Grade 9 Astronomy

SCIENCE WORKS
A SERIES OF WORKSHOPS BY STAO

Pathways to Astronomy/Space
In the
Revised Ontario Grade Nine Science Curriculum

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FRONT MATTER

The following Astronomy resource is a guide for use by teachers teaching the Earth and Space Science strand in either the grade nine academic (SNC1D) or applied (SNC1P) science course from the newly released (2008) Ontario Science Curriculum, from the Ministry of Education, Ontario (available at: *http://www.edu.gov.on.ca/eng/curriculum/secondary/science910_2008.pdf*)

The timing of the release of the new science curriculum is also significant as the year 2009 is the International Year of Astronomy. The following is an excerpt from the IYA2009 homepage:

> *The International Year of Astronomy 2009 is a global effort initiated by the International Astronomical Union (IAU) and UNESCO to help the citizens of the world rediscover their place in the Universe through the day- and night-time sky, and thereby engage a personal sense of wonder and discovery. (IYA2009)*

Many visible changes to the old science curriculum are evident, but the most obvious difference is the layout of ordering of the expectations. Previously, the *Relating Science to Technology, Society and the Environment* (STSE) expectations were listed at the end of the strand's expectations, but are now located at the beginning of the specific expectations and are written for the teacher and student to see the 'big ideas' of the science. The STSEs are an important aspect of the curriculum, as all the science is contextualized through these big ideas as a means for students to see the meaning of the science to their day-to-day lives. This Astronomy resource document utilized the same approach in planning and executing deliverables, insofar as the big ideas were always the main 'goal' of the planning process. With the big ideas in place, three pathways emerged for going about planning this unit.

This document will provide three possible themes in which the curriculum for the Earth and Space Science strands – *The Study of the Universe* in the academic course and *Space Exploration* in the applied course – may be taught. Of the three pathways that have been developed, one is designed with the intent of being for an academic class, one is designed with the intent of being for an applied class, and one is designed to be used in either an academic or applied class (with teacher modification); see Table 1: 'LENSES.' The order in which they are taught is merely a suggestion and can be modified to suit individual needs. The material is flexible enough so that the lessons could be ordered and taught in a more conventional way: Earth → Universe.

Each of these pathways is a pedagogical structure including: the lens, the mental hook, some misconceptions in Astronomy, the content (presented in lesson format), the big ideas and the culminating activity.

Each pathway has an assigned theme: a means of engaging the students with a mental hook, followed by a series of six modules, by which all of the expectations may be covered. To complete the pathway, the big picture is then revisited and a culminating activity is also provided. Each pathway allows the teacher to travel through the curriculum expectations in a creative and meaningful way that is hands-on and minds-on for students and acknowledges the four broad areas of skills as outlined by the Ministry of Education Science document (p.20): Initiating and Planning (IP), Communicating (C), Performing and Recording (PR) and Analyzing and Interpreting (AI). The knowledge and skills of each lesson is discussed, activities are suggested with appropriate timelines, misconceptions are dealt with and various resources are also linked to support teacher implementation (e.g. literacy and numeracy links, Canadian connection etc…). The highly visual nature of Astronomy also means that a variety of links to images, graphics, and other online resources such as videos and visual presentations have been suggested in the form of web links.

"International Year of Astronomy 2009," 2009, IYA2009, <http://www.astronomy2009.org/general/>

From this point forward, theses pathways shall now be referred to as lenses. They will also follow an inquiry-based approach.

Choose your Lens!

Mission to Mars
(Academic or Applied)

Challenge: Throughout this unit, your students will plan a successful mission to Mars

Mental Hook: Draw a picture of your mission team and create biographies for the team members. Who should go to Mars?

Proposed lesson order:
1. To Mars
2. Other Planets
3. The Sun
4. Other Stars
5. The Big Bang
6. Humans in Space
7. How do we know about space?

Topics addressed throughout the challenge:
- Space Exploration
- Challenges
- Canadian Contributions
- Materials/Technology
- Costs/Risks
- Careers

Made Contact
(Applied)

Challenge: Throughout this unit, your students will create the message to be used when making first contact with an alien species.

Mental Hook: Draw a picture or create a piece of music to present a first impression of humans to an alien culture. What do we want them to know about us?

Proposed lesson order:
1. Other Stars
2. The Sun
3. Other Planets
4. Properties of the Earth
5. The Big Bang
6. How do we know about space?

Topics addressed throughout the challenge:
- Space Exploration
- Challenges
- Canadian Contributions
- Materials/Technology
- Costs/Risks
- Careers

Canadian Space Station
(Academic)

Challenge: Throughout this unit, your students will design the soon-to-be-launched Canadian Space Station (CSS).

Mental Hook: Draw a picture or write a proposal of your vision of the CSS. What rooms are necessary in an orbiting laboratory and residence?

Proposed lesson order:
1. Properties of the Earth
2. Humans in Space
3. The Sun
4. Other Planets
5. Other Stars
6. The Big Bang
7. How do we know about space?

Topics addressed throughout the challenge:
- Space Exploration
- Challenges
- Canadian Contributions
- Materials/Technology
- Costs/Risks
- Careers

Culminating Activity

Q. WHAT ARE THESE 'LENSES?'

A. The lenses are suggested pathways of teaching the six large-scale modules that cover the majority of the curriculum expectations. Essentially they represent one way of viewing the curriculum in some linear pathway to achieving all the curricular expectations.

Q. HOW DO I CHOOSE THE LENS MOST APPROPRIATE FOR MY STUDENTS?

A. Each of the three lenses is geared towards a particular level. There is one for academic, one for applied, and one that can be for either academic or applied. Probably the best way to decide is to think about the types of students that are in your class, and plan with their abilities in mind. It may be more appropriate for you to select the lens we have designated as applied for your class, or it may be more appropriate for you to select the lens that can be modified to suit both needs. Or you may wish to choose the one that interests you the most.

Q. WHAT IS COMMON AMONG THE THREE LENSES?

A. The common thread with all the lenses is the topics of the lessons, and fundamentally the curriculum itself. You will notice the only thing different among them is the order by which they are suggested to be taught and how.

Q. CAN I DO MY OWN MODIFICATION TO THE LENSES?

A. Yes. As a science teacher it is naturally understood that modifications to any resource would be done to specifically meet the needs of the students. What is concrete about the sciences within the province is that students need a firm understanding of the content and should be provided with activities in class that are meaningful and rich to help them grow academically day by day.

Q. WHAT PRIOR LEARNING DO MY STUDENTS HAVE IN ASTRONOMY?

A. The only real astronomical connection that students will have is from the grade six curriculum *Understanding Earth and Space Systems: Space* in the newly revised Grade 1-8 Science and Technology Curriculum (2007), where they look at how Earth is part of an interrelated system as well as at how technological and scientific advances have enabled humans to study space, and consequently see how those advances affect their lives.

Q. HOW DO I HOOK MY STUDENTS?

A. Teachers are responsible for developing appropriate teaching strategies to help students achieve the curriculum expectations. Much of the learning will need to take place through observation and hands-on activities and will largely be individualized. A set of rich photographs (easily available from the web) can serve as the hook to get students interested in Astronomy and become engaged with the study of Earth, its near Earth environment and space. The National Research Council has an image gallery at: *http://www.nrc-cnrc.gc.ca/eng/education/astronomy/gallery.html* . These can be displayed on either a data projector, or printed onto overheads. The photos can also serve as discussion points (based on the lesson) or be used as a creative writing exercise. More Canadian images can be found at *http://www.galaxydynamics.org/iya2009/* This site includes curated amateur and professional images.

Q. APPLIED VS. ACADEMIC. HOW WOULD YOU MODIFY EACH?

This resource can be used to teach both *The Study of the Universe* in the SNC 1D and *Space Exploration* in the SNC1P courses. The three lenses are each designed with a pathway in mind. The Mission to Mars lens is the one pathway that is designed with the idea that it can be used in either an academic or applied class. The Made Contact lens is designed specifically for use in the applied class, and the Canadian Space Station is designed specifically for use in the academic class.

…SO WHERE ELSE CAN I GET HELP

Community and business partners are vital resources. They can provide students and teachers with additional information, as well they can also serve to demonstrate how the knowledge and skill learned in the classroom relates to the life outside the classroom.

• **NRC (National Research Council Canada) Teachers' Corner** contains information on topics on astronomy, skygazing and images. *http://www.nrc-cnrc.gc.ca/eng/education/teachers/index.html*
• **The Ontario Science Center** has programs designed by grade level and subject matter. Visit often, as the dates change and new programs are added. *http://www.ontariosciencecentre.ca/school/curriculum/senior.asp*
• **Royal Astronomical Society of Canada** has a planesphere project (PDF file) and other related teacher sites. *http://www.rasc.ca/education/teachers/curriculum.shtml*
• **CASCA (Canadian Astronomical Society)** has ideas for astronomy lessons and complete unit plans at *http://www.cascaeducation.ca/files/teachers_secondary.html*, and the home page has other relevant links at *http://www.cascaeducation.ca*
• **Local Astronomy Clubs/Societies:** a parent directory for clubs throughout Canada and further information about local clubs can be found at SkyNews Magazine website *http://www.skynews.ca/pages/clubs.html*
• **NASA (National Aeronautics and Space Administration)** *http://www.nasa.gov/audience/foreducators/9-12/programs/index.html*
• **CSA (Canadian Space Agency)** lists resources by topic. *http://www.asc-csa.gc.ca/eng/educators/resources/highschool.asp*
• **Canadian Images** (curated) from IYA2009. *http://www.galaxydynamics.org/iya2009/*
• **Photographic Tour of the Universe** from the CASCA Education website. *http://www.cascaeducation.ca/files/tourUniverse/tourUniverse.html*
• **SkyNews Magazine** (Canadian astronomy magazine) also has images from their Photo of the Week contest. *http://www.skynews.ca/pages/pow_winners.html*
• **Ken Tapping**'s weekly article, Skygazing, can be found at: *http://www.nrc-cnrc.gc.ca/eng/education/astronomy/tapping/index.html*

It is important to maintain a balance between astronomy and basic science on one hand, and space science and technology on the other. By progressing through one of the lenses presented here, your students will be able to experience both facets of astronomy and space science in Canada. Clear skies!

