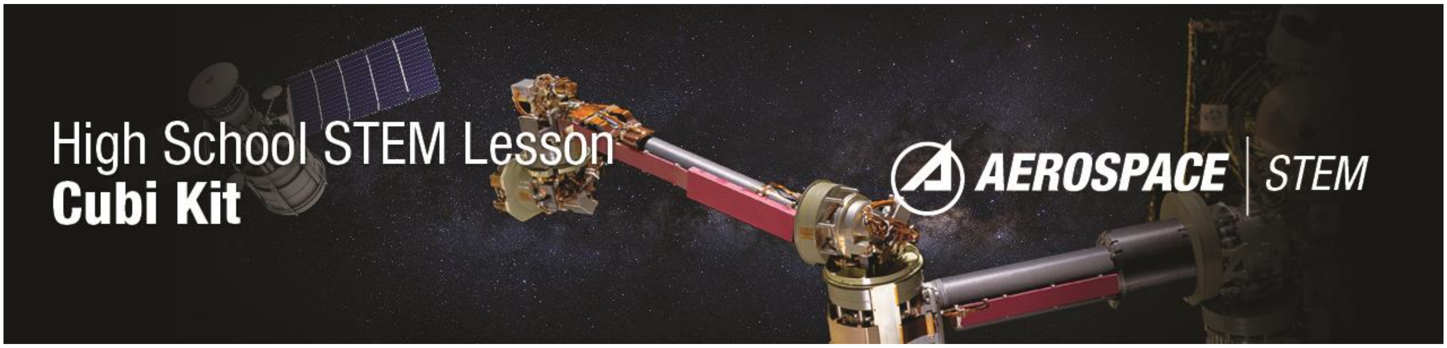


Team Name:		Date:	

ROBOTIC SATELLITES HS

High School Science Lesson

Lesson Overview	Career Highlight
In this lesson, students will explore how a CubeSat positions itself in space through an interactive activity. Students will participate in an activity to demonstrate transmission of satellite components. Students will learn about attitude and control and will demonstrate their understanding of satellite positioning through hands-on experiences with the Aerospace CubiKit.	**Guidance, Navigation and Control Engineer**: design, manufacturing, testing systems for aircraft/ spacecraft. **Flight Dynamics Officer/ Engineer**: responsible for trajectories, flight paths and orbital mechanics. Make sure all parts follow the correct path and physics. **Systems Engineer**: works with all teams, manufacturers, designs to ensure product works **Communication Engineer/ Specialist**: research and design ways of communication in space with Earth. **Computational Analyst**: calculates how much memory, data, what type of data and computer processing will be needed for all the scenarios.

STEM Course Connections	21st Century Skills	CTE Alignment
High School Engineering High School Earth & Space Science	Collaboration Communication Critical Thinking	Engineering and Design Industry Sector (ED)

Engineering Activity	
Science and Engineering Practice #2	Students will program a CubeSat to navigate a maze and capture an image of a celestial object.

Materials

Teacher Note about the Teacher Slides: Each day's slide includes a video (Space Spark) to spark a quick discussion and/ encourage curiosity as well as a trivia question (answer in speaker notes). The teacher may choose to use these at the beginning of the lesson, to initiate a transition in the lesson activities, to be viewed individually as students complete activities, or as a way to end class.

Days 1-3 Materials

- Student Handout
- Baseball bats
- Cones
- Stopwatch
- Poster paper
- Colored Pens
- CubeSat communication activity image
- Smart Phone

Day 4 & 5 Lessons WITH CubiKit:

  - Aerospace CubiKit for student groups
  - CubiKit Student Handout
  - Student laptops/ devices
  - Flashlights
  - Rulers
  - Various objects for students to manipulate the magnetometer (cell phone, lap top, pen, watch, battery, etc.)
  - *Optional: stamp/stickers from teacher to approve student teams to continue with mission after systems check- this can easily be done with teacher initials as well.*

Day 4 & 5 Lessons WITHOUT CubiKit:

  - Commander Notesheet
  - Satellite Orientation Activity Classroom Set Up
  - QR Code Printout
  - Blindfold
  - Painter's Tape

Essential Questions

1. What are CubeSats, or other small satellites, and what do they do?
2. How do CubeSats, and other spacecraft, position themselves in space for a mission?
3. How do CubeSats, and other spacecraft, use/ adjust orientation system algorithms to maintain control of position?

