Console Handbook

ETHOS
Environmental and Thermal Operating Systems (ETHOS)

The ETHOS (pronounced ee-those) flight controller manages the systems which help provide a clean, safe and comfortable living area for the crew, including the monitoring of air and water onboard the International Space Station (ISS).

Every day, the ETHOS flight controller makes sure that the life support systems are working properly. This person also helps plan activities for the crew when working with environmental and thermal systems, and keeps track of the oxygen, nitrogen and water resources that are depleted, or “used up”. Since it would be costly to continually deliver these resources to the ISS, the onboard life-support equipment recycles (or reuses) them as much as possible.
ETHOS
Environmental and Thermal Operating Systems

Systems Managed: ACS, ARS, ITCS, PTCS, Regen ECLSS and Emergency Response

Atmosphere Control and Supply System (ACS)

How is the cabin atmosphere created?
The comfort of the crew on the ISS is very important since they may live in space for long periods of time. It would not be practical for crewmembers to always wear pressurized suits onboard, so the Atmosphere Control and Supply System (ACS) provides oxygen and nitrogen to keep the ISS at a proper air pressure, between 14.0 and 14.9 pounds per square inch (psi). This allows the crew to live and work in an environment similar to that on Earth, and provides for proper air flow without exceeding the pressure limits of the ISS walls.

The amount of each oxygen and nitrogen in the ISS cabin atmosphere has to be monitored carefully as well. The exact mixture of these two gases is important. Some equipment may not work if the pressure is too low. If too much oxygen is present, fire can become a serious hazard on the ISS. Additionally, air pressures change when airlocks are opened for spacewalks, or when other space vehicles dock to the ISS. The ETHOS flight controller plans the appropriate amounts of oxygen ($O_2$) and nitrogen ($N_2$) required for these types of activities.

The ACS begins with oxygen and nitrogen tanks, which are attached to the outside of the ISS and have gas lines running throughout the ISS. These lines are connected to systems which use the gases (e.g., such as in onboard experiments), and to pressure control valves, which allow oxygen or nitrogen into the ISS atmosphere as needed.

Atmosphere Revitalization System (ARS)

How is fresh air maintained?
While the ACS keeps the pressure and mixture of the air ideal for healthy human living, the Atmosphere Revitalization System (ARS) monitors atmospheric gases on the ISS. Air revitalization is simply getting rid of "the bad stuff" onboard, such as carbon dioxide, air particles and contaminants.
This system consists of three main functions. The equipment (using mass spectrometry) measures the levels of gases in the atmosphere. It monitors a filter which removes air contaminants, such as chemicals released into the air by heated equipment or surfaces, crew perspiration (sweat) and fumes. It also monitors a piece of equipment which removes excess carbon dioxide (CO₂) released into the air each time the crew exhale.

The crew from Apollo 13 learned quickly the importance of atmosphere revitalization. During the mission, an onboard oxygen tank exploded. As a result, the crew was forced to shut down the fuel cells in the Service Module, which provided power, oxygen and water to the Command Module. Without power and oxygen in the Command Module, the three crewmembers had to move into the Lunar Module. In this module, the environmental systems were capable of removing the excess carbon dioxide of two people for only 30 hours, instead of three people for four days. The flight controllers in the Mission Control Center had to quickly come up with a way to make carbon dioxide filters in the Command Module fit the Lunar Module. They succeeded, and in doing so, created a working atmosphere revitalization system “on the fly”.


**Internal Thermal Control System (ITCS)**

*How does the ISS maintain a safe and comfortable temperature?*

To maintain crew safety and comfort, the ETHOS flight controller oversees the humidity (water vapor in the air) and temperature on the ISS. Too much moisture can harm the equipment and computers, causing them to fail. And while space can be very cold, the temperature onboard can vary. The ISS receives additional heat from the crew, computers and other equipment, and sunlight.

Air conditioners and fans are used to cool, circulate and remove moisture from the ISS air, which is collected and recycled into fresh water. The fans also blow air across the smoke detectors, which is extremely important in detecting a possible fire. While air conditioners and fans are helpful, the ISS utilizes an Internal Thermal Control System (ITCS), featuring cold water loop systems to help keep the computers, equipment and crew cool.