How do we Know About Space?

Curriculum Expectations:
D1.1 Assess, on the basis of research, and report on the contributions of Canadian governments, organizations, businesses and/or individuals to space technology, research and/or exploration (e.g. as part of the International Space Station mission.) *(Academic)*
D1.2 Assess some of the costs, hazards, and benefits of space exploration. *(Academic)*
D2.4 Investigate a technological challenge related to the exploration of celestial objects that arises from the objects' specific properties, and identify the solution that has been devised. *(Applied)*

Mission to Mars: How have we learned what we know about Mars so far? How can we learn about other systems even further away?

Made Contact: How do we know where these other civilizations can be found? Where (and how) are astronomers looking for distant worlds?

Canadian Space Station: The CSS is designed to perform research while in orbit, specifically infrared, sub-millimetre, microwave and X-ray observations. How do each of these contribute to our knowledge of the universe?

The Big Idea:
Learning about the universe requires the proper methods and tools. These include telescopes of increasing size and quality located in the best locations on Earth or in space; satellites orbiting Earth, other planets or the sun; computers and simulations; high quality detectors such as CCDs; and innovative theories, based on the laws of physics, to explain observations and make predictions. Analyzing light, and the rest of the electromagnetic spectrum, is the only way to study distant objects.

Activities:
1. How Telescopes Changed our Understanding of the Universe: This PowerPoint and suggested script is about major discoveries made with telescopes and their technologies that changed the way we understand our universe. *http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=143*

2. Magnification vs. Resolution: A question often asked about telescopes is 'How much does it magnify?' or 'How powerful is it?' The important questions to ask are 'How much light does it gather?' (the more light, the fainter the object that can be detected) and 'What is its resolving power?' (i.e. the ability to discriminate between two closely spaced points). This site includes an instructional video and activity.
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=337

3. Stellar Parallax: Determining distances to the nearest stars uses the idea of parallax. These sites have background information and interactive demonstrations.
http://sci2.esa.int/interactive/media/flashes/2_1_1.htm
http://www.astro.princeton.edu/~clark/ParBkgd.html

4. Tour the International Space Station: *http://www.nasa.gov/externalflash/ISSRG/* and *http://www.asc-csa.gc.ca/eng/iss/default.asp*

5. Tour the Gemini North Observatory in Hawaii: *http://www.gemini.edu/public/movie.html*

6. What can *you* see? Buy and use an inexpensive reproduction of Galileo's telescope.
https://www.galileoscope.org/gs/

7. Research the issue of light pollution at the International Dark Sky Association website: *http://www.darksky.org/mc/page.do* and participate in light pollution research at *http://www.redshiftnow.ca/starwatch* or *http://www.globeatnight.org*

8. To understand what is meant by theoretical astrophysics: Research the Canadian Institute for Theoretical Astrophysics at *http://www.cita.utoronto.ca/*

How have methods of studying space changed over time?

1609 – Galileo uses a telescope to observe stars in the Milky Way, the phases of Venus and the moons of Jupiter.
1931 – Karl Jansky detects natural radio signals from space: birth of radio astronomy.
1857 – Sputnik, first artificial satellite, launched into space (by U.S.S.R.).
1961 – First human, Yuri Gagarin, launched into space (by U.S.S.R.).
1971 – First space station, Salyut 1, launched into space (by U.S.S.R.).

Top Misconceptions/Questions:

1. *The main purpose of a telescope is to magnify.* Telescopes do magnify but their main job is to collect as much light as possible (to see faint or distant objects) and to provide greater resolution (the ability to see detail).
2. *Astronomers spend all their time looking through telescopes*. Astronomers rarely look through telescopes anymore because instruments more sensitive, and objective, than the eye (e.g. cameras, CCD detectors) can be used instead. With the advent of remotely operated telescopes, astronomers don't even have to visit the observatory at all!
3. *All light is visible to the eye*. Some light is visible to the eye i.e. red through violet, but other wavelengths of electromagnetic radiation, such as infrared, ultraviolet, radio, X-rays and gamma rays, require special detectors. Each is a window into processes in the universe.

Glossary:

Simulation – A prediction, based on computer calculations of the known laws of physics, about the nature and behaviour of a cosmic object, which can then be compared with observations.
Telescope – A device to collect light (or other radiation) and focus it to a sharp image.
Observatory – A building housing an instrument such as a telescope used for observing objects in the sky such as the sun, moon, stars, galaxies, and comets.
CCD – Charge-Coupled Device; an electronic device sensitive to light and used in almost all astronomical imaging applications (and in your digital camera!).
Theory – An established explanation accounting for known facts or phenomena and making predictions about that which has yet to be discovered or observed.

Canadian Connection:

1. **Jaymie Matthews** is the Principal Investigator for the Microvariability and Oscillation of Stars (MOST) satellite, Canada's "Humble Space Telescope."
2. **Alouette**, designed and built in Canada, makes this country the third in space after the U.S.A. and U.S.S.R.
3. Using methods he, in part, developed, **Christian Marois** led a team that made what is generally accepted as the first image of a planet orbiting another star
4. The **Canada-France-Hawaii Telescope** on Mauna Kea is situated at one of the best observing sites in the world.
5. Canada is a partner in the **Square Kilometre Array**, a giant radio telescope. When completed it will be the largest telescope ever built.

Connections:

Investigate the work of space artists such as Jon Lomberg, Chelsey Bonestell and Don Dixon. Write about how accurate their work may be based on our current astronomical understanding or what they might have been trying to evoke in their images.

Reading room:

1. The Canadian Space Agency is involved in selecting and training astronauts, monitoring Earth and exploring planets. Its website is *http://www.asc-csa.gc.ca/index.html*

2. Cutting-edge research has been done for many years at the Canada-France-Hawaii Telescope. Read more at *http://www.cfht.hawaii.edu*

Properties of Earth

Mission to Mars:
In the past, Mars was the most Earth-like of all the planets. By studying Earth, we can learn about Mars' past and how it has changed over time.

Made Contact:
We can understand our own planet better by studying and understanding other planets like the distant planet our alien is on.

Canadian Space Station:
Since the CSS will be orbiting Earth, we need to explore the movements and properties of Earth to ensure our space station functions well.

Curriculum Expectations:

D3.5 Explain the causes of astronomical phenomena and how various phenomena can best be observed from Earth *(Academic)*

D2.2 Use direct observation, computer simulation, or star charts to determine the location, appearance and motion of well-known stars and other celestial objects that are visible in the night sky (e.g., the stars Polaris, Sirius, Betelgeuse; the planet Venus) *(Academic)*

The Big Idea:
Earth rotates on its own axis and revolves around the Sun. These motions are apparent when we examine the patterns and phenomena in the night sky. Properties of Earth, such as our proximity to the Sun, make it possible for life to evolve and flourish.

Activities:
1. This activity has a good explanation of the apparent motion of the night sky based on Starry Night, a planetarium simulation software.
http://www.cascaeducation.ca/CSA/CSA_Astro9/files/html/module1/lessons/lesson3/ApparentMotions.html
Download a free trial of Starry Night at *http://www.starrynight.com*

2. Eclipses are caused by the relative positions of the Moon, the Sun and Earth. The best way to explain this is for the kids to act it out physically, with flashlights and holding balls:
http://sunearthday.nasa.gov/2006/images/eclipsing_the_sun2.pdf

3. A PowerPoint presentation explaining the Aurora Borealis (northern lights) by referring to the solar wind and how it interacts with Earth's magnetic field:
http://www.authorstream.com/Presentation/Dahaka-498435-aurora-northern-southern-polar-lights/

4. The changing phases of the Moon are based on the movements of the Moon and Earth with respect to the Sun. Encourage your kids to observe the Moon over a few nights and explore the Moon's phases with the worksheets here:
http://www.cascaeducation.ca/CSA/CSA_Astro9/files/html/module3/lessons/lesson4/phasesMoon.html

5. National Geographic has a lesson at *http://www.nationalgeographic.com/xpeditions/activities/07/season.html* which explains the seasons with the aid of a globe. Use the 'Cosmic Map' quiz to check student understanding on-line.

