Integrating CubeSats into Classroom Lessons

Companion for

[Next Generation Science Standards: Middle School]

This guide is meant to be a companion to the Middle School Next Generation Science Standards. The intent of the guide is to provide middle school teachers with an easy way to connect working with CubeSat flight experiments in the classroom to as many of the NGSS as possible. Regardless of how interesting our CubeSat curriculum may be, it is important for teachers and administrators to be able to see the alignment to the standards so that this curriculum can be implemented in the classroom.

Included with each standard are the clarification statements, how the standard can be aligned to CubeSat experiments, and details on the specific hardware and activities that can be used to satisfy the standard. The order of the standards in this guide follow the order presented in the linked NGSS document, so some of them may look to be out of order, but that is how they were originally written. If you have further questions regarding a standard or activity please don't hesitate to reach out to noah@tis.org.

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MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form synthetic material. Examples of new materials could include new medicines, foods, and alternative fuels.

How You Can Use CubeSats to Meet this Standard

Discuss usage of synthetic materials in CubeSat frames and components. CubeSats are made of various materials depending on the type of mission to be conducted. 3D printed plastics, derived from corn, are most often used for CubeSats that will not be exposed to the vacuum of space, whereas more robust materials are used for those that will. Aluminum and 3D printed metals, including selective laser sintering (SLS), are used for those CubeSats needing to stand up to the rigors of spaceflight.

Additionally, analysis of various flight platforms that can carry CubeSat payloads can include examples of synthetic materials, such as carbon composites in the Perlan stratospheric glider and multiple rockets that have carried TIS CubeSats. Upcoming rocket companies are also working on alternative fuels derived from natural sources. These rockets could be future carriers of student-made CubeSats.

Furthermore, students can participate in all three aspects of this standard by obtaining data from a classroom built CubeSat, evaluating that data based on the Engineering Design Process, and then communicating those results to their school, district, and wider scientific community.

Sample Questions:

- What is a CubeSat?
- How do CubeSat frames of different sizes/materials compare to each other?
- How are different frame materials produced such as 3D printing, metal, plastic, wood?
- How do different designs of frames or enclosures compare to each other?
- What are
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

3D Printers/Filament - Wikipedia

Selective Laser Sintering - Wikipedia

The Perlan Project

bluShift Aerospace

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Teachers in Space CubeSat Parts List

MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.

How You Can Use CubeSats to Meet this Standard

This standard can be used to show the versatility of CubeSats as an experiment and data collection platform. Just about any sensor that can be used to collect data about chemical reactions is available to be used with the Arduino microcontrollers that act as the primary control hardware for our CubeSats. Various Arduino compatible sensors can be integrated into a CubeSat build to collect data about reactions. This data can then be analyzed and interpreted by students.

Additionally, there are the specifications of density, temperature, flammability, off gassing, etc. that must be taken into consideration when designing and conducting CubeSat experiments, depending on which flight platform they will be a payload on. The discussion and planning of a CubeSat mission includes properties of substances before and after substances interact with each other and various environmental variables.

Sample Questions:

- What is a CubeSat?
- How can you collect data on different types of reactions using CubeSat sensors?
- Which types of sensors are best suited for specific types of reactions?
- What are the positives and negatives for using different CubeSat frame materials in various environments such as the classroom, outside, stratosphere, and space?
- How do different designs of frames or enclosures help in more extreme environments?
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

Arduino Microcontrollers

Adafruit Learning System

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit Environmental Sensors - Air Quality Sensors

SparkFun Environmental Sensors - Air Quality Sensors

DFRobot Environmental Sensors - Air Quality Sensors

Teachers in Space CubeSat Parts List

MS-PS1-6 Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.

How You Can Use CubeSats to Meet this Standard

Undertake a design project, engaging in the design cycle, by building a simple CubeSat with onboard thermal sensors. CubeSats provide experimental platforms for all manner of scientific inquiry. You can use sensors onboard a CubeSat to monitor thermal energy output and absorption of the chemical processes in many experiments. This can include the use of thermometers, thermal imagers, light sensors, and other environmental sensors to monitor the transfer of energy as it flows through a designed or natural system.

While the intention behind our CubeSat program is to emulate orbital satellites, these CubeSats provide excellent platforms for sensors that can specifically detect changes in thermal release and absorption.

