This lesson introduces students to vocabulary related to space and focuses on explaining concepts, both orally and in writing. Students practise reading and writing analogies, take notes and summarize technical readings, and write a short explanation. The lesson prepares them for the final project of the module.
Sequence 1

Activation

a) Show a short segment of a video about space travel. How do the humans travel? Do you think this will be possible some day? What is the difference between space and atmospheric travel?

b) Ask for volunteers to describe how a rocket works (this will be difficult).

- Define “concept”—an idea, theory, principle, belief, something abstract. How can you explain concepts?

Language Features

<table>
<thead>
<tr>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Words related to space</strong>: advent, asteroid, astronaut, biodome, boost, constellation, crew, debris, drift, exert, friction, galaxy, gravity, hazardous, launch, meteorite, momentum, navigate, orbit, parabola, payload, planet, probe, propulsion, radiation, remote, rendezvous, robot, satellite, solar, spinoff, thrust, trajectory, ultra, underway, velocity, viable, weightlessness</td>
</tr>
<tr>
<td><strong>From AWL</strong>: alternative, analogy, attain, attainable, components, concept, convert, enable, eventual, facility, fund, innovation, precedent, structure, transfer, unattainable, unprecedented</td>
</tr>
</tbody>
</table>

Structures

- compound adjectives

Academic Language Function

- **describing**: steps in process (rocket launch)
### Student Learning Tasks

- a) View the video, and answer the teacher’s questions. (C)
- b) Describe how a rocket works. (C)

### Teacher Notes and References

- Video of any popular movie or television program based on space travel, preferably a clip showing some method of transportation (teacher-provided).
- **Internet Resources:**
  - “How Rocket Engines Work” at: [http://science.howstuffworks.com/rocket1.htm](http://science.howstuffworks.com/rocket1.htm), or find a short reading that uses analogies to explain the basics of rockets.
c) Have students read independently **Handout 3-27**: “How Do Rockets Work?” and find the analogies.

d) Practise making analogies:

1. Give the students a common event or process (e.g., a traffic jam, selling something, building a bridge across a river) and have them think of some more complex things it could help explain (blood pressure, a job interview).

2. Give two lists: Column A contains familiar concepts or processes, and Column B contains more complex ideas. Students choose an item from Column A to help explain any item in column B. See Language Features below.

There is no one answer—the goal is to think and explain the similarity. In this step, students state the similarity explicitly (x is like y because...).

### Writing Task

a) Have students write a paragraph that explains one of the previous concepts, using an analogy.

b) Students read paragraphs to one another and have listeners question the explanation and ask for clarification and justification of the analogy.
c) Read **Handout 3-27: “How Do Rockets Work?”** to find the analogies. (I)

d) Practise making analogies. (I)

---

**Assignment**

a) Write a paragraph that explains one of the previous concepts, using an analogy. (I)

b) Read paragraphs to one another and have listeners question the explanation and ask for clarification and justification. (G)

---

**Teacher Notes and References**

**Handout 3-27: “How Do Rockets Work?”**

Analogies: Analogies use simpler, more familiar ideas to explain unfamiliar or complex concepts. Note that the comparison implied in an analogy must be accurate and the relationship must be explained (note examples in reading).

At this point, students should avoid using “because” and let the analogy flow naturally. Note the importance of a clear topic sentence and conclusion, and the need for students to explain unfamiliar terms in their own words.
**Outcomes**

<table>
<thead>
<tr>
<th>SLO 1.2</th>
<th>Respond to texts with increasing independence…</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLO 2.1</td>
<td>Show sufficient control over linguistic structures…</td>
</tr>
<tr>
<td>SLO 6.1.2</td>
<td>Use organizational planning…</td>
</tr>
<tr>
<td>SLO 6.2.2</td>
<td>Use repetition to imitate a language model…</td>
</tr>
<tr>
<td>SLO 6.2.4</td>
<td>Use note taking…</td>
</tr>
<tr>
<td>SLO 6.2.9</td>
<td>Use summarization…</td>
</tr>
<tr>
<td>SLO 6.2.12</td>
<td>Use inferencing to guess the meanings…</td>
</tr>
<tr>
<td>SLO 6.3.2</td>
<td>Use co-operation…</td>
</tr>
</tbody>
</table>

**Instructional and Learning Sequence**

**Advanced Readings**

Distribute the four readings on methods of propulsion among groups of students. Using the Jigsaw technique, students develop a summary of each of these possible means of space propulsion, noting any analogies that aid understanding. Students may formulate simple questions to guide the summary. Students regroup and share their findings. The class may discuss the feasibility of the ideas, based on foreseeable technology.

