AVIATION'S EVOLUTION OF TRANSPORTATION
EXPLORATION: THEN AND NOW

Grade level: 6-8

Subject Area: Social Studies

Objective: The students will be able to compare vessel design, navigation, and propulsion used by early Jamestown explorers to those used by the National Aeronautics and Space Administrations. Students will use maps and coordinate planes to demonstrate the Global Positioning System and to compare 17th century mapmaking to modern Technology. Students will conduct experiments about sails and other propulsion systems.

Related CBC Objective: Define key geographic terms and concepts; e.g. boundary, compass rose, hemisphere, latitude, legend, longitude, map, map projection, scale, symbols.

Sunshine State Standards: (SS.B1.3.1) (SS.B.1.3.3) (SS.B.2.3.9)

Suggesting time: 1 day

Vocabulary: Astrolabe, Global Positioning System, gravity well, hypersonic, inertia, inertial guidance systems, latitude, longitude, magnetic compass, navigation, propulsion, shallop, trigonometry.

Description of activities:

Day 1:

1. Begin lesson by creating a chart to help organize student learning (chart available in handout).
2. Activate prior knowledge by asking students if they had gone on a trip and where they were and what were some of the problems. Discuss. Then ask students to think about the journeys made by early explorers and the problems they mighty have encountered.
3. Take students to a large area (gymnasium, playground). Measure out 17 meters long and 5 meters wide. Have students make area with masking tape or string. This area will represent the deck size of the Godspeed, the middle-sized ship used by the Jamestown settlers.
4. Have students stand inside and make observations.
5. Give students the third dimension for each vehicle. Have students determine if the third dimension would make a difference or not.
6. Students will complete Journal Prompt #1.

6. Students will complete Journal Prompt #1.
7. Students will do activity one: Geospatial Technology. Follow directions in the guide page 8.

Assessment:

1. Evaluate class/students charts for new information learned during these activities.
2. Assess students' journal responses.

Vocabulary

astrolabe: an instrument used by navigators to determine latitude, longitude, and time of day by measuring the altitude of heavenly bodies

Global Positioning System (GPS): a satellite navigation system that gives special satellite signals that can be processed in a GPS receiver to compute position, velocity, and time

gravity well: the pull of gravity that a large body in space exerts; entering space from the surface of a planet means a spacecraft must have enough energy to overcome the gravitational pull of the planet, or be able to "climb out of the gravity well"

hypersonic: speeds that are greater than Mach 5, or about five times faster than the speed of sound (the speed of sound at the temperature and altitude planes fly is 1,225 kilometers per hour [761 miles per hour])

inertia: one of the properties of matter in which objects in motion remain in motion unless outside forces act to change the motion

inertial guidance systems: the use of a gyroscope to measure changes in speed and direction

latitude: the angular distance measured in degrees north or south of Earth's equator

longitude: the angular distance of Earth's surface measured in degrees east or west of the prime meridian at Greenwich, England

magnetic compass: an instrument that uses Earth's magnetic field to point north

Instructional Procedure

Teaching Suggestion: *Prior to beginning this lesson, create a chart that is displayed throughout the lesson to help organize student learning. Ask the students to create similar charts in their journals. The charts may be formatted as follows, but should be large enough to organize information.*

How do vessel design, navigation, and propulsion affect exploration?

	JAMESTOWN	MOON	MARS
VESSEL DESIGN			
NAVIGATION			
PROPULSION			

Engage

1. Discuss the following questions with the class:
   - Have you ever been on a long trip?
   - How did you get where you were going?
   - What was good about the trip?
   - What were some of the problems?

2. Ask students to think about the journeys made by early explorers, such as the Jamestown settlers, or modern day explorers, such as the astronauts who traveled to the Moon. What kinds of problems might they have encountered?

Assign Journal Prompt # 1
Using what you have learned from this activity, what do you think the next generation of exploration vehicles should look like? You may want to include illustrations to support your answer. How does vessel design affect exploration?

Explore

Changes and improvements in navigation and propulsion affect exploration. These activities help your students understand some of these changes.