6. Check out this PowerPoint presentation with an overview of the entire curriculum related to the motions of Earth at *http://www.authorstream.com/Presentation/Paolina-59873-Sun-Earth-System-Total-Solar-Eclipse-Annular-Revolution-History-the-s-Education-ppt-powerpoint/*

7. Research the topic of 'space junk,' the thousands of bits and pieces of broken satellites and garbage in orbit around Earth. What harm could they cause Earth-orbiting satellites?
http://www.nrc-cnrc.gc.ca/eng/education/astronomy/tapping/2009/2009-02-25.html

How have theories of the Earth's motion changed over time?

2000 BCE – Ancient cultures had various reasons for explaining the seasonal variations and yearly changes in constellations including supernatural influences.

1000 BCE – Ancient cultures generally described the objects moving through the night sky along spheres that orbited around Earth, which was thought to be at the centre of the universe.

1540 – Polish astronomer Nicolas Copernicus proposed that objects appeared to move in the night sky because Earth itself was rotating on its own axis every 24 hours, and that Earth orbited the Sun every year which changed the night sky through the year.

1957 – In recent years, satellites have been launched that orbit Earth to observe the physical properties of our planet including RADARSAT, a Canadian project, and NASA's Earth-observing system.

Top Misconceptions/Questions:

1. *Seasons are caused by Earth being closer/further away from the Sun.* In reality, Earth experiences seasons because the Earth's axis is tilted at 23.5°, causing summer when a hemisphere is pointed towards the Sun and winter when it is pointing away from the Sun.
2. *The Earth's sky appears blue because it reflects blue light from the oceans.* In reality, the sky is blue because the molecules in our atmosphere reflect blue-wavelength light the most. The oceans are blue because they reflect the blue sky.
3. *The Earth is at the centre of the solar system/galaxy/universe.* In reality, Earth orbits around the Sun, which itself orbits around the centre of the Milky Way at a distance of 26,000 light years. Our galaxy is one of billions – our position in the universe is probably not special in any way.

Glossary:

Rotation – The spinning of an object around its own axis (i.e. Earth rotates once every 24 hours).

Revolution – The movement of an object around a larger object (i.e. Earth revolves around the Sun once every 365¼ days).

Orbit – The path taken by a planet as it travels around a star.

Ecliptic – The plane in which Earth orbits our Sun.

Celestial Equator – The great circle on the celestial sphere midway between the celestial poles.

Equinox – The two points in Earth's orbit when the ecliptic plane intersects with the celestial equator. This causes 12 hours of daylight and 12 hours of night on March 21 and Sept. 21.

Solstice – The two points in Earth's orbit when the Northern hemisphere is most tilted towards the Sun (June 21) and most tilted away from the Sun (Dec. 21). These are the days with the most and least sunlight, respectively.

Eclipse – The phenomena when the Sun is blocked by the position of the Moon (solar eclipse) or the Moon is blocked by the shadow of Earth (lunar eclipse).

Canadian Connection:

1. **RADARSAT** and **RADARSAT2** are satellites launched by the Canadian Space Agency that take RADAR measurements of Earth's surface. They have been successful in gathering information concerning weather patterns, geological disturbances, and resource analysis (mining, forestry etc.).
2. Canada's first satellite, **Alouette 1**, allowed Canadians to continue research on the upper atmosphere of Earth (magnetosphere), including explaining the auroras above the poles.
3. Canadian **Tuzo Wilson** was the first to describe the motions of Earth's plates and how it has shaped our planet over time.

Connections:

1. Eclipses are often features as plot points in books, TV shows and movies (i.e. *Heroes* (TV), *King Solomon's Mines* by Henry Rider Haggard, *A Connecticut Yankee in King Arthur's Court* by Mark Twain, *Prisoners of the Sun* (Tintin) by Herge, *Nightfall* by Isaac Asimov, etc.).
2. Astrology seeks to predict the actions of people based on what constellation the Sun was in when they were born, which is caused by the motions of the Earth around the Sun. Students should be encouraged to explore the psychology of astrology and test is astrology has a scientific basis: *http://www.astrosociety.org/education/astro/act3/astrology.html*

Reading room:

1. The Baltimore Astronomical Society has collected poetry describing astronomical phenomena in the night sky at *http://www.baltastro.org/AstroPoetry.html*

2. Read about the Earth's changing magnetic field at *http://news.nationalgeographic.com/news/pf/76158139.html*

To Mars

Mission to Mars:
Since we are planning a trip to Mars, it helps to know as much as we can about the planet before we go there!

Made Contact:
No other planet (that we know of!) is like the Earth. By studying other planets, we can learn more about extreme conditions on planets on which other civilizations may be found.

Canadian Space Station:
One of the purposes of long-term stays on space stations such as the CSS is to acclimatize humans for prolonged missions away from Earth. How could we design the station to mimic a long stay on Mars?

Curriculum Expectations:

D2.4 Gather and record data, using an inquiry or research process, on the properties of specific celestial objects within the solar system *(Academic)*
D2.5 Compare and contrast properties of celestial objects visible in the night sky, drawing on information gathered through research and using an appropriate format *(Academic)*

D2.3 Use a research process to compile and analyze information on the characteristics of various objects in the universe *(Applied)*
D2.4 Investigate a technological challenge related to the exploration of celestial objects that arises from the objects' specific properties, and identify the solution that has been devised *(Applied)*
D3.1 Describe the major components of the universe, the motion of the difference types of celestial objects, and the distances between certain objects using appropriate scientific terminology. *(Applied)*

The Big Idea:
Mars is the most Earth-like of the other planets. It used to have geological activity, and a warm, wet atmosphere billions of years ago. Now it is airless, waterless and almost dead geologically. But signs of earlier life may remain!

Activities:
1. This site allows you to search the entire surface of Mars, and visit all the various locations of the landing sites for past landers and rovers. There are video files attached that will go through the history of exploration of Mars and describe what is already known (even a feature narrated by Bill Nye). *http://www.google.com/mars/*

2. This site is home to the Thermal Emission Spectrometer which is mapping the surface-atmosphere interaction on Mars. Dust devils can be observed as well as diurnal temperature changes. *http://tes.asu.edu/*

3. This site has video downloads from the rovers Spirit and Opportunity as they roam across the surface of Mars (images as recent as January 2009). *http://mars.jpl.nasa.gov/gallery/video/index.html*

4. This site has activities and assignments which you can assign to students e.g. making and mapping a volcano. *http://mars.jpl.nasa.gov/classroom/pdfs/MSIP-MarsActivities.pdf*

5. Lessons and activities, e.g. studying craters, relative dating, landing sites, mapping Mars, Earth and Mars analogies. *http://www.lpi.usra.edu/education/explore/mars/*

How have theories Mars changed over time?

Late 1800s – Astronomers see 'channels,' which turn out to be an optical illusion.

1900+ – Writers popularize the idea that these 'channels' may be canals, built by intelligent life. Scientists observe seasonal changes which might be due to simple life.

1960s-90s – Probes and Orbiters were launched to Mars to study the geology, atmosphere and climate, as well as capture images of the surface, and Mars' moons Phobos & Deimos.

2000s – Orbiters and Rovers were launched to map the surface of Mars and also look for future landing sites.

2009 – Mars Science Laboratory is underway.

Future missions – More launches are scheduled to study various aspects of Mars.

Top Misconceptions/Questions:

1. *There is water on Mars.* There is no liquid water on the surface of Mars. Only frozen water in the polar caps has been observed, however hematite found on the surface may indicate the presence of liquid water.

2. *Life is known to exist on Mars*. There has been a great deal of speculation that life may or may not have existed on Mars, but to this point no such evidence has been found. Evidence of past life does not mean evidence of current life. Each is a window into processes in the universe.

Glossary:

Valles Marineris – A 4000km long canyon along the equator of Mars that resulted from cooling & contracting of the Martian crust.

Crater – A circular shaped depression caused from either a collision of a celestial body with Mars, or formed by volcanic activity.

Spirit – Rover sent in June 2003 & landed in January 2004 that is taking samples of the Martian rocks and studying the surface features. It is still active today.

Opportunity – Rover launched July 2003 & landed in January 2004 on the meridiani planum, explored craters along the plain, while also having its wheels temporarily lodged in the sand dunes on the surface.

Phoenix – Lander sent by NASA that has a meteorological station on board and a wind sensor in May of 2008. The mission was declared ended in November 2008.

Hematite – A mineral, iron oxide (Fe_2O_3), which typically forms in areas of hot standing pools of water (e.g. hot springs) is reddish-brown-grey in colour and is found in abundance on the surface of Mars.

Meridiani Planum – A plain located just 2 degrees south of the Martian equator where Opportunity landed and may be the site where there is thought to have once been hot springs.

Regolith – Different particles of soil. The soil is made up of rock fragments and dust particles.

Canadian Connection:

NASA's **Phoenix Mars Lander** carrying **Canada's meteorological station** touched down on May 25, 2008. It measured Mars' temperature and pressure, and probed clouds, fog and dust in Mars' lower atmosphere. Most significantly, the weather station's LIDAR (uses infrared) instrument confirmed that it snows on Mars by detecting snowflakes falling from clouds about 4 km above the spacecraft's landing site.
http://www.asc-csa.gc.ca/eng/astronomy/phoenix/default.asp

Connections:

1. Link to geography with mapping and using latitude and longitude, topographical maps *http://pubs.usgs.gov/imap/i2782*

2. Link to mathematics with calculations, look at proportionality calculations, comparing Earth to Mars in size, orbital period, distance from the Sun – visual learners will appreciate the visual nature of this content → all the images/videos.

