Canadian Space Agency Agence spatiale canadienne

Teachers' Guide
Grades 7-9

SURVIVING IN A CLOSED ENVIRONMENT: LIFE BEYOND EARTH

Educational Expectations

This activity has been designed for teachers and students to examine concepts related to space exploration. In particular, to propose solutions to practical problems, analyze and interpret data and predict outcomes. The material presented is intended to provoke discussion and lead to the formulation of interesting questions like, "Is Earth the only suitable home for humans?"

Specific Expectations

Students will:
a) demonstrate an understanding of a closed ecosystem, including cycling;
b) investigate factors which limit the exploration of space by humans; and
c) evaluate the contributions of the International Space Station research to our understanding of biological systems.

Concepts that could be explored include: microgravity, free fall, orbits, radiation, open and closed ecological systems, cycling of matter, energy, interrelationships.

BACKGROUND INFORMATION

The International Space Station (ISS) is an orbiting laboratory 450 km above Earth's surface with an inclination of 51.6 degrees. This orbit provides excellent views of over 75% of Earth containing 95% of our population.

Earth is essentially a closed ecological system (excluding sunlight and the odd cosmic visitor) wherein matter and energy is cycled through non-living and living components. The ecological system, or ecosystem, is a conceptual scheme upon which predictions about interrelationships can be made. A closed environment is one that is isolated by boundaries.

The International Space Station is an entity unto itself as it orbits above us. Fortunately for the inhabitants it is a sustaining environment but it does require energy and matter inputs. Our Canadian astronauts are involved in the input process. Julie Payette, on STS-96, is responsible for the stowage of resources including food and other life-sustaining materials. Marc Garneau, STS-97, will affix solar arrays to the ISS, providing a source of electricity for all kinds of work and energy transfers. Chris Hadfield, STS-100, will walk in space in his own closed environment (a spacesuit) while tethered to the Station. He will install on it the Canadian-built robotic arm the Space Station Remote Manipulator System (SSRMS).

Humans will require a life support system to survive on the International Space Station. And, if humans are destined to explore further we will need a regenerative life support system. Why?

Spacecraft life support systems are designed for short duration missions with small numbers of crew. The closed environment and life support system (CELSS) is a technology relatively simple, that depends upon expendable sources of stored oxygen, water and food. Waste products are either returned to Earth or dumped overboard. On the Space Shuttle, Carbon Dioxide is removed chemically using lithium hydroxide (LiOH) contained in large expendable canisters. This process, while very important would be inefficient and costly in a long-term space flight scenario because it uses launch mass and volume. The Shuttle launch cost is approximately $20,000 Canadian per kilogram. Longer duration missions to the Moon or Mars will require self-sufficiency, minimal resupply and a suitable Earth-like environment if humans are to be successful.

SPACE: A HOSTILE ENVIRONMENT

At 20 km above Earth you would be above 90% of the atmosphere where the sky begins to turn black. At the 51.6° orbit of the International Space Station, 450 km above the Earth's surface, there are few molecules of hydrogen and helium that gradually merge with interplanetary gases. They exert almost no pressure compared to that at sea level on Earth of 101 kilopascals. Therefore, space travelers must carry their own pressurized atmosphere in a sealed cabin or space suit.

In orbit portions of the ISS will be exposed to direct sunlight 16 times per Earth day. Temperatures on these occasions can climb to over 120 degrees Celsius. The ISS will also be exposed to complete darkness or lack of radiant energy. Temperatures can plummet to -100 degrees Celsius. Thus, the internal environment of both spacecraft and space suit, developed for extravehicular activity, must have an active temperature regulation system that maintains a narrow range of thermal comfort.

Other harmful factors include ultraviolet radiation, electrically charged particles from the Sun, galactic cosmic rays and small particles called micrometeoroids, travelling at very high velocities.

The human body is not equipped to survive if a closed environment is breached in space. The vacuum would immediately have disastrous effects on the human body. Dissolved gases would expand quickly, forcing solids and liquids apart. Bubbles of air would come out of solution and form in the tissues and blood. The skin would expand much like an inflating balloon and underlying tissues would rupture. The "bends" or decompression sickness is characterized by pain in the joints and muscles and in extreme cases by circulatory system collapse and shock. In less than 15 seconds a person would become unconscious from tissue damage, swelling and oxygen deprivation to the brain.

A life-sustaining space environment requires an appropriate temperature, pressure, relative humidity and gaseous atmosphere. It must protect the astronauts/cosmonauts from harmful radiation, the vacuum of space, extremes of temperature and impacts by micrometeoroids and other space debris.

A SUSTAINING SPACE ENVIRONMENT

Astronauts require substantial amounts of oxygen water and food to sustain life. The International Space Station life support requirements are shown in Table 1 below. Basic life resources require in excess of 24 kg per person per day while in orbit. Human metabolic processes convert food to waste products that must be stored if they cannot be recycled.

For longer duration missions plants can be an important part of a regenerative life support system. In addition to supplying food, plants have the capacity to regenerate air by converting carbon dioxide into oxygen and through evapotranspiration convert wastewater into drinking water. However in microgravity there are problems for plant growth. Which way is up or down? How will the stems and roots grow? How can you deliver water and nutrients to the plants effectively? What plants will grow best in this environment?

DEVELOPING THE ACTIVITY

This activity involves developing the concept of a closed ecosystem or isolated environment. The role of living organisms, producers, consumers, and their relationship to physical factors, like temperature, atmospheric conditions, and soil nutrients can be characterized. Energy flow and nutrient cycling can be diagrammed to show interrelationships.

