T.A.G. Lesson
Advanced Programming Challenge with EV3

Objectives

Students Will:

- Research and receive background knowledge on asteroids, specifically Bennu.
- Engineer a device that will be able to travel autonomously down and retract back to start position using Lego EV3 Mindstorms® bricks (or "junk engineer" as an alternative).
- Program their device to "Touch and Go" on a simulated surface of Bennu and collect an asteroid sample in one try.

Suggested Grade Level

6^{th} – 12^{th}

Subject Areas

Engineering, science

Timeline

60 minutes

Standards

NGSS Standards

- 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-ETS1-4. 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.
- HS-ESS1-6. Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.
- HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

- HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

21st Century Essential Skills

- Critical thinking/Problem solving
- Collaboration and Teamwork
- Technology literacy
- Obtaining/evaluating/communicating ideas

Background

Asteroids can be found all throughout our galaxy, in all different shapes and sizes. No two asteroids are the same because they are formed from different locations, different distances from the sun and different kinds of rocks. There are two asteroid belts in our solar system: one between Mars and Jupiter, and another between Neptune and Pluto. There's much debate when classifying Ceres and Pluto as a dwarf planet or asteroid. The larger asteroids are sometimes called minor planets or planetoids, since the composition is similar to that of a rocky planet, like Earth.

Sometimes, asteroids get a little crazy, and follow a different orbit, where it can fall into Earth's atmosphere. When that happens, it's called a meteor. If the meteor is able to travel past Earth's atmosphere and land on the surface, it's considered a meteorite. Scientists study asteroids and meteorites because it can give us information on how the solar system was formed. Asteroids were formed at the same time as the planets. NASA has sent several spacecrafts to study asteroids near Earth and in the asteroid belt. They were able to get images of these space rocks.

One asteroid in particular, Bennu, has significant, scientific importance. It has a fast rotation, low gravity, a tilt of 176 degrees, numerous boulders, and is about the size of the Empire State Building. It is believed that this primitive asteroid has prebiotic molecules that could be linked to hydrated carbonaceous chondrites, the key ingredients to make organic chemicals, amino acids and water. This information could be the key to understanding how our solar system was formed. To better research this asteroid, NASA sent Osiris-Rex, a specialized satellite in 2016, to orbit Bennu and collect a sample of the asteroid. It took two years to travel there! It mapped out the asteroid, calculated its mass and took many images. This spacecraft also set a world (universe) record by getting 680 meters above Bennu's surface, the closest orbit of any planetary body! In 2020, NASA plans to collect samples of the asteroid and return back in 2023.

During this seven-year mission, Osiris-Rex has taken extensive images of Bennu. NASA discovered that particles are being ejected from Bennu into space. These pictures also

allowed NASA to map Bennu's terrain. Due to its small size, there is a small number of hazard-free areas where it is possible to land and collect samples. NASA has enlisted the help of the public to count boulders and select possible landing sites using an interactive website (bennu.cosmoquest.org). Due to the small number of safe landing sites, NASA decided to utilize a "Touch and Go" or TAG sampling maneuver to collect loose regolith from the asteroid. This maneuver requires an arm to extend out, touch the asteroid with minimal tilt and retract back to Osiris-Rex. Then, the arm rotates to place the sample back into the satellite to return back to Earth in 2023.

This lesson will focus on simulating the robotic arm on Osiris-Rex. Students will engineer and program an arm using Lego Mindstorms EV3® robotics to "touch" the dusty terrain, collect it and "go" back to the satellite. They will only get one chance to perform this task. Students with a background in programming will have an increased chance of success.

