SUGGESTED REFERENCES

- *NASA's Beginner's Guide to Propulsion*
  http://www.grc.nasa.gov/WWW/K-12/airplane/bgp.html
- *NASA's Propulsion Systems of the Future*
  http://www.nasa.gov/vision/space/travelinginspace/future_propulsion.html
- *NASA's Advanced Flight Projects Office*
  http://spaceflightsystems.grc.nasa.gov/Advanced/ScienceProject/ISPT/
- *University of Washington – Advanced Electric Propulsion*
  http://www.ess.washington.edu/Space/propulsion.html

NATIONAL SCIENCE EDUCATION STANDARDS

Grades 9 – 12

Science and Technology

Abilities of technological design

Understandings about science and technology

Grades 9 - 12

Physical Science

Motions and forces

Interactions of energy and matter

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

CREDITS

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Science Screen Report

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PROPULSION - *Technological Advances*

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www.jets.org

SYNOPSIS

From fireworks to missiles to space flight – the science of propulsion makes a major impact on our world. This program takes a look at how the process of propulsion is developed for use in space science. Its application to crucial military technology helps keep the military strong and secure. In the future, new technologies will propel us into the far reaches of our solar system and beyond. This program describes several different propulsion systems including airplanes, rockets, missiles, and trains, with a detailed description of the differences in solid fueled and liquid fueled rockets.

CURRICULUM UNITS

- CHEMISTRY
- ENGINEERING
- PHYSICS

RUNNING TIME

14 minutes

BACKGROUND

Rocketry moved into the realm of science and discovery in the latter part of the 17th century when English scientist Sir Isaac Newton laid the scientific foundation for modern rocketry with his “Three Laws of Motion.” The first two laws dealt with inertia as well as the relationship between an object’s mass, its acceleration, and the applied force. Newton’s 3rd law explains the principle of “action-reaction” which states that “for every action there is an equal and opposite reaction”. That ultimately laid the foundation for the future development of propulsion technology. With Newton’s laws in mind, propulsion is the act of affecting an object’s inertia or momentum through a mechanical force called thrust. Thrust is a vector quantity having both magnitude and direction.

Konstantin Tsiolkovsky, Hermann Oberth, and Robert Goddard are commonly reffered to as the fathers of rocketry and astronautics. Early in the 20th century, Robert Goddard conducted some of the first practical rocket experiments. In 1919, his work titled “A Method of Reaching Extreme Altitudes” described his suggestions about travelling to the moon. Despite much criticism for his claims, Goddard persisted onwards. In spite of great difficulties, he achieved the first successful flight of a liquid-fueled rocket on March 16, 1926 at Auburn, Massachusetts.

German scientist Hermann Oberth was one of the men who developed and flew the V-2 military rocket which was used heavily during World War II. After the war, Oberths pupil Wernher Von Braun immigrated to the United States, and Oberth later followed.

Dr. Oberth’s legacy continues at Aerojet where his son, Dr. Adolph Oberth, and his grandson, Michael Oberth, have furthered his work by developing several new ingredients and components, including 15 patents, that are used in many of today’s rocket fuels and motors.

Most rockets work from either solid or liquid propellants. Propellants are not just fuels; they are sometimes both fuel and oxidizer. For burning to take place, and oxidizer like oxygen, must initiate the burn. Whereas jet planes draw oxygen into their engines from surrounding air, rockets might not have that luxury in space, so they must carry oxygen with them where there is no air.

Solid fuel propulsion systems deliver paramount rocket thrust. The system includes a nozzle, a case, insulation, propellant, and an igniter. The case usually consists of a thin metal that is lined with insulation. Most solid fuel rocket engines have a hollow core throughout the propellant. If they do not have a hollow core, they are ignited at the lower end and burning occurs gradually from one end to the other. But the hollow core systems allow for higher thrust because of increased surface area of the propellant that is allowed for burning. The nozzle is the opening at the back end of the rocket that allows the expanding gases to escape. Burning propellant builds up in the cone and continues past the throat where thrust is created as it expels out of the nozzle.

Liquid fuel propulsion systems serve as the main engine on many rockets. Liquid propellants are forced into the engine by pressure. This is a more complicated engine than the solid fuel rocket. They have separate storage tanks for the fuel and oxidizer. Fuel is often kerosene or liquid hydrogen, and the oxidizer is usually liquid oxygen. These are combined in the combustion chamber where they are burned and build up very high temperatures and pressures. The expanding gas exists through the nozzle, creating thrust.

For maximum power, the propellants in a liquid fuel system must be mixed with efficiency. Injectors in the combustion chamber spray and mix the propellants. Due to high pressures, the propellants must be forced into the chamber by lightweight turbine pumps. They provide less thrust per fuel load than solid fuel systems, and have much greater volatility. Liquid fuel engines are advantageous because they can be turned on and off as needed. This creates greater efficiency over the life of the engines.

CRITICAL THINKING EXERCISES

1. Compare and contrast solid and liquid fuel rocket propulsion. Which is most appropriate for rockets designed to explore Mars? Which is most appropriate for the design of fireworks?
2. Identify the sustainable advantages of rocket propulsion using the solar wind. Distinguish between sustainable and non-sustainable propulsion methods.
3. Acting as a NASA engineer, prioritize future projects, and the methods of propulsion that will be used. Defend the reasons for your sequence of prioritizing.
4. Design a plan to use a method of propulsion to solve a transportation issue in your local community.
5. Research balloon rockets online, and demonstrate the use of balloon rockets in class. Conclude which type of propulsion fuel, solid or liquid, is most closely demonstrated using balloon rockets.

CAREER POSSIBILITIES

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

ADVANCED ORGANIZERS

Prior to showing 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 and 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 and 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.
- Nuclear reactions release energy without the combustion products of burning fuels, but the radioactivity of fuels and their by-products poses other risks.
- 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

Thrust . . . . The act of applying force to propel something.

Inertia . . . . The resistance of a body to changes in its momentum. A body at rest remains at rest, and a body in motion continues moving in a straight line and at a constant speed, unless a force is applied to it. Mass can be considered a measure of a body's inertia.

Momentum . . . . A measure of the motion of a body equal to the product of its mass and velocity.

Vector Quantity . . . . . . A quantity which is fully described by both magnitude and direction.

Liquid Oxygen . . . . A clear, pale blue liquid obtained by compressing oxygen, then cooling it below its boiling point; often used as an oxidizer in liquid rocket propellants.

Solid fuel . . . . Commonly used in rockets with a motor that uses solid propellants - a fuel and an oxidizer.

Liquid fuel . . . . Combustible or energy-generating molecules that can be harnessed to create mechanical energy.

Volatility . . . . The property of changing readily from a solid or liquid to a vapor with traits of being unpredictably irresolute.

Fischer-Tropsch Process . A catalyzed chemical reaction in which synthesis gas, a mixture of carbon monoxide and hydrogen, is converted into liquid hydrocarbons of different forms. Common catalysts are iron and cobalt. The principal purpose of this process is to produce a synthetic petroleum substitute.