Prerequisite Knowledge

This lesson builds on content developed in the Value of Space Lesson, and while this is not necessarily a prerequisite lesson, there are concepts introduced that may help student understanding in this lesson.

Day 1: Understanding Orientation (Teacher Slides)

Anticipatory Set:
Display the NASA Worldview images from Sept. 13, 2017 vs. November 18, 2017 (gif on slide 3 of Teacher Slides).
Ask, "What do you notice as the image slides from Sept. 2017 to Nov. 2017?" Answers will vary and all are accepted. *(Note the electricity outages in September that were not fixed until mid-November of 2017)*
Ask, "What do you wonder as the image slides from Sept. 2017 to Nov. 2017?" Encourage all questions/wonderings.
Explain that these two satellite images are from before and after Hurricane Maria hit Puerto Rico in 2017 and allow scientists the ability to track the effects of the hurricane & communities recovery over time (note the electricity outages in September that were not fixed until November of 2017). (For more information, click here.)
Over the next few classes we'll be exploring satellite and CubeSat positioning in space to understand how data, like the images from Hurricane Maria, can be gathered. The next two slides give information basics about cubesats and mentions the CubiKit.

Section A - Dizzy Bat (25 mins)
Teacher Note: Students will participate in a hand-on experience that will simulate orientation and attitude before they are exposed to the academic vocabulary. This will help activate prior knowledge about an experience when they learn about the 5 main components of a satellite.

Display slide 6 to introduce the activity.
Outside in an open field, students will participate in a dizzy bat activity.
Teacher Note: Tables and chairs could be moved to the edge of the classroom as an alternative to an open field.

- Students will be placed in teams of two with one baseball bat for each team. Students will stand 10 yards apart and away from other teams. One student will place their forehead on the end of a baseball bat with the other end of the bat on the ground. The student will then spin around the bat five times, keeping their forehead down. After the fifth rotation, the student will stand up and let go of the bat, and then they will need to get to their partner as quickly as possible. The student without the bat will start the timer when the bat hits the ground and will record in Section A of the Student Handout how long it takes for the student to reach them and give a high five. Then students will switch roles.
- After both students have attempted the dizzy bat, place cones on the ground between the two students in a random pattern. When students attempt the dizzy bat again, they must avoid the cones. For any cone that they hit, add 5 seconds to the final time on the score. Students will then switch roles. Again, they will record their results in Section A of the Student Handout.
- Finally, blind fold the student attempting the dizzy bat. Without moving, timekeeper will need to help the blindfolded student reach them by offering audible instructions that will orient the student to their location. Again, for any cone that they hit, 5 seconds should be added to the total time recorded. Record results in Section A of the Student Handout.

Section B - Dizzy Bat Class Data (10 mins)
- Back in the classroom, data will be compiled from everyone into a class spreadsheet.
- Students will conduct an analysis on the data to find the class average for each round: regular dizzy bat, dizzy bat with cones, dizzy bat with blindfold and cones.
- Students will then record their findings into Section B of the Student Handout.
- *Extension: Students can modify the data using other statistical analyses or math applications for mean, median, or mode.*

Section C - Strategies for Orientation (10 mins)
- In small groups, students discuss their strategies for how they made their way across the field to their partner. In Section C of the Student Handout, students describe the challenges and successes they had as they navigated the field.
- In the large group, ask students to share answers. Example teacher prompts:
  - Which round was easiest for you? Why? *Answers will vary.*

- What senses did you rely on to navigate to your partner? *Answers will vary.*
- With fewer senses (when you were blind folded), how did that change your ability to navigate toward your partner? Use data to tell this story. *Answers will vary.*
- What additional data would you have wanted to collect? *Answers will vary.*

Day 1 Wrap-Up: What's Your Satellite IQ? (2 minutes)

- Individually, students reflect on the day's learning/ activity and write one thing they found interesting and one lingering question. Have them share their answers with neighbors or the whole class, if time.

