NASA Exploring Space Challenges, where today's students are tomorrow's explorers.
Encourage students to create, design, research and use technology at
http://esc.nasa.gov.

Mission: Habitat Moon - Design your own CELSS

Grade Levels: 6-8, 9-12

Focus Question: Can you design an experiment to test the variables necessary to sustain life within a **C**losed **E**cological **L**ife **S**upport **S**ystems (CELSS)?

Instructional Objectives:

1. Students will demonstrate knowledge of understanding of enclosed ecosystems.
2. Students will demonstrate knowledge of the requirements to sustain life in deep space.
3. Students will demonstrate knowledge of water, nutrient and/or carbon cycles.
4. Students will demonstrate understanding of scientific principles behind living and working in space.
5. Students will provide a final project and oral presentation of their work.

National Standards for grades 6 - 8:

Science as Inquiry, Science and Technology, History and Nature of Science:

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry
- Understanding about science and technology
- Abilities of technological design
- Science as a human endeavor

Life Science:

- Regulation and Behavior (i.e. Regulation of an organism's internal environment involves sensing the internal environment and changing physiological activities to keep conditions within the range required to survive.)
- Populations and ecosystems (i.e. For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.)

Mathematics:

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
- Understand measurable attributes of objects and the units, systems, and processes of measurement. Develop and evaluate inferences and predictions that are based on data.

- Apply appropriate techniques, tools, and formulas to determine measurements.

Technology:

(from International Society for Technology in Education):

- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications and produce other creative works.
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.
- Use content-specific tools, software, and simulations (e.g., environmental probes, graphing calculators, exploratory environments Web tools) to support learning and research.

(from International Technology Educators Association)

- Attributes of design (e.g. Design is a creative process; Designs need to be refined)
- Engineering design (e.g. Models; Influence of personal characteristics)
- Information and communications technologies.

National Standards for grades 9 - 12:

Science as Inquiry, Science and Technology, History and Nature of Science:

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry
- Understanding about science and technology
- Abilities of technological design
- Science as a human endeavor

Life Science:

- Matter, energy and organization in living systems (e.g. Living systems require a continuous input of energy to maintain their chemical and physical organizations.)
- Behavior of organisms (e.g. Organisms have behavioral responses to internal changes and to external stimuli)

Earth and Space Science:

- Energy in the Earth system (e.g. Global climate is determined by energy transfer from the sun at and near the Earth's surface.)
- Geochemical cycles (e.g. Movement of matter between reservoirs is driven by Earth's internal and external sources of energy.)

Mathematics:

- Understand measurable attributes of objects and the units, systems, and processes of measurement. Develop and evaluate inferences and predictions that are based on data.
- Apply appropriate techniques, tools, and formulas to determine measurements.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them (i.e. Understand the meaning of measurement data and categorical data, of univariate and bivariate data, and of the term variable;

understand histograms, parallel box plots, and scatterplots and use them to display data)

- Develop and evaluate inferences and predictions that are based on data (i.e. evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis, and the validity of conclusions)

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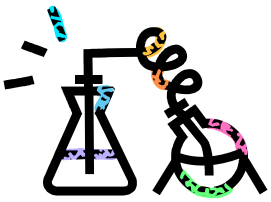

INTRODUCTION

Within the next decade, humans will once again return to the Moon. The ultimate goal is to build a base to live and work on the Moon. To do this, the lunar base must be self-sufficient: to recycle its own materials and grow its own food. The first inhabitants of this lunar base will be engineers and scientists. The engineers will design and construct the enclosed habitat, as well as monitor its maintenance. Meanwhile, scientists will research the Moon and how life can be sustained in this remote environment.

