Space Weather

NOAA Space Weather Scales

Solar Radiation Storms: Coronal Mass Ejections and Solar Proton Events

Category*	Descriptor	Effect	Frequency per Solar Maximum**
Protons >100,000 **S 5**	**Extreme**	**Biological:** Unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); high radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 100 chest x-rays) is possible. **Satellite operations:** Satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. **Other systems:** Complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	Fewer than 1 per cycle
Protons >10,000 **S 4**	**Severe**	**Biological:** Unavoidable radiation hazard to astronauts on EVA; elevated radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 10 chest x-rays) is possible. **Satellite operations:** May experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. **Other systems:** Blackout of High Frequency radio communications through the polar regions and increased navigation errors over several days are likely.	3 per cycle
Protons >1,000 **S 3**	**Strong**	**Biological:** Radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in commercial jets at high latitudes may receive low-level radiation exposure (approximately 1 chest x-ray). **Satellite operations:** Single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. **Other systems:** Degraded High Frequency radio propagation through the polar regions and navigation position errors likely.	10 per cycle
Protons >100 **S 2**	**Moderate**	**Biological:** None. **Satellite operations:** Infrequent single-event upsets possible. **Other systems:** Small effects on High Frequency propagation through the polar regions and navigation at polar cap locations possibly affected.	25 per cycle
Protons >10 **S 1**	**Minor**	**Biological:** None. **Satellite operations:** None. **Other systems:** Minor impacts on High Frequency radio in the polar regions.	50 per cycle

*Flux level of >= 10 MeV particles (ions). Flux levels are 5 minute averages. Flux in particles$\cdot s^{-1} \cdot ster^{-1} \cdot cm^{-2}$. Based on this measure, but other physical measures are also considered.

** These events can last more than one day.

Solar X-Ray Storms: High Frequency Radio

Category*	Descriptor	Effect	Frequency per Solar Maximum
X-Ray Measure (microwatts) >2000 **R 5**	**Extreme**	**High Frequency Radio**: Complete high frequency radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no high frequency radio contact with mariners and en route aviators in this sector. **Navigation**: Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	Less than 1 per cycle
X-Ray Measure (microwatts) >1000 **R 4**	**Severe**	**High Frequency Radio**: HF radio communication** blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. **Navigation**: Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	8 per cycle
X-Ray Measure (microwatts) >100 **R 3**	**Strong**	**High Frequency Radio**: Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. **Navigation**: Low-frequency navigation signals degraded for about an hour.	175 per cycle
X-Ray Measure (microwatts) >50 **R 2**	**Moderate**	**High Frequency Radio**: Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. **Navigation**: Degradation of low-frequency navigation signals for tens of minutes.	350 per cycle
X-Ray Measure (microwatts) >10 **R 1**	**Minor**	**High Frequency Radio**: Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. **Navigation**: Low-frequency navigation signals degraded for brief intervals.	2000 per cycle

*GOES 8 X-ray peak brightness. Flux, measured in the 0.1-0.8 nm range, in $W \cdot m^{-2}$. Based on this measure, but other physical measures are also considered.
** Other frequencies may also be affected by these conditions.

ALARA

Ionizing radiation can be harmful, especially if the body receives too much of it. For this reason, nuclear scientists, engineers, and technicians are constantly refining a set of rules, or "best practices," which should be followed to keep anyone who works in an area exposed to dangerous radiation protected as much as possible. The set of rules, or practices, is called ALARA. ALARA stands for "as low as reasonably achievable." The Brookhaven National Laboratory maintains these rules and keeps records of all discussions about them.

Some of the ALARA rules come from common sense. Since radiation is invisible and we cannot feel it, common sense has to be turned into rules. Here's an example of how, by using common sense, you would avoid unnecessary exposure to radiation in everyday life by using common sense. You are invited to an outside pool party at your friend's house. The weather is chilly, and your friend builds a large fire in the grill near the pool to help keep everyone warm. Do you sit on top of the flames? No. Do you move closer to the fire until you feel its warmth begin to take away the chill? Probably.

You feel your skin getting warm, maybe even hot. What do you do? You might walk around until you cool down. You might jump in the pool. The water is warmer than the chill night air. When you begin to grow cold, you get out and move closer to the flames. If you happen to meet someone with whom you enjoy talking, you might decide to stand where the fire is neither too warm nor too cold. In this way you won't have to keep moving. (Note: The fire stays the same; it is the air that changes)

As the night progresses, your eyes become tired from staring into the bright glow of the flames. What do you do? You might put on your sunglasses to shield your eyes, cover them with you hand, or turn and look away from the flames.

At the party your body tells you where to stand and where to move to regulate its exposure to the heat of the fire. Ionizing radiation requires the same behaviors; the only problem is that we don't know when we are standing in the flames.