3. FICTION BOOKS → *War of the Worlds* by H.G. Wells, *Stranger in a Strange Land* by R.A. Heinlein, *Red Mars, Green Mars, Blue Mars* trilogy by Kim Stanley Robinson.

Reading room:

This article discusses the potential evidence of liquid water on Mars: *http://bit.ly/9bzbMc*

Other Planets

Mission to Mars: In this lesson, students will learn the major components of the solar system and gain an understanding of how the planets form from the solar nebula theory through use of data collection and research. This lesson will better equip students to make decisions about their mission to Mars.

Made Contact: Should we be looking in our own solar system for life on one of our 8 planets, or should we be looking at other planets orbiting other stars? Where is the most probable location to find life?

Canadian Space Station: What information can the new CSS tell us about the other planets within our solar system?

Curriculum Expectations:
D3.2 Describe observational and theoretical evidence relating to the formation of the solar system (e.g., evidence that supports the theory that the solar system was formed from a contracting, spinning disc of dust and gas). *(Academic)*
D3.3 Describe the major components of the solar system and the universe (e.g., planets, stars, galaxies), using appropriate terminology and units. *(Academic)*
D3.2 Compare the characteristics and properties of celestial objects that constitute the solar system, including their motion and distance from other celestial objects in the solar system. *(Applied)*

The Big Idea:
The Earth is one planet in an eight planet solar system that has satellites, dwarf planets, and millions of small bodies such as: asteroids, comets, icy objects from the Kuiper belt and other celestial objects bound to the Sun by gravitational forces, including dust particles.

Activities:
1. This site has a photo gallery of Mars, expressed in a very artistic manner. This could be useful as a tool for use in a writing exercise; e.g. select one photo, put up on the overhead and have students do a creative writing exercise (each photo has a description of what and where it is on the planet).
http://www.nasa.gov/externalflash/Mars_as_art/index_noaccess.html

2. A planetary database activity can be done using this website for the information. Students can do independently from home, or bring the entire class to a computer lab, where each student has access to a computer. Each student/group can be assigned one planet and can report back to the class. *http://www.nineplanets.org/*

3. This site is excellent for students to navigate through the solar system in an interactive format, complete with PDF. Activity sheets, ready for download, can be found at the bottom of the page. This site also is home to World Builder (planet 10) where students design and 'launch' a planet into the solar system and determine what physical/chemical/biological properties their planet has. This site also has student pages 'looking for life' and 'changing the Earth' as well as a quiz with answers. *http://www.scienceyear.com/randomise/index.html?page=/planet10/*

4. This site has 7 modules with lesson plans for each of the different lessons (approx 6 per module; 37 in total) on topics related to the entire space curriculum. Suggestions for teaching are also included (mental set, hands-on, anticipatory practice, extension, evaluation tools [e.g. rubrics] and closure.
http://www.cascaeducation.ca/CSA/CSA_Astro9/files/html/lessons.html

5. This National Geographic site contains various short videos on topics related to the solar system.
http://video.nationalgeographic.com/video/player/science/space-sci/solar-system/solar-system-sci.html

6. The National Geographic film *Journey to the Edge of the Universe* is featured in 10 x 10 minute clips. The first seven deal with planets, their satellites, solar nebula theory, the sun, while the latter three deal with stars, and development of the universe. These can be shown all at once in sequence as an introduction to the theme of the planets and formation of the solar system and can also be linked to other modules within this and other lenses. Go to: *http://www.youtube.com* and search "*Journey to the Edge of the Universe 1 of 12*" to begin.

7. Canadian Space Agency main page, and modules each with: Lesson plan, evaluation rubric with student pages – planetary database sheet and recording sheets.
http://www.asc-csa.gc.ca/eng/educators/resources/astronomy/default.asp#module4
http://www.asc-csa.gc.ca/eng/educators/resources/astronomy/module4/lesson1.asp

How have theories of other planets changed over time?

~400 BCE – Plato believed the sun, stars, moon and planets to be connected by crystal spheres.

~100 CE – Geocentrism. Ptolemy reasoned the Earth was the center of the solar system by modeling the movements on epicycles.

~1513 – Heliocentrism. Copernicus proves the Earth revolves around the Sun.

1970 – Probes were sent to the other planets beginning in the 1970s. Many were successful, e.g. Viking, Voyageur and Pioneer.

2004 – The Cassini satellite explored Saturn and flew by many of its moons. In 2005, it launched the Huygens probe on Titan.

1997 - Present – Mars Rovers: Sojourner, Spirit, Opportunity collecting soil samples and studying the surface of Mars.

Top Misconceptions/Questions:

1. *Pluto is still a planet*. In fact, in 2006 the International Astronomical Unit (IAU) demoted it to dwarf planet status. *http://www.iau.org/public/pluto/*

2. *Mars is a red planet*. The colour is more greyish rust/brown colour due to the presence of iron oxide in the hematite minerals. This website contains a host of misconceptions that students have about astronomy and space in general: *http://stars.astro.illinois.edu/class/miscon.html*

Glossary:

Dwarf Planet – This is defined by the IAU as a celestial body orbiting the sun that is massive enough to have its own gravity, but has NOT cleared its neighbouring region of planetesimals and is not a satellite. Examples include: Ceres, Pluto, 2003 UB 313 and Eris.

Trans-Neptunian Objects (TNO) – Objects larger than Pluto that orbit beyond Neptune (also called Plutoids). The dwarf planet Pluto is an example of this type of TNO.

Planet – According to the IAU, a planet is: A celestial body that (a) is in orbit around the sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared its neighbouring region.

Satellite – A celestial body that orbits around a common center of gravity that is deep inside the massive planet that it orbits, e.g. Moon is a satellite to Earth, Titan is a satellite to Saturn, Europa is a satellite to Jupiter.

Astronomical Unit – The average distance between the Earth and the Sun. Its average value is 150 000 000 km.

Ceres – The largest body found within the asteroid belt at 2.77AU that has enough mass and size (d=>1000 km) that it can pull itself into a sphere and be considered a dwarf planet.

Canadian Connection:

Canadian amateur astronomers have been known for their discoveries of comets, e.g. **Shoemaker-Levy 9**, a comet that crashed into the surface of Jupiter in 1994. *http://www.cascaeducation.ca/files/cdn_amateur.html*

Connections:

Art Connections:

Georges Méliès: *A Trip to the Moon*
http://www.moma.org/collection/browse_results.php?object_id=89492

Joan Miró: *Woman and Dog in Front of the Moon*
http://www.moma.org/collection/browse_results.php?object_id=64349

Sandro Boticelli: *Birth of Venus*
http://www.loggia.com/art/renaissance/botticelli02.html

Reading room:

The early migration of planets within our solar system may explain why the asteroid belt is littered with asteroids in some places and not in others… suggesting that the large gravitational tug from the larger planets like Jupiter may have had some influence.
http://www.sciam.com/article.cfm?id=asteroid-belt-planet-migration

The Sun

Mission to Mars: For a long mission to Mars, it's likely that we'll have to rely on solar power for the spacecraft or powering life support systems. Also, any life present on Mars would ultimately receive its energy from the Sun.

Made Contact: Our alien lives on a planet that gets its energy from a star, much like how Earth gets its energy from the Sun. How does this process work, and how is the Sun similar to other stars?

Canadian Space Station: Much of the power needed to generate life support systems on the CSS will be generated by solar power. Knowing about the properties of the Sun will help with this process.

Curriculum Expectations:
D3.4 Describe the Sun's composition and energy source, and explain how its energy warms Earth and supports life on the planet. *(Academic)*
D3.4 Describe the characteristics of the Sun and the effects of its energy on Earth and Earth's atmosphere. *(Applied)*
D2.1 Use appropriate terminology related to the study of the universe. *(Academic)*
D2.4 Gather and record data, using an inquiry or research process, on the properties of specific celestial objects within the solar system. *(Academic)*

The Big Idea:
The Sun is the closest star to Earth, and all the planets in the solar system, including Earth, orbit around it. Unlike the planets, it creates its own energy through nuclear fusion, and this heat and light is essential to life on Earth.

Activities:
1. For your students who are auditory learners, download this podcast on the topic of the Sun and its properties. A good opportunity for students to practice their listening skills and extract key information. (Also, check out episode #108: The Life of the Sun.)
http://www.astronomycast.com/astronomy/episode-30-the-sun-spots-and-all

2. At the site below, you can download PowerPoint presentations with images and information covering the entire curriculum related to the Sun. Includes an excellent lesson on tracking sunspots, with lesson plans and student workbooks. *http://www.astro.utoronto.ca/~percy/epo/sun/index.htm*

3. The Solar and Heliospheric Observatory (SOHO) is a space-borne observatory designed to take pictures and gather data about the Sun. Check out the 'Gallery' for images and movies to show in class and encourage them to draw what they see. *http://sohowww.nascom.nasa.gov/*

4. In this activity, students analyze data in a computer lab in order to track cycles of solar activity. Great for honing skills of data analysis in MS Excel.
http://www.cascaeducation.ca/CSA/CSA_Astro9/files/html/module2/lessons/lesson7/solarCycle.html

5. Observe the Sun daily, both on the Internet and at least once (safely!) with binoculars or a small telescope by projection. Describe the Sun and how it changes from day to day.
http://spaceweather.com/sunspots/doityourself.html

6. The National Solar Observatory keeps an updated website of current Sun images. The 'Projects' page provides some excellent content for students keen to learn more about the details of current scientific investigations into the Sun's behaviour: *http://www.nso.edu/*

7. A resources for students interested in doing projects with real solar data on sunspots, magnetic field mapping, rotation, and analyzing coronal mass ejections. They also have quizzes on solar structure and properties. *http://www.suntrek.org/classroom-projects/Using-real-solar-data.shtml .*

How have theories of the Sun changed over time?