CELSS stands for **C**losed **E**cological **L**ife **S**upport **S**ystems. Years of research have been devoted to studying enclosed biological systems for the exact purpose that we, as humans, may one day live outside of Earth's atmosphere and into deep space. The NASA CELSS Breadboard Project began in 1986 to study the growth of crops in environmentally controlled chambers to optimize food productivity. Food crops such as wheat, soybeans, potatoes, sweet potatoes, strawberries, rice, peanuts, and radishes have all been tested and continue to be tested upon. These experiments will eventually be repeated at the lunar base in hopes to discover which crops perform best to help sustain human life on the Moon. But plants have not been the only biological form tested in a CELSS. A varying amount of aquatic species have also been tested. For example, algae is grown to determine its value to the recycling of carbon dioxide. And think one step further, if there is fish farming here on Earth, couldn't there be fish farming on the Moon?

Imagine if you were to become one of those NASA engineers or scientists to inhabit that first lunar base. Your mission is to design your own enclosed system and the experiment you would test within in it. Don't limit yourself to just food crops. Think about studying krill, or plankton, which will ultimately be the food source for future aquaculture.

Students must work in teams of two, with each group creating their own CELSS and experiment to be conducted within that closed system. Students then have 6-8 weeks to complete their project. The school or class then hosts a local challenge where student teams present their design and research. Student teams who score highest in their local challenges have the opportunity to then present their projects to a NASA panel of judges through the Digital Learning Network.

Special Note: This Challenge was designed to supplement NASA's STS-118 Engineering Design Challenge, aka "Lunar Plant Growth Chamber Challenge":

http://www.nasa.gov/audience/foreducators/plantgrowth/home/index.html.

You will not receive basil seeds from the ESC Project Office if you choose to register for the Habitat Moon Challenge. You must register for the STS-118 Engineering Design Challenge separately and complete its evaluation to receive your seeds. However, all activities conducted within this Challenge can be easily applied to the STS-118 Design Challenge and vice-versa. We strongly encourage teachers to review ITEA's teacher guides to the NASA Engineering Design Challenge and utilize the lessons and activities within.

CHALLENGE REQUIREMENTS

Pre-Challenge Requirements

1. **Online Teacher Registration.** Teachers must register their class via email to nasa-esc@nasa.gov and include the school's name and contact information, the approximate number of participating students and their grade level.
2. **Pre-assessment.** This is an optional activity. Please utilize the assessment questions within the STS-118 Engineering Design Challenge Guides with your students. (*Moon Munchies*, page 8; *Packing up for the Moon*, page 6; *Lunar Plant Growth Chamber*, page 7 – see link on page 4.)
3. **Complete a Pre-Challenge Activity.**
    - Review Unit 3 of NASA's *Exploring the Moon Resource Guide*, pages 99-140. (designed for grades 6-8, but a good source for 9-12 as well)
    - Hold a class discussion on the requirements for sustaining life. See page 13 for this activity.
    - Research some experiments NASA has performed in space:
        i. http://www.nasa.gov/centers/ames/news/releases/2002/02_34AR_prt.htm
        ii. http://www.nasa.gov/audience/forstudents/9-12/features/spacescents_feature.html

Objective One

- **Participate in a Habitat Moon Challenge kick-off event.** Sign your class up to talk with a NASA scientist or educator about this Challenge through NASA's Digital Learning Network. Contact the GSFC DLN Coordinator to schedule your event during the week of September 10.[1]
    a. Students will watch a recording of the launch of STS-118 and a message from Barbara Morgan, the educator astronaut that participated in the 118 Shuttle mission.
    b. Students will learn why NASA is returning to the Moon after 35 years.
    c. Students will be assigned their mission for this Challenge and will be allowed time to ask questions about the Challenge.

Objective Two

- **Design a sustainable habitat.** Students are to divide into teams of two. Designate team member roles. One member of your team is your engineer, who must design the closed chamber per the requirements of the scientist's experiment. Draw your design and get it approved before you build.
- **Design an experiment for the closed chamber.** The scientist of your team must then ask a question, create a hypothesis, and determine the method of the experiment to be contained within the closed chamber the engineer designed.

[1] This event can be made available as a webcast for those schools unable to connect via videoconference.

