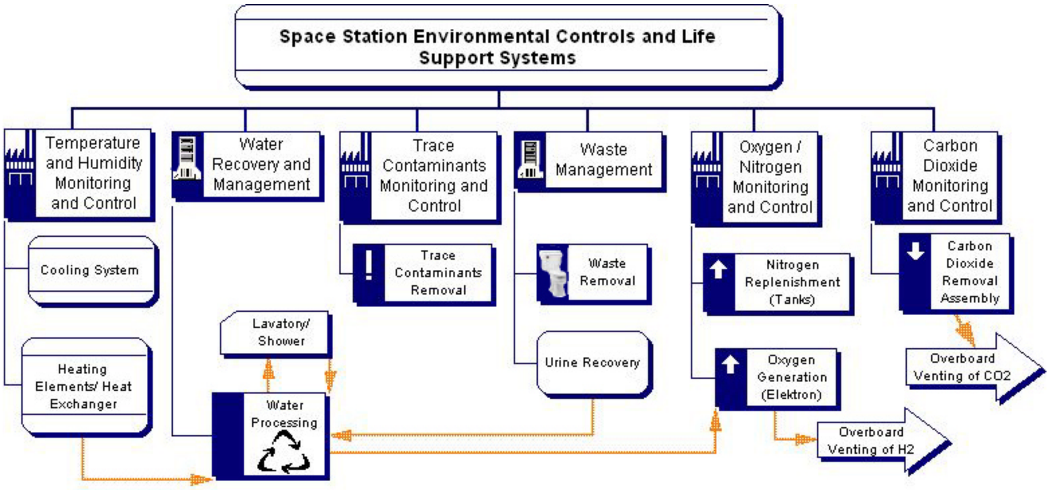
Life Support Reference Guide

Topics: ECLS System Components, Oxygen, Carbon Dioxide

During massive solar storms, life support command and control computers on board Space Station Alpha may be subject to communications or software glitches. Fortunately, NASA is able to monitor the levels of vital environmental components and compensate if needed.

Environmental Controls and Life Support System

The space station Environmental Controls and Life Support (ECLS) system includes the following components:



The **Major Constituent Analyzer (MCA)** reports the total and partial pressures of each major gas in the environment. The MCA uses mass spectrometry to analyze the air.

Cabin Air Fans circulate the gas mixture throughout the space station. Without fans, the air would not circulate because in the microgravity environment, there is no natural convection.

Temperature and Humidity Monitoring and Control

The **Temperature and Humidity Control** system carefully monitors the temperature inside the space station. The cooling systems and heating elements are always turned on. The electricity powering this and all other systems comes from the solar panels and/or the batteries.

Circulating cool, dry air keeps the temperature comfortable and the humidity low. The **Heat Exchanger** controls the humidity by taking water vapor out of the air. Water vapor is primarily generated from the astronauts' breathing processes, but also from activities such as cooking and bathing. The water is then sent to the **Water Recovery and Management** subsystem for reprocessing.

Water Recovery and Management

The **Water Recovery and Management** subsystem gathers water, removes all the chemicals and minerals, and recycles it. It is used for a number of vital purposes including the production of oxygen by electrolysis.

Drinkable water is delivered during each mission of the space shuttle from Earth.

Controlling the level of water vapor in the air is important. If there is too much water vapor there is a danger of excessive *condensation* on sensitive equipment. If there is not enough humidity there is a danger of sparks caused by a buildup of *static electricity*. Sparks could cause very serious fires on board a Space Station in which oxygen, hydrogen, and other flammable gases are being mixed.

Trace Contaminants Monitoring and Control

Methane is produced in the intestines. Ammonia is created by the breakdown of urea in sweat. People also emit acetone, methyl alcohol, and carbon monoxide in their urine and their breath. Some of these gaseous compounds cause unwanted odors. Others are extremely poisonous and must be removed quickly from the atmosphere in Space Station Alpha or the crew will become sick. Activated charcoal filters are the primary method for removing these chemicals from the air.

Waste Management

In the **Waste Removal** and **Urine Recovery** system, human waste and food-related refuse are collected and stored in tanks. Water is mechanically and chemically salvaged and recycled. The space shuttle collects the tanks of waste, and ejects the waste to be burned upon the shuttle's reentry into the Earth's atmosphere.