The ALARA Rules

The ALARA rules are followed by radiation workers to protect them from too much radiation exposure. Astronauts are considered radiation workers. While monitoring the astronaut's exposure to radiation, you will want to keep in mind the three ALARA rules of time, distance, and shielding.

- Time: Spend the least amount of time around or exposed to radiation. Your body "measured" the heat of the fire and you adjusted your position accordingly. It told you when to move. Instruments on the space station measure the levels of radiation the astronauts are exposed to and tell the astronauts when to move.

  Distance: Keep your distance from a radioactive source. You could feel the heat from the fire lessen as you moved farther away. Under most conditions, distance from radiation helps limit exposure. The astronauts are not this lucky. The space station's orbit and the lack of atmosphere between it and the sun expose the astronauts onboard to dangerous levels of radiation.

- Shielding: Lead, water, and polyethylene are three examples of effective shielding from radiation. They either stop or slow down the ionizing photons and radioactive particles. The astronauts have shielded sleeping and work areas. They can move into these areas during dangerous periods of radiation in the same way you turned away from the fire or put on your sunglasses to shield your eyes from the brightness of the flames.

What is a TEPC?

How do astronauts know how much radiation they are receiving while they are in the space station? There are many types of monitoring devices that can aid the astronauts in the detection of radiation. One such monitoring device is called a Tissue Equivalent Proportional Counter, or TEPC. It is slightly larger than a Game Boy and has a cell filled with low-pressure propane gas. This hydrocarbon gas is used to simulate the hydrocarbon content of a human cell. When radiation passes through the counter, an appropriate radiation quality factor can be estimated to see how much radiation the astronaut has received.

Effects of Radiation Exposure on the Human Body

Exposure Limits

NASA has adopted the recommendations of the National Council on Radiation Protection and Measurements (NCRP) as the basis for spaceflight crew radiation exposures. The maximum exposure limits are shown below. Monthly and annual limits exist to prevent short term physiological effects of exposure. Career limits exist to contain radiation risk of cancer. These astronaut exposure limits are greater than those who stayed on earth.

Organ specific exposure limit

Exposure Interval	Depth (5 cm)	Eye (0.3 cm)	Skin (0.01 cm)
30 Days	25 rem	100 rem	150 rem
Annual	50 rem	200 rem	300 rem
Career	100 to 400 rem	400 rem	600 rem

Note: Organs at 5 cm include heart, lungs, stomach

Career exposure limits for males and females by age

Sex	Age			
	25	35	45	55
Male	150 rem	250 rem	325 rem	400 rem
Female	100 rem	175 rem	250 rem	300 rem

Exposure to radiation yields the following physiological effects. At lower exposure levels, the body is sometimes able to recover. At higher levels of exposure, damage is permanent. These impacts are based on career exposure. Specific effects to the human body at varying exposures are described below.

0-100 rem

Effects	Symptoms
Cells may die	Body replaces them
Abnormal cells can be	Cells could become cancerous

produced	
Blood changes	Changes in blood count and bone marrow
Gastrointestinal Tract	Nausea, vomiting, fatigue, temporary hair loss 2-3 days after exposure
Reproductive organs	Temporary sterility in men
Eyes	Acute conjunctivitis

100-400 rem

Effects	Symptoms
Blood system	Depression of bone marrow
Blood system	Platelet count falls
	Death may occur 1-2 months after exposure if not medically treated
Gastrointestinal Tract	Nausea, vomiting, fatigue, increase in temperature
Reproductive organs	Temporary sterility in women

400-600 rem

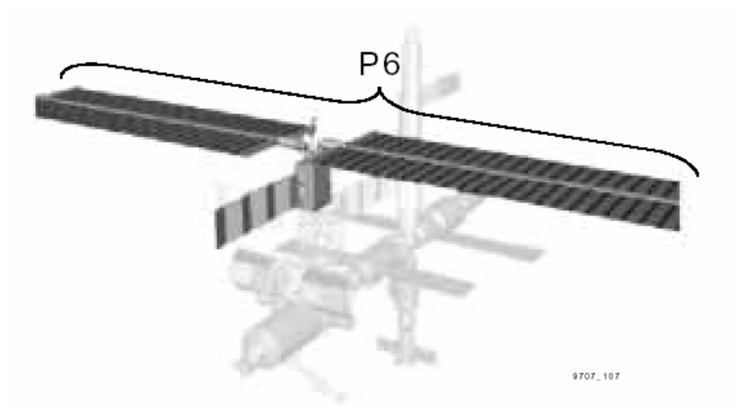
Effects	Symptoms
Blood system	Bone marrow is almost completely destroyed

1000 rem

Effects	Symptoms
Gastrointestinal Tract	Destruction of intestinal lining, nausea, vomiting, and diarrhea soon after exposure
Blood system	Complete destruction of bone marrow
	Death within several weeks even with medical attention

Power System Reference Guide

Electrical Power System



This is the system that provides all electrical power to the ISS. It is comprised of the Solar Arrays, the Voltage Converters, Storage Batteries and power delivery systems throughout the ISS.