Objective Three

- **Submit a proposal to NASA.** Get feedback from NASA! Send a short proposal to NASA via your teacher's email.
    a. The proposal should be 500 words or less.
    b. Describe your experimental set-up, your hypothesis and the method you plan to implement. What type of organism are you using? What biological factor are you testing – growth, rate of respiration, survivability? Then decide on a physical variable for your experiment: Are you testing the effects of temperature, humidity, light, nutrient levels or something else?

Objective Four

- **Collect data!** Work as a team to build the enclosed chamber and begin your experiment. You have four to six weeks to collect data. Make sure to keep a detailed data log. Track the changes that occur within your system. Is condensation building up inside? Is it staying warm or is the temperature varying? How much light does it receive each day? Are their any "side effects" happening inside your chamber you didn't expect?

Objective Five

- **Present your work.** All scientists and engineers must communicate to others about the data they acquired. Describe the variables you tested and the results those variables produced. Part of your mission is to present your work to your fellow classmates!
    a. Students must prepare an oral presentation about their design process, the experiment and the final results. Your oral presentation should be *no longer than ten minutes.*
    b. Prepare an electronic presentation to accompany your oral report. Providing visual aids to assist your presentation is a must. Make sure to include pictures of your experimental set-up and include charts or tables that illustrate your data.
    c. Teachers must arrange a local Habitat Moon Challenge in their class or school. Student teams give an oral presentation about their project to a panel of judges. Team with highest score is recommended to NASA ESC for participation in the Regional/National Challenge.

Post-Challenge Requirements

1. **Online submission of students' presentations.** Teachers can submit the winning team's electronic presentations[2] by email to nasa-esc@nasa.gov.
2. **Post-assessment.** This is an optional activity. Please utilize the assessment questions within the STS-118 Engineering Design Challenge Guides with your students. (*Moon Munchies*, page 8; *Packing up for the Moon*, page 6; *Lunar Plant Growth Chamber*, page 7.) When complete, please submit both pre and post responses to the ESC Project Office.
3. **Regional/National Habitat Moon Challenge.** Winning teams of local challenges will present their projects via the NASA DLN[3].
4. **Certificate of participation.** Each team and their teacher that participates in the National/Regional Challenge will receive a certificate. Upon request, teachers can be sent a certificate template to complete and distribute to students that participated in the Local Challenge.

[2] If file is too big to submit as an email attachment, teachers must request a password via email to an ftp site to upload the file.

[3] If videoconferencing is not possible, then we recommend the presentation to be filmed, converted to a QuickTime file and mailed on CD or DVD to the NASA ESC Project Office.

2007 CHALLENGE TIMELINE

Date:	Event:	Notes
August 6 – September 30	Registration	Teachers must register their class by sending an email to nasa-esc@nasa.gov
September 10 - 14	Habitat Moon DLN Kick-Off Event	Schedule a time with the GSFC DLN Coordinator to participate in this event.
September 21	Student proposals due	Teachers submit their students' proposals via email.
November 16	Local Challenge	Each school must host its own local Challenge by this date.
December 10 - 11	National Challenge	One team from each school is selected to present their project to a panel of NASA scientists and engineers.

GENERAL RULES AND REGULATIONS FOR NASA ESC

1. All participants must successfully register online.

2. Participation is restricted to students and teachers attending U.S. Schools (this includes U.S. possessions and schools operated by the U.S. for the children of American personnel overseas).

3. Teachers or administrators must register his/her students[a] by emailing nasa-esc@nasa.gov. Include teacher name, school name, school address, number of students participating, grade level, and email address.

4. There is no limit to the number of student participants from each school.

5. Only students whose names have been submitted through his/her teacher's registration will be allowed to submit entries to the NASA ESC Challenges.

6. All schools must have access to the internet in order to participate in a NASA ESC Challenge or NASA DLN event.

7. All entries are evaluated according to the published rubrics and requirements for each respective challenge. Judges' decisions are final.

8. Each registered student/class/school must submit separate entries for their respective challenge.

9. Each document submitted to the NASA ESC project office must include the student last name, or the school's name and the challenge abbreviation in the title of the document. Please see the following examples:

Challenge	Example
Habitat Moon	YourName_HM.ppt
Moon Math	YourName_MM.ppt
Hurricanes	YourName_Hurr.doc
Teacher Challenge	YourName_TC.doc

10. All work submitted to the NASA ESC challenge's must be original and free from copyright.

11. NASA maintains the right to accept or reject any submitted work. All entries become the property of NASA and the Exploring Space Challenges.