Oxygen / Nitrogen Monitoring and Control

The **Atmosphere Control and Supply Subsystem** in the Unity module specifically monitors the amount of nitrogen and oxygen in the space station's air. Reports are sent to the **Major Constituent Analyzer**. The **Pressure Control Panel** monitors the atmospheric pressure of the space station's cabin.

The **Nitrogen Replenishment System** consists of pressurized tanks of nitrogen with electrically and manually controlled valves. The nitrogen is shipped to the space station via the shuttle.

Oxygen Generation

A machine called **Elektron** produces oxygen continually using "electrolysis." This machine runs at 75% of its full capacity when there are three astronauts on board. It is powered by the solar panels and batteries.

Electrolysis separates water (H_2O) into oxygen and hydrogen gas (O_2 and H_2) when an electric current is passed through it. The oxygen is pumped into tanks and the hydrogen is "dumped" into space.

A Solid Fuel Oxygen Generator, or "**Perchlorate Candle**," produces oxygen through a chemical reaction. Perchlorate (per-KLOR-ate) is packed inside a metal canister, and the astronauts heat the canister to begin the reaction. Each canister releases enough oxygen for one person for one hour in one room. The canisters are used only in emergencies. Perchlorate is the same chemical used in the breathing masks that drop down during emergencies on airplanes.

In very critical situations, the astronauts can also use a **Portable Breathing Apparatus (PBA)**, which is like a gas mask. The PBAs give the astronauts 15 minutes of oxygen. During this short period of time, the astronauts must fix any oxygen problems that have occurred. The PBA is always used when a fire extinguisher is used, because the CO_2 from the extinguisher displaces much of the oxygen in the room.

In case of complete loss of oxygen, the PBAs may also be plugged into oxygen ports in the tubes of the Atmosphere Control and Supply Subsystem in the Unity module. However, being "plugged in" keeps the astronauts from moving easily around the space station to fix things.

Oxygen and Astronaut Health

Hypoxia: A Concern for Astronauts

Hypoxia is a physical condition caused by a decrease in oxygen entering the blood in the lungs and flowing to the brain and muscles. This occurs on Earth when the partial pressure of oxygen drops below 159 mmHg (typically around 21%). Hypoxia is very dangerous because people often do not notice its symptoms.

Hypoxia keeps the brain and other organs of the body from working the way they should. For instance, dizziness is an early warning symptom of hypoxia. Dizziness may be brought on by drinking too much alcohol, or flying at an unpressurized altitude of 8,000 to 9,000 feet without an oxygen mask. Flying or working on sensitive equipment while you're "dizzy" can be very dangerous.

Victims of hypoxia have been studied on the Earth, especially in regard to various altitudes. We know for instance, that if you hold all temperature and pressure variables constant, but decrease the level of O_2 you would expect to see the following symptoms:

Indifferent Stage: 5,000-10,000 feet or ppO_2 159 mmHg / 20.95%	No real change in bodily or mental functions except for an inability to see at night. Under these conditions, oxygen should be used during night exercises.
Compensatory Stage: 10,000 to 15,000 feet or ppO_2 134 mmHg / 17.59%	People experience an increased heart rate, rapid breathing, and hyperventilation. They feel tired and cranky. They develop headaches and *have trouble making clear decisions.* Simple tests that require a sharp mind or physical coordination are difficult.
Critical Stage: 15,000-25,000 feet or ppO_2 115 mmHg and lower / 15.14% and lower Note : Without a gas mask at 20,000 feet, human beings can only last for 15 to 20 minutes.	Symptoms may include headache, hyperventilation, fatigue, weakness, and extreme dizziness. Vision is impaired and things become blurred. Touch and pain senses are lost. Hearing is one of the last senses to be affected. Clear thinking becomes difficult, and people may have difficulty recognizing an emergency situation. Thinking can be slow, memory can be faulty, and judgment can be poor. Muscular coordination is reduced, and the performance of fine or delicate tasks may be impossible. As a result, there is poor handwriting, stammering, and poor coordination in flying. There are also psychological effects of oxygen deprivation. Basic personality traits and emotions may come to the surface, making people behave as though they had consumed too much alcohol.

