National Aeronautics and
Space Administration

21CCLC NASA STEM Challenge

Design a Crew Exploration Vehicle

Facilitation Guide

FACILITATOR'S WELCOME

Dear 21CCLC STEM Facilitators,

Welcome to the 20142015 STEM Engineering Design Challenge Team! As part of this team, you will play an integral part in helping today's students become tomorrow's scientists, technicians, engineers, and mathematicians. Through the Engineering Design Challenge (EDC) students, will participate in authentic learning experiences that will allow them to develop valuable skills through rigorous and engaging science, technology, engineering, and mathematics (STEM) content.

As a 21CCLC STEM facilitator, you are helping your students use their creativity, curiosity, and analytical thinking as they follow the **Engineering Design Process (EDP)**. Solving problems using the EDP will be key to the success of NASA's future engineering workforce.

Through the design challenge, ***Design a Crew Exploration Vehicle (CEV)***, students will work in small teams of no more than four students to design and construct a Crew Exploration Vehicle. Each team's CEV must carry two toy astronauts. Each astronaut will be two centimeters in length and must travel safely while fitting into a specified volume. The volume is defined by you, the facilitator, to help students begin to work scientifically and learn how to design with identified constraints.

The major real-world concepts of this challenge are:

1. **Measuring**
2. **Calculating**
3. **Designing and building**
4. **Evaluating**
5. **Repeatability and reliability**

This Facilitator's Guide is designed to provide you with important information to use in planning and conducting the challenge. It includes simple explanations of relevant background information, clear step-by-step instructions, reflective data sheets, and concise rubrics for evaluation of student performance. While you will be expected to use all of the included materials with your students, you can also adapt the timeline to fit your classroom schedule.

NASA supports educators and facilitators, like you, who play a key role in preparing students for careers in STEM fields through engaging content. Thank you for helping us share this learning experience with your students.

Engineering Design Challenge Team

U.S. Department of Education
NASA Office of Education

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This challenge was adapted and content modified from "NASA's BEST Students, Beginning Engineering, Science, and Technology (An Educator's Guide to the Engineering Design Process: Grades 6-8)" EG-2011-3-034-GSFC.

INTRODUCTION

FACILITATOR'S OVERVIEW

The U.S. Department of Education and NASA's Office of Education worked together to create an **Engineering Design Challenge (EDC)** that gets students involved in using the **engineering design process (EDP)** to complete the Engineering Design Challenge**.**

The EDC serves as an authentic standards-based investigation that allows students to engage in the process of solving problems like today's scientists and engineers are utilizing. This EDC provides students with opportunities to gain tangible skills that are essential in STEM careers.

This guide is organized into the following sections:

1. Introductory materials – Establish a common basic level of understanding about the EDP and relationship to this challenge. The introductory materials also include an alignment to Next Generation Science Standards and the Common Core State Standards for Mathematics, as well as background information highlighting NASA's science and research related to the Crew Exploration Vehicle.
2. Facilitator pages – Provide instructions for facilitators to use throughout the design challenge. Tools are also included in this section for you to use to assess student understanding throughout each step of the challenge.
3. Student challenge journal – Contains prompts and tools to guide students through the cycle of steps in the EDP, while documenting their work for each step.
4. Support materials – Consist of information to supplement and enhance the EDC.

These user-friendly sections help you support your students as they work in teams to complete the EDC. At the conclusion, your students will be required to articulate the steps taken in the EDP in a video each team will create. Good luck as you help create the next generation of STEM professionals!

For more information and to access the Help Desk visit the NASA STEM Challenges website at http://y4y.ed.gov/stemchallenge/nasa.

THE BASICS OF ENGINEERING DESIGN

What is an engineer? Engineers are at the heart of every Engineering Design Challenge. Engineers are people who design and build things that we use every day. The video at the link below will explain the role of an engineer and can be shared with your students: http://youtu.be/wE-z_TJyziI.

Figure 1: Aerospace Engineer Chris Randall tests that rocket parts and life support systems to ensure they work as planned. (NASA)

Figure 2: Simulation System Engineer Debbie Martinez works on developing a general aviation flight simulation software. (NASA)

What is an Engineering Design Challenge? An Engineering Design Challenge is developed to help students understand the engineering design process. Students are presented with a challenge or problem and, using the process, work in teams to complete activities and experiments to develop solutions to the original problem. These challenges facilitate teamwork, problem solving, and brainstorming ideas very similar to what real-world engineers encounter.

Engineering Design Process

What is the engineering design process? The engineering design process is a cycle of steps that leads to the development of a new product or system. The cycle repeats and continuously refines and improves the product or system. In this challenge, students should complete each step and document their work as they develop and test their design. To do this, students need to perform each of the steps in the EDP and repeat the cycle, as often as time and resources allow to develop the best end product. Some steps, like “Researching the need or problem”, will only need to be briefly revisited to confirm that teams are still on track. Other steps, like “Test and evaluate the solution”, will need to be completely redone.

THE ENGINEERING DESIGN PROCESS

STEP 1: Identify the Need or Problem – Working in teams, students state the problem in their own words. Example: How can I design a __________ that will __________?

STEP 2: Research the Need or Problem – Teams use resources from the Internet, the library, or discussions with subject matter experts (SMEs) to examine the how this problem is currently being solved or how similar problems are being solved.

STEP 3: Develop Possible Solutions – Team members draw on their mathematic and scientific knowledge and brainstorm all the possible ways that they might solve the problem. They choose the most promising options, and refine their solution by quickly sketching in two or three dimensions. Labels and arrows should be included to identify parts.

STEP 4: Select the Best Possible Solution(s) – Team members share their ideas and answer questions from other team members. Each team discusses and records strengths and weaknesses from each design and determine which solutions best meet the original need or solves the original problem, possibly including features from more than one design. The group writes a statement that describes why they chose their solution.