**Language Features**

**Vocabulary**
expressions for description, clarification, interrupting, expressing opinions

**Academic Language Functions**
summarizing
expressing opinions

**Discussion**

Why do people want to go into space? Would you want to be an astronaut? Is the cost of space exploration justified by the benefits? Have you personally benefited from space travel?
<table>
<thead>
<tr>
<th>Student Learning Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the Jigsaw technique, meet in Expert Groups of four to read and summarize one</td>
</tr>
<tr>
<td>of the handouts. Come up with a common summary. (G)</td>
</tr>
<tr>
<td>Meet in Home Groups to share summaries of all four articles. (G)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Teacher Notes and References</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Handout 3-28:</strong> “Space Sails”</td>
</tr>
<tr>
<td><strong>Handout 3-29:</strong> “Momentum Exchange Tether Propulsion”</td>
</tr>
<tr>
<td><strong>Handout 3-30:</strong> “Ion Propulsion”</td>
</tr>
<tr>
<td><strong>Handout 3-31:</strong> “Plasma Sails”</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>“Canadian Space Agency Educator Resources” at:</td>
</tr>
<tr>
<td>&lt;www.space.gc.ca/asc/eng/youth_educators/educators/resources/all.asp&gt;</td>
</tr>
<tr>
<td>“SEDS: Students for the Exploration and Development of Space,” images, articles,</td>
</tr>
<tr>
<td>statistics, short texts suitable for dictation, at: &lt;www.seds.org/&gt;</td>
</tr>
</tbody>
</table>
### Outcomes

<table>
<thead>
<tr>
<th>SLO 6.23</th>
<th>Use grouping of items to classify…</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLO 6.2.7</td>
<td>Use elaboration…</td>
</tr>
<tr>
<td>SLO 1.2</td>
<td>Respond to texts with increasing independence…</td>
</tr>
<tr>
<td>SLO 1.3</td>
<td>Develop and express a personal position in a variety of ways…</td>
</tr>
<tr>
<td>SLO 1.4</td>
<td>Show awareness of organizational patterns</td>
</tr>
<tr>
<td>SLO 6.2.6</td>
<td>Use substitution to select alternate approaches…</td>
</tr>
<tr>
<td>SLO 6.2.7</td>
<td>Use elaboration…</td>
</tr>
<tr>
<td>SLO 6.2.4</td>
<td>Use note taking…</td>
</tr>
<tr>
<td>SLO 6.2.9</td>
<td>Use summarization…</td>
</tr>
<tr>
<td>SLO 6.3.2</td>
<td>Use co-operation…</td>
</tr>
</tbody>
</table>

### Instructional and Learning Sequence

#### Sequence 2

Post on the board teacher-provided visuals of spinoff products or, alternately, a Word Splash page of such products. Ask students what the pictures or words have in common. Have the students or their family members ever used any of the items depicted? (See Handout 3-32: “Spinoffs from the Space Program.”)

Alternative readings (teacher-provided). Search for websites that discuss spinoffs from space research.

**Language Features**

<table>
<thead>
<tr>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>present perfect tense</td>
</tr>
</tbody>
</table>

**Task**

Students will use the headings to take notes and summarize with a partner. As a class, select the most revolutionary or most surprising spinoffs. Note that the language is highly technical and students should not try to understand every word, but rather use key vocabulary and reading strategies to understand the main ideas.

**Discourse Features**

<table>
<thead>
<tr>
<th>note form</th>
</tr>
</thead>
</table>

**Academic Language Functions**

<table>
<thead>
<tr>
<th>rereading for main idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>summarizing</td>
</tr>
</tbody>
</table>

**Further Discussion**

1. What is Canada’s role in space research?
2. Are the students’ home countries involved in space research?
3. Do you think there is life on Mars? Ask students to back up their opinions with facts they have learned. What do they know about attempts to explore Mars?

**Language Features**

<table>
<thead>
<tr>
<th>Discourse Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>debate format</td>
</tr>
</tbody>
</table>

**Academic Language Functions**

<table>
<thead>
<tr>
<th>analyzing and interpreting data</th>
</tr>
</thead>
<tbody>
<tr>
<td>hypothesizing</td>
</tr>
<tr>
<td>listening for information</td>
</tr>
</tbody>
</table>

**Speaking**

Debate whether human missions should be replaced by robotic ones.
### Student Learning Tasks

- Discuss what the pictures or words have in common.
- Have you or your family members ever used any of the items depicted?

Look at **Handout 3-32**: “Spinoffs from the Space Program.”

### Teacher Notes and References

#### Visuals of spinoff products (teacher-provided), or write names of products on the board

**Handout 3-32**: “Spinoffs from the Space Program”


This activity gives good background information and reading about how the earth is a closed ecosystem and what is necessary to maintain life. Students have the opportunity to analyze and interpret data, predict outcomes, and propose solutions to problems. This prepares students for Topic 7B.

“Liftoff to Learning Mathematics of Space-Rendezvous.” This accompanies a video, but contains useful information for talking about mathematics related to space travel. <http://vesuvius.jsc.nasa.gov/er/seh/Mathematics_of_Space.pdf>

“Canadian Space Agency Educator Resources” at: <www.space.gc.ca/asc/eng/youth_educators/educators/resources/all.asp>

“SEDS: Students for the Exploration and Development of Space,” images, articles, statistics, short texts suitable for dictation, at: <www.seds.org/>

“Basics of Space Flight” from the Jet Propulsion Laboratory, California Institute of Technology at: <www.jpl.nasa.gov/basics/>
Rockets push stored materials in one direction and experience a thrust force in the opposite direction. They make use of the observation that whenever one object pushes on a second object, the second object exerts an equal but oppositely directed force back on the first object. This statement is the famous “action-reaction” concept that is generally known as Newton’s Third Law. While it seems sensible that when you push on a wall it pushes back on you, this situation is extraordinarily general. For example, if you push a passing car forward, that car will still push backward on you with an equal but oppositely directed force. If you push on your neighbour, your neighbour will push back on you with an equal but oppositely directed force, even if your neighbour is asleep! In the case of a rocket, the rocket pushes burning fuel downward and the burning fuel pushes upward on the rocket with an equal but oppositely directed force. If the rocket pushes its fuel downward hard enough, the fuel will push up on the rocket hard enough to overcome the rocket’s weight and accelerate it upward into the sky and beyond.
Space Sails

Sailing in space could be one way to go to the stars. Researchers at NASA's Marshall Space Flight Center in Huntsville, Ala., are pursuing space sails as an advanced concept for interstellar travel.