The space station requires electrical power for all functions: command and control, communications, lighting, life support, etc. The electrical power system (EPS) must generate and store power, convert and distribute power to users, protect both the system and users from electrical hazards, and provide the means for controlling and monitoring system performance. These functions are performed by several pieces of interrelated ISS hardware and software.

For the Flight 5A (Feb 2001), all primary power is provided by the P6 photovoltaic module (PVM). The P6 PVM arrived on Flight 4A. As shown in Figure 3-3, the P6 PVM is temporarily located on the Z1 truss until it is moved to its Assembly Complete location on the lateral truss at Flight 13A (see Figure).

Power Load Components

I. C&DH (12%): Command and Data Handling. This is the main computer system that controls many of the essential support functions on the ISS. It is linked to practically all other systems.

II. CTS(14%): Communication and Tracking. This is the communications and guidance systems that link with ground control to exchange data and positioning information. Includes Guidance, Navigation and Control.

III. ECLSS (28%): Environmental Control and Life Support Systems. This is the system that monitors all life support systems (Air Quality, Temperature, Water) and continually keeps all systems in proper balance.

IV. FCS, Flight Crew System (12%): FCS subsystems and hardware consist of: Crew Health Care, Stowage, Portable Emergency Provisions, Housekeeping and Trash Management, On-Orbit Maintenance (OOM), Lighting, Personal Hygiene, Operational and Personal Equipment, Galley and Food System, & Inventory Management

V. TCS (34%): Thermal Control Systems. This is the cooling radiators for the solar arrays and battery compartments.

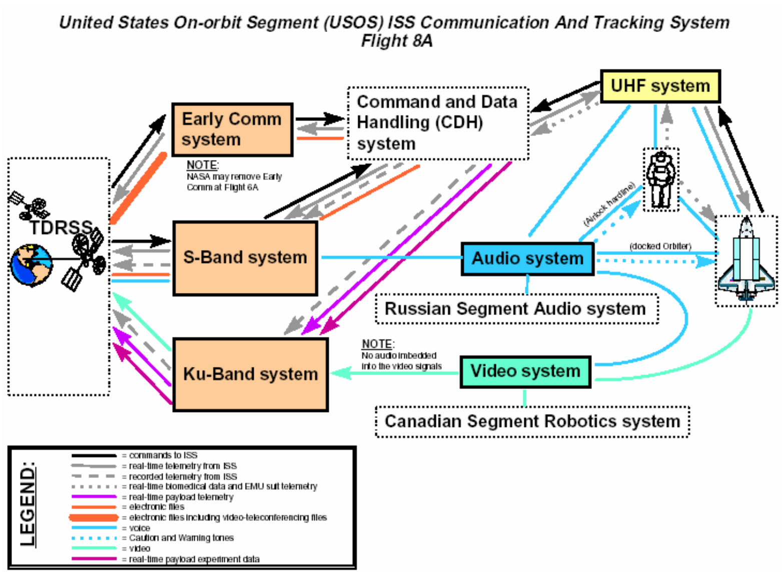
Components Descriptions

I. Command and Data Handling
This is the main computer system that controls many of the essential support functions on the ISS. It is linked to practically all other systems.

There are a total of over 100 different computers on the Station at assembly complete which are primarily used to collect data from onboard systems and payloads; process that data with various types of software; and distribute commands to the right equipment.

II. Communication and Tracking.
This is the communications and guidance systems that link with ground control to exchange data and positioning information.

Communication is without question an integral component of the International Space Station (ISS). Without extensive communication with the ground, neither the safe, stable, reliable operation of the Station, nor would the dissemination of scientific research would be possible.
The ISS Communication and Tracking System (C&TS) is designed to support these two important functions, Station operations and scientific research.