3000 BCE – Early cultures viewed the Sun as a deity that brought heat and light to Earth every day. A common image was of the Sun being transported across the sky by a chariot or monster.

450 BCE – Greek philosopher Anaxagoras was the first to suggest the Sun might be a giant ball of fire.

350 CE – Greek philosopher Aristotle argued that the Sun orbited around Earth.

1540 – Polish astronomer Nicolas Copernicus proposed that Earth and the other planets orbited around the Sun.

1910-1940 – Scientists gradually understand that the Sun's energy source is nuclear fusion of hydrogen into helium.

1995 – NASA launches the SOHO satellite, the most successful solar observing project to date, collecting useful data in many wavelengths.

Top Misconceptions/Questions:

1. *The Sun is the biggest/brightest object in the universe.* In reality, it only seems so bright and big because Earth is so close to it. There are millions of stars that are bigger/hotter than the Sun, they're just a lot further away.

2. *The Sun is a unique star.* In reality, it has an average temperature and size. There are millions of other yellow stars pretty much like our Sun.

3. *The Sun will blow up in a supernova and turn into a black hole when it runs out of fuel.* (In reality, it is not big enough for this – as it runs out fuel in around 5 billion years, the Sun will slowly lose its exterior layer and the interior will turn into a white dwarf star.

Glossary:

Sunspot – An area on the surface of the Sun of intense magnetic activity that looks dark from Earth because of its lower temperature.

Solar flare – Explosions of energy in the Sun's atmosphere, usually in the region of sunspots.

Solar wind – Highly-energetic charged particles that are ejected from the Sun's atmosphere and travel through space to Earth.

Corona – The halo of hot gas that makes up the outer layer of the Sun's atmosphere extending million of kilometres into space. Prominent during a solar eclipse when the disk of the Sun is covered.

Chromosphere – The cooler layer of the Sun's atmosphere just underneath the corona.

Prominence – A huge loop of plasma anchored just underneath the Sun's surface.

Radiation – Electromagnetic radiation includes visible light, but also invisible kinds of radiation such as ultraviolet and X-Ray radiation.

Canadian Connection:

1. The Canadian Space Agency (CSA) launched the creation of an on-line observatory called **AuroraMAX** dedicated to examining images of aurora borealis (the northern lights) over Yellowknife.
2. The CSA is also contributing to a series of satellites launched by NASA in 2007 called **THEMIS**, devoted to studying how Earth's magnetic field interacts with the solar wind.
3. After WWII, many RADAR experts turned their skills to radio astronomy, and in 1946 Canadian astronomer **Arthur Covington** made the first series of radio observations of sunspots in order to determine their properties.

Connections:

1. References to the Sun appear often in pop music. Challenge your students to come up with examples (i.e. *Here Comes the Sun* by the Beatles and *Music of the Sun* by Rihanna)
2. Impressionist painters such as Monat and Pissaro were interested in how light from the Sun illuminated objects at different times of the day (the name of the movement came from Monet's painting *Impression Sunrise*).
3. Many cities around the world (including Toronto) have daily papers called *The Sun*. Why do you think this is?

Reading room:

1. Read about the power of solar flares from the Sun: *http://www.nrc-cnrc.gc.ca/eng/education/astronomy/tapping/2007/2007-10-10.html*

2. Read how scientists at the University of Toronto have been experimenting with solar power at microscopic scales: *http://news.nationalgeographic.com/news/pf/59438741.html*

Other Stars

Mission to Mars: Traveling to and colonizing Mars is the first step toward getting to other planets. One of the ways to get around in space is to navigate by the stars. What are these distant objects?
Made Contact: Knowing what types of stars likely have planets orbiting them can narrow down where we look for other intelligent beings. Is the alien's sun much like ours?
Canadian Space Station: What information can the new CSS tell us about other stars, as well as their evolutions and fates?

Curriculum Expectations:
D2.2 Use direct observation, computer simulation or star charts to determine the location, appearance and motion of well-known stars and other celestial objects that are visible in the night sky *(Academic)*
D2.3 Plan and conduct a simulation that illustrates the interrelationships between various properties of celestial objects visible in the night sky. *(Academic)*
D2.5 Compare and contract properties of celestial objects visible in the night sky, drawing on information gathered through research and using an appropriate format. *(Academic)*
D3.3 Describe the major components of the solar system and the universe using appropriate scientific terminology *(Academic)*
D2.2 Investigate patterns in the night sky and the motion of celestial objects *(Applied)*

The Big Idea:
The Sun is the closest star to Earth. The stars visible at night are distant suns, although they may be very different from our sun. The next closest star, Proxima Centauri, is 4.3 light years away. Stars may be characterized based on their mass, size, temperature, etc. Stars change ('evolve') over time through birth and life (via nuclear fusion) to death (forming a white dwarf, neutron star or black hole). These changes are solely determined by the star's mass.

Activities:
1. Life Cycle of Stars: This website contains extensive background information on the changes stars undergo (i.e. how they 'evolve') as well as lesson plans. *http://imagine.gsfc.nasa.gov/docs/teachers/lifecycles/LC_title.html*

2. Are Other Stars Like Our Sun? The Sun is a star but are all stars like the Sun? This site contains a PowerPoint and script for use in the classroom.
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=182

3. HR Diagram Interactive Simulator: The Hertzprung-Russell diagram is a plot of stellar brightness vs. temperature and may be manipulated to demonstrate stellar properties and evolution.
http://www.astro.ubc.ca/~scharein/a311/Sim/hr3/HRdiagram.html

4. Star Finder: Download this master and print copies for each student. Using the starfinder (or software) predict the appearance of the stars and constellations in the sky tonight. Go out and (safely) observe them.
http://www.star-finder.ca
An online, interactive star finder is at
http://www.nrc-cnrc.gc.ca/eng/education/astronomy/constellations/planisphere.html

5. Take a chart showing only the visible stars in the sky (no constellation or star names) and make up your own constellation patterns, names and their stories.

6. Research the names of the bright stars: a good multicultural activity.

7. Supernova Star Maps: Here you will find an instructional video, a PowerPoint, classroom activities and a star map indicating which naked eye stars are likely to explode violently as supernovae.
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=341

8. Distance to Stars Using Parallax: Numerous activities for the classroom including those dealing with parallax (to answer the question, 'How do we know how far…?')
http://www.astro.princeton.edu/~clark/teachersguide.html (#14-17)

9. Stellar Evolution: A short, student research-based activity dealing with how stars change over time.
http://www.carolina.com/text/pdf/earth/A_Star_is_Born.pdf

How have theories about the stars changed over time?

1609 – Galileo used a telescope to determine that the Milky Way is made of stars and that stars are distant suns.

1838 – Bessell determined the distance to a star other than the Sun: 61 Cygni.

1860 – William Huggins made the first spectral analysis of a star. Photography developed; with spectroscopy it is an essential tool for analyzing starlight.

1916 – Birth of astrophysics: Eddington proposed the currently accepted theory of what powers the stars, i.e. nuclear fusion.

2003 – Canadian space telescope MOST (Microvariability and Oscillation of Stars) launched.

Top Misconceptions/Questions:

1. *Polaris (the North Star) is the brightest star in the night sky.* An examination of the night sky, using a star chart if necessary to identify the North Star, will reveal that Polaris is far from being the star with greatest apparent brightness. This status goes to Sirius. *See http://www.badastronomy.com/bad/misc/badpole.html*

2. *All stars are white.* A look at some of the brightest naked-eye stars will reveal some that are reddish e.g. Betelgeuse & Aldebaran (winter sky), Antares (summer sky), and Arcturus (autumn sky). See *http://www.badastronomy.com/bad/misc/starcolors.html*

3. *The hottest stars are red-hot.* On Earth, red-hot means really hot. But hot stars are yellow, really hot stars are blue and really, really hot star are white. See *http://www.badastronomy.com/bad/misc/starcolors.html*

Glossary:

Star – A massive ball of gas held together by its own gravity and powered by nuclear fusion so that it produces its own light.

Galaxy – A huge assembly of stars (millions to hundreds of billions), gas and dust held together by gravity; the basic unit of the universe.

Light Year – The distance light travels in one year, about 3.09×10^{13} km.

White Dwarf – Small, dense stellar corpses that have exhausted their nuclear fuel and have a maximum mass of 1.4 solar masses.

Neutron Star – Small, very dense, rare stellar corpse composed mainly of neutrons.

Black Hole – A mass of great density such that the escape velocity from its surface is greater than the speed of light, i.e. nothing, not even light can escape.

Supernova – Explosion of a (usually) massive star resulting in the formation of a neutron star or black hole.