Sample Questions:

- What is a CubeSat?
- How can you collect data on different types of reactions using CubeSat sensors?
- Which types of sensors are best suited for specific types of reactions?
- How can a probe type sensor be used to collect data from thermal reactions?
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

Arduino Microcontrollers

Adafruit Learning System

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Adafruit Learning System

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit Environmental Sensors - Probe Temp Sensor

SparkFun Environmental Sensors

DFRobot Environmental Sensors

Teachers in Space CubeSat Parts List

MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.

How You Can Use CubeSats to Meet this Standard

System and system models can be explored through the effects of collisions between objects in space; planning CubeSat orbital trajectories, lifespans, and orbital decay; the effects of orbital debris on future space missions and space exploration.

This problem can involve various topics related to CubeSat launch, operation, and retirement. Rocket launches and trajectories, orbital parameters, and objects burning up when colliding with particles of the Earth's atmosphere are all related to meeting this standard. This can also be made into a durability experiment using different materials for the CubeSat's frame.

Sample Questions:

- What is a CubeSat?
- What are different types of flight platforms for CubeSats and how do their flight characteristics differ?
- What is orbital debris, why is it a problem for humans, how did it get into Low Earth Orbit (LEO), and what is being done about it?
- How can CubeSats be used to deal with orbital debris?
- What is the Engineering Design Process

Resources

CubeSat - Wikipedia

Rocket Launch Vehicles - Wikipedia

High Altitude Balloons - Wikipedia

Newton's Laws of Motion - Wikipedia

A deorbiter CubeSat for active orbital debris removal - ScienceDirect

Development of a CubeSat for Orbital Debris Detection - AIAA

CubeSats for in orbit observation of mm sized space debris - ESA

NASA Small Spacecraft Structures, Materials, and Mechanisms

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit

Sparkfun

DFRobot

Teachers in Space CubeSat Parts List

MS-PS2-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.

How You Can Use CubeSats to Meet this Standard

Stability and change can be investigated through the forces that will be enacted upon a CubeSat during flight, orbit, and deorbit. CubeSat orbital profiles vary depending on mission requirements. After a mission has come to an end CubeSats are usually deorbited and burned up from the friction of atmospheric reentry.

An investigation into how an object's motion depends on the sum of the forces on the object and the mass of the object can include inertial measurement units (IMU) connected to a CubeSat. Using an IMU, with a gyroscope and accelerometer, you and your students can take direct measurements of forces and variables enacted upon a CubeSat in flight and free-fall.

Data can be collected, graphed, and analyzed after experimentation in order to support claims and hypotheses made before experiments are conducted. This can help to identify what tools are needed to do the gathering, how measurements are recorded, and how much data is needed to support a claim.

Sample Questions:

- What is a CubeSat?
- How can a CubeSat be used to detect forces and changes in motion?
- What is an IMU and what can it be used for?
- How do CubeSat frames of different sizes/materials compare to each other?
- How are different frame materials produced such as 3D printing, metal, plastic, wood?
- How do different designs of frames or enclosures compare to each other?
- What is the Engineering Design Process?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Newton's Laws of Motion - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Inertial Measurement Unit: Accelerometer, Gyroscope, Magnetometer - Wikipedia

Adafruit Inertial Measurement Units

SparkFun Inertial Measurement Units

Teachers in Space CubeSat Parts List

MS-PS2-3 Ask questions about data to determine the factors that affect the strength of electrical and magnetic forces.

Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.

How You Can Use CubeSats to Meet this Standard

A CubeSat emulator can be constructed that includes sensors that can be used to detect and measure electric or magnetic fields. Utilizing a current sensor, magnetometer, and coiled magnetic wire students can detect the relative strength of magnetic interactions between objects. The strength of a magnetic field can be recorded and the data can be used to make charts and data for visual representation.

Experiments like this were conducted using TIS CubeSats aboard the Perlan stratospheric glider and Blue Origin's New Shepard rocket in 2023. CubeSats are often used to collect data about the Earth's magnetic field. Utilizing inexpensive sensors and copper wire, a CubeSat can be used to detect fluctuations in magnetic fields of all kinds.

Data can be gathered from various sources using the CubeSats onboard sensors, and that data can be used to demonstrate cause and effect. Whether working with magnets in the classroom, or on a flight to detect the Earth's magnetic field, CubeSats are excellent platforms for detecting electromagnetic fluctuations. Current sensors, magnetometers, and various other sensors are available to be used with CubeSat hardware.