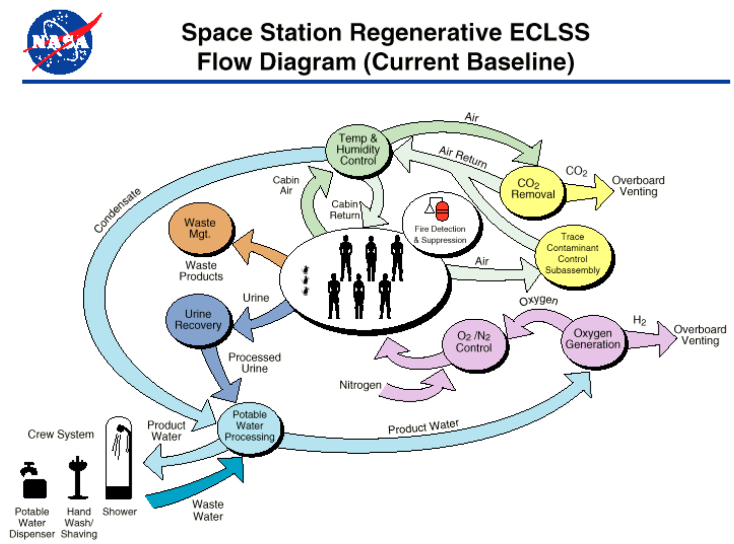


II. A. Guidance, Navigation, and Control
The Station's Guidance, Navigation, and Control (GNC) System can be divided into six functions. These functions are Guidance, State Determination, Attitude Determination, Pointing and Support, Translational Control, and Attitude Control. The inputs from GNC sensors are processed in Navigation and Control software, which implements these functions, using the GNC effectors.

III. Environmental Control and Life Support Systems

This is the system that monitors all life support systems (Air Quality, Temperature, Water) and continually keeps all systems in proper balance.

The Environmental Control and Life Support System (ECLSS) maintains a pressurized habitable environment, provides water recovery and storage, and provides fire detection and suppression within the International Space Station (ISS).



IV. Flight Crew Systems

Flight Crew Systems (FCS) subsystems and hardware consist of the following categories of equipment:

Inventory Management
On-Orbit Maintenance
Restraints and Mobility Aids
Hardware: equipment restraints, crew restraints, and mobility aids
Purpose: support IVA personnel and equipment restraint and personnel mobility
Stowage
Hardware: stowage racks, lockers, trays, containers
Purpose: stow loose equipment, supplies, and consumables
Portable Emergency Provisions
Hardware: PBA, missed resupply provisions
Purpose: sustain the crew in the event of an emergency and ensure the survival of the crew if a pressurized element is lost
Decals and Placards
Hardware: cue cards, stowage tray cards, and decals
Purpose: display crew instructions, procedures, and location coding nomenclature.
Housekeeping and Trash Management
Hardware: vacuum cleaner and attachments, wipes and cleansers, trash collection bags
Purpose: facilitate routine cleaning and trash management
Closeouts
Hardware: rack seals, standoff closeouts, utility interface panel closeouts, rack volume closeouts, endcone closeouts, window shades
Purpose: segregate volumes for noise and particulate control, and for aesthetic value.
Lighting
Hardware: general lighting, portable utility lights, and emergency egress lighting
Purpose: facilitate productivity
Personal Hygiene
Hardware: waste management compartment, and hygiene supplies
Purpose: support personal hygiene and metabolic waste collection
Operational and Personal Equipment
Hardware: clothing, cameras, calculators, pens and pencils, recreational equipment, battery charger
Purpose: Facilitate routine daily activities
Wardroom and Galley and Food System
Hardware: food and food preparation hardware, ovens, food trays

Purpose: provide nutritional support for the crew

Crew Privacy
Hardware: crew quarters
Purpose: provide a private area for sleeping, changing of clothes, and off-duty activities

IV. A. Crew Health Care System

The Crew Health Care System (CHeCS) is required to maintain the health of the International Space Station (ISS) crew. CHeCS is composed of three subsystems, each of which meets one of three major health concerns associated with long-duration spaceflight. These health concerns include physiological countermeasures to spaceflight, environmental monitoring, and medical care. The three CHeCS subsystems each address one of the concerns.

- The Countermeasures System (CMS) evaluates crew fitness, provides countermeasures, and monitors the crew during countermeasures. The CMS consists of exercise hardware, including a treadmill, resistive exercise device, and cycle ergometer, and monitoring devices, including a portable computer, heart rate monitor, and Blood Pressure (BP) and Electrocardiogram (ECG) monitor.
- The Environmental Health System (EHS) monitors air and water quality for chemical and microbial contaminants, monitors radiation levels, and monitors surface microbial contaminants.
- The Health Maintenance System (HMS) monitors crew health, responds to crew illness or injury, provides preventive health care, and provides stabilization and emergency transport between vehicles. The HMS is designed to supply daily needs and basic life support, as well as advanced life support for a crew of three for 180 days. The HMS is composed of six components, the Ambulatory Medical Pack (AMP) provides for daily needs and periodic health examinations, the Crew Contaminant Protection Kit protects the crew in case of a toxic spill or contamination, and the remaining four, including the Advanced Life Support Pack, Crew Medical Restraint System, defibrillator, and Respiratory Support Pack, provide for advanced life support and transport.

V. Thermal Control Systems
This is the cooling radiators for the solar arrays and battery compartments.

Throughout the life of the Space Station, experiments and equipment inside the modules are generating heat that must be removed. Outside the modules, experiments and equipment must be protected from the environment in low Earth orbit. The purpose of the Thermal Control System (TCS) is to maintain Space Station equipment and payloads within their required temperature ranges.

