To the Moon, and Back

Programming and Apollo 11

From the USS Hornet Museum Education Department

Alissa Doyle, June 2018

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About This Document

Taking into account orbital shifts, gravity, and necessary changes in velocity, the Apollo 11 engineers launched astronauts to the moon, and ensured they returned safely. Students will observe the various orbits and trajectories involved in the lunar mission and model it with simple, hands-on robotics. Using Ozobots allows students to practice the basics of coding, and link the work of the Apollo engineers with the latest in STEM learning technology. Students 3rd grade through high school will engage with this program.

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Goals

In this program, students will:

- Manipulate simple robotics to express elliptical patterns
- Practice the basics of coding
- Work collaboratively to come up with creative solutions to actual engineering problems

Objectives

In this program, students will:

- Understand the different orbital trajectories present in the Apollo 11 lunar mission
- How the Apollo 11 engineers applied physics to meet the challenges of space flight

Big Questions…and Answers

How did the engineers ensure the Apollo 11 spacecraft reached the moon?

Careful calculations determined the specific changes in acceleration needed to compensate for the orbital and gravitation effects on the spacecraft. Precise construction of the spacecraft meant boosters would increase its acceleration when necessary.

How do engineers solve problems?

Engineers come up with an idea, they create it, and test its validity. They then refine their creation until the optimal solution is achieved. They record the final solution, so it may be replicated by others in the future.

Program Outline

Prerequisite-

This program was created specifically to connect the Apollo 11 lunar mission and re-entry with the modern programming mechanics of Ozobots. Purchase of a classroom set of Ozobots and the accompanying materials would be advised. Familiarity with the basic functioning of an Ozobot- both the instructor and students- is advised.

<u>Approximate Program Timeline-</u>

45 minutes total:

-Overview of Apollo mission, STEM concepts- 20-25 minutes

-Activity- 15-20 minutes

-Debrief- 5-10 minutes

<u>Suggested materials-</u>

-5-10 Ozobots, depending on classroom size

-markers with a ¼" thick tip in red, black, green, blue

-blank white paper, or butcher paper

-printout of Ozocodes; see Appendix

-printout of the diagrams illustrating the trajectories and orbits of the Apollo 11 rockets; see Appendix

-for instructor-large writing surface- whiteboard or chalkboard

First illustrate for students the difference in orbital shape created by throwing an imaginary ball around the Earth at varying speeds. The infographic in the Appendix is useful.

Discuss the concepts of velocity, gravitational pull, and Newton's First Law.

Illustrate how the lunar capsule returned the Earth. The infographic in the Appendix is useful.

Review briefly with students how Ozobot turns on, its basic functions, and how to recalibrate and when. A short demonstration may be helpful.

Divide students into groups of 3-5. Give each group an Ozobot, Ozocode sheet, calibration sheet, set of markers, paper, and elliptical infographics if desired. The infographics are simply for reference.

Challenge students to design a route for Ozobot that illustrates the Apollo 11 spacecraft's trajectory to and from the moon. While it does not have to completely replicate the actual path taken by Apollo 11, the final route should include variations in speed and curvature. Scratch paper may help some groups plan their initial design.

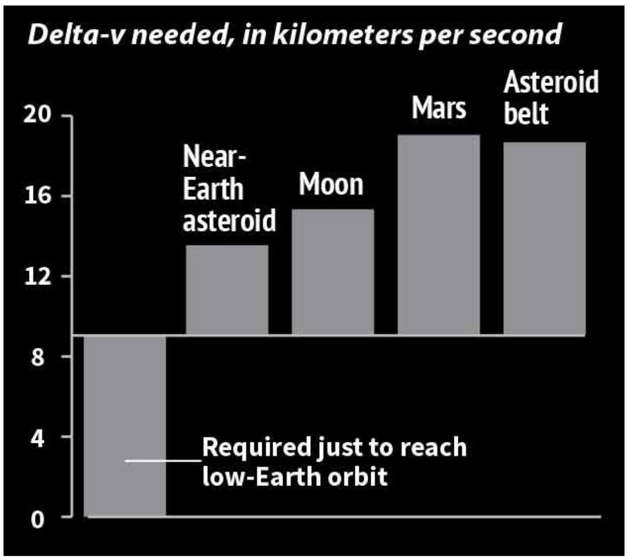
Optional- Discuss the Design Process and how engineers solve problems. They come up with an idea, they create it, and they test it out. Engineers then refine their idea until satisfied with the outcome.