Activity One: Geospatial Technology
Using geospatial technology, every feature on Earth's surface is assigned a unique address. These addresses are expressed as coordinates, using latitude and longitude. One geospatial tool with which students may be familiar is the Global Positioning System (GPS). A GPS is able to show people their exact position on Earth. GPS satellites orbit at 20,000 kilometers (11,000 nautical miles) above Earth. The satellites transmit signals that can be detected with a GPS receiver. Each GPS satellite transmits data that indicate the satellite's location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant. The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are farther away than others. The distance to the GPS satellites can be determined by estimating the amount of time it takes for their signals to

reach the receiver. When the receiver estimates the distance to at least four GPS satellites, it can calculate a position in three dimensions.

1. Introduce the students to geospatial technology.

Teaching Suggestion: *You may want to show the 30-second NASA KSNN™ (Kids Science News Network) video, "How can you find your place in space?"* http://ksnn.larc.nasa.gov/webtext.cfm?unit=geospatial

2. Demonstrate how a GPS works using the following example:
Imagine you are somewhere in your town. You are completely lost. You ask someone, "Where am I?" They tell you that you are about 8 kilometers (5 miles) from the fire station.

The information you have lets you know you could be anywhere on a circle 8 kilometers (5 miles) around the fire station. See Diagram 1.

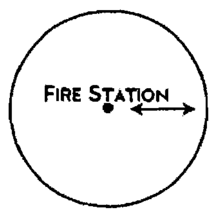

Diagram 1

A second person may tell you that you are about 11 kilometers (7 miles) from the library. By combining this information with the fire station information, you have two circles that cross. You now know that you must be at one of the two points where the circles cross, if you are 8 kilometers (5 miles) from the fire station and 11 kilometers (7 miles) from the library. See Diagram 2.

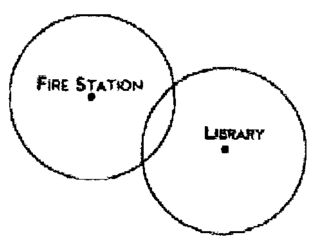

Diagram 2

A third person tells you that you are about 6 kilometers (4 miles) from home. The three circles will only cross at one point. See Diagram 3. You can now precisely pinpoint your location.

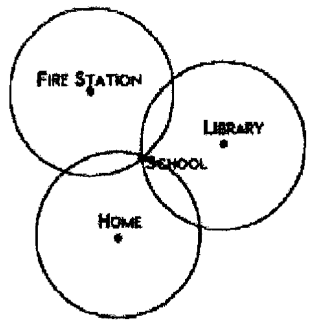

Diagram 3

Teaching Suggestion: *This is a two dimensional example. In the real world of three dimensions, the three circles are replaced with four spheres.*

JAMESTOWN	NASA
Ships in the 17th century, like ships of ancient times, were designed to sail with the wind behind them. These ships, known as "downwind sailers" could make little progress against winds from the wrong direction. Ships often had to wait at port or at sea for the right wind direction to continue their journeys. The rigs for these ships consisted of large square sails and the 75 lines used to control them. Most sailing ships of the time were between 9 and 28 meters (30 and 90 feet) in length. The three ships that sailed to Jamestown in 1607, the *Discovery*, the *Godspeed*, and the *Susan Constant*, were no different. The *Discovery* was the smallest of the three ships. She was 11.6 meters (38 feet) long at the waterline and could carry 21 people. This ship was about the size of a modern-day school bus. The *Godspeed* was a larger ship, boasting a deck that measured 19.5 meters (64 feet). This ship carried 52 people and was a little larger than a modern-day semi-truck. The third ship in the fleet, on which Captain Christopher Newport sailed, was the largest of the three. The *Susan Constant* was more than 23 meters long (76 feet) and carried 71 people. The *Susan Constant* was about the same length as a car on a modern-day passenger train. Each ship carried smaller longboats, or shallops, that could be rowed and were used to explore the lakes and rivers	Vessel design was very challenging at the dawn of space exploration. NASA scientists and engineers had to design and build craft that would withstand the extreme conditions experienced in the vacuum of space. The first capsules to be shot into space were very small and designed only to hold a single crewmember. The total length of each of the Mercury capsules was only about 3.5 meters (11 feet) and the pressured volume was a small 1.5 cubic meters (55 cubic feet). In spite of being crammed into a vehicle not much larger than a refrigerator, Alan Shepard made history when he completed America's first suborbital flight. John Glenn later became the first American astronaut to orbit Earth, spending 4 hours 55 minutes and 23 seconds in space. The space program continued with the design of Gemini capsules, which were a bit larger, having a pressurized volume of nearly 2.3 cubic meters (80 cubic feet). These capsules were about the size of a phone booth or the front half of a Volkswagen Beetle, yet carried two crewmembers. Astronaut Pete Conrad once remarked that his time on Gemini 5 was like "spending 5 days in a garbage can." Gemini gave U.S. astronauts their first real experience at living and working in space. As NASA made plans to land on the Moon, a new capsule was designed. The Apollo capsules were much larger than the Gemini capsules, almost 6 cubic meters (210 cubic feet), and were