Thin, reflective sails could be propelled through space by sunlight, microwave beams or laser beams—just as the wind pushes sailboats on Earth.

The concept of space sails is nothing new. About the same time Jamestown was being established as America's first permanent colony, German astronomer Johannes Kepler penned a letter to Italian astronomer Galileo, advocating “strip or sails adapted to the heavenly breezes” to travel to Jupiter or the Moon. Having observed that a comet’s tail always faces away from the Sun, Kepler concluded that a force that pushes its tail away.

The rays of light emanating from the Sun provide tremendous momentum that could push a solar sail about 150,000 mph. Space sails could make interplanetary travel four to six times faster than today's propulsion systems. In addition to moving remarkably faster than traditional systems, solar sails require no fuel. The Sun supplies all the energy.

And while the notion of sailing in space has been around for centuries, it’s only become a real possibility in the last few years—with the advent of strong, lightweight composite materials.

Sails in space would have a very large surface area—almost a half-mile wide—but could be thinner than cellophane. The density of a space sail is less than one-tenth ounce per square yard, the equivalent of flattening one raisin to the point that it covers a square yard. A solar sail might be composed of a carbon fiber material with a thin coating of reflective aluminum.

Another space sailing concept, dubbed mini-magnetospheric plasma propulsion, or M2P2, uses a huge magnetic bubble as a sail. The “sail” would be pushed along by charged particles of the solar wind, instead of rays of sunlight. The charged particles of the solar wind would interact with the magnetic field to push the magnetic bubble, or sail.

Sail propulsion will be used initially for robotic missions and eventually could be considered for human space travel. A space sail may power an interstellar precursor mission NASA hopes to launch in the next decade to explore the edge of our solar system and study its interaction with nearby interstellar space.

The Marshall Center is leading NASA's propulsion research for the unmanned probes that will venture billions of miles in space. Its engineers are conducting laboratory experiments as they begin to evaluate and characterize materials for space sails. Challenges include how to build, package and unfurl a solar sail and control its direction of travel through space. Since the sail would get very close to the Sun, thermal protection is also of major importance.

Marshall is partnering with NASA's Jet Propulsion Laboratory in Pasadena, California, and the University of Washington in Seattle to develop sail propulsion for interstellar precursor missions. The Marshall effort is managed by the Advanced Space Transportation Program, NASA's core technology program for all space transportation. The Advanced Space Transportation Program is pushing technologies that will dramatically increase the safety and reliability and reduce the cost of space transportation.

Momentum Exchange Tether Propulsion

NASA's Marshall Space Flight Center in Huntsville, Ala., is developing experiments to show that tether-based propulsion—which requires no on-board propellant but instead draws power from the near-Earth environment—could dramatically reduce the cost of raising and maintaining the orbits of other spacecraft, including communications satellites and probes destined for the outer planets of our solar system.

Using the scientific principle of "momentum exchange"—the action of transferring momentum from one body to another—tether propulsion systems provide a viable alternative to traditional chemical propulsion systems, enabling a variety of missions along the highway to space.

By briefly linking a slow-moving object with a faster one, the slower object's speed may be dramatically increased as some of its counterpart's momentum is transferred to it—much the way ice skaters play "crack the whip" to launch one another at high speed across the ice. Similarly, a spinning, tether-based satellite in low Earth orbit might snare slower-moving objects and hurl them at increased speed toward higher orbits.

Researchers at the Marshall Center are developing the "Momentum Exchange, Electrodynamically Reboost" tether propulsion system, or MIXER, which would use momentum exchange to transfer satellites from low-Earth orbit to geosynchronous orbit—a journey roughly 22,300 miles (36,000 kilometers) above the equator—and beyond. MIXER also would employ electrodynamically reboost to maintain its own elliptical orbit: an orbiting circuit that would bring MIXER to within 248 miles (400 kilometers) of Earth at periapsis, its nearest point, and shoot out to more than 4,970 miles (8,000 kilometers) at apoapsis, or its farthest point.

Intended for launch by rocket to a circular low-Earth orbit, MIXER would deploy a 93-mile-long (150 kilometers) tether that uses a combination of electrical current and gravity to pull the tether into a tight spin, altering its orbit into an elliptical pattern. As communications satellites and other high-orbit payloads are launched by rocket into low-Earth orbit, they could rendezvous with MIXER, which would "snare" them via a net-like catch mechanism and hurl them toward their final destination—without the need for the costly, fuel-heavy upper-stage booster rocket usually associated with the climb to geosynchronous orbit.

And because MIXER would remain in orbit, repeating its orbital transfer duties throughout its lifespan, it could greatly reduce costs associated with upper-stage rockets, which normally fall back into the atmosphere and burn up after a single use.