Canadian Connection:

1. For a brief history of Canadian astronomy, go to *http://www.cascaeducation.ca/files/canadianContributions.html*
2. The **MOST** satellite (Canada's 'humble space telescope') has provided a scientific return out of all proportion to its small size. The public is invited to suggest observing targets. See *http://www.astro.ubc.ca/MOST*
3. High school students may become involved in real variable star research. See *http://www.aavso.org/sites/default/files/webpublications/ejaavso/v35n1/284.pdf*
4. **Helen Sawyer Hogg**, an expert on star clusters and variable stars, was one of Canada's greatest astronomers. See the Hall of Fame on the National Museum of Science and Technology website: *http://www.sciencetech.technomuses.ca*

Connections:

1. How would you evaluate the work of such artists as Jon Lomberg, Chesley Bonestell or Don Dixon in terms of art? Of science?

2. Does the music of artists such as John Nemy, Mychael Danna or John Serrie evoke visions of space?

3. Evaluate the merit of old star atlases in terms of art and science, e.g. see *http://www.lhl.lib.mo.us/events_exhib/exhibit/exhibits/stars/welcome2.htm*

Reading room:

John Goodricke, an 18th century amateur astronomer, was the first to observe variable stars and propose the correct mechanism for some of their variability. He was deaf for most of his life and died before the age of twenty-two. See *http://en.wikipedia.org/wiki/John_Goodricke*

Formation of the Solar System

Curriculum Expectations:
D3.2 Describe observational and theoretical evidence relating of the formation of the solar system (e.g., evidence that supports the theory that the solar system was formed from a contracting, spinning disc of dust and gas) *(Academic)*

D3.3 Describe the major components of the solar system and the universe (e.g., planets, star, galaxies), using appropriate scientific terminology and units (e.g., astronomical units, scientific notation, light years) *(Academic)*

Mission to Mars: Mars is one of many planets in our solar system. Before we travel there we must have an understanding of its history and the process that created it in the first place.
Made Contact: To understand the star system the alien lives in, we must analyze our own solar system and figure out how it formed and evolved. Alien star systems are much like ours.
Canadian Space Station: The CSS will orbit around Earth so that astronauts can conduct experiments on human health. The molecules that make up our bodies come from the original solar nebula that created our solar system. How did these molecules come about?

The Big Idea:
Our planetary system was created out of a flat, circular disc of gas and dust surrounding the early Sun. We have recently obtained evidence to support this theory by observing the formation of distant planetary systems out of gas clouds with infrared and radio telescopes around young, distant stars.

Activities:
1. For the kinesthetic learners in your class, here is an excellent activity where students model the solar nebula theory by moving around the classroom as hydrogen atoms. Also a very complete summary of the solar nebula theory with appropriate vocabulary.
http://www.cascaeducation.ca/CSA/CSA_Astro9/files/html/module4/lessons/lesson3/solar_nebula.html

2. Check out James Schombert's page on his course 'Formation and Evolution of the Solar System' at the University of Oregon. Lecture #24 has a good summary of the origins of the solar system, including the nebular theory, and a quiz to check student learning. *http://abyss.uoregon.edu/~js/ast121/*

3. Here is a PowerPoint presentation on recent discoveries of exoplanets and distant star systems. There's a lot of detail in the second half, but it can easily be trimmed.
http://epsc.wustl.edu/classwork/classwork_171/SP2008/Lectures/EPSC171A-Spring08-24-Exoplanets.pdf

4. Design a realistic scale model of the solar system for your schoolyard:
http://www.exploratorium.edu/ronh/solar_system/

5. If you have access to a computer lab, encourage your students to explore the giant timeline at this site. It takes the students from the initial solar nebula right up to the evolution of life. Activity cards included on site.
http://www.lpi.usra.edu/education/timeline/mural.shtml#right

6. The following is another PowerPoint presentation that explains the formation of the solar system in terms of the distribution of the terrestrial and gas giant planets and the recent discovery of exoplanets.
http://homepages.spa.umn.edu/~skillman/lecturesF10/AST1001.ch6a.ppt

7. Two excellent videos (among others) at YouTube explaining the formation of the solar system by National Geographic *http://www.youtube.com/watch?v=B1AXbpYndGc&feature=related* and *http://www.youtube.com/watch?v=tFLOsRSuW0E&feature=related*

8. You need to communicate, to extra-terrestrials, the most important properties of your solar system, and you only have 50 words in which to do it. What are the most important, fundamental properties?

How have theories of other planets changed over time?

1633 – Galileo remained under house arrest for insisting the Earth was one of many planets that orbited around the Sun.

1734 – Emanuel Swedenborg put forth the nebular hypothesis, which suggested the planets in the solar system formed out of a giant cloud of gas surrounding the early Sun.

1900 – Astronomers thought the solar system formed as a result of a near collision between two stars.

1935 – Arthur Eddington showed that the Sun generated its energy through nuclear fusion, and was much older than previously thought, lending support to the nebular theory.

1984 – Protoplanetary disks (proplyds) found around distant stars lends more support for the nebular hypothesis.

1991-present – Since 1991, over 490 exoplanets have been detected orbiting around distant stars. Some have been directly observed.

Top Misconceptions/Questions:

1. *The solar system was created with the rest of the Universe during the Big Bang.* The Big Bang occurred almost 14 billion years ago and the solar system formed out of the second or third generation of stars 4.5 billion years ago.

2. *The solar system is the universe/galaxy.* In reality, the solar system is only composed of the objects that orbit the Sun, and is a tiny speck compared to the distant stars in our Milky Way galaxy as well as the billions of other galaxies in deep space.

3. *The planets are all equally spaced.* In reality, the inner planets are close together and the gas giants are spread out through space, getting further apart as the distance from the Sun increases.

Glossary:

Solar nebula – The giant cloud of gas and dust that swirled around the early Sun, eventually giving rise to the planets in the solar system.

Exoplanet/Extrasolar planet – Any planet that orbits a star outside of our solar system.

Protostar – A dense accumulation of gas and dust that will soon start the process of nuclear fusion, turning into a star.

Protoplanet – A clump of gas and dust orbiting around a distant star that will soon collapse into a spherical planet.

Canadian Connection:

1. Canadian astronomers in British Columbia developed the technique for identifying exoplanets by the gravitational effect they have on their star.
2. Another Canadian astronomer has detected exoplanets when they pass in front of their star, causing the light to dim.
3. Canadian astronomers at the **University of Toronto** have recently been part of the teams that have directly captured images of Jupiter-sized planets orbiting around distant stars.

Connections:

1. Science fiction novels and movies contain imaginary distant solar systems of different configurations (*Star Wars*, *Battlestar Galactica*, *Star Trek*, *Foundation* by Isaac Asimov, *Dune* by Frank Herbert).

2. The Planets is a seven-movement orchestral suite by British composer Gustav Holst, with one movement for each of the seven planets except Earth. Great for music fans in your class.

3. Because exoplanets can't be visited (yet?), we rely on artists for imagined pictures of star systems. Check out William K. Hartmann and Lynette Cook for images.

Reading room:

1. "First Exoplanet Imaged," in *Astronomy*. Read an account of the first direct picture of an exoplanet by American and European astronomers.

2. *Cosmicomics* by Italo Calvino contains an excellent short story called "The Daybreak," where the protoplanets in the nebula forming our solar system are personified as members of a family.

The Big Bang

Mission to Mars: With only a thin atmosphere, the surface of Mars is not as protected from coldness of space (~ -270°C) as the Earth is. Why is space that temperature? Studying the origin of the universe will provide us with some theories for this.
Made Contact: If we were to look for alien civilizations in other galaxies, they would appear to be moving away from us. Why is this? Studying the origin of the universe will provide us with some theories for this motion.
Canadian Space Station: The instruments and techniques available on the CSS will be applied to the study of distant objects such as galaxies to learn how the universe may have originated.

Curriculum Expectations:
D3.1 Describe observational and theoretical evidence relating to the origin and evolution of the universe (e.g., evidence supporting the Big Bang theory). *(Academic)*

The Big Idea:
Until relatively recently, the universe was considered to be infinite in terms of size and age. The Big Bang theory, supported by theory and observations, indicates that the universe had a definite beginning in a great explosion some 13.7 billion years ago and has continued expanding since then.

Activities:

1. Formation of the Universe: Theories and Evidence Background information, demonstrations and classroom activities:
http://www.cascaeducation.ca/CSA/CSA_Astro9/files/html/module6/lessons/lesson3/formation_universe.html

2. The Expanding Universe: Lesson plans and six activities dealing with the origin and nature of the universe including a simple balloon model that demonstrates the expansion of space and allows students to observe Hubble's Law (activity #2). Six activities in total.
http://btc.montana.edu/ceres/html/Universe/uni1.html

3. A Teacher's Guide to the Universe (#1-11): Many activities dealing with our current understanding of the size and expansion of the universe.
http://www.astro.princeton.edu/~clark/teachersguide.html

4. Canadian Astronomy Education: Assessment ideas based on the arts, activities, thinking skills, technology & media and inquiry & research.
http://www.cascaeducation.ca/files/teachers_summative.html

5. Tune a TV to a blank station and observe the static. Research how some of the static is produced by photons from the cosmic microwave background radiation from the Big Bang.

