



Space engineering

Environmental control and life support (ECLS)

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS-E-ST-34C Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

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1 Scope

This Standard addresses the discipline of environmental control and life support (ECLS) and the interfaces to other disciplines of engineering and to the domains of management and product assurance.

It also introduces the structure and applicability of the associated Level 3 Standards.

The environmental control and life support systems (ECLSS) covered in this Standard includes those aspects relating to the assurance of a safe and comfortable environment for human beings undertaking a space mission.

When other forms of life are accommodated on board, the ECLSS also ensures the appropriate environmental conditions for those living organisms.

This Standard applies to all ECLSS for:

- all manned space endeavours and man-rated space products, and
- any other form of life to be maintained on board.

This standard may be tailored for the specific characteristics and constraints of a space project in conformance with ECSS-S-ST-00.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications, do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system— Glossary of terms
ECSS-E-ST-10-02	Space engineering — Verification

3

Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 anoxic

gas or atmosphere containing no oxygen

3.2.2 closed-loop ECLSS

ECLSS based on recycling, regeneration, and recovery of materials or elements

NOTE The closed-loop ECLSS implies that the use of significant expendables and consumables is excluded from the processes.

3.2.3 compression

EVA related action to increase total pressure

3.2.4 decompression

EVA related action to reduce the total pressure

3.2.5 depressurization

action to reduce the total pressure

3.2.6 environmental control and life support (ECLS)

engineering discipline dealing with the physical, chemical and biological functions to provide humans and other life forms with suitable environmental conditions

NOTE The objective of ECLS is to create a suitable environment by controlling the environmental parameters, providing resources, and managing waste products.

3.2.7 environmental control and life support system (ECLSS)

system that includes the hardware and software to perform ECLS functions

3.2.8 hypoxic

gas or atmosphere containing oxygen that provides a partial pressure of oxygen below the specified range of oxygen partial pressure in the atmosphere of habitable volumes

3.2.9 open-loop ECLSS

ECLSS based on external resupply of resources

3.2.10 partial pressure

participation of one of the constituents of a gas mixture or an atmosphere in the total pressure

NOTE 1 Examples include:

- PCO_2 , stands for partial pressure of carbon dioxide,
- PH_2O , stands for water vapour partial pressure.

NOTE 2 To calculate a partial pressure, the fraction of the constituent is multiplied by the total pressure. For example, the partial pressure of oxygen on Earth is:

$$PO_2 = 0,21 \times 1,013 \times 10^6 \text{ Pa} = 0,213 \times 10^6 \text{ Pa.}$$

NOTE 3 Abbreviation for partial pressure is P followed by the chemical formula of the constituent.

3.2.11 pressurization

action to increase the total pressure

3.2.12 re-compression

<EVA>

EVA related action to restore the total pressure after decompression or to treat decompression illness

3.2.13 re-compression

<Other than EVA>

action to restore the total pressure after depressurization

3.2.14 re-pressurization

action to restore the total pressure after depressurization

3.2.15 safe haven

facility capable of sustaining human life under emergency conditions as a minimum, in the case of a life threatening situation

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
CFU	colony forming unit
DCI	decompression illness
ECSL	environmental control and life support
ECLSS	ECLS system
EM	engineering model
EMC	electromagnetic compatibility
EMU	EVA mobility unit
EVA	extra-vehicular activity
FDIR	failure detection, isolation and recovery
FM	flight model
FOV	field of view
GSE	ground support equipment
ICD	interface control document
ISS	International Space Station
IVA	intra-vehicular activity
multi-g	more than 1-g acceleration situation
QM	qualification model
SMAC	spacecraft maximum allowable concentration
TCS	thermal control system

4 Requirements

4.1 Overview

Requirements defined in this Standard are specific to ECLSS, including requirements for functional objectives of the system or requirements for the safety of life.

Requirements are not quantified with values for the parameters. Quantified specifications are established on a case-by-case basis for project dependent items. Examples of parameters to be specified are listed in Annex A

4.2 Mission and system

4.2.1 General

- a. The ECLSS shall be designed for a specific mission and all phases within that mission as defined in 4.2.2, up to the end of the operational lifetime.

4.2.2 Mission

4.2.2.1 Overview

Basic requirements on the ECLSS vary according to the mission scenarios and the mission phases of the selected mission. The most important parameters affecting the requirements are the mission duration, the size of the crew, the type and quantity of living organisms, the availability of a source of resupply (e.g. Earth and space cargo) and the feasibility or duration of any saving, rescue or evacuation procedure.