Vocabulary

Asteroid, meteor, meteorite, prebiotic molecules, chondrites, regolith, daisy-chain, master and slave bricks

Materials

- 2 Lego EV3® bricks, two touch sensors, connectors and compatible Lego building bricks - per group
- String the same length as the connectors – per group
- 1 Hand-held device (i.e. iPad) with Lego Mindstorms Education EV3® application already downloaded - per group
- Very sticky tape – 1 roll per group
- Pictures of different asteroids and Bennu
- AV in the classroom to display internet to the whole class (optional)

Lesson

1. Introduce lesson by talking about asteroids. Explain what they are, where they can be found and how it is important to space history (see background information). Display photos of different asteroids.
2. Explain to the class that we're going to focus on Bennu, an asteroid named after an Egyptian mythological bird, and the satellite, Osiris-Rex, that will be monitoring it (see background information).
3. Show photos of Bennu. If you have the ability to display the internet to the whole class, post this link: bennu.cosmoquest.org. (This step is optional, as it requires the user to create a login. An alternative would be for the teacher to create a login and

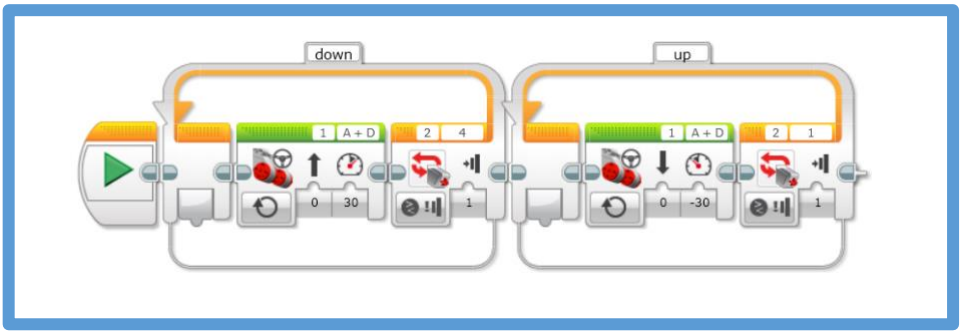
perform this step as a whole class). Explain to students that NASA needs their help finding a collection site for Osiris-Rex. Using the images Osiris-Rex took, NASA needs them to help mark all the rocks. Explain to students, "NASA determines where to collect samples by examining each photo."

4. Ask students, "Since the terrain on Bennu is extremely rocky and satellites cannot safely land there, how do you think NASA will collect samples? What will this look like?" Answer: NASA is going to do a "Touch and Go" or TAG on the asteroid. That means, a robotic arm is going to extend out from the satellite, "touch" Bennu, collect a sample and retract to "go" back and deposit it into Osiris-Rex.
5. Assign the design challenge. Explain to students that since Osiris-Rex can't land on Bennu to retrieve a collection, you must devise a way for the satellite to collect a sample. Have students create a device using recycled materials (i.e. "junk engineering"). If you're using recycled materials, let students know they will need to construct a retractable arm that can "touch" the surface and bring it back to the satellite.
6. Assign the design challenge using robotics. Engineer a device using Legos Mindstorms EV3® robotics and program it to collect a sample from a suspended height above the collection site. (Students should already have experience with programming, especially with EV3s). If you are short on time, you could have this step already done for them; have students focus on the programming aspect of this lesson. If students are having difficulty with creating a device, guide them to incorporate the following:
    a. Use a daisy-chain to allow the master (lead brick) to communicate with the slave (second brick). Optional: you can have them go to youtube.com to research how to daisy-chain EV3.
    b. Place one touch sensor on the bottom of the slave brick (with very sticky tape on the sensor) and another at the top.
    c. Place two motors on the master brick.
    d. Connect the two bricks by using string. Wind up the string onto a wheel and attach it to the motors on the master brick. Tie the loose end of the string to the slave brick (see figure one).

Figure 1

7. Inform students they will only have ONE chance to collect the sample! Have students test their design before going to collect the sample. They will need to program their device to release the arm to go down autonomously, touch the sample, return back up and stop all on its own. If students are having difficulty with the programming, it should look something like this (see Figure Two):
8.