If time allows- have students record their final path on a separate sheet. This links to how engineers actually work- by recording their work in a step-by-step process, their creation can be replicated by others.

Background Reference Material

Velocity- the rate of change of an object over a specified amount of time. While speed describes only how fast something is moving, velocity gives both speed and in what direction the object moves.

To simply leave Earth and get into orbit, a rocket's velocity must change at a rate of 30,500 feet per second. This is expressed at Δv, or **delta-v**.



Gravitational two body problem- motion of two particles that interact only with each other, due to gravity. The two bodies stay clear of each other, do not collide, and one body does not pass through the other's atmosphere. Even if they do, the theory still holds for the part of the orbit where they don't.

Common examples include the parts of a spaceflight where the spacecraft is not undergoing propulsion and atmospheric effects are negligible, and a single celestial body overwhelmingly dominates the gravitational influence.

Newton's 1st Law- an object in motion will stay in motion unless an outside force acts upon it. In the absence of any forces, a moving object tends to move along a straight line path indefinitely.

Objects in space remain traveling at whatever speed they were going when they stopped accelerating. If the astronauts turned off the boosters prior to achieving 35,000 feet per second, the spacecraft would eventually fall back to Earth. Once launched with enough speed to escape the Earth's orbit, a spacecraft still needs to use its rockets to enter an orbit about the moon.

Next Generation Science Standards

Grade Level	Standards
3-5	*Engineering Design:* 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
5	*Space Systems- Stars and the Solar System:* 5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.
6-8	*Space Systems:* MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. MS-ESS1-2 Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system. *Engineering Design:*

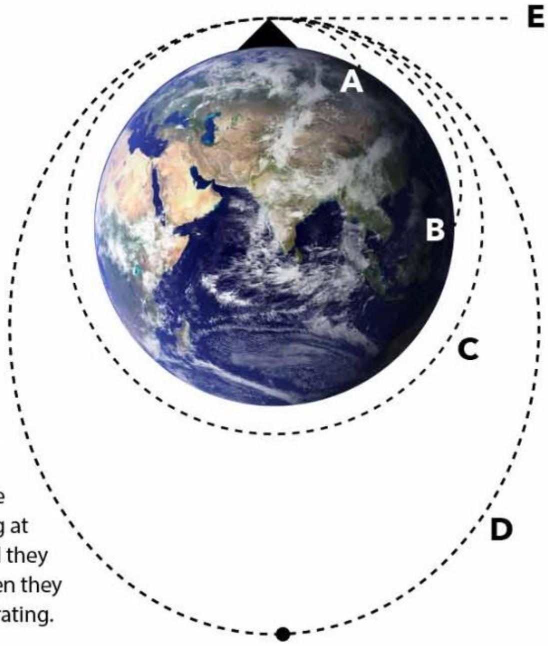
	MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
9-12	*Space Systems:* HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. *Forces and Interactions:* HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Appendix: Reference Materials

Link for Ozocodes: https://files.ozobot.com/stem-education/ozobot-ozocodes-reference.pdf

Elliptical and orbit diagrams:

Imagine throwing a ball off of a high mountain. The **Earth's gravity** will pull the ball down to the ground.