Once basic concepts have been established students are ready to develop their own closed ecological system. This can take many forms depending upon the student's interest. Individual closed ecosystems can be created to mimic some of the processes and cycles found on the International Space Station (see Student Activity 1). The students could design and build a large habitation module complete with systems to control lighting or other physical factors. Using mylar or plastic film and duct tape inflatable structures can be created to simulate a space mission complete with experiments and crowded living conditions.

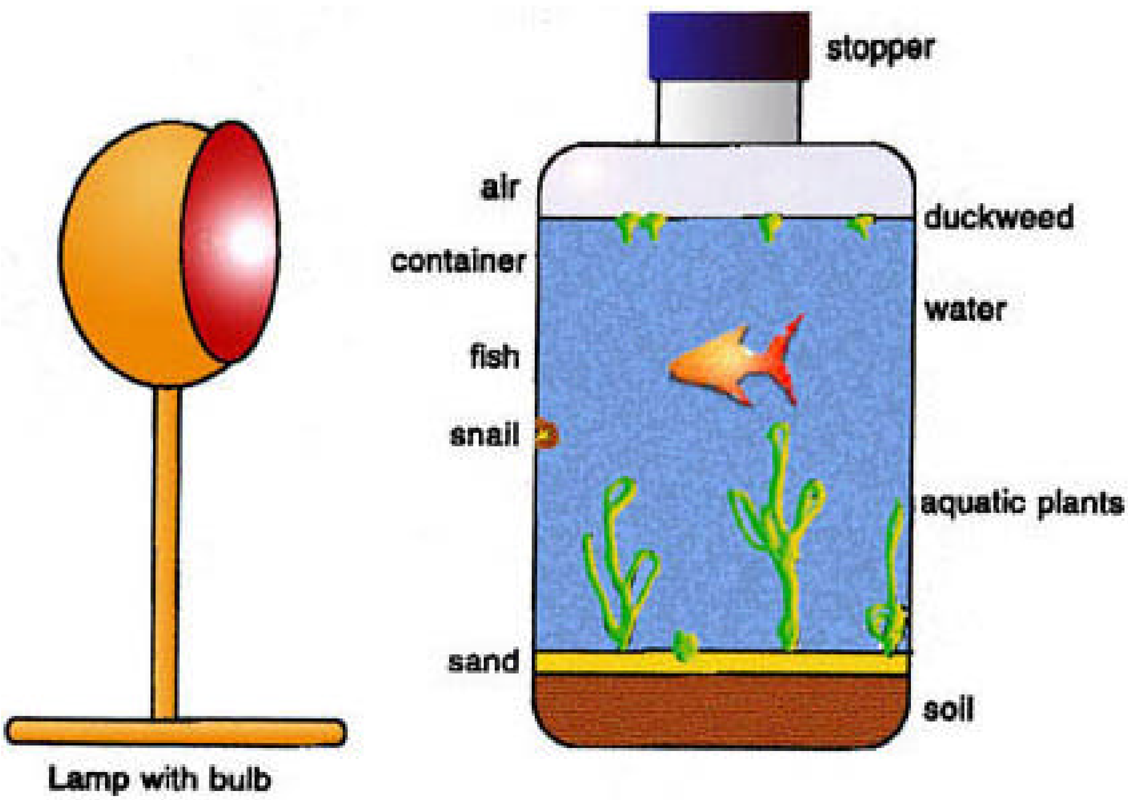
More advanced work could explore the procedures by which Canadian and American scientists are developing regenerative life support systems. The BIO-Plex laboratory at the Johnson Space Centre is developing biomass production chambers that will provide 95% of the food for a crew of four on a continuous basis. Crops that have been identified for space vehicle food systems, in priority order are tomato; carrot; lettuce; radish cabbage; spinach; chard and onion. Currently wheat is being tested as one staple crop for planetary food systems.

In the Horticultural Science program of the University of Guelph Dr. Mike Dixon is into "SALSA", Space and Advanced Life-Support Agriculture. The totally sealed environment is designed to investigate the contribution of plants to life support in space. The SALSA team is experimenting in a number of areas including using recycled hydroponic nutrient solution, new lighting techniques to improve photosynthesis, and gas sampling. Using the Internet students can see how the chambers were constructed and can follow the development of the space crop. Real experimental data is provided including carbon uptake and oxygen production. These experiments could act as templates for student designed investigations.

Table 1 — Life Support Requirements for a Crew Member on Space Station

Consumables	kg/pers.-day		Wastes	kg/pers.-day	
Gases		**0,8**	**Gases**		**1,0**
Oxygen			Carbon Dioxide	1,00	
Water		**23,4**	**Water**		**23,7**
Drinking	1,62		Urine	1,50	
Water Content of Food	1,15		Perspiration / respiration	2,28	
Food Preparation	0,79		Fecal Water	0,09	
Shower and Hand Wash	6,82		Shower and Hand Wash	6,51	
Clothes Wash	12,50		Clothes Wash	11,90	
Urine Flush	0,50		Urine Flush	0,50	
			Humidity Condensate	0,95	
Solids		**0,6**	**Solids**		**0,2**
Food	0,62		Urine	0,62	
			Feces	0,03	
			Perspiration	0,02	
			Shower and Hand Wash	0,01	
			Clothes Wash	0,08	
Total:		**24,8**	**Total:**		**24,9**

Source: NASA


stopper
air
duckweed
container
water
fish
snail
aquatic plants
sand
soil
Lamp with bulb