A tether-based propulsion system such as MIXER could be flying in 10-15 years, raising or lowering satellites or deep-space probes for scientific and engineering purposes, and boosting commercial satellites to geosynchronous orbit. Some forward thinkers among NASA's industry partners are already developing ways to use the technology to cheaply and efficiently transport payloads beyond low-Earth orbit—paving the way for an eventual human return to the Moon, as well as journeys to Mars and the outer planets.

NASA's MIXER technology development team includes the University of Illinois at Urbana-Champaign, Tennessee Technological University in Cookeville, and Tethers Unlimited of Lynnwood, Wash.

The MIXER experiment is managed by the Marshall Center's Advanced Space Transportation Program, which is paving the highway to space by developing innovative technologies to dramatically reduce the cost of space transportation.

For more information about space tethers and their potential applications, visit: http://www.tethers.com

Ion Propulsion

Ion propulsion — a futuristic technology that for decades catapulted spacecraft through the pages of science fiction novels — is now a reality. An ion engine, developed by NASA and measuring just 12 inches (30 centimeters) in diameter, is the main propulsion source for Deep Space 1, a 20th Century spacecraft now completing its primary mission: to validate technologies for 21st century spacecraft.

An ion propulsion system converts spacecraft power into the kinetic energy of an ionized gas jet. As the ionized gas exits the spacecraft, it propels the craft in the opposite direction. An ion engine is fueled by xenon, a colorless, odorless, tasteless and chemically inert gas. The xenon fuel fills a chamber ringed with magnets. When the ion engine is running, electrons emitted from a cathode strike xenon atoms, knocking away an electron orbiting each atom’s nucleus and turning it into an ion.

The spacecraft contains a pair of electrically charged metal grids. The force of the electric field generated by the grids exerts a strong, electrostatic pull on the xenon ions, much the way bits of lint are pulled to a pocket comb that has been given a static electric charge by rubbing it on wool. The xenon ions shoot past the grids at speeds of more than 88,000 miles (146,000 kilometers) per hour, continuing out the back of the engine and into space. These exiting ions produce the thrust that propels the spacecraft.

Ion propulsion is 10 times more fuel efficient than on-board chemical propulsion systems. This greater efficiency means less propellant is needed for a mission. In turn, the spacecraft can be smaller and lighter and launch costs lower.

Deep Space 1 carries 178 pounds (81 kilograms) of xenon propellant, capable of fueling engine operation at one-half throttle for more than 20 months. Ion propulsion will increase the craft’s speed by 7,900 miles (12,700 kilometers) per hour over the course of the mission.

NASA has studied ion engines since the 1950s. Dr. Harold Kaufman, a technologist at NASA’s Glenn Research Center (formerly Lewis Research Center) in Cleveland, Ohio, designed and built the first broad-beam electron bombardment ion engine in 1959, using mercury as fuel. Suborbital ion engine tests were underway by the early 1960s.

In the early 1990s, NASA identified improved electric propulsion as an enabling technology for future deep space missions. Glenn Research Center and the Jet Propulsion Laboratory in Pasadena, Calif., partnered on the NASA Solar Electric Power Technology Application Readiness project, or NSTAR. Its purpose: to develop a xenon-fueled ion propulsion system for deep space missions.

Ion engines with extended performance and higher-power, NSTAR-type engines — in the 10-kilowatt and 0.08 pound-thrust range — are candidates for propelling future spacecraft to visit Pluto, the moons of Jupiter and other large bodies in the outer solar system. Low-power (100 to 500 watts) systems also could be used to deliver miniaturized robotic spacecraft to visit and study comets, asteroids and other smaller bodies. Laboratory tests to develop high- and low-power, lightweight ion propulsion system components and subsystems are now underway.

For more information about the Deep Space 1 mission, visit:
http://nmp.jpl.nasa.gov/ds1/
Plasma Sails

NASA researchers and their partners in industry and academia are pursuing plasma sail technologies as a potential future source of in-space propulsion — one that could enable a new era of scientific discovery throughout the solar system.

Plasma sail research is being conducted under the leadership of NASA’s In-Space Propulsion Program, managed by the Office of Space Science in Washington, D.C. The program is implemented by NASA’s Marshall Space Flight Center in Huntsville, Ala.

The concept of the plasma sail stems from NASA’s goal of using natural energy sources found in the environment of space — rather than heavy and costly chemical fuels — to provide alternative means of propulsion for future interplanetary craft. Space-based sail technologies seek to harness the “solar winds,” billions of tiny, electrically charged particles constantly jetted away from the Sun by the force of its powerful, overlapping magnetic fields. These particles travel through the solar system at top speeds of more than a million miles per hour.

Researchers say an innovative plasma sail craft could be carried on this constant, inexhaustible flow like a hot air balloon in a strong wind stream, reaching flight speeds previously unattainable by chemical propulsion.

Such an idea was first proposed by science fiction writer Carl Sagan in 1951, and advanced as a scientific possibility by physicist Richard Garwin later that decade. But it wasn’t until the mid-1990s that practical research into harnessing plasma — or the super-energized gas that would serve as the foundation of such a unique propulsion system — was undertaken.