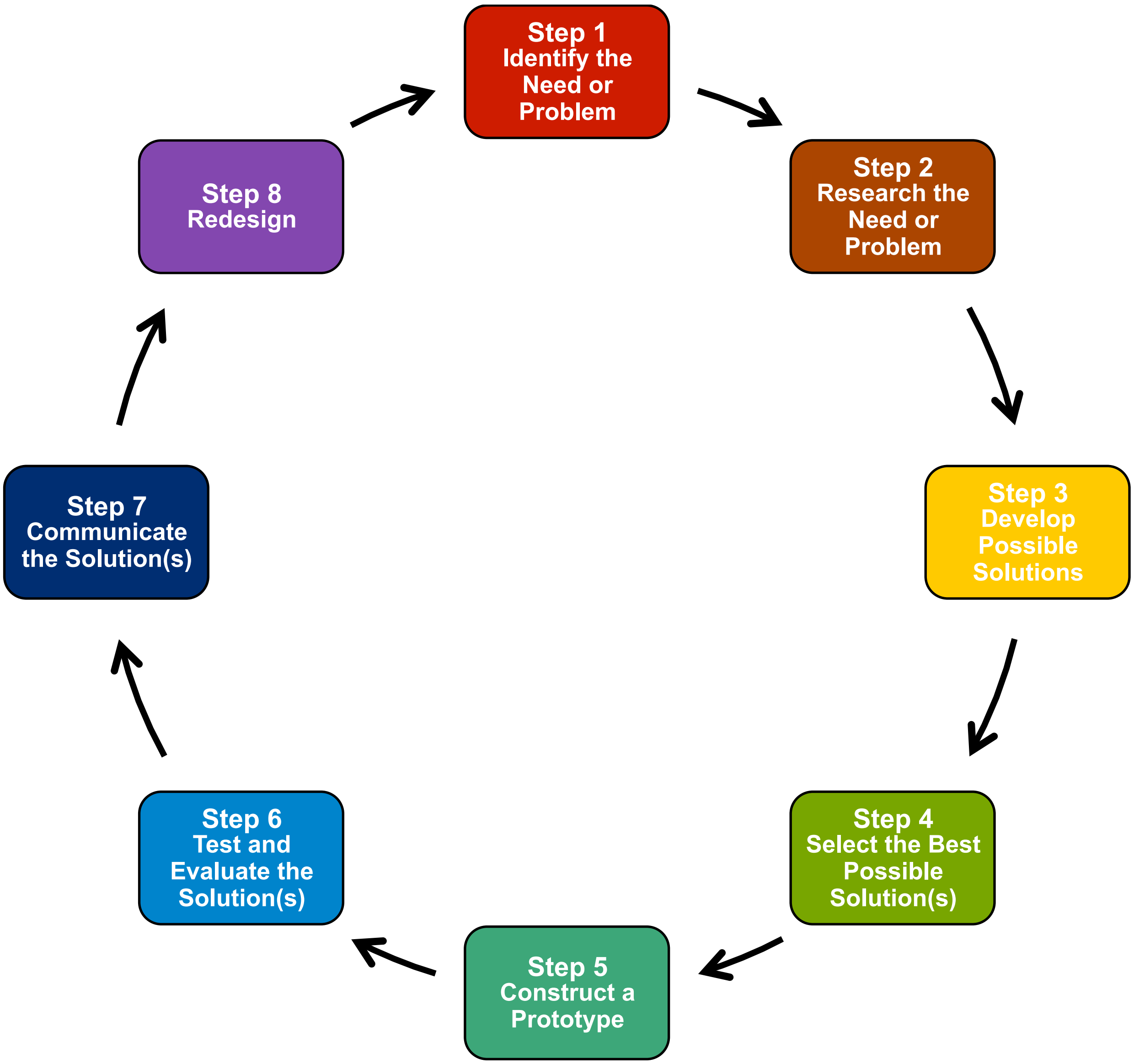
STEP 5: Construct a Prototype – Team members construct a full-size or scale model of the selected solutions in two or three dimensions. The facilitator helps to identify and acquire appropriate modeling materials and tools.

STEP 6: Test and Evaluate the Solution(s) – Teams test their models to determine how effectively they solved the need or problem. Data is collected to serve as evidence of their success or need for improvement.

STEP 7: Communicate the Solution(s) – Team members record and share what was learned about their design based on testing. They make a presentation that includes how their solution(s) best solved the need or problem and any improvements that could be made. They could ask students from other groups to review the solution and help identify changes.

STEP 8: Redesign – Team members consider modifications to their solution(s) based on the information gathered during the tests and presentation. Students review the original need or problem to ensure their modifications still meet the necessary criteria and constraints, and restart the EDP cycle.

THE ENGINEERING DESIGN PROCESS



This Engineering Design Process model was adapted from the Massachusetts Science and Technology/Engineering Curriculum Framework (published October 2006, http://www.doe.mass.edu/frameworks/scitech/1006.pdf).

STANDARDS ADDRESSED

Next Generation Science Standards	Common Core State Standards Mathematics
Practices 1. Asking questions, defining problems 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using math and computational thinking 6. Constructing explanations and designing solutions 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information *Cross-Cutting Concepts* 1. Patterns 2. Cause and effect 3. Scale 4. Systems and system models 5. Energy and matter 6. Structure and function *Core and Component Ideas* *Physical Science* PS2: Motion and stability PS2.A: Forces and motion PS2.B: Types of interactions *Earth and Space Science* ESS1.B Earth and the solar system engineering, technology, and applications of science ETS1.A: Defining and delimiting an engineering problem ETS1.B: Developing possible solutions ETS1.C: Optimizing the design solution ETS2.A: Interdependence of science, engineering, and technology	*Standards for Mathematical Practice* MP1: Make sense of problems and persevere in solving them MP2: Reason abstractly and quantitatively MP3: Construct viable arguments and critique the reasoning of others MP4: Model with mathematics MP5: Use appropriate tools strategically MP6: Attend to precision Grades 6 to 8 *Expression and Equations* – Reason about and solve one- variable equations. Represent and analyze quantitative relationships between dependent and independent variables *Geometry* – Solve real-world and mathematical problems involving area, surface area, angles, and volume *Statistics and Probability* – Develop understanding of statistical variability. Summarize and describe distributions **ISTE NETS and Performance Indicators for Students** *Critical Thinking, Problem Solving, and Decision Making* **Students:** • Identify and define authentic problems and significant questions for investigation • Plan and manage activities to develop a solution or complete a project • Collect and analyze data to identify solutions and/or make informed decisions • Use multiple processes and diverse perspectives to explore alternative solutions

BACKGROUND INFORMATION: THE ORION CEV

What Is NASA's Orion?

Figure 3: – NASA's Orion Multi-Purpose Crew Vehicle (MPCV). (NASA)

For the first time in a generation, NASA is building a new human spacecraft that will usher in a new era of space exploration. A series of increasingly challenging missions awaits and this new spacecraft will take humanity farther than we've gone before, perhaps even to Mars.

Named after one of the largest constellations in the night sky and drawing from more than 50 years of spaceflight research and development, the Orion spacecraft is designed to meet the evolving needs of our nation's deep space exploration program for decades to come. It will be the safest, most advanced spacecraft ever built, and it will be flexible and capable of taking us to a variety of destinations. Orion will serve as the exploration vehicle that will carry the crew to space, sustain the crew during the space travel, provide emergency abort capability, and provide safe re-entry from deep space at return velocities.

