a high-quality, organized, engaging presentation that included all necessary information for the audience to fully understand the team's project and their final design.	(0)	(1)	(2)	(3)	(4)	____ **/4**
Penalties?						
Time – 10-point deduction if the presentation exceeds the allotted 10 minutes 0 seconds					Points deducted: ____	
					Video-Recorded Presentation with Demonstration Section Total:	____ ***/60***
					TOTAL SCORE (×/100 points):	_____**/100**