The longer the mission duration and the larger the distance from the source of resupply (e.g. Earth) are the more difficult the rescue becomes and the higher the dependence is on ECLSS closed loops.

4.2.2.2 Identification of requirements

- a. ECLSS requirements related to each mission phase shall be identified in project Phase A.

NOTE For project phases and planning, see ECSS-M-ST-10.

4.2.2.3 Mission phases

- a. The applicable conditions for the following mission phases shall be included in the ECLSS definition:

1. ground and pre-launch operations;
 - (a) storage, transport;
 - (b) functional check out;
 - (c) waiting on launch pad.
2. launch and ascent;
 - (a) launch time;
 - (b) external environment;
 - (c) specific requirements during multi-g phases;
 - (d) impact of depressurization and re-pressurization (IVA);
 - (e) launch abort situation.
3. planetary orbital phase;
4. transfer phase;
5. docking, docked and separation phases, rendezvous and parking;
6. extra-vehicular activity: pre-breathing
7. planetary phase;
 - (a) landing, mission on planet;
 - (b) planetary walk;
 - (c) excursion, rover, supported excursion.
8. return to Earth, descent, reentry and landing;
9. post landing phases, quarantine.

NOTE Manned and unmanned phases can be part of a given mission.

- b. The storage and transport conditions for supplies shall be specified.
- c. External environmental conditions, both on ground and in space shall be taken into account.

4.2.3 System

4.2.3.1 Multi-ECLSS phases

4.2.3.1.1 Applicability

The requirements in 4.2.3.1.2 apply to each of the several pressurized volumes that can be involved in a given mission, each with its own ECLSS to work independently during some phases of the mission, for the duration of the independent operations (example EVA suit).

4.2.3.1.2 Requirements

- a. Interfaces shall be defined for the period of time when several pressurized volumes having independent ECLSSs are mated.
- b. When an ECLSS is not in operation during a given phase of the mission, standby mode conditions shall be defined.
- c. When docking to another spacecraft, the various ECLSSs involved shall be compatible.

4.2.3.2 Reusable systems

- a. When a vehicle is used for several missions, the following issues shall be addressed during the design phase (project Phase B):
 1. standby, storage and parking conditions between missions;
 2. recommissioning procedure before next mission.

4.3 General

4.3.1 Forms of life

4.3.1.1 Humans

The ECLSS can be designed for a mixed or an unmixed crew.

For human factors such as metabolism and anthropometrics, see ECSS-E-ST-10-11.

4.3.1.2 Forms of life other than humans

4.3.1.2.1 Metabolism

- a. Requirements for energy and for overall intake and output of consumables shall be defined at the beginning of the ECLSS development programme (project Phase A).

4.3.1.2.2 Environmental conditions

- a. Environmental conditions for the forms-of-life to support shall be defined at the beginning of the programme (project Phase A).

NOTE It is important to define such environmental condition because it is usually form of life dependent.

4.3.2 ECLSS engineering

4.3.2.1 Humans

- a. In engineering of the ECLSS for human missions, the following system modes of operation shall be defined:
 1. nominal,
 2. degraded, and
 3. emergency.

NOTE Environmental conditions for each mode are based on the threshold limit values of the concerned parameters.

- b. In the case that, in emergency mode, the mission cannot be aborted to ensure a safe return to Earth, the crew shall have the capability to restore (at least) the state of degraded mode without external resources for the remaining duration of the mission eventually by entering safe haven.

NOTE Some missions can include low orbital flights where abortion of the mission is a feasible scenario for emergency rescue.

4.3.2.2 Forms of life other than humans

- a. For forms of life other than human, requirements shall
 1. define the environment suitable for the forms of life to be supported, and
 2. take into account the potential interference with the human mission requirements.

4.3.3 Environmental condition

- a. The variation in the parameters defining the human natural and imposed environment, shall be taken into account during project Phase A.

NOTE Examples of such parameters are gravity, pressure, atmosphere composition and ionizing radiation.

4.4 Functional

4.4.1 Overview

The functions defined in this clause 4.4 are part of the general tailoring of the ECLSS requirements for a given project.

The functional requirements defined in 4.4.2 to 4.4.6 are applicable to human missions. For other forms of life, relevant requirements can be obtained by tailoring them.

4.4.2 Maintain environment

4.4.2.1 General

- a. To support and maintain health, safety and well being, the ECLSS shall maintain the nominal environmental conditions in the pressurized volume.

NOTE Classification of pressurized volume is given in Table 4-1.