12. Final documents for each respective challenge must be electronically submitted by their deadlines, deadlines, as follows:

Challenge	Deadline	Documents
Habitat Moon	November 16, 2007	Slide presentation
Moon Math	November, 30, 2007	Slide presentation and report
Hurricanes!	November 2, 2007	Character story
Teacher Challenge	January 4, 2008	Proposal

If you encounter any difficulties, or have any questions please direct them to the NASA ESC project office at nasa-esc@nasa.gov.

[a] The NASA ESC Project Office understands that some students may drop out during the course of their Challenge. If such an event occurs please notify the NASA ESC Project Office. If this event leaves a team with only one student, the student remaining in the Challenge will not be penalized and may have the choice to continue with their project of his/her own or join another team. It is the teacher's responsibility to contact the NASA ESC Project Office if any changes occur in a team's participation status.

Rules for Mission: Habitat Moon! Design your own CELSS

1. This activity is intended for students in grades 6-12. If younger grade levels wish to participate, it is the responsibility of the teacher to modify this activity and rubric for that grade. Modifications must be sent to the ESC Project Office for review.

2. If necessary, grades 6-8 and 9-12 will be judged in two separate categories during the National/Regional Challenge.

3. Each *Mission: Habitat Moon* challenge team must be composed of at least two students.

4. Each team must submit a proposal to the NASA ESC. Teams will not be permitted to participate in the National Challenge if the proposal is not complete.

5. All Local Challenges must be completed by November 16th, 2007. Only one team project per class may be submitted to the National/Regional Challenge.

6. Multiple entries from one school will be permitted if more than one class or teacher participates in this activity as long as there is a corresponding registration for each submission.

7. One student team will be selected as the national winner. Each student will receive a certificate plaque and a $100 gift card. Teacher of winning team will receive a $100 credit towards purchases at NASA Core[2].

[2] NASA and the Exploring Space Challenges have the right to change any prize as resources may allow. If circumstances beyond our control necessitate the invalidation of a prize to any student, teacher, class or school, then NASA and the Exploring Space Challenges cannot be held liable.

INTERNET RESOURCES

- NASA's Engineering Design Challenge – Lunar Plant Growth Chamber.
  - http://www.nasa.gov/audience/foreducators/plantgrowth/home/index.html

- Basic Moon facts:
  - http://solarsystem.nasa.gov/planets/profile.cfm?Object=Moon

- Earth as a model - A remote base within a harsh environment completely devoted to scientific research is McMurdo Base and Palmer Station in Antarctica.
  - http://www.tamug.edu/Labb/Projects/Weddell/McM2001/McMurdo/McMurdo_2001.htm

  - http://pal.lternet.edu/

- View NASA educator guides and lithographs related to the Moon at
  - http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html

  - http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Earths_Moon_Lithograph.html

- This is an example of a hydroponics experimental set-up of varying scales:
  - http://quest.nasa.gov/smore/teachers/act3.html

Pre-Challenge Activity - Requirements to sustain life in deep space[4]

Break up into small groups within your class. Each group must then spend 10-15 minutes to create a list of requirements to *sustain life* in deep space, such as a lunar habitat. Once complete, have students reconvene and discuss the lists each group created. Ask each group to ponder: How did your group's list differ from other groups?

List should include, but not limited to:

Oxygen

Water

Food

Gravity

Magnetic Field

Communication network

Pressurized environment

Protection from harmful solar radiation

Carbon (either as carbon dioxide or other form)

Further Discussion Questions

1. How are the requirements for *sustaining life* different from the requirements *for life*?

Answer: The most important difference is reproduction. On Earth, scientists define the requirements for life to include the ability to produce offspring. This is true. However, we do not need to produce offspring if we are simply talking about sustaining life. In addition, the requirements for life may be different from organism to organism depending on what kind of environment they live in. The worms living on the ocean floor near black smokers do not need sunlight to survive, but living things at the surface of the Earth do require the Sun's energy to survive.