Figure 4: - Launch Abort System. (NASA)

Orion features dozens of technology advancements and innovations that have been incorporated into the spacecraft's design including a crew compartment with the capacity of four crew members, a service module, a spacecraft adaptor, and a revolutionary launch abort system that will significantly increase crew safety. Orion will utilize advances in propulsion, communications, life support, structural design, navigation, and power, and draw from the extensive space flight experience of NASA and industry partners. These systems have been developed to facilitate integration of new technical innovations as they become available in the future.

Orion has been rigorously tested as engineers prepare it for journeys beyond low Earth orbit. A successful test launch of the vehicle's launch abort system was completed at the White Sands Missile Range in New Mexico to verify Orion's escape capability in the event of an emergency on the launch pad. A series of rigorous acoustic and modal tests on the Orion ground test vehicle validated Orion's ability to withstand the harsh environments of launch, abort, re-entry, and space flight at Lockheed Martin's test facilities in Denver, CO.

Figure 5: - Orion splashdown testing at NASA Langley Research Center. (NASA)

To simulate the final phases of landing, the spacecraft's parachutes were proved reliable through a series of tests at the Yuma Army Proving Grounds. To simulate Orion's landing conditions, tests in both the ocean and at NASA's Hydro Impact Basin recreated how Orion will behave during its splashdown in the Pacific Ocean. All of these lead-up tests played a role in the uncrewed orbital test flight of Orion in December 2014.

During the test flight, Orion was launched aboard a Delta IV Heavy rocket from Cape Canaveral Air Force Station's Space Launch Complex. The test consisted of a two-orbit, four-hour flight that evaluated launch and high-speed re-entry systems, such as avionics, attitude control, parachutes, the heat shield, and many of the systems most critical to safety. The uncrewed flight sent Orion farther from Earth than any spacecraft built to carry humans has gone since the Apollo 17 astronauts landed on the Moon in 1972. The spacecraft traveled 3,000 miles into space and reached more than 20,000 mph before re-entering the Earth's atmosphere. Orion put its critical systems to the test by enduring temperatures twice as hot as molten lava. This test provided engineers with invaluable data on Orion's performance in every phase of launch, re-entry, and landing. Following this flight, further tests of the launch abort system will take place as Orion gears up for its first crewed exploration flights.

Figure 6: - Orion uncrewed test December 5, 2014. (NASA)

Although the test flight was launched on a heavy-lift cargo rocket, the crewed Orion vehicle will be launched aboard NASA's new Space Launch System (SLS). More powerful than any rocket ever built, SLS will be capable of sending humans to deep space destinations. Exploration Mission-1 will be the first mission to integrate Orion and the SLS. Orion will carry astronauts into a new era of exploration to destinations that include near-Earth asteroids, our own Moon, the moons of Mars, and eventually Mars itself.

For more information visit

- Orion website - http://www.nasa.gov/exploration/systems/orion
- Space Launch System website - http://www.nasa.gov/exploration/systems/sls
- "Trial by Fire" video - https://www.youtube.com/watch?v=KyZqSWWKmHQ

SAMPLE TIMELINE

The EDC must be completed within the eight-week challenge period. The following timeline serves as a suggestion for implementation. Feel free to structure the sessions to fit your needs.

EDC Week	EDP	Actions
Pre-EDC	Pre-EDP	Attend training and order materials
Week 1	Step 1 Step 2 Step 3	Identify the Need or Problem Research the Need or Problem Develop Possible Solutions
Week 2	Step 4 Step 5	Select the Best Solution Construct a Prototype
Week 3	Step 6 Step 7	Test and Evaluate Solution Communicate Solution
Week 4	Step 8 Step 1 Step 2	Redesign Identify the Need or Problem Research the Need or Problem
Week 5	Step 3 Step 4	Develop Possible Solutions Select the Best Solution
Week 6	Step 5 Step 6	Construct a Prototype Test and Evaluate Solution
Week 7	Step 7 Step 8	Communicate Solutions (compare Iterations) Redesign (recommendations for the future)
Week 8	Post-EDP	Create and upload student videos

SAFETY

Safety, an important issue for all curricular areas of education, is a special concern for STEM-based activities and courses. Many national and state academic standards address the need for schools and subject areas to promote development of student knowledge and abilities in a safe learning environment.

School administrators, teachers, and facilitators are responsible for providing a learning environment that is safe, up-to-date, and supportive. Facilitators are also responsible for their students' welfare in the classroom and laboratory.

Facilitators must be knowledgeable and diligent in providing safe learning environments. Students should receive safety instructions about the topics being taught. Safety assessments should accompany lessons and records must be kept on student results. The facilitator must properly supervise students while they are working; inspect and maintain equipment and tools to ensure they are in proper working condition; keep all students safe; and ensure that a safe environment exists and that proper procedures are being followed in the classroom and laboratory. Parents should be informed that a safe environment exists during the program.

Students should:

1. Demonstrate respect and courtesy for the ideas expressed by others in the group.
2. Use tools and equipment in a safe manner and assume responsibility for their safety, as well as for the safety of others.
3. Make safety a priority during all activities.
4. Wear safety goggles when conducting the EDC.

Facilitators should:

1. Approve all drawings before students start building their designs.
2. Look for potentially hazardous combinations of materials and flimsy designs of structures.
3. Be sure resources are clean and dry with no sharp edges.
4. Be the only ones using hot-glue guns and sharp instruments.
5. Make sure all materials are not damaged or in disrepair.
6. Prohibit students from bringing in or using additional materials for their designs without prior approval.

FACILITATOR PAGES

USING A KLEW CHART

FACILITATOR DIRECTIONS: This KNOW, LEARN, EVIDENCE, WONDER (KLEW) chart can be used as a starting point for science investigation. Before you start the challenge, students should complete the **KNOW** section of this chart. It will allow students to share their prior knowledge and experiences, whether accurate or inaccurate. Complete the **LEARN** section after students are given background information about the CEV. This background information may come from videos, articles, and other supplemental information. Use the **EVIDENCE** section to help students reinforce concepts they learned using the background information and during the challenge by providing supporting information to validate what they stated in the LEARN column. Students share any new questions they may still want to explore in the **WONDER** section.

Please allow students to have flexibility in their answers. There are no right or wrong answers as long as the students answer the questions. Questions can be modified at the discretion of the Facilitator.

KNOW	LEARN	EVIDENCE	WONDER
What do I know about CEVs and space travel?	**What did I learn about CEVs and traveling into space based on my research?**	**What evidence do I have that supports what I learned about CEVs and space travel?**	**What am I still wondering about CEVs and space travel?**
Students should complete this column before researching about CEVs and space travel.	Students should complete this column after researching CEVs and space travel.	Students should complete this column using supporting information from articles, background information research, direct observation, and SME connections.	Students should complete this column as they move through the process to document questions.