Table 4-1: Classification of pressurized volume

	Non-accessible volume	Accessible volume	
		Habitable volume	Non-habitable volume
Definition	Volume that humans cannot enter, even with dismounting operations	Volume that humans can freely enter	Volume that humans can enter, only with preventive dismounting operations.
Examples	Within a component	Cabin Crew quarter	Behind racks, panels, floor or ceiling which can be removed

4.4.2.2 Control atmosphere total pressure

4.4.2.2.1 Total atmospheric pressure

- a. The nominal value and the limit values for the total atmospheric pressure in the pressurized volume shall be specified.

4.4.2.2.2 Monitor atmosphere total pressure

- a. The range and the accuracy to monitor the atmosphere total pressure in the pressurized volume shall be specified.

4.4.2.2.3 Means for adjusting pressure

- a. Means for adjusting pressure at the selected value (up or down) inside the specified range applicable for each type of pressurized volume shall be provided.

4.4.2.2.4 Prevent over-pressurization

- a. Over-pressurization shall be prevented.

4.4.2.2.5 Equalize atmosphere pressure

- a. The capability to equalize the maximum pressure differential, as defined by the pressure control range, between adjacent, isolated pressurized volumes shall be provided.

4.4.2.2.6 Add inert diluent gas to atmosphere

- a. Addition of inert diluent gas (for example nitrogen) into the pressurized volume shall be provided at a rate capable of maintaining the atmospheric pressure within the control range.
- b. Addition of inert diluent gas (for example nitrogen) into the atmosphere shall be provided at a rate capable of atmospheric restoration after decompression of the habitable volume.
- c. When adding inert diluent gas (for example nitrogen) into the atmosphere the levels of anoxic or hypoxic zones in the accessible volume shall be specified.
- d. The limits for pressure adjustments, decompression, compression and re-compression shall be specified.
- e. Means to manage pressure change rates within the specified limits shall be provided.

4.4.2.2.7 Add oxygen to atmosphere

- a. Addition of gaseous oxygen into the atmosphere shall be provided at a rate capable of maintaining the oxygen partial pressure in the accessible volume within the specified range.
- b. Addition of gaseous oxygen into the atmosphere shall be provided at a rate capable of restoring the atmospheric condition after decompression of the accessible volume.
- c. Addition of oxygen shall not create risk of fire.

4.4.2.3 Control thermal nominal condition

4.4.2.3.1 Maintain thermal nominal condition:

- a. The limits of the atmosphere effective temperature in the habitable volume shall be specified.

NOTE The atmosphere effective temperature is a combination of dry bulb temperature, wet bulb temperature and ventilation.

4.4.2.3.2 Maintain temperature

- a. The atmosphere dry bulb temperature in the habitable volume shall be selectable within the operational range.
- b. The accuracy for the stabilized dry bulb temperature in the habitable volume shall be specified.
- c. Removal of excess sensible heat from the atmosphere or addition of sensible heat into the atmosphere shall be provided at a rate capable of maintaining the atmosphere temperature within the specified range.
- d. The points of measurement for the dry bulb temperature shall be representative for the habitable volume situation.

4.4.2.3.3 Maintain atmosphere humidity

- a. The range for the atmosphere relative humidity in the habitable volume shall be specified.
- b. The range for the atmosphere dew point in the pressurized volume shall be specified.

NOTE Relative humidity is in relation to human comfort evaluation; dew point limits are intended to prevent condensation. Both measurements indicate the water vapour content of the atmosphere.

4.4.2.3.4 Monitor atmosphere humidity

- a. The range and the accuracy to monitor the atmosphere relative humidity in the habitable volumes shall be specified.
- b. The range and accuracy of the atmosphere dew point temperature to be monitored in the pressurized volumes shall be specified.
- c. Water vapour shall be removed from or added to the pressurized volume atmosphere at a rate capable of maintaining the specified range.

4.4.2.3.5 Circulate atmosphere

- a. Ventilate habitable volume: atmosphere velocities in the habitable volume shall be maintained within the specified air velocity ranges, adapted to total atmospheric pressure situation.
- b. Gas velocity ranges can differ between habitable and non-habitable volume.
- c. Exchange of atmosphere between pressurized volumes: atmosphere exchange between connected pressurized volumes shall be specified.
- d. Monitor ventilation and atmosphere exchange: Location of ventilation and atmosphere exchange monitoring shall be specified.

NOTE Since atmosphere circulation in the habitable volume is intended to maintain thermal nominal condition and atmospheric composition, the previous requirements are included to control of atmosphere circulation.

4.4.2.4 Control oxygen partial pressure

4.4.2.4.1 Maintain oxygen partial pressure

- a. The limits for the oxygen partial pressure in the atmosphere of habitable volume shall be specified.