There are two internal cold water loops in the United States (U.S.) segment of the ISS, both of which fall under the responsibility of the ETHOS flight controller. The Low Temperature Loop (LTL) is kept below the dew point (the temperature at which water vapor condenses into water). It runs through the air conditioners, cooling the air and collecting condensation. The Moderate Temperature Loop (MTL) stays above the dew point and cools the computers and equipment used for experiments aboard the ISS.

In addition, pumps from the ITCS move cold water through pipes, past the warm equipment. The heat from the equipment is transferred to water in the cool pipes through conduction (a transfer of thermal energy from a substance with high temperature to a lower temperature). This keeps the crew comfortable and the equipment from overheating as they orbit the Earth. Valves in the ITCS then allow the crew to mix the cold water with warm water to keep it at the right temperature; much like faucets can control the temperature of tap water.

**Passive Thermal Control System (PTCS)**

*Why doesn’t the ISS rust?*

The Passive Thermal Control System (PTCS) is used in the areas of the ISS that often get too cold. In the walls of the ISS, the temperature cannot be easily controlled by the water loops. For these areas, the ETHOS flight controller can activate the PTCS, which includes electric heaters, heat pipes and insulation. This keeps the ISS above the dew point, preventing condensation from forming on the metal which could lead to mold or corrosion (such as rust).
Regenerative Environmental Control and Life Support System (Regen ECLSS)

*How are air and water recycled?*

ISS crewmembers need fresh water in order to drink and to prepare their food. The ETHOS flight controller ensures there is enough water onboard. Like oxygen, water is valuable. It has to be transported from Earth to the ISS. Since the ISS is over 200 miles above the Earth, fresh water supplies are not easy to obtain. Water is heavy and it is costly to transport into space. Therefore, it is important to keep and reuse as much of it as possible.

The ETHOS flight controller monitors the equipment on the ISS which collects wastewater (i.e., condensation and urine) and recycles it into clean drinking water and oxygen. This is done through the Regenerative Environmental Control and Life Support System (Regen ECLSS) – one of the most complex systems on the ISS.

This system is made up of the Urine Processor Assembly (UPA), the Water Processor Assembly (WPA) and the Oxygen Generation System (OGS). (The OGS is comprised of both the Oxygen Generator Assembly [OGA] and the Sabatier Reduction System, or more commonly referred to as the Sabatier Reactor.)

The UPA distills (heats) the collected urine to evaporate and extract the water (H\textsubscript{2}O), which is fed into the WPA.

The WPA mixes the distilled water with the moisture collected from the air conditioners. Then, the system purifies the mixture before it is used for drinking or for making oxygen (O\textsubscript{2}) in the OGS.

The OGS creates oxygen from water by electrolysis (the break-down of water into oxygen gas and hydrogen gas by electrical current). The OGA, the major component of the OGS, produces both oxygen (O\textsubscript{2}) for the crew to breathe, and hydrogen (H\textsubscript{2}) which is sent to the Sabatier Reactor. The Sabatier Reactor uses the leftover hydrogen and the excess carbon dioxide (CO\textsubscript{2}) exhaled by the crew to create water and methane gas (CH\textsubscript{4}).
The water is then fed back into the system (making a complete circle of water recycling on the ISS) and the methane gas is released out of the ISS into space.

**Emergency Response**

*How are emergencies contained on the ISS?*

Crew safety on the ISS carries the most importance. Each crewmember is trained to respond to three possible types of emergencies: fire, rapid loss of pressure (when the air in the ISS leaks into space) and toxic atmosphere (ranging from a water spill to a potentially fatal ammonia spill).

**Fire**

If there is a fire on the ISS, unlike on Earth, the crew cannot go outside and keep a safe distance. They must put the fire out or close the hatch to the area which contains the fire. The ISS contains several smoke detectors and is designed to be non-flammable, but where there is powered equipment and oxygen, there is a risk of a fire.

If a fire is detected, an automatic response system immediately powers off all equipment and isolates any oxygen sources. All internal vents are shut down to contain contaminants and prevent fresh air from feeding the fire. If the crew can see the fire, they can use fire extinguishers similar to the ones used on Earth. If they cannot see the fire (e.g., if it is inside an experiment or a piece of equipment), they use a handheld smoke detector to help find the fire.

