SUGGESTED REFERENCES

- *The Commercial Spaceflight Federation Homepage*
  www.commercialspaceflight.org
- *Space Adventures Homepage*
  www.spaceadventures.com
- *Space Tourism Society – To stimulate a profitable and expanding space tourism industry*
  www.spacetourismsociety.org
- *SpaceX Homepage – extensive photo & video galleries*
  www.spacex.com
- *Virgin Galactic Homepage*
  www.virginglactic.com
- *XCOR Aerospace Homepage*
  www.xcor.com
- *X Prize Foundation Homepage*
  www.xprize.org
- *Private companies hold the key to space travel's future:*
  www.cnn.com/2011/US/06/30/future.of.space.travel/index.html

NATIONAL SCIENCE EDUCATION STANDARDS

Grades 9 - 12
Science & Technology
Abilities of technological design
Understandings about science & technology

Grades 9 - 12
Science in Personal & Social Perspectives
Science and technology in local national and global challenges

Grades 9 - 12
Physical Science
Motions and forces
Interactions of energy and matter
Chemical reactions

**Source: National Science Education Standards, 1996, National Academy Press*

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FOOTAGE COURTESY OF:

Space Adventures, SpaceX,
Virgin Galactic, XCOR, & X Prize

PRODUCTION CREDITS

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VOLUME 41 ISSUE 3

SPACE SCIENCE - *Everyday Astronaut*

ABET
Accreditation Board for Engineering and Technology
www.abet.org

NMOE
National Museum of Education
www.nmoe.org

CILC
Center for Interactive Learning and Collaboration
www.cilc.org

JETS
Junior Engineering Technical Society
www.jets.org

SYNOPSIS

With the retirement of NASA's space shuttle fleet in 2011, the role of getting people, satellites and other instruments into space falls to private companies. As of June 2011, there have been only 523 people to reach the 100 kilometer mark (considered human spaceflight), and only 24 have traveled beyond low Earth orbit. It is projected that within ten years, the number of people who will have flown into space will increase by about 600 percent due to the increasing market of suborbital spaceflight and the possibility of private citizens utilizing space flight.

This edition explains suborbital and orbital spaceflight and the requirements necessary for vehicles to achieve these journeys. We go behind the scenes of many of the private companies involved in taking on the tasks to travel to low Earth orbit and beyond and uncover some of the technology used to accomplish these goals.

CURRICULUM UNITS

- CHEMISTRY
- ENGINEERING
- PHYSICS
- PHYSICAL SCIENCE

RUNNING TIME

16 minutes

BACKGROUND

Orbital spaceflight occurs when a spacecraft is placed on a trajectory where it can remain in space above 100 kilometers for at least one orbit of Earth. To remain in orbit at this altitude requires an orbital speed of approximately 7.8 kilometers per second. Orbital speed is slower for orbits higher than 100 kilometers above the earth's surface, but attaining a higher orbit requires a larger thrust. Sub orbital spaceflight, however, is accomplished when a spacecraft has reached an altitude where its trajectory intersects the atmosphere or surface of the gravitating body from which it was launched so that it does not complete one orbital revolution.

The Ansari X-Prize competition was created in 1996 to motivate private companies to pursue radical breakthroughs in spaceflight. SpaceShipOne was awarded the prize in 2004. The ship was carried up by a mother-ship, called the White Knight, then launched into the upper atmosphere. It was powered by a hybrid rocket motor that combined nitrous oxide as the oxidizer with a rubber compound fuel. Both are benign and stable as well as containing none of the toxins found in most solid rocket motors. A valve control allows the oxidizer and the fuel to mix and the motor to be shut down as needed. This system pushes the craft to Mach-3.

XCOR has developed and tested their EZ-Rocket and the X-Racer. They are also hard at work perfecting their reusable launch vehicle, the LYNX. The LYNX is evolved from the X-Racer engine design, and will enter into the commercial reusable launch vehicle market. The LYNX is designed to carry more than tourists to space, it will also be available to run in-cockpit experiments, astronaut training, atmospheric sampling, launch micro-satellites and conduct ballistic trajectory research.

Space Adventures is a company that will take private citizens on sub orbital and orbital flights, and ultimately one day missions to circumnavigate the Moon. Through Space Adventures, Richard Garriott, an entrepreneur and video game developer, purchased a ticket to space aboard the Soyuz TMA-13 and spent several days aboard the International Space Station. He made the trip to promote space tourism and conducted experiments such as protein crystallization in space, immune system monitoring in space, visual acuity, and sleep study.

SpaceX is privately developing the Dragon crew and cargo capsule and the Falcon family of rockets. Their projects include main and upper stage engines, the cryogenic tank structure, avionics, guidance & control software and ground support equipment. The goal of SpaceX is to ultimately reduce the cost and increase the reliability of space access by a factor of ten, and consequently they were awarded Commercial Orbital Transportation Services (or COTS) funding by NASA to demonstrate delivery and return of cargo to the International Space Station.