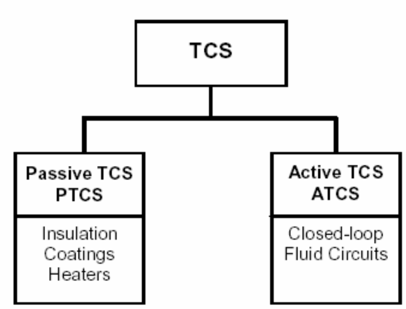


Figure 5-1. Space Station TCS architecture

- The Passive Thermal Control System (PTCS) consists of insulation, coatings, and heaters. Its components generally have few operational requirements and require low maintenance. PTCS components are also less complex and easier to implement.

- The Active Thermal Control System (ATCS) uses a mechanically-pumped fluid to perform heat transfer. Although this approach is more complex, the ATCS handles much greater heat loads and provides a higher degree of control over how the heat loads are managed.

The USOS and ROS use this same architecture, modified to meet the needs of individual elements. ROS TCS is very similar in design to the Mir space station and functionally similar to USOS TCS. The main difference is that each module has its own internal and external TCS (i.e., the modules do not share an internal and external systems as in the USOS).

Early External Thermal Control System (EETCS):

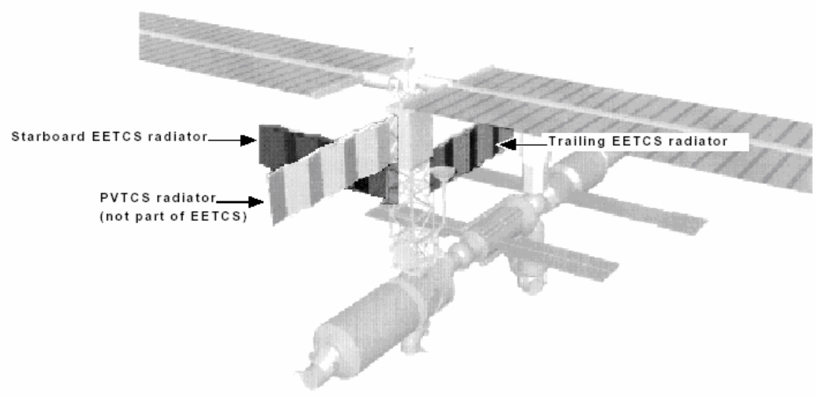


Figure 5-7. EETCS radiators

Life Support Reference Guide

Carbon Dioxide

The Basics of Carbon Dioxide

Carbon dioxide is an important gas in the Earth's atmosphere. Plants absorb much of the carbon dioxide and "exhale" 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 $ppCO_2$ 0.2736 mmHg. If the amount of carbon dioxide increases, problems can arise.
In the space station, the natural cycle breaks down. Astronauts continue to 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 in the space station.

Effects of Carbon Dioxide on the Human Body

Please note : Do not confuse carbon dioxide (CO_2) with carbon monoxide (CO). Carbon monoxide is lethal even at low levels. Carbon monoxide concentrations above ppCO 0.304 mmHg are life-threatening. Levels above ppCO 1.22 mmHg will cause human death within an hour!

At $ppCO_2$ 0.2508 mmHg / .03%	No side effects.
At $ppCO_2$ 0.456 mmHg / .055%	Air seems "stuffy".
At $ppCO_2$ 0.76 mmHg / .092%	Some people may begin to experience shortness of breath, difficulty in breathing, rapid pulse rate, headaches, hearing loss, hyperventilation, sweating, and fatigue. Astronauts are conditioned to avoid these symptoms.
At $ppCO_2$ 3.8 mmHg / .46%	Continuous exposure may be dangerous to the astronauts' health, **especially** if accompanied by lower levels of oxygen.
At $ppCO_2$ 11.4 mmHg / 1.38% (Critical level)	The astronauts can suffer serious symptoms within an hour or two. These symptoms include nausea, dizziness, mental depression, shaking, problems with seeing, and vomiting.
At $ppCO_2$ 22.8 mmHg / 2.75%	Astronauts can suffer serious symptoms almost immediately. If exposure persists, they may pass out. If the levels continue to increase, the astronauts may die.

Two Concerns for Astronauts

- <u>Hyperventilation</u>
  When under stress, we unconsciously begin to take rapid, shallow breaths. In other words, we hyperventilate. This kind of breathing reduces the carbon dioxide level in the blood, causing blood vessels to constrict. This may bring about feelings of anxiety. Another effect of hyperventilation is loss of oxygen to the brain. This may lead to muscle tension, headaches, tingling in the hands and feet, nervousness, lightheadedness, sleepiness, or dizziness.