Sample Questions:

- How does the static electricity of multiple electrically charged objects compare?
- How do the magnetic forces of various sizes and types of magnets compare to each other?
- How does the distance and orientation of a magnet affect the readings collected by the magnetometer?
- What is the Engineering Design Process?
- What is a CubeSat?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Magnetometer - Wikipedia

Adafruit Magnetometer - Current Sensor

SparkFun Magnetometer - Current Sensor

DFRobot Magnetometer - Current Sensor

Teachers in Space CubeSat Parts List

MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.

How You Can Use CubeSats to Meet this Standard

Plan and build a CubeSat experiment that includes an inertial measurement unit composed of an accelerometer and gyroscope. The IMU can be used to detect gravitational forces being enacted upon your students' CubeSat emulator. By changing the orientation of the CubeSat emulator, your students will be able to see that the gravitational force will always act upon the axis that is perpendicular to the Earth's surface, proving that gravity pulls in a downward direction.

CubeSat flights, whether orbital or suborbital, can be used to demonstrate how gravitational interactions depend on the masses of interacting objects. Inexpensive and easy to use inertial measurement units that include accelerometers, gyroscopes, and magnetometers can be used onboard CubeSat experiments to collect data regarding how different masses are affected by gravity.

Additionally, study of currently orbiting CubeSats, and those that have reached the end of their service life and deorbited, can further support the claim that gravitational interactions are attractive and depend on the masses of the interacting objects. Comparing a CubeSat's orbital trajectory and mission characteristics to those of a larger satellite can illustrate how Earth's gravity affects satellites of different mass.

Sample Questions:

- How does an accelerometer detect the pull of gravity?
- How does a gyroscope determine the orientation of a CubeSat?
- How can an accelerometer and gyroscope work together to detect the direction of gravity's pull?
- What is the Engineering Design Process?
- What is a CubeSat?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Inertial Measurement Unit: Accelerometer, Gyroscope, Magnetometer - Wikipedia

Adafruit Inertial Measurement Units

SparkFun Inertial Measurement Units

Teachers in Space CubeSat Parts List

MS-PS2-5 Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.

How You Can Use CubeSats to Meet this Standard

Utilize CubeSat magnetometer experiments to provide data for conventional magnet and static electricity experiments. Data can be graphed to provide visual representations of the electromagnetic fields present before, during, and after a magnet or statically charged object is introduced into the vicinity of other objects. Beyond visually seeing the effects of the fields on various objects, students can compare what they saw with their eyes to what the CubeSat's sensors were able to "see".

Sample Questions:

- How does the static electricity of multiple electrically charged objects compare?
- How do the magnetic forces of various sizes and types of magnets compare to each other?
- How does the distance and orientation of a magnet affect the readings collected by the magnetometer?
- What is the Engineering Design Process?
- What is a CubeSat?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Magnetometer - Wikipedia

Adafruit Magnetometer - Current Sensor

SparkFun Magnetometer - Current Sensor

DFRobot Magnetometer - Current Sensor

Teachers in Space CubeSat Parts List

MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.

How You Can Use CubeSats to Meet this Standard

Utilize the Engineering Design Process to plan and/or build a CubeSat emulator experiment to collect data about speed and direction of an object with a push, pull, or collision. Change or refine your experiment to see how results differ. Different CubeSat frame materials, sizes, and designs will most likely yield different results.

CubeSat experiments can include simple sensors that include accelerometers, gyroscopes, and magnetometers to record data in X,Y,Z coordinates.

These simple sensors can be built into a CubeSat emulator and used to collect and chart data collected by students to make visual representations of pushes and pulls on the motion of an object. Collisions can be recorded and visualized to see how much force interacts with CubeSats of different types or configurations.

Students can learn about the basics of engineering and electronics by planning and/or building a CubeSat emulator. The CubeSat will be a perfect object to push, pull, swing, etc. Data can be recorded while it is in motion which can then be used to make simple charts and graphs using spreadsheets. The motions and interactions of your students' individual objects can be used to illustrate these concepts.

Sample Questions:

- What is the Engineering Design Process?
- What is a CubeSat?
- How do CubeSat frames of different sizes/materials compare to each other?
- How are different frame materials produced such as 3D printing, metal, plastic, wood?
- How do different designs of frames or enclosures compare to each other?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Inertial Measurement Unit: Accelerometer, Gyroscope, Magnetometer - Wikipedia

Adafruit Inertial Measurement Units

SparkFun Inertial Measurement Units

Teachers in Space CubeSat Parts List

MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.