Figure 2



9. Test student's device by collecting a sample of the asteroid. Suspend student's device above the collection site (a pan full of loose, tiny rocks and sand). A successful mission would indicate a working TAG arm that touches the surface, returns back to starting position and stops all on its own.
10. Come back together as a class and analyze test results. Ask students (Answers will vary):
    a. Who had a successful mission?
    b. What worked well? What didn't work?
    c. What factors influenced your outcome?

d. How could you improve your device/programming?

Extensions

- Write a persuasive essay on why Ceres and Pluto should or should not be considered an asteroid.
- Calculate the orbital speed of Bennu. How fast will Osiris-Rex have to travel to maintain the proper distance and angle to collect another sample from the asteroid?

Resources

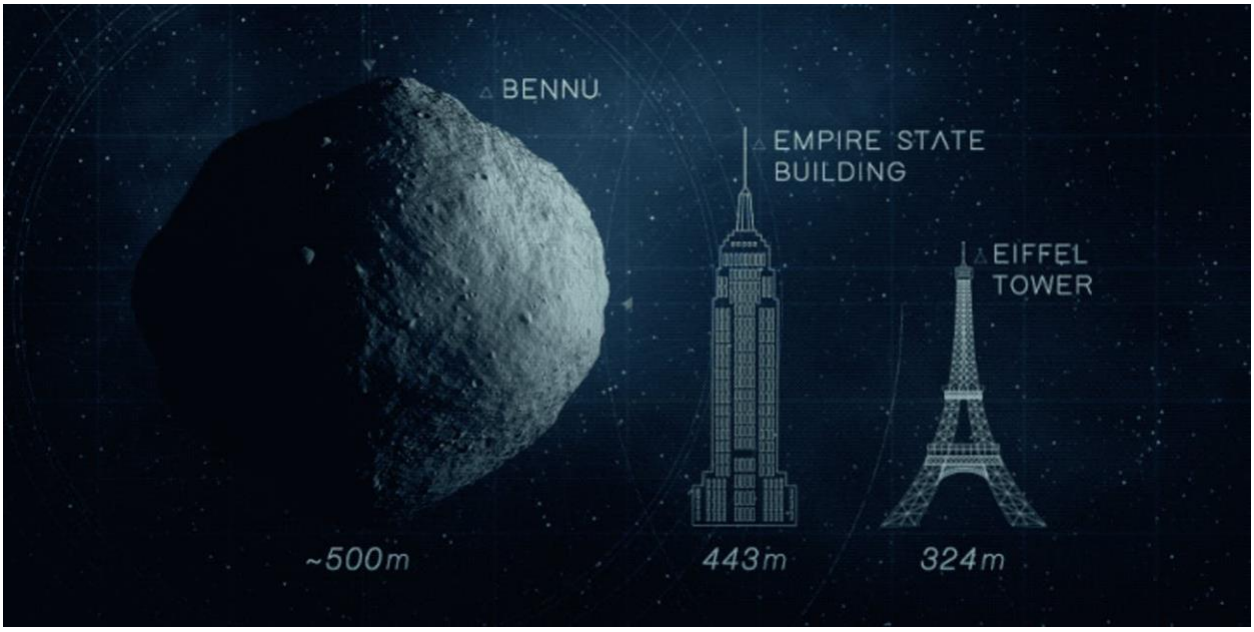
(n.d.). Retrieved from https://spaceplace.nasa.gov/asteroid/en/