4.4.2.4.2 Monitor oxygen partial pressure

- a. The range and accuracy to monitor the atmosphere oxygen partial pressure shall be specified.

4.4.2.4.3 Add oxygen into the atmosphere

- a. For adding oxygen into the atmosphere, requirements in 4.4.2.2.7 shall apply.

4.4.2.5 Control carbon dioxide partial pressure

4.4.2.5.1 Maintain low carbon dioxide partial pressure

- a. The threshold values for the carbon dioxide partial pressure in the atmosphere of habitable volume shall be specified.

4.4.2.5.2 Remove carbon dioxide from atmosphere

- a. Removal of carbon dioxide from the atmosphere shall be provided at a rate capable of maintaining the carbon dioxide partial pressure below the specified threshold value.

4.4.2.5.3 Monitor carbon dioxide partial pressure

- a. The range and accuracy for the monitoring of the atmosphere carbon dioxide partial pressure shall be specified.

4.4.2.6 Control carbon monoxide partial pressure

4.4.2.6.1 Maintain low carbon monoxide partial pressure

- a. The threshold values for the carbon monoxide partial pressure in the atmosphere of the accessible volume shall be specified.

4.4.2.6.2 Remove carbon monoxide from atmosphere

- a. Removal of carbon monoxide from the atmosphere shall be provided at a rate capable of maintaining the carbon monoxide partial pressure below the specified threshold value.

4.4.2.6.3 Monitor carbon monoxide partial pressure

- a. The range and accuracy for monitoring the atmosphere's carbon monoxide partial pressure shall be specified.

4.4.2.7 Control trace gases and odour

4.4.2.7.1 Maintain low trace gases partial pressures and odour

- a. The partial pressure of trace gases in the atmosphere of the accessible volume shall be maintained below a specified SMAC values for various exposure periods.
- b. The threshold values for the odour in the atmosphere shall be specified.

4.4.2.7.2 Remove trace gas and odour from atmosphere

- a. Removal of trace gases from the atmosphere shall be provided at a rate capable of maintaining the trace gases partial pressures and odour below specified threshold values.

NOTE Trace gases arise from equipment offgassing, systems failures and human (or any other form of life) metabolism.

4.4.2.7.3 Monitor trace gases in atmosphere

- a. The detection limits and the accuracy for monitoring the trace gases in the habitable volume atmosphere shall be specified.

NOTE Trace gases to be monitored are project dependant.

4.4.2.8 Control airborne particles

4.4.2.8.1 Maintain low level of airborne particles

- a. The threshold values for the concentration of airborne particles in the atmosphere of the habitable volume shall be specified.

4.4.2.8.2 Remove airborne particles from atmosphere

- a. Removal of airborne particles from the atmosphere shall be provided at a rate capable of maintaining the particle concentration below the specified threshold values.

4.4.2.8.3 Monitor airborne particles in atmosphere

- a. The detection limit and accuracy for the monitoring of the airborne particles in the atmosphere shall be specified.

4.4.2.9 Control microorganisms

4.4.2.9.1 Maintain low level of airborne microorganisms

- a. The threshold values for the concentration of airborne microorganisms in the pressurized volume atmosphere shall be specified.

4.4.2.9.2 Remove airborne microorganisms from atmosphere

- a. Removal of airborne microorganisms from the atmosphere shall be provided at a rate capable of maintaining the microbial concentration below the specified threshold value.

4.4.2.9.3 Monitor airborne microorganisms in atmosphere

- a. The detection limit and accuracy for the monitoring of airborne microorganisms in the atmosphere shall be specified.

4.4.2.9.4 Monitor surface microorganisms

- a. The capability to monitor microbial contamination of surfaces shall be provided in the accessible volume.

4.4.2.10 Support ionizing radiation control

4.4.2.10.1 Monitoring

- a. The capability to monitor the ionizing radiation environment both inside and outside the accessible volume shall be provided.

4.4.2.10.2 Shielding

- a. Ionizing radiation limits shall be specified.
- b. The capability to provide shielding to maintain the ionizing radiation below the specified limits shall be provided.

4.4.2.11 Support non-ionizing radiation control

- a. Non-ionizing radiation limits should be specified.

4.4.3 Respond to environmental contingencies

4.4.3.1 Respond to uncontrolled depressurization

4.4.3.1.1 Detect uncontrolled depressurization

- a. An uncontrolled depressurization event shall be detected in the following cases:
 1. when the rate of depressurization is higher than a specified value;
 2. prior to the habitable volume total pressure decreases below a threshold limit value.