THE ENGINEERING DESIGN CHALLENGE

You will be using the Engineering Design Process (EDP) to solve the challenge problem. The following pages will help you guide the students through the Challenge. Break the students into teams of up to four students and follow each step of the EDP. Note that both the Facilitator pages and the Student journal section are organized to align with the each EDP step.

THE CHALLENGE:

NASA needs a new vehicle to take astronauts to the Moon because the Space Shuttle was never designed to leave the Earth's orbit. NASA and its industry partners are currently working on a space vehicle that will take astronauts to the Moon, Mars, and beyond. This spacecraft is called the Crew Exploration Vehicle (CEV). The CEV is a vehicle that transports human crews beyond low-Earth orbit and back again. Each CEV must be designed to serve multiple functions and operate in a variety of environments.

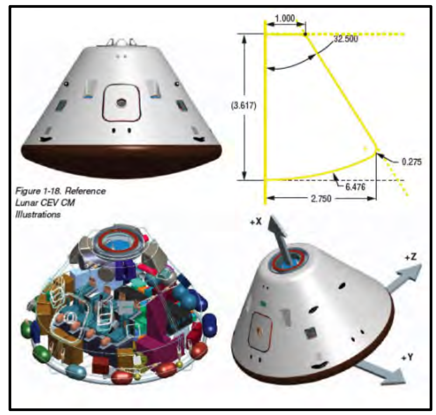


Figure 7: Illustrations of a CEV command module for lunar missions. (NASA)

You will work in a team to design and build a CEV with the following criteria and constraints:

1. The CEV must carry two astronauts safely. Each astronaut is two centimeters long. You must design and build secure seats for both astronauts, without gluing or taping them in place. The astronauts should stay in their seats during each drop test.

2. The CEV must fit within the ______________ (fill in the constraint based on the Pre-Activity Set up in the Materials section). This item serves simply as a size constraint. The CEV should not be stored in or launched from this item.

3. The CEV must include a model of an internal holding tank for fuel with a volume of 30 cm^3 (Note: Your tanks will not actually be filled with a liquid.)

4. The total mass cannot exceed 100 grams. Use a scale or balance to measure the mass of your design components.

5. The CEV must have one hatch that opens and closes, and is sized so that your astronauts can enter or exit easily. The hatch should be closed during all drop tests.

MATERIALS

The following is a suggested list of materials needed to complete this challenge. The quantity will depend on the number of students participating. Alternatives can be used if necessary.

- Digital scale or balance (1)
- Measuring tape (1)
- Rulers (1 per team)
- Mailing tube, oatmeal canister, or small coffee can (used as size constraint)
- 2 cm plastic people (for example, Lego® or Playmobil®) (2)
- Grid paper
- General building supplies for CEV assembly could include:

aluminum foil
balloons
binder clips
bubble wrap
buttons or beads
cardboard or cardstock
clothespins
cloth
coffee filters
cotton balls
craft sticks or tongue depressors
empty paper towel or toilet paper tubes
glue sticks
masking, electrical, transparent, and duct tapes
mini foil pie plates
modeling clay
paper bags
paper clips
pennies
pipe cleaners
plastic cups
plastic eggs
plastic wrap
rubber bands
skewers or stirrers
scissors
staplers and staples
straws
string

Pre-Activity Set-Up:

- Select a size constraint, like a mailing tube, oatmeal canister, or coffee can and share the selected size constraint with your students. Have students fill in the blank for the size constraint in the student journal located in Step 1 on page 29.
- Determine a unit cost for each of the materials and decide the maximum budget each team has to design their model. This value can be raised (budget increase) or lowered (budget cut) to adjust the level of challenge difficulty. Teams should itemize their budget using the Budget Planning Worksheet on page 39.

STEP-BY-STEP FACILITATION INSTRUCTIONS

Introduce the Challenge

Provide students the information covered in the challenge description found on page 15. Use the Challenge Rubric on page 26 in the Student Journal section to show students how their work during this challenge will be evaluated.

The Engineering Design Process Steps with Guiding Questions

STEP 1: Identify the Need or Problem

- Facilitate learning by asking the following guiding questions:
  - How can our team design a _____ that will _____?
  - What needs to be solved or improved?
  - What are we trying to accomplish?
- Review the Engineering Design Process with the students.
- Show the NASA Beginning Engineering Science and Technology (BEST) video titled "Repeatability" found at https://www.youtube.com/watch?v=-2Az1KDn-YM.
- Ask students why it is important to test their own designs.
- Ask students to identify the specific criteria and constraints of the design challenge. The Crew Exploration Vehicle must keep the two passengers safe (not broken or thrown from their seats) during drop tests from one to three meters high. The CEV must have one hatch large enough for their astronauts to enter and exit that opens and closes. Note the hatch must stay closed during all drop tests. The CEV will include a holding tank for fuel (NO FUEL OR LIQUIDS WILL BE USED for this challenge) the vehicle, astronauts, and holding tank (for fuel) cannot exceed a total mass of 100 grams.
- Have students fill out Step 1 on page 29 in the Student Journal section.

STEP 2: Research the Need or Problem

- Facilitate learning by asking the following guiding questions:
  - Where can you find more information about the topic?
  - What questions could you ask an expert?
- Help students answer any questions they have about the challenge. Use the Internet or school library to research answers. Sample resources are listed in the NASA Resources section on page 41. Any unanswered questions should be written down and saved to ask during the NASA SME connections.
- Have students fill out Step 2 on page 30 in the Student Journal section.

STEP 3: Develop Possible Solutions

- Facilitate learning by asking the following guiding questions:
    - What are all the ways your team can imagine to solve this?
    - What do we need to do to add _____ to the design?
    - What might go wrong if we add _____ to the design?
- Ask each team member to brainstorm, make sketches representing their ideas for a solution, and clearly label and identify each part of their drawing.
- Each team member should make sure that designs meet all constraints and criteria.
- Have students fill out Step 3 on page 31 in the Student Journal section.

STEP 4: Select the Best Possible Solution(s)

- Facilitate learning by asking the following guiding questions:
    - Would it be better to _____ or _____?
    - Can we combine more than one plan?
    - Would a _____ fulfill the constraints of the challenge?
    - Do we have the resources to build a _____?
- Ask each student in the team to discuss their ideas and drawings with the rest of the team.
- Have students record the strengths and weaknesses of each of the designs.
- Have students fill out Step 4 on page 32 in the Student Journal section.