How have theories of the evolution of the universe changed over time?
1920s – Shapley estimates size of Milky Way; Curtis theorizes that 'spiral nebulae' are other galaxies.
1923 – Edwin Hubble demonstrates that the 'spiral nebulae' are other galaxies.
1929 – Edwin Hubble secures observations indicating universe is expanding.
1949 – Cosmic microwave background (CMB) predicted.
1950 – Fred Hoyle scoffs at evolutionary theory of universe and calls it a 'Big Bang.'
1965 – Arno Penzias and Robert Wilson discover CMB and subsequently receive Nobel Prize.
1989 – NASA launched the COBE satellite which mapped the CMB and measured its temperature to be 2.725 K.

Top Misconceptions/Questions:
1. *In the Big Bang, the universe expanded into already existing space.* In the Big Bang, matter, energy, time and space were formed. There was no pre-existing space in which the Big Bang occurred. The expansion of the universe is the expansion of space, not the movement of stars, galaxies, etc. into space that was already there.

2. *The universe is static or unchanging.* Since the Big Bang, the universe has expanded and cooled, galaxies have formed and stars have been born and died. See *http://www.astrosociety.org/education/publications/tnl/56/changing3.html*

3. *The Universe has always existed.* Observation and theory suggest that the universe formed in the Big Bang about 13.7 billion years ago. Its ultimate fate is unknown. See *http://archive.ncsa.uiuc.edu/Cyberia/Cosmos/InTheBeginning.html*

Glossary:
Big Bang – The currently accepted theory in which the universe (all matter, energy, space and time) originated in a fireball 13.7 billion years ago; the universe continues to expand and cool from its original hot, dense state.
Cosmic Microwave Background Radiation – Leftover radiation from the early hot, dense universe, the universe now has a temperature of about 3 K (-270°C).
Universal Expansion – The universe is growing larger as indicated by the galaxies moving apart; this is the result of space expanding due to the Big Bang.
Galaxy – A huge assembly of stars (millions to hundreds of billions), gas and dust held together by gravity.
Red Shift – Movement of spectral lines toward the red due to recession of the object emitting the light.

Canadian Connection:
1. **Dr. Wendy Freedman** obtained her PhD. from the University of Toronto and headed a team at the Carnegie Observatories that pinned down the age and size of the universe. This was done by measuring the distance to 'standard candles,' i.e. distant stars of known brightness. Read more at *http://obs.carnegiescience.edu/research/wfreedman/*
2. Canada's most famous astronomer, **Dr. Richard Bond**, is a world leader in studying the cosmic microwave background radiation and determining the properties of the universe. See his home page *http://www.cita.utoronto.ca/~bond/*

Connections:
1. Research creation myths from different times and places around the world. How are they different from scientific theories and each other? Are there any similarities? Why do so many cultures create these stories?

2. Create art evoking ideas of the power and all-pervasiveness of the Big Bang.

3. Listen to the percussion concerto *Big Bang* by Andrew Staniland (archived by the CBC). How does it convey ideas from cosmology?

Reading room:

For information on An Ancient Universe: How Astronomers Know the Vast Scale of Cosmic Time see *http://www.astrosociety.org/education/publications/tnl/56/*

Humans in Space

Mission to Mars: For a manned mission to Mars, humans will be in a zero gravity environment for a long time. They will have to be aware of the effects on the human body.

Made Contact: If we are considering a voyage to the distant galaxy in which our alien lives, we will have to research the effects of space travel on the human body.

Canadian Space Station: The astronauts in the CSS will be in microgravity for the duration of their stay aboard the CSS. What are the effects of such motion on the human body?

Curriculum Expectations:
D1.2 Assess some of the costs, hazards, and benefits of space exploration (e.g., the expense of developing new technologies, accidents resulting in loss of life, contributions to our knowledge of the universe), taking into account the benefits of technologies that were developed for the space program but that can be used to address environmental and other practical challenges on Earth. *(Academic)*
D1.1 Research the challenges associated with space exploration and explain the purpose of materials and technologies that were developed to address these challenges and how these materials and technologies are now used in other fields of endeavour. *(Applied)*

The Big Idea:
Allowing humans to travel into outer space is extremely risky to human health and costs a lot of money. These risks, however, need to balanced with the benefits human space travel has given humanity in the form of space-program "spin-offs."

Activities:
1. The concept of free-fall is difficult for many students to grasp (even in Gr. 12) as distinct from "zero-gravity." Newton's Cannon is an excellent demo of this concept and exists as several applets online. Try *http://www.waowen.screaming.net/revision/force&motion/ncananim.htm* and *http://www.smaphysics.ca/phys40s/field40s/newtmtn.html*

2. The current methods for getting humans into outer space are NASA's space shuttle and Russia's Soyuz craft. Both drop off and pick up payload from the ISS. Explore the ISS being built in the interactive timeline below. Encourage your students to build a low-tech version with boxes and connectors taking into consideration the support systems needed for human habitation. *http://i.usatoday.net/tech/graphics/iss_timeline/flash.htm*

3. The Mars Society (*http://www.marssociety.org/portal*) is an advocacy group dedicated to the colonization of Mars. A short video explaining their vision is at: *http://www.youtube.com/watch?v=x_UnsgIgOpY*

4. OSTEO is a project run by the Canadian Space Agency that seeks to understand and explore the phenomenon of bone deterioration in space. Experiments were recently performed on John Glenn during his recent mission to the ISS. *http://www.asc-csa.gc.ca/eng/sciences/osteo.asp*

5. Encourage your students to design a training program (weights, cardio, flexibility etc.) that would keep the astronauts healthy when in orbit around Earth or during a deep space flight. Remind them they need to work under the constraints of the fact that gravity doesn't provide resistance.

6. Testing is now underway to use space robotics to conduct remote robotic surgery (telesurgery). Recently, researchers at the University of Calgary and at McMaster University in Hamilton, Ontario, conducted experimental projects in which the surgeon directed medical staff from an operating console while conducting robotic surgical operations on patients hundreds of kilometres away in a hospital in North Bay, Ontario. Check this link for more information, including videos of telesurgery. *http://www.intersurgtech.com/tele-medicine.html*

7. NASA has a website which documents technological spin-offs from the space program. Encourage your students to choose one and perform some research on its use. *http://www.sti.nasa.gov/tto/*

How has human space travel changed over time?

1957 – The first living organism to travel to space was Laika, a dog, launched in the satellite Sputnik 2.

1961 – The first human being in space was Russian Yuri Gagarin. On April 12, Gagarin orbited the Earth once before landing safely.

1963 – NASA's Apollo Program, designed to compete with the Russians in space travel, began with the goal of landing a person on the Moon. They achieved this goal in 1969. A total of 48 astronauts flew into space as part of the Apollo program.

1977 – NASA begins the space shuttle program: reusable spacecraft designed to bring humans into Earth orbit and back safely. 133 shuttle missions have been launched to date, although two of them – Challenger (1986) and Columbia (2003) – ended in disaster, killing the crew.

1998 – International partners launch the first stage of the International Space Station, a space laboratory designed for human habitation for months at a time.

Top Misconceptions/Questions:

1. *Humans float in the International Space Station (and any other vehicle in Earth orbit) because there is no gravity*. In reality, the crew are in "free-fall" around the Earth, and are falling towards the Earth with an acceleration the same as the craft they are in.

2. *The moon landing was faked.* It wasn't: *http://www.badastronomy.com/bad/tv/foxapollo.html*

3. *Mars is fit for human habitation.* Mars is far too cold for humans to comfortably inhabit, but more importantly, the atmosphere is very thin and has no oxygen, making it inhospitable for human life.

Glossary:

The International Space Station (ISS) – A partnership between many countries, the ISS is a space laboratory for experiments to be conducted and to house astronauts (Eng.), cosmonauts (Rus.) and taikonauts (China). Astronauts can stay up to six months at a time.

Space Shuttle – One of the reusable spacecraft developed by NASA in the late 1970s to transport crew into Earth orbit or onto the ISS. Scheduled to retire in 2011.

Microgravity – A preferable term to zero gravity, microgravity refers to the gravity astronauts are experiencing when they are in free fall around the Earth.

Payload – The cargo taken into space such as new material for the construction of the ISS.

Canadian Connection:

1. The **Canadian Space Agency** (CSA) performs world-class research on health and safety in space travel. The CSA's view is that any research into space travel must benefit Canadians.
2. **OSTEO** is a CSA project dedicated to exploring osteoporosis through human space-flight subjects.
3. Robotic surgery has been explored in Canada through companies such as **MD Robotics** based on their work in the **CanadArm**.
4. Canada was also the third country (after the USSR and the USA) to build a spacecraft which was launched into space.

Connections:

1. There are countless movies that feature a crew of humans travelling in outer space. Encourage your students to pick their favourite and explore the accuracies and inaccuracies in the depiction of human space travel (i.e. *Star Trek*, *Apollo 13*, *2001: A Space Odyssey*, *Mission to Mars*, *Hitchhikers Guide to the Galaxy* etc.)
2. Pretending they are astronauts, encourage your students to write letters home, write emails, blog, create podcasts, videos or sketches and paintings of their experiences as astronauts. What value do these methods of communication have? Can you think of anyone else who might be interested in the thoughts of a space traveller?