**Rapid Depress**

The ISS has a special shielding which protects the walls from being pierced by small pieces of space “junk” (broken up satellites or jettison items from EVAs) as it circles the Earth. However, if something large enough struck the ISS, it could potentially cause damage which might send the breathable air out into space. This type of emergency is called a rapid depress, which is a sudden loss of cabin pressure.

Because the air supply on the ISS is limited, the crew would need to quickly find the leak in the event of a rapid depress. Pressure sensors are located all over the ISS, and these sensors would alert the crew and the Mission Control Center of the emergency.

If a rapid depress were detected, the onboard emergency response system would automatically close all the vents which release gas overboard. The ETHOS flight controller would work with crewmembers to check each module of the ISS for leaks. By determining the location of the collision, the ETHOS flight controller and other teams in the Mission Control Center could provide instructions and a plan for the crew to repair the hole, if possible.

**Toxic Atmosphere or Spill**

Any spill onboard the ISS must be cleaned up immediately. Even water can damage equipment and become a breeding ground for bacteria. Without gravity, any spilled liquid or broken pieces of glass will float. This can get into the equipment or possibly injure the crew.

While water spills in the cabin can simply be wiped up, an ammonia leak can be considered fatal. The entire crew would need to be isolated from the affected areas, and would require oxygen masks to ensure that they are breathing clean air. Spills are considered an emergency
on the ISS, and the ETHOS flight controller is responsible for monitoring the air quality following a spill.

To learn more about the environmental and thermal operating systems on the ISS, return to the International Space Station Live! (ISSLive!) website at www.isslive.com. Select “Interact”, and then select “Visit Space Station”.

**ETHOS Console Displays**

A wireless signal sends data from the ISS to the Mission Control Center. This data is updated on the ETHOS console displays. The current atmosphere, oxygen and water production of the ISS modules is displayed on the consoles. The ETHOS flight controller checks the data on the console displays to make sure everything is working as expected.

Pictured above are simplified versions of the ETHOS console displays. To view these displays, return to the ISSLive! website at www.isslive.com. Select “Interact”, and then select “Explore Mission Control”.

**Space Station Live Data**

To learn more about the live data streaming from the ISS to the ETHOS console display, return to the ISSLive! website at www.isslive.com. Select “Resources,” and then select “Space Station Data”. There will be a table which includes the names and brief descriptions of all the data values used to update the interactive Mission Control Center console displays.
# Acronyms and Abbreviations

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<tr>
<th>Acronym</th>
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<td>ACS</td>
<td>Atmosphere Control and Supply System</td>
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<td>ARS</td>
<td>Atmosphere Revitalization System</td>
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<tr>
<td>CH₄</td>
<td>methane gas</td>
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<td>CO₂</td>
<td>carbon dioxide</td>
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<td>ETHOS</td>
<td>Environmental and Thermal Operating Systems</td>
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<tr>
<td>H₂</td>
<td>hydrogen</td>
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<td>H₂O</td>
<td>water</td>
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<td>ISS</td>
<td>International Space Station</td>
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<td>ITCS</td>
<td>Internal Thermal Control System</td>
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<td>LTL</td>
<td>Low Temperature Loop</td>
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<td>Moderate Temperature Loop</td>
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<td>N₂</td>
<td>nitrogen</td>
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<tr>
<td>O₂</td>
<td>oxygen</td>
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<td>OGA</td>
<td>Oxygen Generator Assembly</td>
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<tr>
<td>OGS</td>
<td>Oxygen Generation System</td>
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<tr>
<td>psi</td>
<td>pounds (or pounds of force) per square inch</td>
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<tr>
<td>PTCS</td>
<td>Passive Thermal Control System</td>
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<tr>
<td>Regen</td>
<td>Regenerative Environmental Control and Life Support System</td>
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<td>ECLSS</td>
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<tr>
<td>UPA</td>
<td>Urine Processor Assembly</td>
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<td>U.S.</td>
<td>United States</td>
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<td>WPA</td>
<td>Water Processor Assembly</td>
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