STEP 5: Construct a Prototype

- Facilitate learning by asking the following guiding questions:
    - What resources does each team need to gather?
    - What is the plan?
    - Who is doing what?
- Ask each team to identify the design that appears to solve the problem.
- A final diagram of the design should be precisely drawn and labeled.
- Each team is to determine what materials they will need to build their design and assign responsibilities for each team member for prototype completion.
- The final drawings should be approved by the facilitator before building begins.
- Students will receive the materials they will need to build their model and complete a budget sheet representing the cost of their model.
- Using the drawings, the teams are to construct their prototypes.
- Have teams fill out Step 5 on page 33 in the Student Journal section.

STEP 6: Test and Evaluate the Solution(s)

- Facilitate learning by asking the following guiding questions:
  - How did the prototype perform when tested?
  - Was the design successful?
- Review calculations necessary to determine volume and volume of a cylinder. (The internet can provide formulas to help calculate the volume of a cylinder.)
- Visit each team and test their designs to ensure they fit within the parameters of the size constraint.
- Each student team will test their model and record the results of each test.
- After the tests, teams should document the data they gathered from each test.
- Have teams fill out Step 6 on pages 34 and 35 in the Student Journal section.

STEP 7: Communicate the Solution(s)

- Facilitate learning by asking the following guiding questions:
  - What did or did not work? Why?
  - What are the pros and cons of this solution?
- Ask teams to document and report the results of their designs, identify what changes were made with each iteration of design, and what the team believed caused the design to succeed or fail during the tests.
- Have teams fill out only one row of Step 7 on page 36 in the Student Journal section.

STEP 8: Redesign

- Facilitate learning by asking guiding questions.
  - How did the prototype perform when tested?
  - What did and didn't work?
  - What could be improved in the next iteration of this design?
- Ask teams to identify the causes of any problems that were observed during testing and to consider possible modifications to solve these problems.
- Have teams check their redesigned model to make sure it still meets all the criteria to solve the problem.
- Have teams fill out Step 8 on page 37 in the Student Journal section.

From here on, the cycle will repeat with redefined problems and redesigned solutions as often as time and resources allow. Depending on the amount of redesign students put into each iteration, some steps may only need a quick revisit to be sure students are on track, while some steps will need to be completely redone. **In those cases, additional copies of cycle step pages should be made and added into the Student Journal section.**

Submit Final Design

On the final design iteration, use the documentation from Step 7 to create a video of the design development and final design solution according to the Video Criteria and Video Rubric found on pages 27 and 28. Also use the Engineering Design Process worksheet on page 24 to test student knowledge of the entire design cycle.

STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What were the greatest challenges for your team through this process?

2. What strategies did your team prove effective in overcoming your greatest challenge?

3. How did you use the Engineering Design Process to help you with your design?

4. Why was it important for the hatch stay closed during the drop tests?

5. What obstacles would an actual CEV endure? How would this influence the seat design?

6. Would you like to be a passenger in your CEV? Why or why not?

CHALLENGE CHECKLIST

Prior to the Challenge

Things to download, print, review, and copy:

- ❑ 1. Download and review the presentation slides for students.
- ❑ 2. Download, print, and review the Video Criteria and Rubric. Make a copy for each team of students.
- ❑ 3. Download, print, and review the Educator Guide, Design a Crew Exploration Vehicle. Print the Student Journal pages for each team.
- ❑ 4. Download or bookmark the Introductory Video, Telling Our Story with Video, and any other videos needed for your presentation.
- ❑ 5. Download and review the Technical Requirements for Video.
- ❑ 6. Download, review, and print enough media release forms for each student.

Things to schedule, set up, or test:

- ❑ 1. Review the online Event Schedule and select at least one live event for students to interact with a NASA Subject Matter Expert.
- ❑ 2. Gather and organize materials from the materials list for each activity.
- ❑ 3. Test your technology set up to make sure students can see and hear videos, slides, etc.
- ❑ 4. Select a suitable and safe area to deploy CEVs. It could be an open stairwell area balcony or stable ladder. The capsule drops must be from at least three meters high, the higher the better.
- ❑ 5. Check your video or digital cameras to ensure they are fully charged and have enough memory or tape for recording challenge activities.

During the Challenge

- ❑ 1. Distribute media release forms to each participating student and set a due date for return.
- ❑ 2. Ask each group of students to come up with a unique team name.
- ❑ 3. Use the presentation slides for students to lead the students through the challenge.
- ❑ 4. Encourage each team to take pictures and video throughout the challenge for use in their final video.
- ❑ 5. Help students prepare questions and information to share with NASA Subject Matter Experts for the live event for students.
- ❑ 6. Participate in one or more live events for students.

After the Challenge

- ❑ 1. Review Video Criteria and Rubric and Telling Our Story with Video with students.
- ❑ 2. Assist students as they plan and create their final video.

- ❑ 3. Upload student video submissions.
- ❑ 4. Allow enough time to send a separate email with entry information and media release forms for each video by April 16, 2015.
- ❑ 5. Participate in evaluation of the 21CCLC pilot program.