How You Can Use CubeSats to Meet this Standard

Use a CubeSat emulator to measure the differences in forces related to moving it within various arrangements. The inertial measurements of a CubeSat falling or rolling from different heights can be used to develop a model to describe how when distance changes, different amounts of potential energy are stored in the system. By comparing the effects of collisions between a CubeSat and another object and looking at the data collected by the onboard IMU sensors, a clearer picture of how potential energy changes as the arrangement of objects changes.

Sample Questions:

- What is a CubeSat?
- How do CubeSat frames of different sizes/materials compare to each other?
- How does dropping or swinging a CubeSat from various heights change the effect of the collision on another object such as blocks, boxes, etc?
- What is an inertial measurement unit and how can it be used to measure the force of a collision?
- What is the Engineering Design Process?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Inertial Measurement Unit: Accelerometer, Gyroscope, Magnetometer - Wikipedia

Adafruit Inertial Measurement Units

SparkFun Inertial Measurement Units

Teachers in Space CubeSat Parts List

MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.

How You Can Use CubeSats to Meet this Standard

CubeSats provide an excellent platform to conduct research regarding thermal energy transfer. Insulation and conduction experiments can be built into CubeSats that fly aboard high altitude balloons, orbital, and suborbital rockets. CubeSats can also be placed inside insulated containers or in various terrestrial locations to collect data samples. Discussion of insulation is especially relevant to construction of CubeSat components and experiments, as the rigors of spaceflight can play havoc on unshielded hardware and components.

Various inexpensive thermometers, thermocouples, and environmental sensors are available for the Arduino microcontroller that we use in the construction of our CubeSat experiments. These CubeSats can be used to monitor thermal energy flows through designed or natural systems.

Sample Questions:

- What is a CubeSat?
- Which types of sensors are best suited for monitoring thermal energy transfer?
- How can a probe type sensor be used to collect data from thermal reactions?
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

Arduino Microcontrollers

Adafruit Learning System

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit Environmental Sensors - Probe Temp Sensor

SparkFun Environmental Sensors

DFRobot Environmental Sensors

Teachers in Space CubeSat Parts List

MS-PS4-3 Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.

Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.

How You Can Use CubeSats to Meet this Standard

Radio communications are a big part of orbital CubeSat missions. Onboard radios allow ground stations to track CubeSats as they orbit overhead. The radios also allow for the transmitting of commands from the ground stations, as well as downloading of experimental data and CubeSat health information.

A discussion of basic radio communications involving CubeSats can be done to introduce students to the concepts of digitized and analog signals. Transceivers are also available that can be integrated into a CubeSat build. Students can work with actual radio equipment to send and receive data from a CubeSat.

Reach out to local Amateur Radio clubs or ARRL for assistance with teaching radio communications and using radios to talk to space-based satellites and space stations.

Sample Questions:

- What is a CubeSat?
- What is the difference between an analog and digital signal?
- What is an example of an analog signal?
- What is an example of a digital signal?
- Can you briefly describe how radio waves can be used to send data or communications?
- What is the Automated Packet Reporting System (APRS)?
- How can APRS be used to interact with a CubeSat?
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

CubeSat - Wikipedia

Radio Communications - Wikipedia

APRS - Wikipedia

Software Defined Radio (SDR) - Wikipedia

SDR Dongle (RTL-SDR)

Airspy SDR Software

MS-ESS2-5 Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Clarification Statement: Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide. Emphasis is on how weather can be predicted within probabilistic ranges. Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as with condensation).

How You Can Use CubeSats to Meet this Standard

Various environmental sensors are available to be integrated into your CubeSat experiment build. These sensors can be used to collect data regarding temperature, pressure, humidity, precipitation, and wind speeds. Essentially, students can build their own inexpensive weather station in the form of a CubeSat.

Students can use the CubeSat experiments to test design solutions and produce data to serve as the basis for evidence to answer scientific questions. Additionally, a high altitude balloon (HAB) mission can be flown with a CubeSat payload of environmental sensors to collect weather and climate data for a local geographic region.

Sample Questions:

- What is a CubeSat?
- How does air pressure affect the movement of air masses?
- What is wind, and how is it related to air pressure?
- How is air pressure affected by temperature and humidity?
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit Temperature, Humidity, Pressure, & Gas Sensor - Wind Speed Sensor

SparkFun Environmental Sensors

DFRobot Environmental Sensors - Rain Gauge

Teachers in Space CubeSat Parts List

MS-ESS3-5 Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gasses such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.