near the Jamestown settlement. These boats did not have much room for cargo, but were very useful for putting ashore anywhere along the riverbank. Captain John Smith used a shallop to explore and map the area in and around the Chesapeake Bay. The Virginia Indians used a different kind of vessel to travel up and down the Virginia waterways. Their log canoes were square on both ends and had flat bottoms. The design was difficult to steer, but was quite stable, making stepping on and off the boat easier. The canoes were powered by paddles and poles. William Strachey, one of the original Jamestown settlers, described the canoes in one of his published writings. He wrote, "The Indians valued them almost with their lives. When Smith began chopping up the canoes of Nansemonds, we heard their cries." Modern sailing ships of the 21st century use technology that allows them to harness the wind in any direction. The sails and design of the ship work together much like airplane wings, creating lift as the air moves across the sails.	designed to hold a crew of three. The spacecraft was made up of two parts, or modules. The Command Service Module contained the life support systems for the 5-day round-trip to the Moon; the Lunar Module was designed to land on the surface of the Moon and then dock again with the Command Module before returning to Earth. The crew cabin on the Command Service Module was only about 1.8 meters by 1.8 meters by .9 meters (6 feet by 6 feet by 3 feet). Imagine sharing a space smaller than many closets with two other people for several days! NASA is currently working on the next generation of space vehicles. The *Orion* spacecraft will have a shape similar to the gumdrop shape of the Apollo capsules, but *Orion* will be much larger, about 19 cubic meters (671 cubic feet)—about the size of an average bedroom. This cone-shaped spacecraft will provide a safe, economical means of transporting four-member crews to and from space. *Orion* will replace the Space Shuttle, a winged vehicle able to operate on land, in the atmosphere, and in space. The Shuttle combines the features of a rocket, an aircraft, and a glider and has been used to carry satellites and other cargo into Earth's orbit. From its first flight on April 12, 1981, to today, no other spacecraft has been used for so many flights. Once the International Space Station is completed, NASA will retire the Space Shuttle fleet. Cumulatively, the five Space Shuttles—*Atlantis, Challenger, Columbia, Discovery*, and *Endeavor*—have spent over 1,000 days in space.

JAMESTOWN	NASA
Early explorers navigated the water by observing landmarks, such as large rocks or trees along rivers and coastlines. When out of sight of land, they gathered clues about their location by measuring water depth, monitoring wind pattern and wave shape, and observing the position of the Sun as it moved across the sky. At night, they steered by the stars. By the 17th century, navigational tools had been developed that, while not always accurate, gave their users a general idea about location. Captain John Smith listed the astrolabe and magnetic compass as necessary navigational instruments to successfully navigate a ship in his day. Mariners, or sailors, used an astrolabe to find the angle of the Sun or specific stars in the sky. Applying basic trigonometry skills to the angle, a sea captain could calculate the ship's latitude. The astrolabe was not always reliable and could only be used when a clear view of the horizon and an anchor point, such as the Sun or another star, were visible. In later years, celestial navigators replaced the astrolabe with a tool called a sextant. The sextant was a unique precision instrument for measuring angles. To measure the altitude of a celestial body, the navigator pointed the sextant at the horizon and slid a movable sighting arm up until mirrors in the sextant reflected an image of the body onto the horizon. The horizon provided a baseline against which to measure the	Stars have long been a means of identifying one's position on Earth, but they are useful for identifying positions in space as well. The astronauts use star charts to help them manually determine their location. Optical navigational systems consist of a scanning telescope and a modern sextant. Stars are used as anchor points or landmarks. In addition to star-tracker devices, inertial reference systems are used to help keep spacecraft stable and on course. These inertial guidance systems use a kind of gyroscope to sense every change in a spacecraft's velocity or direction. A spinning bicycle wheel behaves like a gyroscope. Gyroscopes are able to sense the slightest change in direction or orientation of spacecraft. Sensors on the gyroscope send information to onboard computers that determine a spacecraft's position and velocity based on these changes. Onboard computer systems receive data from the inertial system and from ground-tracking stations on Earth. These ground-tracking stations use space-based systems like a Global Positioning System (GPS) to compute spacecraft position and velocity. A GPS uses radio signals to pinpoint location and has become a reliable method of navigation. With 24 satellites circling the globe in 12-hour orbits, a GPS provides near total coverage of Earth. A GPS is used for low-Earth orbits, air flight, and ground and sea applications. When at least four satellites are in view, a user can determine an