Now, NASA and its partners are developing an innovative, nearly weightless plasma-drive system that would inflate like a hot-air balloon to surround the entire vehicle, mimicking a natural magnetosphere — the bubble of magnetic power surrounding Earth and other planets — and allowing plasma particles to be converted to a source of propulsion.

Such a craft could, over a period of months, reach maximum flight speeds in excess of 100,000 mph. Compare its speed with that of Voyager 2, the deep space probe launched to the outer planets and beyond in 1977, and powered by a conventional chemical propulsion system. Voyager 2 now travels away from our solar system at roughly 795,000 miles per day. There is enough power in the solar winds to accelerate a 300-pound plasma-drive craft to speeds of up to 160,000 mph — or 4.8 million miles a day.

Using this technology, NASA hopes to increase the number and value of future planetary missions. Their ultimate goals: to send routine probes and survey craft to neighboring planets and their satellites in a fraction of the time; to increase payload sizes, duration of research, and communication between craft and researchers on Earth; and to lower overall mission costs.

Early research into innovative plasma-sail concepts was funded by the NASA Institute for Advanced Concepts (NIAC) in Atlanta, Ga.

NASA expects to award computational and experimental research activities for new and existing plasma sail concepts in 2003.

For more information about NASA’s In-Space Propulsion Program and plasma sails research, visit:
http://www.spacetransportation.com
http://www.msfc.nasa.gov/news

Technological growth is a key to the increasing prosperity of society. Innovations in technology reduce the amount of resources (inputs), such as instance time or money, required to achieve a particular goal (output). For example, through technological innovations, computers are now many times more powerful yet cheaper to build.

How does technological innovation happen? A famous saying is that “necessity is the mother of invention”; this saying is catchy, but partly wrong. Dire need alone does not induce discoveries or inventions (otherwise we certainly would already have cures for AIDS and cancer). Rather, technological innovation is caused by a number of factors, including research and development, a strong education system, places where people can lend and borrow capital, and institutions for sharing information. But for many of society’s most important innovations, chance or good luck had as much to do with their development as any other factor. Therefore, trial and error is also very important to the process of innovation.

Many innovations originally developed for one purpose are later applied for an entirely different purpose. The entirely new and originally unintended application of a technology is called a “spinoff.” In some cases, the spinoff applications of technology are even more effective or successful than the original application. In the case of space and defence technology, technological spinoffs are extremely common and have led to a wide range of very important innovations, including the Internet, the Laser, Satellite Communications and Navigation, Virtual Reality, and the Artificial Heart.

Some examples of space technology spinoffs include:
Spinoffs from the Space Program (continued)

- **CAT Scanners and MRI technology**

  CAT Scanners and MRI technology (Computer-Aided Tomography and Magnetic Resonance Imaging) came from technology developed to computer-enhance pictures of the moon for the Apollo program. The CAT scanner searches the human body for tumours or other abnormalities and is used in hospitals worldwide.

- **Artificial Heart**

  The technology used in Space Shuttle fuel pumps led to the development of a miniaturized ventricular assist pump (artificial heart).

- **Computer Reader for the Blind**

  Optacon is a spinoff technology that enables the blind and deaf-blind to read anything in print. A user passes the Optacon mini-camera over a printed page with his or her left hand. A control unit processes the camera's picture and translates it into a vibrating image of the words the camera is viewing, which the user senses the tactile image with his other hand. Optacon II is a newer version that provides access to both printed words and the electronic information available on most personal computers.

- **De-mining device**

  The same rocket fuel that helps launch the Space Shuttle is now used to save lives by destroying land mines. A flare device, using leftover fuel donated by NASA, is placed next to the uncovered land mine and is ignited from a safe distance using a battery-triggered electric match. The explosive burns away, disabling the mine and rendering it harmless.

- **Water Filter/Conditioner**

  Water filters and conditioners came from technology developed to purify water on the space shuttle.

- **Laser Technology**

  Lasers emit a narrow and very intense beam of light or other radiation and are used to transmit communications signals; to drill, cut, or melt hard materials; and in medical applications. All lasers are spinoffs of a concept developed at NASA's Jet Propulsion Laboratory (JPL) for optical communications over interplanetary distances.

- **Solar Energy**

  Solar energy is a useful alternative and environmentally friendly energy source. When sunlight strikes certain materials, such as silicon, electrons are set in motion that can be drawn off as electricity. This basic principle of (continued)
Spinoffs from the Space Program (continued)

Solar energy is a useful alternative and environmentally friendly energy source. When sunlight strikes certain materials, such as silicon, electrons are set in motion that can be drawn off as electricity. This basic principle of photovoltaic conversion (PV) is used to provide power to nearly all man-made satellites. Although PV power is still too expensive for widespread use on Earth, it has proven a viable alternative energy source in areas where no conventional source exists, such as remote weather stations, sea-based navigational buoys, forest stations, and third world villages.

- **Cordless Products**

One of the most successful commercial spinoffs of space-based technology is a line of cordless products dating back to the Apollo era. One of the Apollo astronauts’ tasks was gathering rock and soil samples from the moon’s surface and required a lightweight and compact drill with its own power source. Black & Decker Corporation developed a successful battery-powered, permanent-magnet motor device. Then they refined this technology into a line of consumer and professional cordless tools and appliances such as the Dustbuster handheld vacuum cleaner.