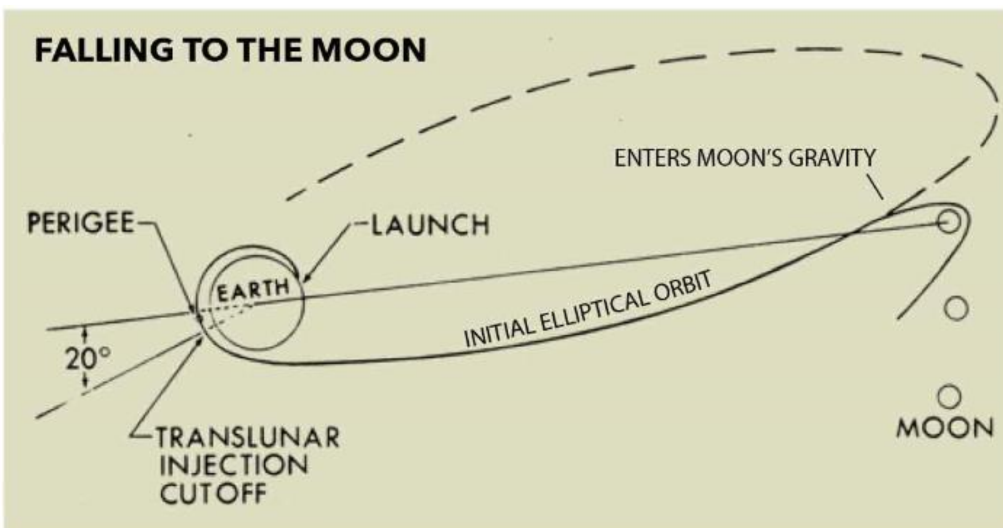


If the ball could be thrown at 24,000 feet per second (7,300 meters per second), it would fall continuously around the curve of the Earth (C in the diagram). This is a **circular orbit**.

If the ball is thrown faster, it continues to gain altitude and will be in an **elliptical orbit** (D).

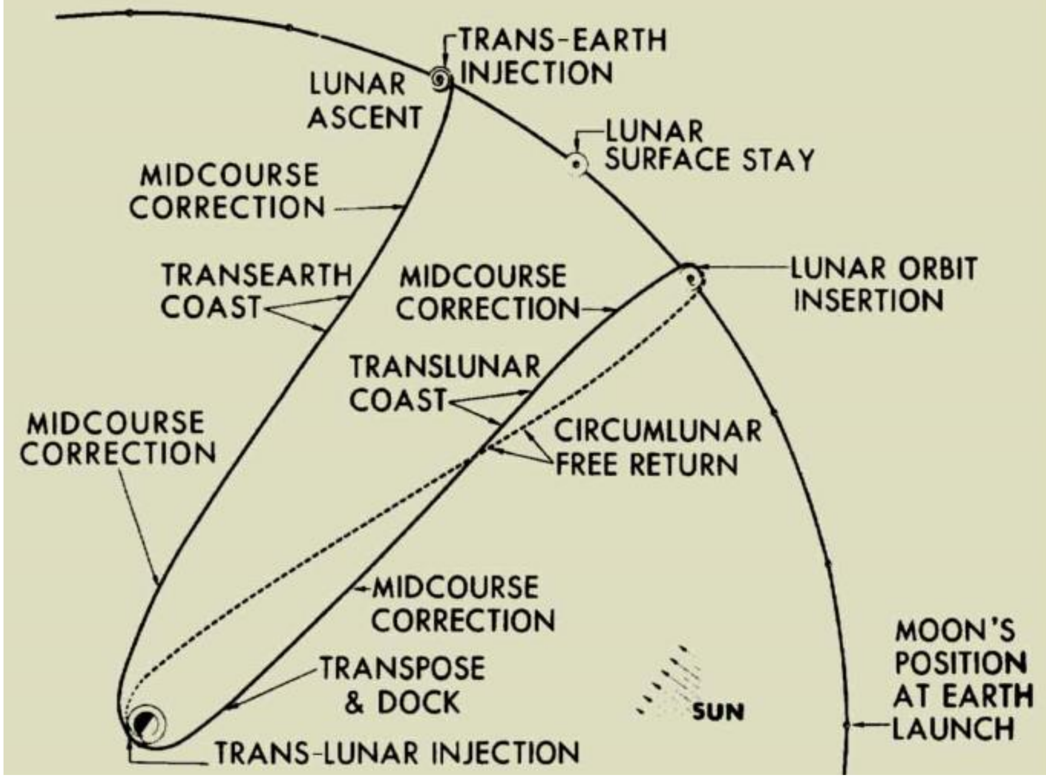
A ball launched really fast – about 36,745 feet/s (11,200 m/s) – is said to have achieved **escape velocity** (E). The ball is no longer in orbit around Earth, but it will still be orbiting the sun.