Carbon Dioxide (CO_2) Monitoring and Control

Carbon dioxide is produced in the body and expelled in human breath.

The **Carbon Dioxide Removal Assembly** (CDRA) removes carbon dioxide from the air by using a material called "zeolite," which acts as a type of molecular strainer. The molecular structure of the zeolite attracts and separates the CO_2 molecules from the air. The effectiveness of the CDRA depends upon constant cleaning and reenergizing of the zeolite beds. Cleaning and reenergizing requires an additional 1 kW/hr of power.

Lithium Hydroxide (LiOH) Canisters may be used in an emergency to clean the air of CO_2:

- There are 10 canisters on board to be used only in case of extreme emergency. These canisters are stored in the Destiny module.
- Each LiOH canister lasts about a day.
- The canisters can only scrub 10 liters of air per hour. One human generates 20 liters of CO_2 per hour.
- Must use air fans to circulate the air throughout the modules. This would require 0.5 kW/hr of additional power.

Carbon Dioxide and Astronaut Health

The Basics of Carbon Dioxide

Please note : Do not confuse carbon *dioxide* (CO_2) with carbon *monoxide* (CO). Carbon *monoxide* is lethal even at low levels.

Carbon dioxide is an important gas in the Earth's atmosphere. For instance, plants use carbon dioxide and give off oxygen. This cycle keeps the atmosphere from being saturated with carbon dioxide. The normal amount of carbon dioxide in the Earth's atmosphere is between 0.033% and 0.036%, or $ppCO_2$ 0.23 mmHg.

In the space station, astronauts breathe out carbon dioxide, but there are no plants to remove it from the air. Air-circulation equipment and the carbon dioxide removal systems are responsible for constantly checking and controlling the levels of CO_2.

Carbon Dioxide Math

The volume of living space in the Space Station is 425 cubic meters, which is 425,000 liters of air. The air is maintained at an average level of 0.37% CO2. An average human exhales about 0.33 liters of CO2 per minute (16 breaths/minute at 4% concentration at 0.5 liters per breath). By assuming a "worst-case scenario" of a complete failure of the life support system, you could calculate the amount of time until critical levels are reached. For example, with a crew of three, the CO2 levels would reach 1% (4250 liters) in about 425 minutes.

Effects of Carbon Dioxide on the Human Body

	Concen-tration	Partial Pressure (mmHg)	Description
Nominal Levels	0.03%	0.23	Normal carbon dioxide concentration in air on Earth.
	0.37%	2.81	This is the average level of CO2 maintained on the Space Station. It would not be unusual for this level to reach as high as 0.7%
	0.50%	3.80	Lung ventilation increases by 5 percent. Continuous exposure may be dangerous to the astronauts' health, especially if accompanied by lower levels of oxygen.
Critical	1.00%	7.60	The astronauts can suffer serious symptoms within an hour or two. These symptoms include nausea, feeling hot and clammy, lack of attention to details, fatigue, anxiety, clumsiness, shaking, and vomiting.
	2.00%	15.2	Lung ventilation increases by 50 percent, severe headache after several hours exposure. Accumulation of carbon dioxide in the body after prolonged breathing of air containing around 2% or greater will disturb body function by causing the tissue fluids to become too acidic. This will result in loss of energy and feeling run-down for several days.
Serious	3.00%	22.80	Lung ventilation increases by 100 percent, panting after exertion, Astronauts can suffer serious symptoms almost immediately. If exposure persists, they may pass out.
	5 - 10%	38-76	Violent panting and fatigue to the point of exhaustion merely from respiration & severe headache. Prolonged exposure at 5% could result in irreversible effects to health. Prolonged exposure at greater than 6% could result in unconsciousness and death.
Extreme	10 - 15%	77-114	Intolerable panting, severe headaches and rapid exhaustion. Exposure for a few minutes will result in unconsciousness and suffocation without warning.
	25% to 30%	190-228	Extremely high concentrations will cause coma and convulsions within one minute of exposure. Certain Death.