How You Can Use CubeSats to Meet this Standard

The CubeSat platform is an excellent way to use various sensors to collect data about human activities and natural processes that may be factors in the rise in global temperatures over the past century. Temperature sensors, and other environmental sensors, that have been discussed in earlier standards can also be used to meet this standard. Environmental data can be used to monitor changes in regional climate and impacts from human activities. There are quite a few arduino compatible gas and air quality sensors available as well. These can be used to further collect important data that can impact the health of both human and other natural ecosystems.

Sample Questions:

- What is a CubeSat?
- What is the greenhouse effect?
- What is a greenhouse gas?
- How do greenhouse gasses affect the atmosphere?
- What are examples of human activities that release greenhouse gasses?
- How do various greenhouse gasses compare to each other?
- How can greenhouse gasses be detected and monitored?
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit Temperature, Humidity, Pressure, & Gas Sensor - Gas Sensors

SparkFun Environmental Sensors - Gas Sensors

DFRobot Environmental Sensors - Gas Sensors

Teachers in Space CubeSat Parts List

MS-ESS3-2 Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).

How You Can Use CubeSats to Meet this Standard

The CubeSat platform and compatible sensors makes for a great tool to collect data on natural disasters and other catastrophic events. Accelerometers and gyroscopes can be used to collect data regarding earthquakes and other earth moving events. Environmental sensors can be used to collect and predict weather data related to large storms. Air quality sensors can collect data related to particulates in the atmosphere from large man-made or natural fires. All of this data can be analyzed to further understand these hazards, and attempt to find ways to mitigate them.

In addition to directly collecting environmental data, orbital CubeSat experiments can be designed by students to monitor larger natural hazards and catastrophic events from space. Your students can play a direct role in the tracking and mitigation of effects from future climate and man-made disasters. Further activities can include discussion or design of flocks of Earth observing CubeSats utilizing cameras of various wavelengths as well as additional sensors.

Sample Questions:

- What is a CubeSat?
- What sensors could be used to create an environmental data collection experiment?
- What is an inertial measurement unit?
- How can environmental data be used to compare the magnitude of various human and natural events?
- How can CubeSats be used to monitor global events?
- What is the Engineering Design Process
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit Environmental Sensors - Gas Sensors - Air Quality Sensors - IMU

SparkFun Environmental Sensors - Gas Sensors - Air Quality Sensors - IMU

DFRobot Environmental Sensors - Gas Sensors - Air Quality Sensors - IMU

Teachers in Space CubeSat Parts List

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).

How You Can Use CubeSats to Meet this Standard

Apply the Engineering Design Process to develop a CubeSat swarm to monitor the Earth. Challenge students to design one, or many, CubeSats that can be deployed to Low Earth Orbit (LEO), or the upper atmosphere, in order to collect data regarding various human impacts on the environment.

Students can work in groups, or individually, to design CubeSats with various data collection instruments onboard. Optionally, you can separate students into teams based on certain CubeSat systems, and they can work on those systems on various CubeSats. For example, if a student is particularly interested in a certain sensor, or aspect of the design process, they can go to various teams and help with that part of the design.

The flexibility of CubeSats allows them to be designed to collect data in both LEO and the upper atmosphere. Depending on the type of data wished to be collected, CubeSats can be designed to operate in both environments. Keep in mind that there are much more stringent requirements, and robustness is far more important, for CubeSat exposed to the rigors of space. This can provide another level of differentiation in the design process.

Additionally, as discussed in earlier standards, CubeSats make for an excellent sensor platform for ground based sensors too. Data on land usage in urban, suburban, rural, and wilderness areas can be collected on the ground, in the air, and from space using CubeSats as a platform.

Sample Questions:

- What is the Engineering Design Process?
- What are the steps of the Engineering Design Process?
- What is a CubeSat?
- What sensors could be used to create an environmental data collection experiment?
- What is an inertial measurement unit?
- How can environmental data be used to compare the magnitude of various human and natural events?
- How can CubeSats be used to monitor global events?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
- How do you make charts and graphs of collected data?

Resources

NASA Beginning Engineering Science & Technology: The Engineering Design Process

CubeSat - Wikipedia

Arduino Microcontrollers

SeeedStudio Microcontrollers

Adafruit Environmental Sensors - Gas Sensors - Air Quality Sensors - IMU

SparkFun Environmental Sensors - Gas Sensors - Air Quality Sensors - IMU

DFRobot Environmental Sensors - Gas Sensors - Air Quality Sensors - IMU

Teachers in Space CubeSat Parts List

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.