- <u>Exercise</u>
  As we exercise, the heart pumps blood containing oxygen, fluids, and nutrients to the muscles. Increased blood flow carries more oxygen to the muscles and removes more wastes produced by the exercising muscles, such as lactic acid and carbon dioxide. That is why more carbon dioxide is breathed out into the air during exercising. The increased blood flow also transfers the heat created by the chemical reactions in the muscles to the skin. The skin helps produces perspiration which helps cool the blood. It is important to drink plenty of fluids while exercising. Fluids prevent dehydration. When dehydrated, your body produces less blood. Your circulatory system doesn't carry enough oxygen and nutrients to your exercising muscles and can't remove all the carbon dioxide or heat from your muscles.

Oxygen

<u>What is Hypoxia?</u>

Hypoxia is a physical condition caused by a decrease in oxygen entering the blood in your lungs and flowing to the brain and muscles. This occurs on Earth when oxygen in the atmosphere drops below 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. Drinking too much alcohol, smoking one cigarette (if you're not a habitual smoker), or flying at an altitude of 8,000 to 9,000 feet without an oxygen mask, make people feel dizzy. This sensation is also an early warning of Hypoxia. Flying or working on sensitive equipment while you're "dizzy" can be very dangerous.

Victims of Hypoxia have been studied on the Earth. Under conditions of standard temperature and pressure (STP), a person in an airplane who is not using an oxygen mask experiences the following symptoms:

Indifferent Stage : 5,000 feet or ppO_2 137 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 : 12,000 to 15,000 feet or ppO_2 115 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.

Disturbance Stage: 15,000 feet or ppO_2 99 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.
Critical Stage: 15,000 feet or ppO_2 99 mmHg and lower / 15.14% and lower	At this stage there is almost complete mental and physical incapacitation, resulting in rapid loss of consciousness, convulsions, failure of respiration, and finally death.

What is Anoxia?

Anoxia is a condition in which there is a total absence of oxygen supplied to an organ's tissues. In severe cases, the patient is often comatose for periods of time ranging from hours to days, weeks, or months. In extreme cases, the patient dies.

Atmospheric Pressure

The sudden loss of atmospheric pressure in the space station can also cause Hypoxia. In extreme conditions, the astronauts can lose consciousness.

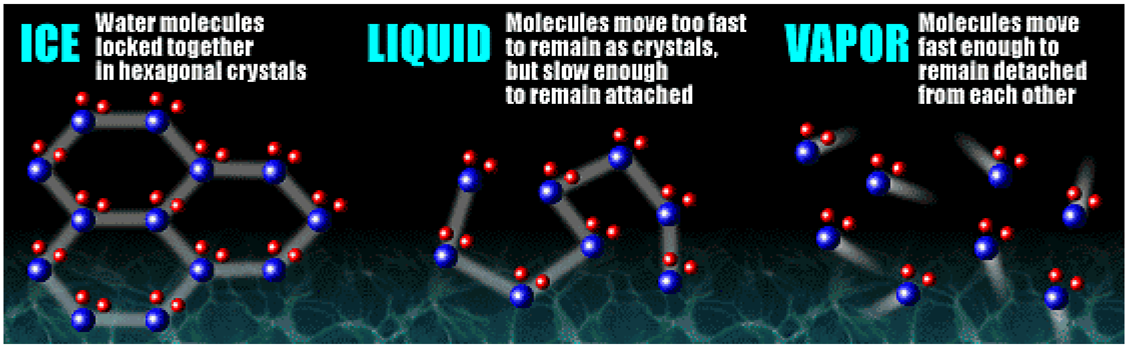
Water Vapor

One of the critical gases in the atmosphere on Space Station Alpha is water vapor. How did it get there? Water enters the air as a gas—called water vapor—from two sources: the astronauts' exhalations and the evaporation of water from the Station's water supply and water and waste recycling systems. Controlling the levels of water vapor in the air is important for two reasons. If there is too much water vapor in the air there is a danger of excessive *condensation* on the pipes and sensitive equipment within the Space Station. If there is not enough water vapor in the air there is a danger of sparks caused by a buildup of *static electricity*.

Condensation

All molecules are in motion—even the molecules in solids such as copper and steel are constantly moving. The molecules in water are constantly sliding around each other. The molecules in gases are floating freely and constantly banging into each other.

The three phases of water



Credit: www.usatoday.com/weather/wevapcon.htm

If you increase the energy of the electrons in any molecular structure by heating them—using a fire, for instance, which is one source of infrared electromagnetic energy—you increase the speed of motion of all the molecules exposed to the energy. When this happens solids melt and become liquid, liquids turn to vapor, and gases "expand," meaning that the molecules speed of motion increases and press harder against their container. Plasma is already very hot, found only in the Sun, and flies off in every direction if not contained in magnetic containers.) [Did you realize that the four terms used to describe the four forms of matter are simply a simplified way to describe three different molecular and one partial-molecular state?]