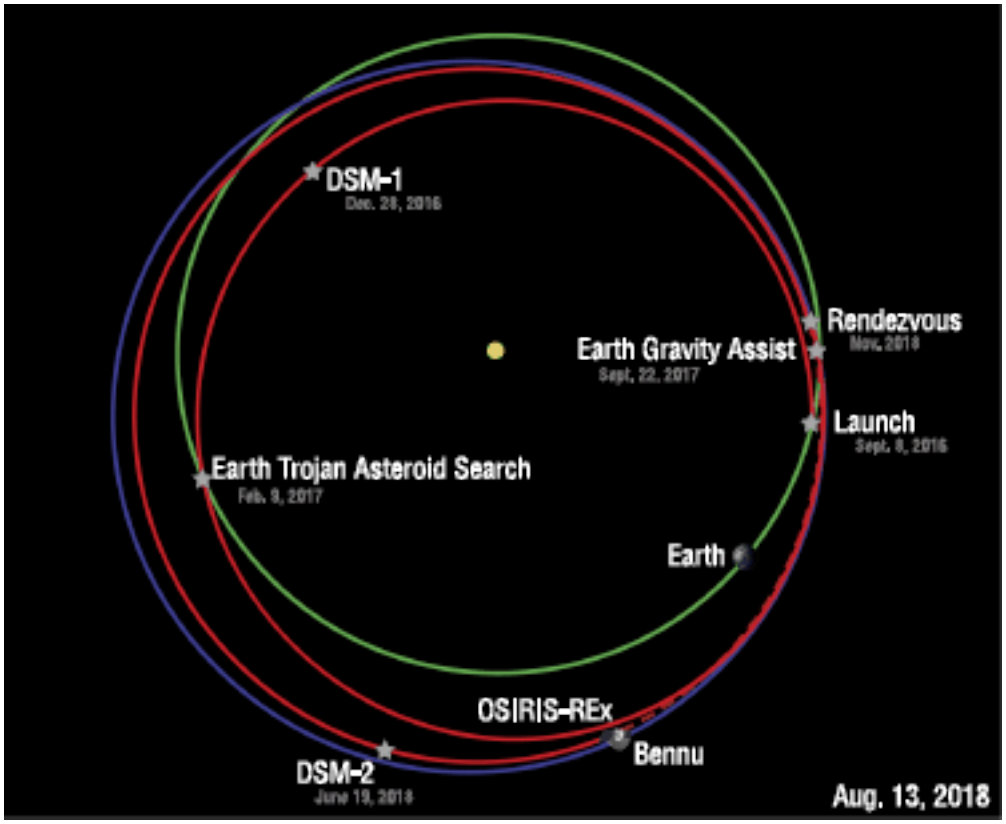
Cosmoquest CSB - Bennu Mappers. (n.d.). Retrieved from https://bennu.cosmoquest.org/