Student Name: ___________________ **Team Name**___________________

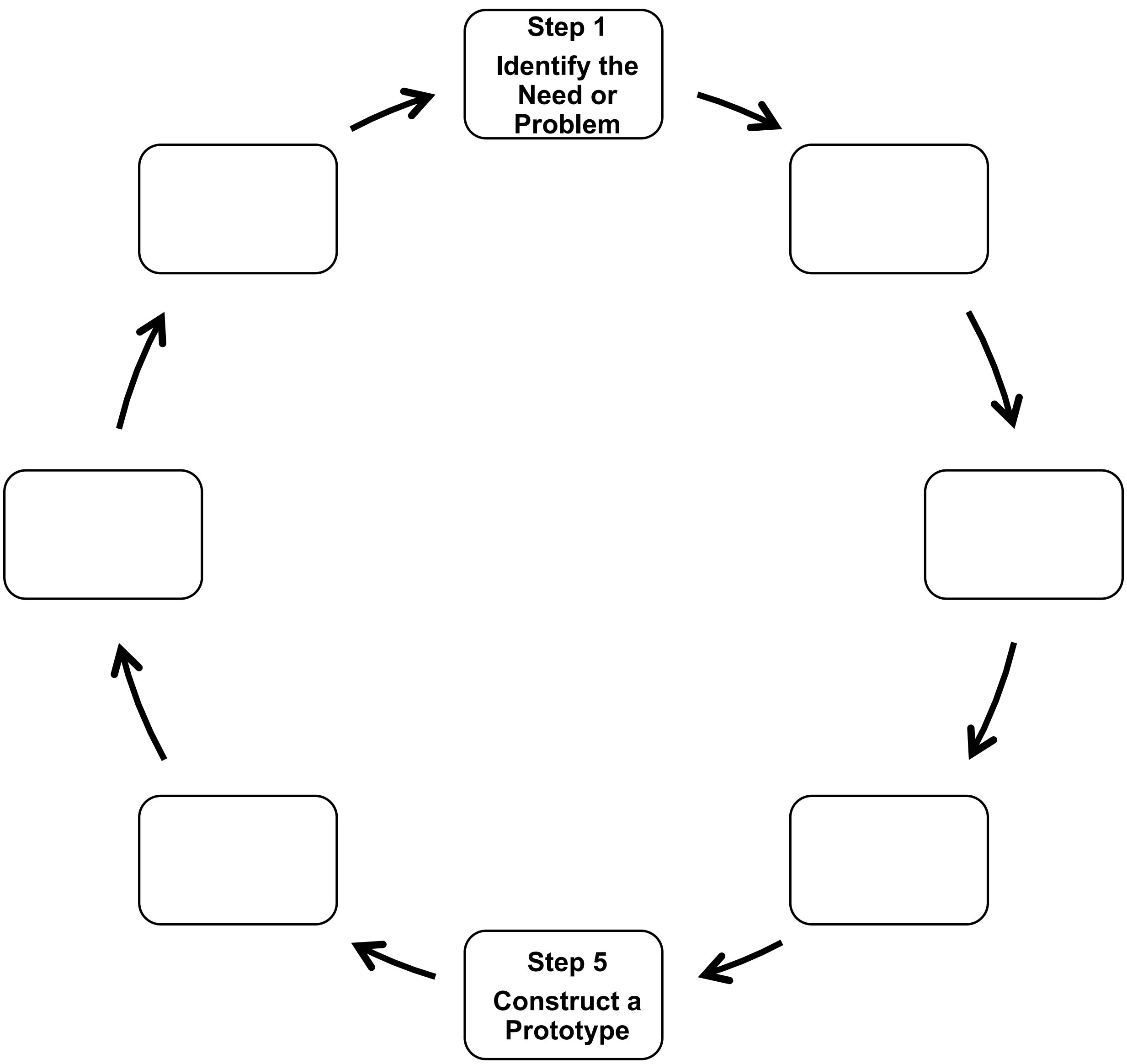
STUDENT TEAM CHALLENGE JOURNAL

ENGINEERING DESIGN PROCESS

<u>Directions for the Students:</u> Can you determine the sequence that engineers take to make a completed design? On your own, try to label the steps of the Engineering Design Process. Put the rest of the steps below in order based on the two that have already been filled in for you.

~~Identify the Need or Problem~~
~~Construct a Prototype~~
Research the Need or Problem
Test and Evaluate the Solution(s)

Select the Best Possible Solution(s)
Communicate the Solution(s)
Develop Possible Solution(s)
Redesign



KLEW CHART FOR STUDENTS

Student Name: ___________________ **Team Name**___________________

This Challenge is: ______________________________

KNOW	LEARN	EVIDENCE	WONDER
What do I know about CEVs and space travel?	What did I learn about CEVs and traveling into space based on my research?	What evidence do I have that supports what I learned about CEVs and space travel?	What am I still wondering about CEVs and space travel?

CHALLENGE RUBRIC

Use the rubric below to assess each team's final design. It may be helpful to have each group explain how they applied Steps 1 to 8 in the Engineering Design Process to create their designs.

Category	Below Target (1)	At Target (2)	Above Target (3)
1. Identifying the Need or Problem	Rephrases the need or problem with limited clarity and fails to identify criteria or constraints.	Rephrases the need or problem clearly and identifies most criteria and constraints.	Rephrases the need or problem precisely and identifies all criteria and constraints.
2. Research the Need or Problem	The need or problem is not well researched and will not be helpful in development of solutions.	The need or problem is adequately researched and may assist in development of solutions.	The need or problem is thoroughly researched and can easily direct development of solutions
3. Develop Possible Solutions	Contributes implausible ideas or no ideas. Produces incomplete sketches. Does not present a concept.	Contributes a plausible idea. Produces marginally accurate sketches of design concepts.	Contributes multiple, plausible ideas. Produces accurate sketches of design concepts.
4. Selecting the Best Possible Solution(s)	Does not adequately analyze strengths and weaknesses of possible solutions. Does not select a solution based on need or problem criteria and constraints.	Satisfactorily analyzes strengths and weaknesses of possible solutions. Selects a solution based on some but not all need or problem criteria and constraints.	Thoroughly analyzes strengths and weaknesses of possible solutions. Selects a promising solution based on thorough analysis of all need or problem criteria and constraints.
5. Construct a Prototype	The prototype meets the task criteria to a limited extent.	The prototype meets the task criteria.	The prototype meets the task criteria in insightful ways.
6. **Test and Evaluate the Solution(s)**	Data is not taken accurately or does not reflect performance of the prototype.	Data is taken accurately that reflects the performance of the prototype	Data is taken accurately that reflects the performance of the prototype and will clearly help in redesign
7. **Communicate the Solution(s)**	Both test results are not accurately reported and areas of improvement are not shared.	Either test results are not accurately reported or areas of improvement are not shared.	Test results are accurately reported and areas for improvement are shared insightfully.
8. Redesign	Refinement is not evident based on prototype testing and evaluation results.	Refinements are made based on prototype testing and evaluation results	Significant improvement in the design is made based on prototype testing and evaluation

Total Score: ____________________

Team Name: ____________________

VIDEO CRITERIA AND VIDEO RUBRIC

Video Criteria

Video submissions showcase your prototype, the process from initial design to final solution, and should include the following information:

1. Teams MUST use the following script to introduce their video:
    a. "This is team (team name) and we worked on the 'Design a Crew Exploration Vehicle' challenge. The title of our video is _______________."
    b. Do not identify the name of any student, teacher, school, group, city, or region in your video. Submissions that do not follow these directions will be disqualified.
1. Introduce special features and unique qualities of your design.
2. Discuss the results of tests from Step 6 and modifications made to improve the device from Step 8 for each design iteration.
3. Based on your results and modifications, explain your best design solution from Step 4. Be sure to give reasons for your choice.
4. Include photos or a video of a summary of your work including drawings of your design, key measurements, and how the prototype was built and tested.
5. Identify any information provided by NASA SMEs that helped you in your design or testing.
6. Explain which characteristics of your design provided the most reliable results and why.
7. Based on your results and the modifications you recorded in Step 7, include advice for the engineers working on this project in the future.
8. The total length of video should be three to five minutes.