Day 2 (Teacher Slides):

Section D - How CubeSats Transmit Information (20 mins)

Teacher Note: Students will participate in an activity that simulates how CubeSats transmit information from space to earth. The classroom should be set up with a blank poster paper (or whiteboard) hung up on each of the four walls for students to be able to draw on.

- Students will break into 4 teams with even numbers of students.
- One student from each team will face each of the four walls with a poster paper hung on the wall. Three students from each team will line up in a single file line behind the student who is drawing on the paper.
- The remaining team members will take turns being the observer. The observer will take a look at the Image provided by the teacher. In each round, the observer will be instructed to only share information about one specific aspect of the image to the student at the end of the line facing the wall.
- The students in line will then play a game of "telephone" sharing what they heard from the person behind them to the person in front of them all the way to the student at the wall.
- The student at the wall will then draw what has been described. Students can iterate on their drawing as they receive more information or can opt to start over at any point when new information comes.
- Rounds of observation:
    - Number of shapes
    - Shapes
    - Location of shapes
    - Size of shapes
    - Orientation of shapes
    - Color of shapes
- After the teams have finished their drawings, compare the final version to the original and allow students to provide feedback in their group. Have them answer these questions in the Student Handout.
    1. Describe the successes you experienced during this activity. *Answers will vary.*
    2. Describe the challenges you experienced during this activity. *Answers will vary.*
    3. What lingering questions/wonderings do you have about CubeSat Information Transmission? *Answers will vary.*

Section E - Vocabulary Development (15 mins)

- Building on the engaging activity, students will develop some academic vocabulary around satellite navigation. To begin, direct students to the vocabulary in Section D of the Student Handout. Ask students how many/ which words they can apply to the dizzy bat activity from the prior class. Allow table discussions and then have volunteers share with the whole class.
- Students should then use words and images located in Section D of the Student Handout to define the following words in their own way.
    - Satellite: *Something that orbits a large object in space.*
    - Cubesat: *A small, cheap satellite designed to fit within 10x10cm dimensions.*
    - Navigation: *The way things get from one place to another.*
    - Orientation: *The way something faces.*
    - Trajectory: *A path that is given to a satellite.*
    - Attitude: *The way something faces compared to the object it orbits.*
    - Control: *Someone's ability to change the attitude or trajectory of something.*
    - Torque: *A rotating force.*

- Drag: *A force acting opposite to the force you're trying to apply.*
  - Gyroscope: *Something that spins and maintains its own rotating force.*
  - Angular Momentum: *An object's ability to maintain a constant direction due to gyro stabilization.*
- Students share their definitions with the class.

Section F - What are Attitude and Control? (10 mins)