- **Scratch-Resistant Sunglass Coating**

Scratch-resistant lenses came from technology originally intended to protect the plastic surfaces of aerospace equipment in harsh environments.

- **Virtual Reality**

Virtual reality combines three-dimensional graphics and sound to create highly realistic simulations. In the mid-1980s, NASA developed one of the first practical VR systems. The Virtual Interface Environment Workstation (VIEW) was a head-mounted stereoscopic display that allowed the operator to virtually "step into" a scene and interact with it. Virtual reality permits three-dimensional scientific visualization, for example to enable medical students to operate on virtual patients in a simulated hospital. The technology has huge potential in entertainment and education.

- **Portable Laptop Computer**

In November 1983, NASA flew a space shuttle mission that marked the space debut of a remarkable high-performance navigation monitoring computer dubbed SPOC, for Shuttle Portable Onboard Computer. The SPOC was the first true portable laptop computer.

- **Fabric Structures**

During the Apollo program, NASA sought to improve upon the fabrics it used in space and began its search for a durable, noncombustible material that

(continued)
Spinoffs from the Space Program (continued)

was also thin, lightweight, and flexible. Owens-Corning developed a glass fiber yarn that can be woven into a fabric and then coated with Teflon for added strength, durability, and the ability to repel moisture. The material met NASA specifications and was used in space suits throughout the Apollo era.

The technology in this material spun-off into the construction field, where a heavier version of the fabric is used as a permanent covering for sports stadiums such as B.C. Place in Vancouver and the Olympic Stadium in Rome. The air-supported stadium at B.C. Place, Vancouver, British Columbia, was Canada’s first covered stadium. It seats up to 60,000 and has a ten-acre fabric roof that weighs only 1/30th as much as a conventional roof of that size. Sixteen giant fans blow air into the balloon-like envelope between the roof’s outer membrane and its inner liner maintaining the pressure differential necessary for roof rigidity. The roof is made of space-based fabric that reduces lighting needs, cooling costs, and maintenance costs by increasing the fabric’s resistance to moisture, temperature extremes, and deterioration. Kilogram per kilogram, the material is stronger than steel and weighs less than 1.53 kilograms per square metre.

• The future technology

Research into space technology continues, bringing concepts that previously belonged only to science fiction into reality. One area of space research with great potential is into new propulsion systems. The goals in developing new spacecraft propulsion systems are to make space travel easier, faster, and less expensive. A lot of this research is into propulsion systems using antimatter, chemical, nuclear, laser, magnetic, or microwave technology. By developing more powerful and less costly ways to propel spacecraft, space travel will become more commonplace and further reaching. When this happens, the possibilities for colonization of other planets opens up as well.

Case Study: Satellites

Research and development for space and aerospace defence created a number of satellite technologies that resulted in very successful spinoffs. Most of these can be described in four broad categories: atmospheric and weather monitoring satellites, communications satellites, satellite navigation, and environmental monitoring and remote sensing satellites.

Atmospheric and weather monitoring satellites and the Alouette-I

Atmospheric and weather satellites collect information for scientists and meteorologists on the different parts of the earth’s atmosphere. Atmospheric satellites are generally focused on the outer regions of the earth’s atmosphere, particularly the gases and particles that make-up the different layers of the atmosphere. Atmospheric monitoring satellites investigate issues such as the depletion of the ozone layer and the effects of solar radiation on other satellites. Weather monitoring satellites focus on the lower regions of the atmosphere, where clouds condense and weather is formed. These satellites give meteorologists an indication of weather patterns and storm activity, including the tracking of hurricanes and typhoons.

(continued)
Spinoffs from the Space Program (continued)

The Alouette-I atmospheric satellite was Canada's entry into the space age when it was launched on September 29, 1962. The Alouette launch made Canada the first nation, after the Russian and American superpowers, to design and build its own artificial earth satellite. Launched into orbit by an American Thor-Agena rocket, the scientific purpose of Alouette-I was to study the earth's ionosphere (a charged layer of the atmosphere) from above. The Alouette-I was only designed to operate for only one year, but stretched out a 10-year mission that produced over one million images of the ionosphere. Alouette-I gave Canadian scientists information about the aurora borealis (the northern lights). The aurora borealis result when electrically charged particles from the sun cause gas atoms in the earth's ionosphere to release light. These same interactions in the ionosphere that create brilliant lights in the northern skies at night also disturb radio communications. As a result of the success of Alouette-I, Canada and the US launched further ionosphere observation satellites, including Alouette-II, ISIS I, and ISIS II.

Weather satellites provide real-time cloud photographs. In addition to the coverage of weather over land, weather satellites are extremely valuable because of the information they provide about weather over water, where few surface observations can be made. Before the deployment of weather satellites, many areas had no advance warning of impending severe storms. Today satellites can spot and accurately track hurricanes and typhoons while they are still far out in the ocean.

Two types of weather satellites exist, depending on what type of earth orbit they use. Geostationary (or geosynchronous) satellites orbit at a distance of 36,000 kilometres above a fixed point on earth. By doing so, these satellites are able to focus on a particular area of the earth, for example the Canadian west. Polar orbiting satellites travel over the North and South poles in a path that closely parallels the earth's meridian (North-South) lines. These satellites travel around the earth at a distance of 850 kilometres, much lower than geostationary satellites. By doing so, polar orbiting satellites give a much more detailed picture of cloud systems and violent storms.