The following Video Rubric will be used by evaluators to review and score each submitted video based on the above criteria and presentation style:

Video Rubric

Student Name: ___________________ **Team Name**___________________

This rubric can be used to review and assess the quality of each video. Each category will be scored 0-3 points. Totals for each column will be added for a final score.

Category	Best = 3 points	Better = 2 points	Good = 1 point	Missing = 0 points
Introduction Statement	Special features are clearly stated with additional words and/or images.	Special features are stated but no additional images are included.	Special feature statement is incomplete.	No statement is included.
Drawings	A detailed drawing of the final design and detailed drawings of each iteration are included.	A detailed drawing of the final design is included but not other iterations.	Rough drawings of the final design or other iterations are included.	No drawings are included.
Engineering design process	All EDP phases are mentioned.	More than four elements of the EDP are mentioned.	At least one element of the EDP is mentioned.	The EDP is not mentioned.
NASA subject matter expert (SME) comments	Interactions with NASA engineers and scientists are discussed and show how the feedback was incorporated into design or testing.	Interactions with NASA engineers and scientists are discussed and gives details about the feedback they provided.	Interactions with NASA engineers and scientists are discussed in only general terms.	NASA engineers and scientists interactions are not mentioned.
Video criteria	All criteria are addressed thoroughly and thoughtfully.	Criteria are addressed.	Some criteria are addressed.	Criteria are not addressed.
Photos or video	Video of the build and test phases are included with additional still shots added.	The build and test phases are included in the photos and video.	Only the build *or* only the test phase is included in the photos and video.	Photos and video showing the build or test phases are not included.
Column score				

Total Score: ______________________

STEP 1: IDENTIFY THE NEED OR PROBLEM

The Challenge:
NASA needs a new vehicle to take astronauts to the Moon because the Space Shuttle was never designed to leave the Earth's orbit. NASA and its industry partners are working on a space vehicle that will take astronauts to the Moon, Mars, and beyond. This type of spacecraft is called a Crew Exploration Vehicle (CEV), and is designed to transport human crews beyond low-Earth orbit and back again.

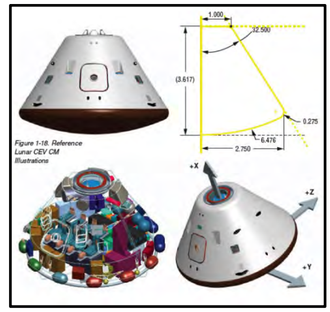


Figure 1-18. Reference Lunar CEV CM Illustrations

In this Engineering Design Challenge, you must design a CEV to safely carry two astronauts through a series of landing trials. The CEV must fit inside the designated size constraint, weigh no more than 100 grams, and carry two astronauts, each measuring two centimeters in length. You must design and build seats to secure the astronauts without gluing or taping them in place. The astronauts should stay in their seats during each drop test, and must be able to enter and exit the CEV through a hatch that opens and closes and is sized so that your astronauts can enter or exit easily. The hatch should be closed during all drop tests. The CEV must include a model of an internal holding tank for fuel with a volume of 30 cm^3. (Note: Your tank will not actually be filled with a liquid.)

Based on this information and the challenge introductory video, answer the following questions.

1. Using your own words, restate the problem in the form of "How can I design a ____________ that will ____________?" Be sure to include all expected criteria and constraints.

____

____

____

____

2. What general scientific concepts do you and your team need to consider before you begin solving this need or problem?

____

____

STEP 2: RESEARCH THE NEED OR PROBLEM

Conduct research to answer the following questions related to the challenge problem. Cite where you found your information on the Source(s) line below.

1. Who is currently working on this or a similar problem today? What solutions have they created or are working on currently?

Source(s):

2. What questions would you ask an expert who is currently trying to solve problems like this one?

3. Who in our society will benefit from this problem being solved? How could this relate to everyday use?

Source(s):

4. What are some innovative options for using the materials that are available to solve this challenge?

Source(s):

STEP 3: DEVELOP POSSIBLE SOLUTIONS

Sketch your Crew Exploration Vehicle (CEV) in the space below and label each part of your drawing. Consider the following questions when brainstorming your ideas:

What shape do you think the CEV should be?
What features would your design have?
What materials could you use to design your CEV?
Are all the criteria and constraints being met by these ideas?

STEP 4: SELECT THE BEST POSSIBLE SOLUTION(S)

Work with your team to analyze each person's final drawing using the table below. Based on the team's discussions, determine which design will be used to solve the problem, and what features will be included to create your team's prototype.

Design # Designer name	Does this design meet all problem criteria and constraints?	What are the strongest elements of this design?	What elements need to be improved?
1.			
2			
3			
4			

STEP 5: CONSTRUCT A PROTOTYPE

1. Make a final drawing of your prototype and have it approved by your facilitator.

Approved by: ____________________________________

What are the resources that will need to be gathered?

____

____

____

____

Who in the group is doing what?

Team member				
Responsibilities in the building process?				

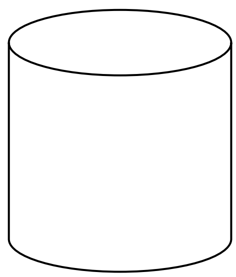
STEP 6: TEST AND EVALUATE THE SOLUTION(S)

Work with your team to complete the table below. Be sure to record the data from each of your trials.

Vehicle components	Use	Measurement or calculation
Astronauts	Crew	Mass: _________ grams each _________ grams total
CEV	Carries crew to Moon	Mass: _________ grams
Hatch	Allows entry and exit	Dimensions _________ cm (long) by _________ cm (wide)
Internal tank	Stores liquid fuel	Mass: _________ grams Volume: _________ cm^3
Size constraint ____________	Tests size constraints	Volume: _________ cm^3

How to calculate the volume of a cylinder:

$V = \pi r^2 h$



1. Find the radius of the circle found at the top and bottom of the cylinder. The radius (r) is half of the measurement of the diameter of the circle.
2. Square the radius value and multiply it by pi (π).
3. Determine the height (h) of your cylinder and multiply it by the value found in Step #2.

Drop your CEV model from three different heights: one meter, two meters, and three meters. The drop height is the independent variable of this experiment. Record a dependent variable from each drop, noting the results of the drop. For example, the number of astronauts that stayed in their seats during the drop is a dependent variable because its results are dependent upon the height of the drop.

CEV Drop Test Table

Independent variable drop height	Dependent variable(s)
1 Meter	
2 Meters	
3 Meters	

STEP 7: COMMUNICATE THE SOLUTION(S)

It is not enough to simply produce raw data. Scientists and engineers need to interpret the data so that they can convince others that their results are meaningful. This step will help you summarize how your design changed through multiple iterations of the engineering design process. Start by filling out the table about your initial prototype.