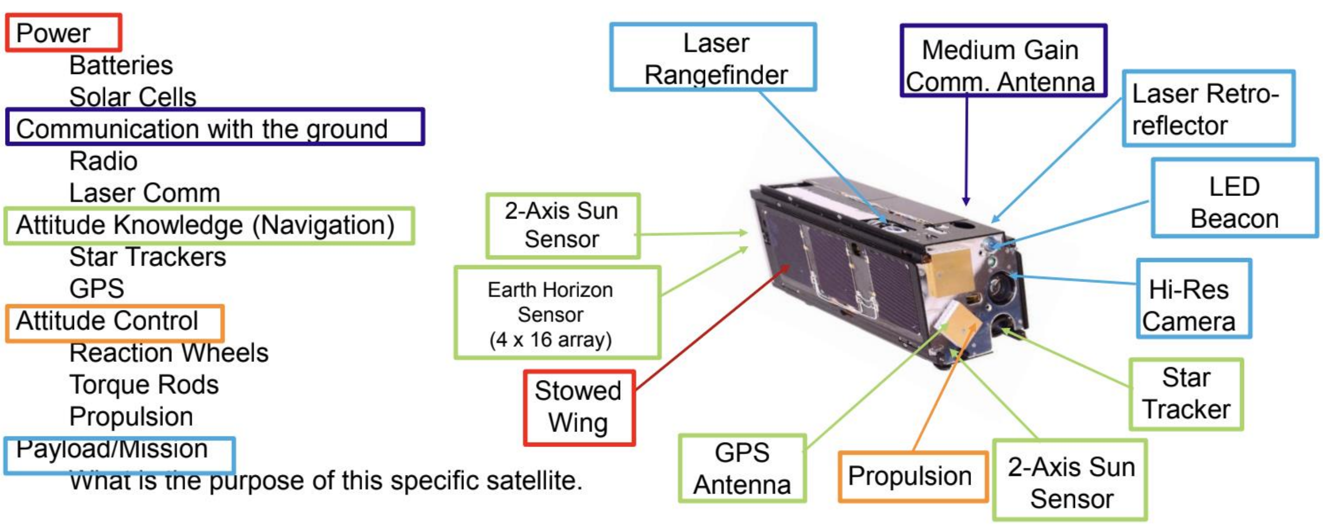
- As a class, students will watch the video on YouTube and answer the questions in Section E of the Student Handout.
  1. What are the two primary external forces acting upon the ISS that require us to continually change its attitude? *Drag (Air Resistance) and Gravity*
  2. What are the two methods of orienting a satellite and maintaining its attitude? *Control Moment Gyros and Reaction Control Thrusters*
- As a class, discuss what students have learned about attitude and control.
  1. What are some differences between CubeSats and the current research satellites employed by scientists? *They are much cheaper to produce, and much smaller, meaning more can be launched into space for less total cost.*
  2. What benefits do CubeSats have over older, larger research satellites? *They can provide valuable information while being much more disposable, and can allow scientists the opportunity to make many more satellites for redundancy.*

Day 2 Wrap-Up: Use your words & think a little differently.
Correctly use at least ___ of the vocabulary from section E to describe the context of a high school student's day.
Answers will vary.
Teacher note: *Choose an amount of vocabulary words to differentiate appropriately for the group of students. 3 is suggested for struggling learners while others will enjoy the challenge of using as many as possible.*

Day 3: Building a CubeSat (Teacher Slides)

Section G - Labeling Parts of a CubeSat (5 mins)

- Students are guided through the process of labeling the components of a CubeSat in their Student Handout.



Teacher Note: Components on the Student Handout begin with Laser Rangefinder as Component 1, and continue in a clockwise direction, making 2-Axis Sun Sensor Component 12.

Section H - CubeSat Transmission Process (5 mins)

- Group students with their team from the previous activity.
- Ask students to reflect on their experience and answer the questions found in Section H of the Student

Handout as a team.

1. Identify which of the 5 main components of a satellite (power, communications, attitude knowledge, attitude control, or payload/mission) were used in the activity. *Communications with ground.*
2. What did the command for "number of shapes," "shapes," "location of shapes," "size of shapes," "orientation of shapes," or "color of shapes" represent? *Different sensors on the payload that communicate different types of information.*

Section I - Satellite Case Study Website (35 mins)