Communications Satellites and the Anik I

Since the beginning of the satellite communications industry in the early 1970s, Canada has been a world leader in satellite communications. On November 9, 1972, Canada launched Anik A1 and became the first country in the world with a domestic communications satellite. Anik (which means "brother" in the language of the Inuit) made it possible to connect all regions of Canada, the world's second largest country. The launch also made Canada pioneers in the first, and now largest, commercial space sector: satellite communications. After Canada began domestic satellite service in 1972, it was joined by the United States (1974), Indonesia (1976), Japan (1978), India (1982), Australia and Brazil (1985) and others.

In 1973, the Canadian Broadcasting Company (CBC) began transmitting radio and television programs from coast to coast and into the North. The launch of more communications satellites in the late 1970s created the industry for satellite television, where people who purchased satellite dishes could receive hundreds and later thousands of television channels. Since 1980, the Toronto based Globe and Mail newspaper has used Anik satellites to transmit images of its pages from Toronto to other cities across Canada. The result is that the newspaper can be printed in cities such as Calgary at almost the
Spinoffs from the Space Program (continued)

same time as Toronto. On January 3, 1996, Canada and the US launched the Mobile Satellite (MSAT). MSAT bounces powerful signals to small and portable antennae, like those found in cellular phones.

Since the launch of Anik A1, at least a dozen more Canadian commercial satellites have been sent into orbit, including five that are currently operational. The most recent of these, the Anik F1, was launched on November 21, 2000 as the most powerful communications satellite in the world. As a result of the Canadian investment in satellite communications, Canada is now one of the most connected nations in the world.

**Satellite Navigation and GPS**

Another use of satellite technology is to provide information about the precise location, speed, and time for a particular receiver. Global Positioning System (GPS) technology was originally developed by the US Department of Defense (DoD) for military purposes, but has now become incredibly popular for civilian applications. Imagine any activity where knowing your precise location or precise time is important and chances are you will have an example where GPS is useful. In the military, GPS is useful for many things, including allowing troops, pilots, or sailors to locate their positions, or in the accurate targeting of weapons. In particular, the military advantages of GPS were demonstrated in the Gulf War — so much so that since 2000 all US weapons platforms are required to have GPS integrated into them. Today, more civilians use GPS than military personnel. These people include commercial pilots and air traffic controllers, construction workers, farmers and fishermen, filmmakers, surveyors and cartographers, and outdoor recreational seekers.

GPS works by referencing the position of a receiver relative to satellite transmitters. The satellite transmitters emit radio signals at the speed of light (299,724 kilometres per second). Based on the amount of time it takes for the signal to travel from the satellite to the receiver, one can figure out how far apart they are (because speed multiplied by time equals distance). By receiving this information from four GPS satellites at once, the three dimensional position and time of the receiver can be established. In reality, the calculations are much more complex, because the radio signals used to measure the distance will bend and deflect off certain things, including parts of the atmosphere, rock formations, or buildings.

The entire GPS Operational Constellation consists of 24 satellites that orbit the earth every 12 hours. Each satellite is roughly 20,200 km from earth travelling at speeds of about 11,800 km/h. The Master Control facility for GPS is located at Schriever Air Force Base in Colorado. By using ground based radars such as the one at Schreiber, the US DoD keeps track of exactly how far each satellite is from the earth, since slight changes in the orbit of the satellite will affect calculations and must be adjusted for.

The concept of GPS was developed in the 1960s. Earth testing in the 1970s culminated with the first GPS satellite launch in 1978. Originally only available for the military, the US government made GPS commercially available in the mid-1980s. GPS provides its signals as coded information that, until 2000, was delivered in two levels of service. Prior to 2000, the most precise signals (P-code) were reserved for the US military. Today all GPS signals are available free of charge to the commercial public, giving people with a receiver the ability to locate their position within about 15 metres. Newer “Differential GPS” technology can pinpoint locations to inside a few metres, because it incorporates ground-based receivers to correct errors and improve accuracy. As technology continues to advance and
Spinoffs from the Space Program (continued)

GPS precision increases, more applications become possible. In the future, GPS will likely be able to pinpoint locations down to the centimetre. This type of accuracy may enable self-guided cars to drive themselves or pilots to land in zero visibility.

Environmental monitoring satellites, remote sensing, and RADARSAT

Remote sensing is the process of using satellites to collect information about the land from high above the Earth. Remote sensing allows both land mapping and observation. The U.S. put LANDSAT, the world’s first remote-sensing satellite, into orbit in 1972. Outside the US, Canada became the first country in the world to use LANDSAT. Canada uses LANDSAT for many things, including helping to manage its forests and crops, look for minerals, and make very accurate maps.

In November 1995, Canada launched its own remote-sensing satellite, RADARSAT, to monitor environmental change and the planet’s natural resources. RADARSAT uses radar instead of light to form pictures of the earth and thus can produce accurate pictures at night and on cloudy days. Specifically, RADARSAT uses a microwave instrument that sends pulsed signals to Earth from its orbiting altitude of 798 kilometres and processes the received reflected pulses. The data from RADARSAT is received at the ground stations operated by the Canada Centres for Remote Sensing in Prince Albert, Saskatchewan and Gatineau, Quebec.