angle of the Sun, stars, or the Moon. By applying math skills and using charts, the navigator could calculate the latitude and identify the ship's position on a map.

The magnetic compass used by the 17th-century explorers was one of the most reliable navigation instruments available at the time. A compass, which always points north, provided navigators with a fixed reference point. Using a compass and a map or chart, a skilled, careful navigator could direct a craft from one destination to another, even in fog or at night. Although reliable tools on Earth, compasses do not work on the Moon because there is little to no global lunar magnetic field.

Cabin boys were taught to "box the compass." The boys had to memorize the 32 points of the compass, as well as learn to tell time with a sandglass or a sundial. They could check the speed the ship was traveling using dead reckoning or a log line.

Dead reckoning was used by early explorers as a technique to estimate position by calculating the distance, direction, and amount of time a craft traveled. Explorers could also use dead reckoning to calculate the distance they traveled on land. By knowing how many paces a person usually walked in a given distance and keeping track of the number of paces walked, a person could estimate the distance traveled and record the distance on a map or in a journal.

A log line was another way to measure speed. This technique involved attaching a rope, divided into equal lengths, called knots, to a log on one

accurate, three-dimensional position in real time.

During the lunar landings, astronauts explored the Moon's surface and collected Moon rock samples in the Lunar Rover Vehicle (LRV), or "Moon Buggy," as it was called. The surface of the Moon is a consistently gray color, making it difficult to identify specific landmarks, such as craters. Apollo 14 astronauts Alan Shepard and Edgar Mitchell abandoned a rock-collecting trip when they became confused by the landscape. Later, they realized they were only about 30 meters (100 feet) from the rim of a targeted crater when they gave up the search. Subsequent Apollo missions included navigational equipment for the LRV.

On January 3, 2004, NASA set a new standard for navigational accuracy. After traveling over 487 million kilometers (302 million miles), the Mars Exploration Rover named *Spirit* landed within 200 meters (656 feet) of its targeted spot. To accomplish this feat, scientists at the NASA Jet Propulsion Laboratory accurately calculated the exact speeds of a rotating Earth, a rotating Mars, and a rotating spacecraft, all simultaneously spinning in orbits around the Sun. Radio signals sent and received by the Deep Space Network (DSN) antennas on Earth were used to compute the spacecraft's position and velocity.

Robotic rovers and probes collect data from the surface of Mars and other planets. Navigational commands are sent by radio signals to the rovers, allowing the rovers to move a few meters each day. With stereoscopic cameras and sophisticated

	the Sun is coated with a highly reflective material so that the sail becomes a huge mirror. A typical solar sail is the size of a football field. Even in space, particles are moving at high enough speeds to exert pressure on a sail roughly similar to that of wind blowing on sails on Earth. Solar sails, however, do *not* harness the ionized particles from the Sun, known as solar winds. The density of solar-wind particles is so small that their combined pressure is much less than the pressure resulting from even a gentle breeze on Earth. The Sun, however, exerts a tiny but perpetual force on the solar sail as the photons of light strike the sail and bounce off the reflective surface. The momentum from these light particles is transferred to the sail, gently pushing the sail forward. Over days, weeks, and months, the snail-paced acceleration builds substantially, resulting in high-speed velocities. "Gravity assist" is another space-flight technique that has helped propel a number of interplanetary missions, including *Voyager, Galileo,* and *Cassini*. Moving spacecraft use the gravitational field of the planets to increase speed and/or change course without using additional fuel. Commonly referred to as the "slingshot effect," gravity assist is more like a pitched baseball that, when hit with a bat, soars out of the stadium in a different direction. One of the most dramatic applications of this technique occurred in 1970—the world watched as NASA used gravity assist to rescue the Apollo 13 astronauts. NASA astronauts and engineers were able to use the Moon's gravity to turn the spacecraft around and send it safely back home.