- Students will complete a webquest on Section I of the Student Handout featuring:
  - JWST: James Webb Space Telescope
  - ICESat-2: Ice, Cloud, and land Elevation Satellite
  - SMAP: Soil Moisture Active Passive
  - MarCO: Mars Cube One
  - ELaNa: Educational Launch of Nanosatellites
  - DART: Double Asteroid Redirection Test
- As a class, students review each of the case studies by sharing their answers.
  - JWST
    - What does this satellite observe? *The satellite uses its sensors to see light from distant galaxies and stars.*
    - What sensors does this satellite use? *It has a near-Infrared camera, a near-IR Spectrograph, a mid-IR instrument, and a Fine Guidance Sensor/Near-IR Imager and Slitless Spectrograph.*
    - How do these individual sensors come together to provide information to scientists that tell the entire story? *All of these sensors together are able to take in multiple types of EM radiation and provide as much data as possible about the part of space they are viewing.*
  - ICESat-2
    - What does this satellite observe? *This satellite observes tree canopy heights, ocean and lake levels, and the elevation of ice sheets, glaciers, and sea ice.*
    - What sensors does this satellite use? *The ICESat-2 uses six lasers split into three pairs (six total beams to better measure the earth), blasting 10,000 laser light pulses per second. These photons return to the satellite and the information is transmitted down to NASA stations on the ground.*
    - How do these individual sensors come together to provide information to scientists that tell the entire story? *These laser light pulses can determine the height of something to within 4 millimeters, which helps them accurately predict sea level heights and rate of ice caps melting.*
  - SMAP
    - What does this satellite observe? *This satellite monitors the topsoil of the earth's surface to create soil moisture estimates and identify drought locations.*
    - What sensors does this satellite use? *The SMAP uses two microwave instruments. A radar and radiometer are a combination of active and passive radar which combine higher resolution and higher soil moisture accuracy.*
    - How do these individual sensors come together to provide information to scientists that tell the entire story? *They are able to map the entire globe in about 3 days and gather soil moisture estimates in approximately a 6-mile resolution.*
  - MarCO
    - What does this satellite observe? *These CubeSats observe the surface of the planet Mars.*
    - What sensors does this satellite use? *They utilize cameras, communication equipment, and navigational equipment.*
    - How do these individual sensors come together to provide information to scientists that tell the entire story? *These two systems were able to work together to gain information about the landing location and status of another, larger project called InSight.*
  - ELaNa

- What does this satellite observe? *ELaNa 36 is designed to observe forest regrowth in the Gatlinburg, Tennessee area from orbit.*
- What sensors does this satellite use? *The CubeSat uses a variety of cameras, a flight navigation computer, and a VHF/UHF radio for communication with the ground.*
- How do these individual sensors come together to provide information to scientists that tell the entire story? *Once it takes photos from orbit, it sends them back to students via the radio. It can also be remotely controlled from the ground through the use of the radio.*

- DART
  - What does this satellite observe? *This satellite was designed to record the results of a small spacecraft slamming its mass directly into an asteroid to determine if the impact will sufficiently redirect the course of the asteroid.*
  - What sensors does this satellite use? *The CubeSat companion for the DART program uses two optical cameras.*
  - How do these individual sensors come together to provide information to scientists that tell the entire story? *The information recorded by the optical cameras can be sent back to scientists on the ground, who will be able to determine whether or not ramming the asteroid with the spacecraft achieved the expected result.*

Day 3 Wrap-Up: How do these case studies relate to the transmission process activity? *Just like in the activity, a single sensor acting alone was not able to provide all of the necessary information. Having more sensors allows scientists to gather more information than they would be able to otherwise.*

Day 4 & 5 WITH CubiKit:

Day 4: CubiKit Mission (Teacher Slides)

Teacher Notes: Students could either participate in this activity with the same team or in a different group from the previous day. Each student team will need ONE STUDENT COMMANDER. You may want to assign this role or allow teams to choose one group member for this role. The teacher will act as flight director for the mission.

Inform students they are now part of a ground control team for a small spacecraft/ cubesat. You, the instructor, are the flight director.