2. How might life be different on Earth if the ozone layer in the upper atmosphere did not exist?

Answer: The ozone filters out most of the harmful ultraviolet radiation Earth receives from the Sun. Without the ozone in our upper atmosphere, life as we know it would not exist on Earth. Even the small amounts of UV radiation that do come through to the Earth's surface can cause illness, such as skin cancer, and death to living things.

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[4] This activity was extracted from the NASA Student Observation Network's Lunar Module "Living and Working on the Moon", written by Dr. Rosemary Millham: http://www.nasa.gov/audience/foreducators/son/home/index.html.

Scoring Rubric

CATEGORY	4	3	2	1
Hypothesis Development	Independently developed a hypothesis well-substantiated by an excellent research question.	Independently developed a hypothesis somewhat substantiated by a good research question.	Independently developed a hypothesis somewhat substantiated by a fair research question.	Independently developed a hypothesis which lacks a research question.
Variables	Identified and clearly defined variables to be changed (independent variables) and which variables to be measured (dependent variables).	Identified which variables to be changed (independent variables) and which variables to be measured (dependent variables).	Only somewhat defined which variables to be changed (independent variables) and/or which to be measured (dependent variables).	Missing the independent and dependent variables of the experiment.
Description of Procedure	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations and included a full list of materials used.	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations and may or may not include a list of materials used.	Procedures were outlined in a step-by-step fashion, but had 1 or 2 gaps that require explanation and may not include a list of materials used.	Procedures that were outlined were seriously incomplete or not sequential.
Chamber Design	CELSS chamber functions extraordinarily well and appropriate materials were selected and creatively modified in ways that made them even better. Great care was taken in construction process so that the structure is neat and attractive.	CELSS chamber functions well and appropriate materials were selected as there was an attempt at creative modification to make them even better. Construction was careful and accurate for the most part, but 1-2 details could have been refined for a more attractive product.	CELSS chamber functions pretty well, but deteriorates under typical stresses. Appropriate materials were selected. Construction accurately followed the plans, but 3-4 details could have been refined for a more attractive product.	Fatal flaws in function with complete failure under typical stresses. Inappropriate materials were selected and contributed to a product that performed poorly. Construction appears careless or haphazard. Many details need refinement for a strong or attractive product.
Chart/Graph/Table	Provided an accurate, easy-to-follow data display with labels to illustrate the results from the process being studied.	Provided a somewhat accurate data display with labels to illustrate the results from the process being studied.	Provided a poor data display with or without labels to illustrate the results from the process being studied.	Did not provide a data display OR the display was quite incomplete.
Evaluation of Experiment	Experiment is thoroughly evaluated on the basis of the student's experience. Student described methods to improve experiment.	Experiment is somewhat evaluated on the basis of the student's experience. Student described only one method to improve experiment.	Experiment is loosely evaluated on the basis of the student's experience. Student did not describe methods to improve experiment.	No evaluation of experiment was provided.

Conclusion/Summary	Student provided a detailed conclusion clearly based on the data, the hypothesis statement(s), and related to NASA's efforts to sustain life in deep space.	Student provided a somewhat detailed conclusion based on the data and related to the hypothesis statement(s), and may or may not have included a description of NASA's efforts to sustain life in deep space.	Student provided a conclusion with some reference to the data and the hypothesis statement(s) and is missing a description of NASA's efforts to sustain life in deep space.	No conclusion was apparent OR important details were overlooked.
Oral Presentation	Speaks clearly at all times and is fully prepared with excellent visual aids (slide presentation). Presentation is given in logical order.	Speaks somewhat clearly and is fully prepared with good visual aids (slide presentation). Presentation is somewhat out of logical order.	Speaks unclearly and may not be fully prepared with visual aids. Presentation is out of logical order.	Oral presentation is unrehearsed and unprepared. No visual aids were used.