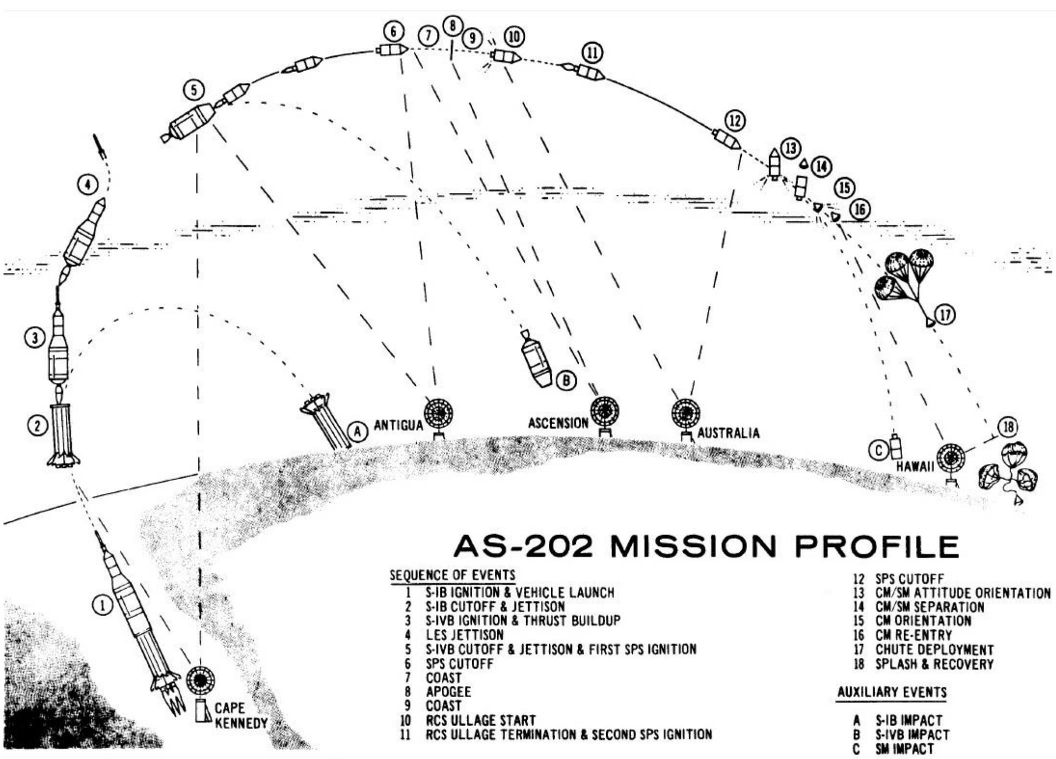
Once in orbit, the rockets can be turned off. Objects in space remain traveling at whatever speed they were going when they stopped accelerating.



Going to the moon requires getting into a high elliptical orbit (dashed line in diagram). A speed of 35,505 feet/s (10,822 m/s) must be achieved when the booster engine is shut down. If nothing else were done, Apollo 11 would pass behind the moon and then fall back to Earth (a "free return" trajectory). Instead, firing a rocket engine firings puts Apollo into orbit around the moon.

To get back from the moon, a rocket is fired to get out of lunar orbit. This is called the "trans-earth injection" maneuver.





Links and Credits

Additional Ozobot lessons: https://ozobot.com/stem-education

Infographics from: https://www.space.com/26572-how-it-worked-the-apollo-spacecraft-infographic.html

This program was created in conjunction with a grant from the Office of Naval Research. It expands upon ideas found in the following lesson: https://storage.googleapis.com/ozobot-lesson-library/eclipses-celestial-mechanics/eclipses-celestial-mechanics.pdf