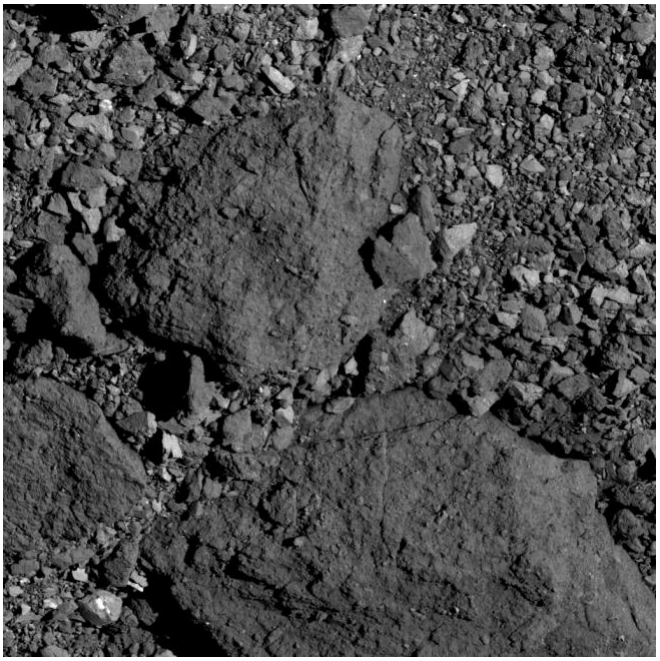
Lego Mindstorms EV3®

OSIRIS-Rex Mission. (n.d.). Retrieved from https://www.asteroidmission.org/

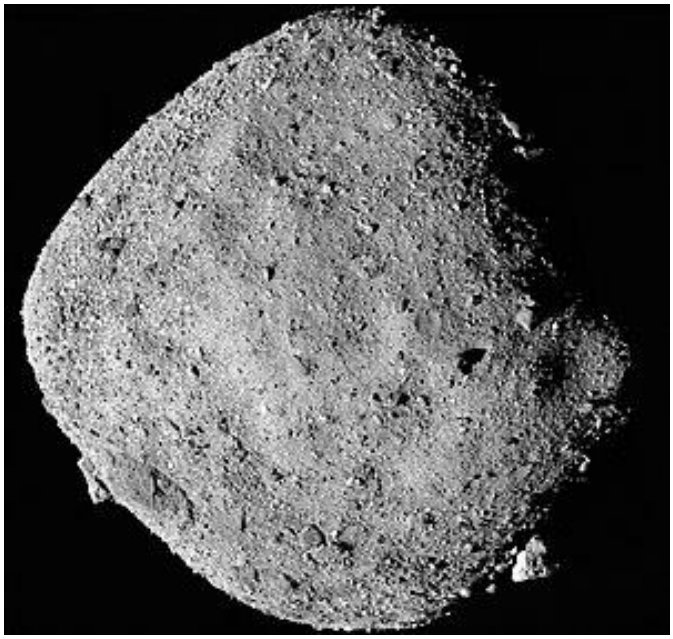
All photographs are taken from Google images.



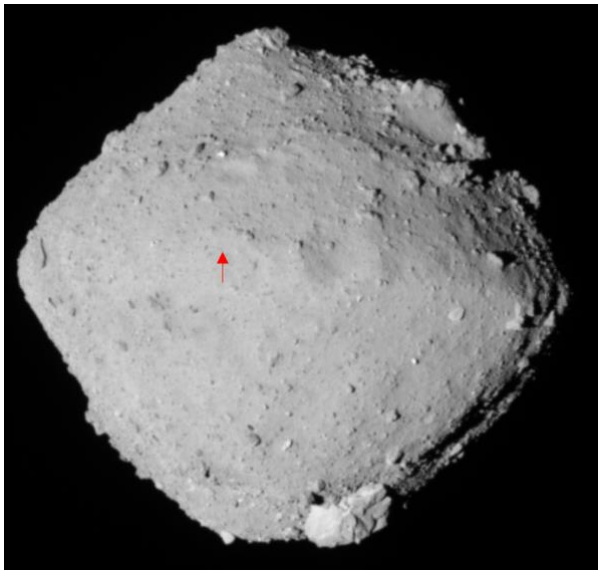




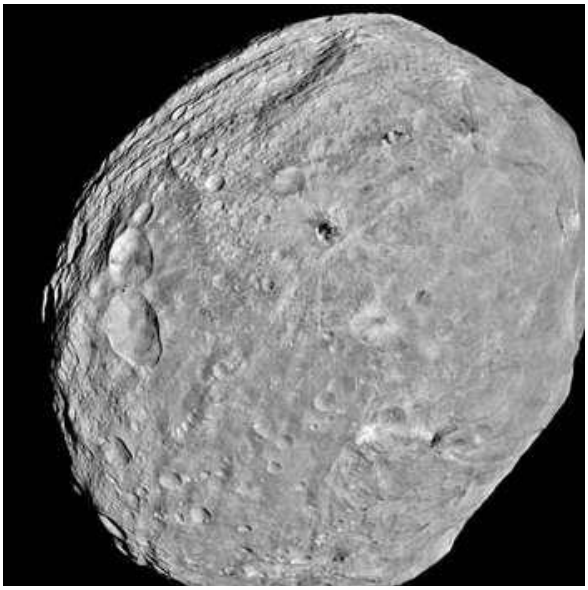
Boulder Fields on Bennu



Bennu



Ryugu



Vesta

Artist's rendition of Osiris-Rex