Iteration #	What are the key components to your initial prototype?	What do you think caused the design to succeed or fail during testing and why do you think that?
1		

All modifications to your design, both major overhauls and minor tweaks, should be recorded below to track the changes made. After every phase of tests, complete the chart below by describing changes and summarizing what results the testing showed.

Iteration #	What was added, removed, or changed in this iteration of your design?	What do you think caused the design to succeed or fail during testing and why do you think that?
2		
3		
4		
5		

STEP 8: REDESIGN

Did this iteration of your design meet all of the constraints of the original problem? ____________

What problem(s) did you discover while testing this iteration?

What will you do to try to improve your design based on this data?

How do you predict that these changes will improve over the iteration you just tested?

STUDENT DEBRIEFING QUESTIONS

Engage the students in a discussion by reviewing all of the data and posing the following questions:

1. What were the greatest challenges for your team today?

2. What strategies did your team prove effective in overcoming your greatest challenge?

3. How did you use the Engineering Design Process to help with your design?

4. Why was it important that the hatch stay closed during the drop tests?

7. What obstacles would an actual CEV endure? How would this influence the seat design?

5. Would you like to be a passenger in your CEV? Why or why not?

BUDGET PLANNING WORKSHEET

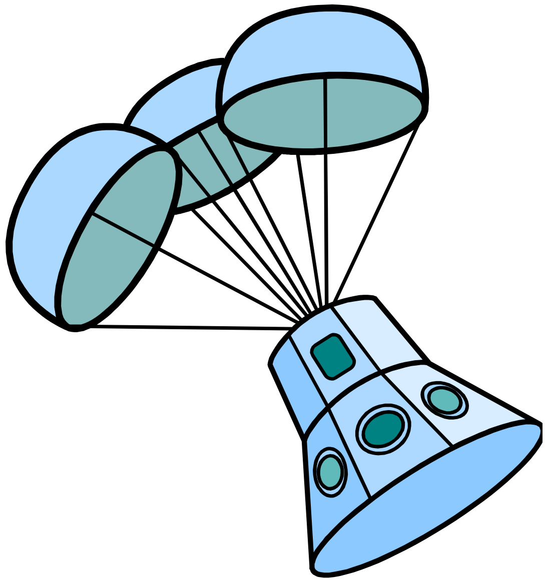
Team Name: ___________________

Directions: As a team, complete the cost sheet below. Be sure to include all of the materials that are needed, quantity, unit cost (determined by your facilitator), and the final total to complete your design. Try to use the least amount of materials to keep the cost of your design low.

Line Item Number	Material	Unit Cost	Quantity	Item Total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

TOTAL COST ____________

SUPPORT MATERIALS



NASA RESOURCES

Videos

https://www.youtube.com/watch?v=SYNDx4blJK8 – NASA Now: Technology and Design -- Orion
https://www.youtube.com/watch?v=_7o13jyXKyg – Orion Water Landing Drop Test - Nov. 8, 2011
https://www.youtube.com/watch?v=DkhRoc-Wpdg – Orion Flight Test
https://www.youtube.com/watch?v=OH0vBtPbZ7M – Orion Exploration Mission-1 Animation
http://education.ssc.nasa.gov/video/mvw/introduction_mvw.mp4 – Mass vs Weight
https://www.youtube.com/watch?v=lohpORgOKVU – Volume and Mass

Websites

Orion Multi-purpose Crew Vehicle – http://www.nasa.gov/exploration/systems/orion
Space Launch System – http://www.nasa.gov/exploration/systems/sls

http://spaceplace.nasa.gov/mars-adventure/en/
For more information and to access the Help Desk, visit the 21CCLC NASA STEM Challenge website at http://y4y.ed.gov/stemchallenge/nasa

EXTENSION ACTIVITY

YOU BE THE TEACHER!

During this challenge, you designed and built a Crew Exploration Vehicle (CEV) model to carry astronauts to the Moon. While at home, see what you can learn about satellites and rockets that are launched into orbit.

Sending humans back to the Moon is a highly debated subject amongst leading scientists, engineers, politicians, and the public. Try hosting a family discussion about this topic. Use these questions as a guide:

1. Do you believe we should send humans back to the Moon? Why or why not?

2. Would you want to go to the Moon?

3. What might be some of the dangers for humans in a new CEV?

4. What is the most dangerous part of the journey to Mars?

GLOSSARY OF TERMS

Aerodynamics – the qualities of an object that affect how easily it is able to move through the air

Capsule – a pressurized modular compartment of an aircraft or spacecraft, one designed to accommodate a crew or to be ejected

Cargo – freight carried by an aircraft or other transportation vehicle

Constraints – the limits placed on the design due to available resources and environment

Criteria – standards by which something may be judged or decided

Dependent variable – a value that is determined based on the values of other traits

Descent – the downward incline or passage of an object

Dimension – a physical property of a mass, length, time, or a combination of any or all

Exploration – the act of systemically investigating an objective for the purpose of discovery

Fragile – easily broken or damaged

Gravity – the force that attracts a body toward the center of the earth, or toward any other physical body having mass

Hatch – an opening in a deck of a ship or in an aircraft, spaceship commonly called the door

Independent variable – a value that is determined without support by other traits

Inferring – to conclude from evidence rather than from definitive statement of fact

Internal – relating to or situated within the limits or surface of something

Iteration – one cycle of a repetitive process

Landing pad – a site for landing an aircraft

Launcher – a device for firing rockets

Mass – a unified body of matter without any specific shape

Model – a small object, usually built to scale, that represents another larger object

Observation – the act of noting and recording something with an instrument

Orbit – the path of a celestial body or artificial satellite as it revolves around another object

Prediction – the act of attempting to tell beforehand what will happen

Payload – things carried by a spacecraft

Robotics – the study and application of a mechanical device that works automatically or by remote control

Supersonic – traveling at a speed that is greater than the speed of sound

Template – a pattern used to guide in making something accurately

Thrust – force that opposes gravity

Volume – is the quantity of three-dimensional space enclosed by some closed boundary, for example, the space that a substance (solid, liquid, gas, or plasma) or shape occupies or contains

Weight – the force on an object due to gravity

"The most important thing we can do
is inspire young minds and to advance the kind of science, math and technology education that will help youngsters take us to the next phase of space travel."

Senator John H. Glenn, Jr.,
NASA Astronaut and United States Senator

National Aeronautics and Space Administration

John H. Glenn Research Center
21000 Brookpark Road
Cleveland, OH 44135

www.nasa.gov

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