This standard does not include a clarification statement.

How You Can Use CubeSats to Meet this Standard

Utilizing the Engineering Design Process to identify a testable question and build a CubeSat to collect data is an excellent way to meet this standard. Designing a CubeSat inherently requires defining the criteria and constraints of a design problem with sufficient precision to ensure a successful solution. This is due to the constraints that will be applied to CubeSat designs in the form of size, weight, electrical, hardware, and software requirements. Flying payloads on various flight platforms means that constraints can vary and designs must be adapted.

Your students' CubeSat experiments will include multiple criteria and constraints, including limits to our current scientific knowledge. This provides your students the opportunity to push that limit further, and contribute to real scientific inquiry that can have potential impacts on people and the natural environment.

Sample Questions:

- What is the Engineering Design Process?
- What are the steps of the Engineering Design Process?
- What is a CubeSat?
- What are common constraints for building a CubeSat experiment?
- Why are constraints a necessary part of the Engineering Design Process for a CubeSat?
- What is the most difficult constraint to meet in the design of your CubeSat experiment?
- What sensors could be used to create an environmental data collection experiment?
- What is an inertial measurement unit?
- How can environmental data be used to compare the magnitude of various human and natural events?
- How can CubeSats be used to monitor global events?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
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Teachers in Space CubeSat Parts List

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

This standard does not include a clarification statement.

How You Can Use CubeSats to Meet this Standard

Students can evaluate competing design solutions utilizing the Engineering Design process to determine how well they meet the criteria and constraints of the flight platform that their CubeSat experiment will be flying on. There are a great many sensors and other data collection devices available for small microcontrollers that can be integrated into a CubeSat. Your students will need to first define their experimental variable, then determine what sensors they will use to collect data on that variable.

Sample Questions:

- What is the Engineering Design Process?
- What are the steps of the Engineering Design Process?
- What is a CubeSat?
- Which step of the Engineering Design Process will most satisfy this standard?
- Why is the chosen design better than others at meeting the constraints of this CubeSat build?
- What sensors could be used to create an environmental data collection experiment?
- What is an inertial measurement unit?
- How can environmental data be used to compare the magnitude of various human and natural events?
- How can CubeSats be used to monitor global events?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
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CubeSat - Wikipedia

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Teachers in Space CubeSat Parts List

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.

This standard does not include a clarification statement.

How You Can Use CubeSats to Meet this Standard

As a continuation of the previous standard, your students can analyze data from various sensors of the same type in order to determine similarities and differences among several design solutions to identify best characteristics of each that can be combined into a new solution to better meet the criteria of success. Students can be broken up into teams to work on coming up with a CubeSat design to collect data on a particular variable. With differences in student designs, data can be analyzed and a determination made as to which design works better given the constraints of the CubeSats' flight platform.

Sample Questions:

- What is the Engineering Design Process?
- What are the steps of the Engineering Design Process?
- What is a CubeSat?
- Which is the best design at meeting the constraints of this CubeSat build?
- Do different sensor types work better for this CubeSat build?
- Do different brands of sensors work better for this CubeSat build?
- What sensors could be used to create an environmental data collection experiment?
- What is an inertial measurement unit?
- How can environmental data be used to compare the magnitude of various human and natural events?
- How can CubeSats be used to monitor global events?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
- How do you collect data with sensors and microcontrollers?
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CubeSat - Wikipedia

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Teachers in Space CubeSat Parts List

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.

This standard does not include a clarification statement.

How You Can Use CubeSats to Meet this Standard

Using the Engineering Design Process; your students can design, modify, and iterate until they achieve an optimal design for their CubeSat experiment. CubeSat experimental design fits perfectly into the iterative testing and modification process of the Engineering Design Process. Your students will be required to go through every part of that process, troubleshoot problems, and come up with optimal solutions.

Sample Questions:

- What is the Engineering Design Process?
- What are the steps of the Engineering Design Process?
- What is a CubeSat?
- Which is the best design at meeting the constraints of this CubeSat build?
- Do different sensor types work better for this CubeSat build?
- Do different brands of sensors work better for this CubeSat build?
- What sensors could be used to create an environmental data collection experiment?
- What is an inertial measurement unit?
- How can environmental data be used to compare the magnitude of various human and natural events?
- How can CubeSats be used to monitor global events?
- How do basic electronics such as bread boards, wires, LEDs, sensors, and microcontrollers work?
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Teachers in Space CubeSat Parts List