Getting to Know the CubiKit:

1. Briefly go over the CubiKit anatomy* & sensors with the students pointing out the sensors they'll be working with using the slides for the day. The first slide is of the CubiKit net with all components. The following slides show each sensor and explains the measurements and shows a sample data chart like the students will see when they start their mission.
   **Labeling parts of a cubesat is difficult because from the outside, it is difficult to tell what apertures do what (ie star tracker, payload camera, Laser Com, sun sensor. These all look very similar from the outside). Some components can not be seen from the outside (ie batteries, torque rods, reaction wheels, etc...). For the purposes of the lesson, having a overview of the CubiKit will aid in student understanding in the simulated mission. Some curious students will be interested in the electronics for the kit as well.*
   a. When discussing the IMU Accelerometer, ask students to speculate why one graph line is off from the other two– due to Earth's gravity. You may want to challenge students to continue to ponder this when they conduct their mission. Ask individual groups for a conclusion as they come to you for approval at the completion of part 2.

Teacher note: The photocell in the CubiKit is the only light-sensing device. The code simulates solar array readings. Currently the CubiKit does not use the solar panel in its current configuration, but the photosensor is similar to the solar panel data for the purposes of the lesson.

2. Distribute a CubiKit to each student group.
3. Explain to students that their spacecraft has been delivered to its orbit around Earth by a rocket; they need to first establish communications with the spacecraft. Students will work in teams through the

CubiKit Mission Student Handout. *It's advisable for the teacher to continually circulate throughout the lesson to monitor progress and performance throughout the session.*

4. Student groups will follow the outline of the student handout:

Part 1: Establish Communication

- Students will follow directions on the student handout to connect to their group's CubiKit wi-fi. Note that the student laptop may need to disable the "connect automatically" function for the school's wi-fi in order to maintain the connection with the CubiKit. *Note: There are no spaces in the address, there is an underscore.*

Part 2: Systems Check

- *Student groups need a flashlight and various objects for students to manipulate the magnetometer (cell phone, lap top, pen, watch, battery, etc.)*
- *Teacher Note (Optional): stamp/stickers from teacher to approve student teams to continue with mission after systems check- this can easily be done with teacher initials as well.*

- Students will become familiar with the senors and data of the CubiKit. The instructor should circulate and assist individual groups as students investigate. They will manipulate the CubiKit, see the effects on the downlink data, and record their answers the questions based on their experiences.
  - Solar array
  - Photocell
  - IMU Accelerometer
  - IMU Gyroscope
  - IMU Magnetometer
- At the end of the systems check, student groups will bring the handout to the instructor for approval to continue with the mission, giving the instructor an opportunity to review student work & bring closure to the learning before they move on. Some student groups may need to revisisit sections of the systems check.
  - Questions to ask groups:
    - What conclusion did your group come to about the accelerometer graph data? Why is one line off from the other two? (*due to Earth's gravity)*
    - Which sensor surprised you? Why?
    - Which sensor do you think is the most important for engineers to consider when building a mission? Why?
    - What other data would you be interested in seeing on the CubiKit? Why?
    - Is there anything you'd like clarified before moving on with your mission?

Teacher Note: It will be helpful for one other student to connect to the CubiKit's Data Downlink for the rest of the activities. One student's browser can continually track data while the commander enters various commands. The student handout indicates the commander will assign this person. If it makes more sense for the instructor to assign this task to a student, please do.

Part 3: Run Mission to Achieve Mission Objective

- *Student groups need a ruler*
- Student commander will input http://192.168.4.1/set?mode=normal command to tell the CubiKit to track the "sun" (flashlight). They'll then measure & record the farthest distance from the "sun" that allows the CubiKit to correctly orient.

Day 5: CubiKit Mission, Continued (Teacher Slides)

Teacher Notes: Students should participate in this activity with the same team from the previous day. The student acting as commander may remain the same as the previous day or teams may choose a different student. The teacher will continue to act as flight director for the mission.

Part 4: Assist *Exploration Robotics Research Orbital Reconnaissance Team (ERROR Team)*

- Student Handout
- *Student groups need a flashlight*

This activity begins with a comical situation with student teams assisting a troubled ground control team working on the fictional **E**xploration **R**obotics **R**esearch **O**rbital **R**econnaissance mission to allow students the opportunity to simulate an error in a simulated error mode. Students will see the CubiKit rotating erratically and not tracking the "sun."