RADARSAT performs a number of features related to environmental monitoring. The satellite monitors ice conditions in the Arctic and disasters such as oil spills, floods, and earthquakes. RADARSAT also maps structural features of the Earth, such as fault lines, and thus provides clues to the distribution of ground water, mineral deposits, and oil and gas in the Earth’s crust. Information provided by remote-sensing satellites such as RADARSAT improves the ability to manage major natural resource industries such as mining, fishing, farming, and forestry. As the need for understanding the environment becomes increasingly important, the work remote-sensing satellites do also becomes more important. A second RADARSAT satellite is scheduled for launch in late 2003.

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Case Study: The Internet

The idea behind the modern Internet was born from a Cold War era problem: in the event of a nuclear war, how could US authorities successfully communicate? A command-and-control network was needed that would link people at military bases and in various cities around the US. The problem was that any central authority and wiring used to connect the different sites was vulnerable to attack; no amount of armour could protect such things. The American defence industry think-tank RAND puzzled over this problem and made the following conclusions in 1964: the network must have no central authority and must be designed to operate even while certain parts were destroyed or disabled.

To overcome this dilemma, the designers assumed the network was vulnerable at all times and that no particular part was perfectly reliable. Each node in the network was made equally important (or rather, equally unimportant). Each node retained the ability to originate, pass, and receive messages. Messages were passed in packets; the direction that the packets took through the system was unimportant, only that they reached their final destination. If a big piece of the network were destroyed, the packet en route through
that part would just traverse other parts of the network until it found a route that worked. Although this “packet-switching” system wasn’t as efficient a way for information to travel, it was very durable.

Beginning in the mid and late 1960s, scientists at RAND, MIT (Massachusetts Institute of Technology), UCLA (University of California Los Angeles), the Pentagon, and Great Britain’s National Physical Laboratory tested ideas for the network. In 1969 the first node (a supercomputer) was set up at UCLA. By the end of that year, four nodes existed on the infant network. Because the US Department of Defense’s Advanced Research Project Agency (ARPA) led the creation of the network, it was named ARPANET.

The computers on ARPANET shared information on high-speed transmission lines and programmers could work on each computer remotely from another on the network. The supercomputer nodes continued to expand throughout the 1970s because unlike standard computer networks, the ARPANET could accommodate many different kinds of machines. Also, since connecting to the Internet cost little or nothing, the network was easy to join.

By only the second year of ARPANET’s operation, the people using the network were using it to trade notes, news, and personal messages (including gossip) rather than long distance computing. Users had their own personal addresses for electronic mail and soon mailing lists were born, where identical messages were broadcasted to a large number of subscribers.

The birth of the Internet as we know it today happened with the introduction of Transmission Control Protocol/Internet Protocol (TCP/IP) software. TCP/IP is the ‘language’ by which data is communicated across the Internet. It surpassed the ARPANET’s original communication tool, Network Control Protocol (NCP), in the late 1970s and early 1980s. TCP converts messages into streams of ‘packets’ at the source computer and reassembles them at the destination computer. IP handles the addressing of the packets and makes sure the packets are routed across several nodes and networks. Together, TCP/IP software is responsible for taking data from one computer and connecting it to another via multiple nodes.

The rapidly expanding network was growing at an amazing rate. First called the “Internet” in 1982, by 1984 it had more than 1,000 hosts. By 1987, more than 10,000 hosts had sprung up. The military part of the network separated to become MILNET in 1983. ARAPNET itself formally expired in 1989/90 as a victim of its own overwhelming success, leaving behind a network of networks involving more than 300,000 hosts. By this time, the four main functions of the Internet were email, discussion groups, long-distance computing, and file transfers.

Success brought problems for the Internet, specifically with regard to privacy and security of the hosts on the network. In 1988, when the terms ‘hacker’ and ‘electronic break-in’ were being used for the first time, a malicious program called the “Internet Worm” temporarily disabled 6,000 of the 60,000 hosts on the Internet.

In 1991 four huge events changed the shape of the Internet. Prior to 1991, commercial traffic on the Internet was banned by the National Science Foundation’s NSFNET, the backbone of the Internet. When this restriction was lifted in 1991, the age of online commerce began. Also in 1991, a programming team at the University of Minnesota led by Mark MacCahill, released “gopher,” the first point-and-click way of navigating the Internet. Gopher was freely distributed and MacCahill called it “the first Internet application my Mom
Spinoffs from the Space Program (continued)

The third major event in 1991 occurred when Tim Berners-Lee posted the first computer code of the World Wide Web [add to glossary information on the difference between Web and Internet – see file on this in readings] in a newsgroup. This code allowed for the combination of words, pictures, and sounds onto web pages. A fourth major event occurred with the development of Mosaic, a graphical browser for the World Wide Web, by Marc Andreessen (who later founded Netscape) and a team of student programmers.

By the next year (1992), the Internet surpassed 1 million hosts and in 1993 expanded at an annual rate of 341.634%. The Government of Canada came online in 1995 (www.canada.gc.ca). By 1996 the number of hosts approached 10 million and more than 40 million people were connected to the Internet in over 150 countries. “E-commerce” had grown to over $1 billion (US) per year.

Today, more than 30 years after its birth, the Internet has grown from a military strategic for communicating in a post-nuclear world to the “information superhighway,” a technology that has dramatically impacted the way people live and work.