When liquids, such as water, are heated, the energized water molecules (H_2O) break away, or separate, from their neighbors and mix with the other gases in the air around them. This is called evaporation. Condensation occurs when the molecules suddenly lose their energy as they come into contact with a cooler object that steels the heat energy away from them—such as a pipe carrying oxygen or nitrogen, or a piece of cooling equipment. The condensation of water vapor is dependant upon the temperatures maintained in the Space Station relative to the temperature of the pipes and other equipment.

If the water vapor levels are not controlled, the amount of condensation might cause the vital equipment to gather condensation. Computer electrical circuits and critical sensing devices may malfunction under conditions that promote condensation of water vapor. Condensed water also promotes the growth of bacteria and fungus, which can damage equipment and create a health problem for the astronauts.

Static Electricity

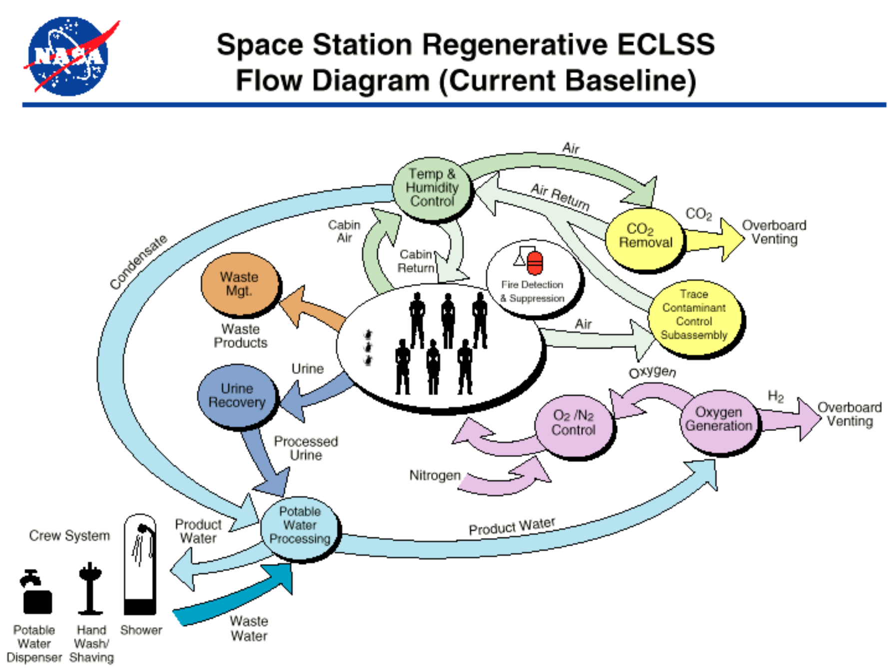
Static electricity is the accumulation in clothing, hair, or moving machinery of negatively charged electrons attracted away from atoms that give up electrons from their outer energy shells. When clothing brushes against a metal or another material object, it tends to pick up electrons. If you take a wool hat off your head on a cold, dry day, your hair will stand on end—the hat stripped electrons off your hair and now each hair has a positive charge (more protons than electrons). If you drag your feet across a carpet in leather-soled shoes, you will pick up a "hoard" of negatively charged electrons. Go up to a brass door handle and see what happens. A spark will fly from your hand to the handle. This spark is made up of all of those excess electrons released at one time. If electrons accumulate on anything, they can be discharged when they come in contact with an appropriate conductor.

Just the right amount of water vapor in the air tends to condense on objects and form a thin coating of water. The water vapor neutralizes the tendency for negatively charged electrons to leave and be gathered by clothes and other objects that are rubbing against one another. In this way, maintaining enough water vapor in the atmosphere eliminates the chance of sparks caused by static electricity. Sparks may cause very serious fires on board a Space Station in which pure oxygen, hydrogen, and other flammable gases are being mixed and removed from the atmosphere, or being produced during electrolysis.

Water Vapor Critical Levels

The high and low critical partial pressures of water vapor are 5.26 ppmmHg (low) and 10.52 ppmmHg. Accumulations of water vapor below or above this range are cause for serious concern. If these levels are exceeded adjustments should be made by adding or removing water vapor from the Space Station's atmosphere.

The Environmental Controls and Life Support (ECLS) System Diagram



<u>Main Compartment</u> (*Area on Image Map with Astronauts Standing in White Circle)*

The **Atmosphere Revitalization Subsystem** is made up of a number of elements. All of them are designed to work together to create a safe and pleasant atmosphere for living and working on Space Station Alpha.

The **Major Constituent Analyzer** sends advisories every twenty minutes. The advisories report the total atmospheric pressure and the percentage of each major gas in Space Station Alpha's atmosphere. Trace contaminants, if present, are also monitored and reported. The **MCA** uses mass spectrometry to analyze the air.

The **Pressure Control Panel** controls the atmospheric pressure. If the atmospheric pressure drops, the Pressure Control Panel releases nitrogen and/or oxygen into the air.