- It's advisable for the teacher to continually circulate throughout the lesson to monitor progress and performance throughout the session.
- Student groups will experience the problem, diagnose the issue, and suggest a solution. *Students should propose the CubiKit ignore the photocell and use the solar array to orient to the "sun."*
- Give students with the correct response the following command to tell the CubiKit to ignore the faulty sensor and begin to track the "sun" again:
    - http://192.168.4.1/set?mode=sp_tracking

      Teacher Note: It may be helpful to have this code printed on a strip of paper and ready to hand out to groups.

Part 5: CubeSat & CubiKit Wrapup:

Student groups will complete one of the following activities as an exit ticket for the day:

- Poetry for People Who Can't Rhyme:
  Write a haiku about CubeSats and satellite missions. (Remember, a haiku is a short 3-line poem following the 5-7-5 syllable format.)
- Force an Analogy: *Suggestions for the object/ action include: "chocolate chip cookie," "paperclip," "a jump rope." "making a sandwich," "planning a party," "sea shell," etc.*
  Explain how cubesats are like a __________ (see your flight director for the object/ action).
- Share Your Thoughts:
  Revisit the case studies and rank the projects based on their importance.
  Justify your most important and least important choices with an explanation.
- Techno-Jargon Rap:
  Write (and maybe perform) a continuation to the ERROR team member's stress-induced rap including your data analysis and solution your team offered.

Revisit the essential questions to discuss.

Extension:

- Students can use readings from the data downlink to calculate other data not specifically shown. For example, students can use the time data from the IMU graphs to calculate angular velocity and linear acceleration.

Alternate Activity WITHOUT CubiKit

Section J - Programming the Orientation of a Satellite (75 mins)

Teacher Note: Students could either participate in this activity with the same team or in a different group from the previous day.

Mission Objective

- The objective for the mission is for two Engineers to write a Code that their human Satellite can complete while blindfolded. The Satellite will need to navigate through obstacles to a Target and then use a cell phone to scan a QR code on the wall. There are two outcomes:
    a. Mission Success - the QR code scans on the Satellite's phone
    b. Mission Failure - the QR code does not open and refinements need to be made to the code

Set Up

Teacher Note: Use the Drawing of the classroom as a model.

- Both sides of the classroom are set up with one station for each team.
    a. *Teacher Note: The classroom should ideally be divided with a wall or other partition so students cannot see the other side of the room. This can also be done in two adjacent classrooms. Another option is to have half of the students inside and the other half outside the classroom.*
- Approximately 10 feet from one wall, a piece of painters tape will be placed on the ground as a Launch Pad. There will be obstacles placed between the Launch Pad and a 1 foot by 1 foot square Target of painters tape on the floor 3 feet away from the wall. Obstacles can include desks, chairs, or cones.
- A QR code should be printed out and taped on the wall in front of the Target.
    a. Teacher Note: Test that the Target is the correct orbital distance from the image by holding a phone up to the QR code while standing in the box and checking that the QR code opens the image on the phone.
- Group students into a team of 4:
    a. Student A: Flight Dynamics Engineer/Commander
    b. Student B: Guidance, Navigation, Control Engineer/Satellite
    c. Student C: Commander/Flight Dynamics Engineer
    d. Student D: Satellite/Guidance, Navigation, Control Engineer
- Students A and B will begin on one side of the room and Students C and D will begin on the other side.
- Each pair of students will begin their role as either a Flight Dynamics Engineer or Guidance, Navigation, Control Engineer. They will need to take measurements and map out the trajectory that their Satellite will need to navigate to reach the Target from the Launch Pad. Students should sketch this map in question 1 of Section J in the Student Handout.
- Students will determine the commands that the Satellite will need to use and they will take notes in question 2 of Section J in the Student Handout.
- Students will then turn these commands into codes that will be written in the first column (green) of the Commander Notes document. Examples of code include:
    a. <walk, # of steps, direction>
    b. <raise arm, degrees>
    c. <step, height of step, direction of step>
    d. <height from floor>
    e. <aim cell phone>
    f. <capture image>
- The Flight Dynamics Engineer or Guidance, Navigation, Control Engineers will provide their Commander Notes to the teacher who will hand it to the other team before switching sides of the room and switching into their new roles: Satellite and Commander. The Satellite will be blindfolded by the Commander. The Commander will help the Satellite make it safely to the Launch Pad.
- The Commander reads each code on the Commander Notes they receive from the teacher that were written by their own teammates. The Commander allows the Satellite to perform the task before reading the next code. If the Satellite is in danger of harming themselves, the Commander can step in and move the Satellite back to the Launch Pad. Otherwise, the Commander cannot touch the Satellite or say anything besides the code written on the Commander Notes.
- After each command is read and the task is executed, the Commander will take detailed notes in the middle column (red) of the Commander Notes to describe the outcome of the command. For example, if the Satellite only raised their arm to 30 degrees instead of 45 degrees as written in the Commander Notes, the Commander should note this discrepancy by writing *Satellite only raised their arm to 30 degrees instead of 45*. Likewise, if the Engineers predicted it would take 5 steps to reach the first obstacle, but the Satellite reached it in 3, this should be noted as well.
    a. Teacher Note: If the student is not at the correct orbital distance from the QR code, the image will not scan on the student's cell phone. Ensure that the tape on the ground at the Target is within the appropriate distance from the QR code to allow a scan.
- After the last code has been read (<aim cell phone>, <capture image>), the Commander checks to see if there is Mission Success or Mission Failure.
    a. If there is a Mission Failure, the Commander takes the detailed notes back to the Engineers in the other room and the blind folded Satellite is escorted back to the starting room. The Engineers