Reading room:

1. Julian Barnes' *History of the World in 10 ½ Chapters* includes a story based on astronaut James Irwin, searching for the resting place of Noah's Ark.
2. Kim Stanley Robinson's *Mars Trilogy* tracks the terraforming of Mars over generations, including political, technical and social problems the project creates. *http://en.wikipedia.org/wiki/Mars_trilogy*

Culminating Activity A

Mission to Mars: After your successful Mission to Mars, the Canadian Space Agency (CSA) wants to hire you as a public relations officer to tell the public about the work the CSA does.

Made Contact: After the successful contact with a distant life form, the Canadian Space Agency (CSA) wants to hire you as a public relations officer to tell the public about the work the CSA does.

Canadian Space Station: After your success launching the CSS, the Canadian Space Agency (CSA) wants to hire you as a public relations officer to tell the public about the work the CSA does.

Curriculum Expectations:
D1.1 Assess, on the basis of research, and report on the contributions of Canadian governments, organizations, businesses and/or individuals to space technology, research and/or exploration (e.g. as part of the International Space Station mission.) *(Academic)*
D1.2 Assess some of the costs, hazards, and benefits of space exploration, taking into account the benefits of technologies that were developed for the space program but that can be used to address environmental and other practical challenges on Earth *(Academic)*
D2.1 Use appropriate terminology related to the study of the universe. *(Academic)*
D2.4 Gather and record data, using an inquiry or research process, on the properties of specific celestial objects within the solar system. *(Academic)*
D3.6 Describe various reasons that humankind has had for studying space and the conceptions of the universe held by various cultures and civilizations. *(Academic)*

The Big Idea:
The Canadian Space Agency is funded by the Canadian government to "advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians." In an effort to convince Canadians that the benefits of space exploration are worth the cost, the CSA has hired your students to publicize their work. They will research several projects in which the CSA is involved, and report their findings back to the class in a medium of their choosing, hitting various parts of the curriculum as they progress through the project.

Instructions:

1. Divide the class up into groups of 4 students. Each member of the group is responsible for picking one project in which the Canadian Space Agency is involved, and researching it. The students must decide on how they want to present the information back to you; it can either be a group effort (a play, a poster), or the students can embark on individual projects that work together (script for a TV commercial, billboard, magazine ad). Another method would be to assign each student a role: researcher, writer, graphic designer, and presenter, and have them share the work-load for each of the CSA projects.

2. Direct the students to *http://www.asc-csa.gc.ca*, the Canadian Space Agency web-site, or *http://www.wikipedia.org/wiki/Canadian_Space_Agency* to get started.

Your library should have some resources, including:

- Canada's Fifty Years in Space by Gordon Shepherd & Agnes Krucio (Collector's Guide, Toronto, 2008)
- Canada in Space: The People & Stories Behind Canada's Role in the Exploration of Space by Chris Gainor (Folklore Publishing, Edmonton, 2006)
- Canada's Space Program and Your Future (DVD); order at: *http://www.asc-csa.gc.ca/*

3. The students must each pick one of each of the following projects in which the CSA is involved to research:

- one project studying the properties of Earth;
- one project involving human space exploration;
- one project involving the observation of distant stars or galaxies;
- one project involving the study of objects in our solar system (the Sun, planets, asteroids etc.)

Instructions: ***(continued)***

4. Encourage the students to consider:
   - how much the project costs;
   - what the project is designed to do;
   - whether the project has resulted in any useful technologies for people on Earth;
   - whether the project is dangerous for humans;
   - how the project has contributed to the scientific community;
   - what the satellite/technology looks like;
   - which companies were responsible for manufacture and design of the technology;
   - its importance to the economy of Canada regarding jobs, research, spin-offs etc.
   - what celestial object the technology is designed to observe (if appropriate);
   - what kind of orbit the satellite is in (low, mid, geostationary);
   - any other considerations you wish to add;

5. Once the students have gathered their information, they need to decide on a method of communication. Taking into consideration different learning styles, IEPs and ESL issues, the students can decide on their own method of presentation. If the group so decides, they can work together on a presentation, acting out a commercial, creating a play, a song, or a PowerPoint presentation. Or, students can present individually, keeping in mind they will be presenting their information with the rest of their group, so the individual methods should work together in some way (i.e. one student could write and act out a television commercial, another could write and create a billboard or poster with similar information.)

Sample Rubric:

	Level 1	**Level 2**	**Level 3**	**Level 4**	
Communication	Communication of information is weak and unfocused.	Communication of information is adequate, somewhat clear and concise.	Communication of information is clear, concise and understandable.	Communication is excellent: creative, clear concise and engaging.	______
Inquiry	Problem solving is poor. Students show weak strategies for thinking through the process of the project.	Problem solving is adequate. Students show adequate strategies for thinking through the process of the project.	Problem solving is good. Students show good strategies for thinking through the process of the project.	Problem solving is excellent. Students show excellent strategies for thinking through the process of the project.	______
Knowledge	Facts and project content is thin, irrelevant to the course, or incomplete.	Facts and project content adequately show knowledge of the course content.	Facts and project content is correct and relevant to the course.	Facts and project content is correct and relevant to the course, and shows an excellent level of mastery of content.	______
Application	Project content shows weak understanding of the relevance to the everyday lives of Canadians and to the environment.	Project content shows an adequate link to the everyday lives of Canadians and to the environment.	Project content shows relevance to the everyday lives of Canadians and to the environment.	Project content shows an excellent understanding of the connection to the everyday lives of Canadians and to the environment.	______
Total: ________					

Culminating Activity B

Mission to Mars: After your successful Mission to Mars, the National Research Council (NRC) wants to hire you as a public relations officer to tell the public about the work the NRC does.

Made Contact: After the successful contact with a distant life form, the National Research Council (NRC) wants to hire you as a public relations officer to tell the public about the work the NRC does.

Canadian Space Station: After your success launching the CSS, the National Research Council (NRC) wants to hire you as a public relations officer to tell the public about the work the NRC does.

Curriculum Expectations:
D1.1 Assess, on the basis of research, and report on the contributions of Canadian governments, organizations, businesses and/or individuals to space technology, research and/or exploration (e.g. as part of the International Space Station mission.) *(Academic)*
D1.2 Assess some of the costs, hazards, and benefits of space exploration, taking into account the benefits of technologies that were developed for the space program but that can be used to address environmental and other practical challenges on Earth *(Academic)*
D2.1 Use appropriate terminology related to the study of the universe. *(Academic)*
D2.4 Gather and record data, using an inquiry or research process, on the properties of specific celestial objects within the solar system. *(Academic)*
D3.6 Describe various reasons that humankind has had for studying space and the conceptions of the universe held by various cultures and civilizations. *(Academic)*

The Big Idea:
The National Research Council is "Canada's premier organization for research in science and technology," including astronomy and space science. In an effort to convince Canadians that the benefits of investing in astronomy research are worth the cost, the NRC has hired your students to publicize their work. They will research several projects in which the NRC is involved, and report their findings back to the class in a medium of their choosing, hitting various parts of the curriculum as they progress through the project.

Instructions:

1. Divide the class up into groups of 4 students. Each member of the group is responsible for picking one astronomy research project in which the National Research Council is involved and researching it. The students must decide how they want to present the information back to you; it can either be a group effort (a play, a poster), or the students can embark on individual projects that work together (script for a TV commercial, billboard, magazine ad). Another method would be to assign each student a role: researcher, writer, graphic designer, and presenter and have them share the workload for each of the NRC projects.

2. Direct the students to the National Research Council web-site devoted to research in astrophysics. Notice there are four strands of research: Instrumentation, Data Archiving, Astronomical Observation, and Public Outreach. *http://www.nrc-cnrc.gc.ca/randd/areas/astrophysics_e.html*

3. The students must each pick one project in which the NRC is involved to research, one from each strand. Examples include:
   i) An instrumentation project such as the Atacama Large Millimetre Array, to be completed in 2012.
   ii) A data archiving project by the Canadian Astronomy Data Centre such as observations made by Canadian astronomers with the Hubble Space Telescope or the Canadian-France-Hawaii Telescope (CFHT).
   iii) Identifying Canada's contributions to astronomical observatories such as Gemini or the CFHT.
   iv) Public outreach projects such as public tours at the Dominion Astrophysical Observatory.

Instructions: ***(continued)***

4. Encourage the students to consider:
   - How has the project advanced our knowledge of astronomy and space?;
   - How could the project be made more exciting to the public?;
   - What kind of technology does the project use? Were any of these technologies developed by Canadians?;
   - How much does the project costs?;
   - Has the project resulted in any useful technologies for people on Earth?;
   - Is the project dangerous for humans?;
   - Are there any companies partnering with the NRC during the project?;
   - Has the project contributed to the economy of Canada regarding jobs, research, spin-offs etc.?;
   - What celestial object is the project designed to observe (if appropriate)?;
   - Who worked on the project? Were any of them students?;
   - Any other considerations you wish to add;

5. Once the students have gathered their information, they need to decide on a method of communication. Taking into consideration different learning styles, IEPs and ESL issues, the students can decide on their own method of presentation. If the group so decides, they can work together on a presentation, acting out a commercial, creating a play, a song, or a PowerPoint presentation. Or, students can present individually, keeping in mind they will be presenting their information with the rest of their group, so the individual methods should work together in some way (i.e. one student could write and act out a television commercial, another could write and create a billboard or poster with similar information.)

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					Total: ________