The **Vacuum Exhaust System** allows the astronauts to remove all the air from Space Station Alpha. This only happens if poisonous gases are detected or in case of a fire. (Remember, a fire will not burn without oxygen!). During the exhaust process the astronauts must be in their space suits or using their gas masks "hardwired" to the **Atmosphere Control and Supply Subsystem**.

Cabin Air Fans circulate the gases throughout the space station. Air is also sent to the different space station modules through interconnecting tubes.

The **High Efficiency Particulate Air Filters** remove dust particles and bacteria from the air.

Temperature and Humidity Control

The **Heat Exchanger** controls the humidity by taking water vapor out of the air. The water is then sent to the **Water Recovery and Management Subsystem**. The water vapor in the air comes from the breath of the astronauts, experiments conducted on the space station, and activities such as cooking and bathing.

The **Internal Thermal Control System Low Temperature Loop** 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 throughout Space Station Alpha keeps the temperature comfortable and the humidity low. Fans, tubes, and ventilation openings within and between the modules of the space station are used for air circulation.

Carbon Dioxide (CO_2) Removal

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

The **Carbon Dioxide Removal Assembly** removes carbon dioxide from the air by using a material called "zeolite," which acts as a molecular sieve. The molecular structure of the zeolite attracts and separates the CO_2 molecules from the air as they pass through it.

The **Carbon Dioxide Removal Assembly** depends upon the constant cleaning and reenergizing of the sorbent beds of zeolite. The waste CO_2 is expelled into space through vents in the space station. The zeolite sieves require cold, dry air. The air must pass through the **Temperature and Humidity Control Subsystem** first.

The **Carbon Dioxide Vent Valve Assembly** releases the collected carbon dioxide into space after cleaning the zeolite beds. Computers and atmospheric sensors control this assembly. The gas release is very gradual so it won't act as a rocket/propellant and change the space station's orbit.

Lithium Hydroxide (LiOH)-based Canisters, which clean the air of CO_2, are available for emergency use in case the **Carbon Dioxide Removal Assembly** fails. Each LiOH canister can last 14 days and can clean the air throughout the space station if the cabin air fans are working properly.

Oxygen / Nitrogen (O_2/N_2) Control

The **Pressure Control Panel** monitors the atmospheric pressure of the space station's cabin. This device is regulated by computers.

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.

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

Oxygen (O_2) Generation

Oxygen is produced continually by a machine called **Elektron**. This machine uses electrolysis and is powered by the solar panels and batteries. Electrolysis is the process whereby water (H_2O) is separated into hydrogen and oxygen when an electric current is passed through water that has been specially treated to conduct electricity. Hydrogen goes to the negative electric pole and then into storage tanks. From there it is "dumped" into space. The oxygen is drawn to the positive electric pole and into tanks. It is then distributed throughout Space Station Alpha's compartments using circulating fans.

A secondary source of oxygen is the pressurized storage tanks that are delivered to Space Station Alpha via the space shuttle. The oxygen tanks can release oxygen directly into the station's atmosphere.

A **Solid Fuel Oxygen Generator**, or "Perchlorate Candle," produces oxygen through chemical reactions. The Candles are used only in emergencies. A chemical called "perchlorate" is packed inside a metal canister. The astronauts trigger the chemical reaction that produces the oxygen. Each canister releases enough oxygen for one person for one day. Perchlorate is the same chemical released in the gas masks that drop down during emergency situations on airplanes.

In critical situations, the astronauts can also use a **Portable Breathing Apparatus (PBA's)**, or gas mask. The PBA packs 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's** may also be plugged into oxygen ports in the tubes of the **Atmosphere Control and Supply Subsystem**. However, being "plugged in" keeps the astronauts from moving easily around the space station to fix things. The **PBA** is always utilized when a fire extinguisher is used, because the CO_2 from the extinguisher displaces O_2. Without oxygen, the astronauts would die.

Trace Contaminants Control Subassembly

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. The filters are located in the **Atmosphere Control and Supply Subsystem.** The gases are removed as the air circulates through the system.

Fire Detection & Suppression

Smoke detectors, fire extinguishers full of carbon dioxide, portable breathing equipment, and a system of alarms and automatic software responses for any fire event are the major elements of the **Fire Detection and Suppression system**.

Waste Management

In the **Urine Recovery System**, wastes are collected, separated from water, and stored in tanks. The space shuttle collects the tanks of waste, and the waste is burned upon the shuttle's reentry into the Earth's atmosphere.

Potable Water Processing

The **Water Recovery and Management Subsystem** gathers water from the **Heat Exchangers** and from what is left after the astronauts' sanitary and housekeeping chores. This system recycles the water, removing all the chemicals and minerals from it. The water is then returned to the system. There it is used for a number of vital purposes including the production of oxygen by electrolysis.

Potable (drinkable) water is delivered during each mission of the space shuttle from Earth.