then go over the notes provided by the Commander from the other room and redesign their codes in the last column (blue) of the Commander Notes to move the Satellite into a better position before the image is captured. This process is repeated until the mission is accomplished.

Section K - Reflection (15 mins)

- In the team of four, bring students together and allow them to answer Questions 1-4 with their teams in Section K of the Student Handout.
  - What did you notice about the notes that were provided to you by your other teammates? *Answers will vary.*
  - What changes did you need to make to your code? *Answers will vary.*
  - What happened if your Satellite was not at the correct orbital distance from the object it was trying to capture? *If the Satellite didn't make it into the Target, the QR code could not be scanned and the image could not be captured.*
  - How did your team work together to achieve the mission? If the mission was not successful, what additional resources would your team have needed to accomplish this task? *Answers will vary.*
- As a class, discuss how the teams worked together and used their experiences from the previous days to accomplish the mission.

Extension:

- If students have access to a CubeSat design kit, repeat days 4 and 5 with a programmable CubeSat that can navigate the maze and take a photo using the gyroscope, laser, and camera. There are options for using computer programming to orient the CubeSat to take the photo.

CA NGSS Standards

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

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.

CTE Alignment

B1.0 Communicate and interpret information clearly in industry-standard visual and written formats.
B1.5 Create reports and data sheets for writing specifications

B6.0 Employ the design process to solve analysis and design problems.
B6.1 Understand the steps in the design process.
B6.2 Determine what information and principles are relevant to a problem and its analysis.
B6.3 Choose between alternate solutions in solving a problem and be able to justify the choices made in determining a solution.
B6.5 Demonstrate the process of developing multiple details, within design constraints, into a single solution.
B6.6 Construct a prototype from plans and test it.
B6.7 Evaluate and redesign a prototype on the basis of collected test data.

B8.0 Understand fundamental control system design and develop systems that complete pre programmed tasks.
B8.1 Identify the elements and processes necessary to develop a controlled system that performs a task.
B8.2 Demonstrate the use of sensors for data collection and process correction in controlled systems.

B8.3 Perform tests, collect data, analyze relationships, and display data in a simulated or modeled system using appropriate tools and technology.
B8.4 Program a computing device to control systems or processes.
B8.6 Assemble input, processing, and output devices to create controlled systems capable of accurately completing a preprogrammed task

Resources

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