Scientists cite many benefits to exploring space, including the possibility that the moon and gas giants like Jupiter contain high levels of Helium 3 that can be used to run nuclear fusion reactors at a much lower cost and without any radioactive waste compared to fission reactors. Another idea is to collect solar power more efficiently since the sun is always shining in space.

Asteroid mining could prove to be profitable. A one mile diameter asteroid could contain over twenty trillion dollars of industrial and precious metals such as nickel, cobalt, and platinum. Many of the metals that we mine on Earth are believed to originate from asteroids hitting the planet after the crust cooled. Another future endeavor includes launching spaceports to take advantage of these resources and to reduce the costs of space travel to distant Mars and other planets.

CRITICAL THINKING EXERCISES

1. Discuss the requirements of vehicles designed for sub-orbital spaceflight, orbital spaceflight, and long distance rockets that will go to the Moon and beyond.

2. Discuss with students what economic and technological hurdles must be overcome to make space travel available to the average person.

3. Ask students to research the technology that was used in the rockets of the first U.S. mission to the moon. Discuss how technology has evolved and what we might see in the future to improve long distance space travel.

4. Judge the value of spaceflight as a tourism industry. Compare and contrast the costs and benefits of tourism on earth with the potential costs and benefits of space tourism.

CAREER POSSIBILITIES

- AERONAUTICAL ENGINEER
- CHEMIST
- COMPUTER SCIENTIST
- ELECTRICAL ENGINEER
- MECHANICAL ENGINEER
- PHYSICIST

ADVANCED ORGANIZERS

Prior to viewing this program, students should have some understanding of the following Benchmarks for Science Literacy, Oxford University Press which are excerpted and, in some cases, abbreviated below. Refer to the Benchmarks for more information.

Benchmark 3. The Nature of Technology
Section A: Technology & Science, Grades 9-12

- Technological problems and advances often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.
- Mathematics, creativity, logic, and originality are all needed to improve technology.
- Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems. Scientific knowledge provides a means of estimating what the behavior of things will be even before they are made. Moreover, science often suggests new kinds of behavior that had not even been imagined before, and so leads to new technologies.

Benchmark 8. The Designed World
Section C: Energy Sources & Use, Grades 9-12

- A central factor in technological change has been how hot a fire could be made. The discovery of new fuels, the design of better ovens and furnaces, and the forced delivery of air or pure oxygen have progressively increased the maximum possible temperature.
- When selecting fuels, it is important to consider the relative advantages and disadvantages of each fuel.
- During any transformation of energy, there is inevitably some dissipation of energy into the environment. In this practical sense, energy gets "used up," even though it is still around somewhere.
- Sunlight is the ultimate source of most of the energy we use. The energy in fossil fuels such as oil and coal comes from energy that plants captured from the sun long ago.

**Benchmarks can be found at www.project2061.org/tools/benchol/bolintro.htm*

VOCABULARY

Delta-V	A scalar which takes units of speed that measures the amount of "effort" needed to carry out an orbital maneuver, (to change from one trajectory to another).
Kármán line	An altitude of 100 kilometres (62 mi) above the Earth's sea level, that is commonly used to define the boundary between the Earth's atmosphere and outer space.
geostationary orbit	(GEO) is a special case of geosynchronous orbit where the satellites stays at an absolutely fixed point relative to the Earth's surface at all times. This must be above the equator.
Gravity Turn	A spacecraft maneuver where the craft rolls over due to the rocket engines shifting slightly to direct thrust to one side. this flattens out the trajectory while increasing velocity.
In-situ Resource Utilization	The production of useful materials from the resources available at a given location. Regarding space exploration, this describes the proposed use of resources found or manufactured on other astronomical objects such as the Moon, Mars, or Asteroids to further the goals of a space mission.
Low Earth Orbit	An orbit within the locus extending from the Earth's surface up to an altitude of approximatley 2,000 km. Given the rapid orbital decay of objects below approximately 200 km, the commonly accepted definition for LEO is between 160 and 2,000 km (100–1,240 miles) above the Earth's surface.
Orbital Spaceflight	A spaceflight in which a spacecraft is placed on a trajectory where it could remain in space for at least one orbit of the Earth.
Sub-orbital Spaceflight	A spacecraft reaches space and then returns to the atmosphere after following a (primarily) ballistic trajectory.
Zero-G	The condition of real or apparent weightlessness occurring when any gravitational forces acting on a body meet with no resistance so the body is allowed to accelerate freely. Bodies in free fall (including trajectories like orbits) experience zero gravity; bodies at rest on the Earth's surface do not, since they are subject to the counterforce of the surface supporting them.