4.4.3.1.2 Recover from uncontrolled depressurization

- a. The time limits for recovering depressurization shall be specified.
- b. The capability to recover from an uncontrolled depressurization shall be provided, as follows:
 1. re-pressurize to total pressure specified values and with the gases specified in 4.4.2, within the specified time limits;
 2. restore atmosphere composition, at least to degraded conditions;
 3. provide means to treat humans from hypoxia, decompression illness or both.

4.4.3.2 Respond to uncontrolled pressurization

4.4.3.2.1 Detect uncontrolled pressurization

- a. An uncontrolled pressurization event shall be detected when the rate of pressurization is higher than a specified value.
- b. An uncontrolled pressurization event shall be detected prior to the accessible volume total pressure increasing above a threshold limit value.

4.4.3.2.2 Recover from uncontrolled pressurization

- a. The time limits for the decompression back to nominal total pressure value shall be specified.
- b. The capability to recover from an uncontrolled pressurization shall be provided as follows:
 1. decompress to total pressure level specified in 4.4.2, within specified time limits;
 2. restore atmosphere composition, at least to degraded conditions;
 3. provide means to handle over-pressurization consequences for the humans, including the risk of decompression illness.

4.4.3.3 Respond to fire

4.4.3.3.1 Detect fire, smoke, smouldering

- a. Fire shall be detected in enclosed locations and in the pressurized volume.

4.4.3.3.2 Isolate fire

- a. Fire events shall be isolated in the affected location.

4.4.3.3.3 Suppress fire

- a. The capability to suppress a fire shall be provided.

4.4.3.3.4 Recover from fire

- a. Means of restoration of a habitable environment shall be provided, at least to reach degraded conditions.

NOTE This includes removal of combustion products from the atmosphere.

4.4.3.4 Respond to hazardous radiation exposure

4.4.3.4.1 Detect hazardous radiation levels

- a. Real-time ionizing radiation levels both inside and outside the accessible volume shall be provided with an alarm system.

4.4.3.4.2 Provide human protection from radiation

- a. Means to provide human protection from radiation (e.g. shelter or safe haven) shall be provided.

4.4.3.4.3 Detect radiation level normalization

- a. Means to detect the radiation level normalization (e.g. dosimeters) shall be provided.

4.4.3.4.4 Inform humans that they can move out from protection

- a. Means to inform humans that they can move out from protection shall be provided.

4.4.3.5 Respond to hazardous atmosphere

4.4.3.5.1 Detect hazardous atmosphere

- a. The hazardous airborne contaminants to be detected, and the detection limits, accuracy and response time, shall be specified.

4.4.3.5.2 Provide human protection

- a. Means for protecting humans from hazardous atmospheres (e.g. IVA, isolating the hazardous atmosphere, or breathing from masks) shall be provided.

4.4.3.5.3 Restore an acceptable atmosphere

- a. The functionality to restore atmosphere quality at least to degraded mode shall be provided.

4.4.3.5.4 Recover from hazardous atmosphere

- a. The functionality to recover from a hazardous atmosphere shall be provided.

NOTE Recovery options can include venting of the habitable volume atmosphere and subsequent atmosphere restoration. Additional recovery options can include throttling up of the existing contaminant removal system, and activation of a secondary contaminant removal system coupled with an emergency source of breathable air.

4.4.4 Provide resources

4.4.4.1 Provide inert diluent gas

4.4.4.1.1 Supply inert diluent gases

- a. An inert diluent gas, as for example nitrogen, shall be supplied to points of use in conformance with the interface specifications for gas temperature, pressure and flow rate.

NOTE An example of diluent gas is Nitrogen.

4.4.4.1.2 Store inert diluent gas

- a. Inert diluent gas usage and contingency needs, including pressurized volumes re-pressurization, shall be specified.
- b. Storage of inert diluent gas shall be provided with the capacity to meet usage and contingency needs specified in 4.4.4.1.2a.

4.4.4.1.3 Monitor inert diluent gas storage

- a. The quantity of stored inert diluent gas, shall be monitored.

4.4.4.1.4 Accept external inert diluent gas

- a. Resupply of inert diluent gas shall be accepted in conformance with the interface specifications.

4.4.4.2 Provide oxygen

4.4.4.2.1 Oxygen needs

- a. The amount of oxygen to support human metabolic needs shall be specified.
- b. Oxygen shall be provided to support human metabolic needs specified in 4.4.4.2.1a
- c. Oxygen shall be provided for EMU recharging to support nominal human metabolic needs, as specified in 1. above.
- d. An EVA suit flush procedure shall be specified.
- e. Oxygen shall be provided for breathing during de-nitrogenation process and the EVA suit flush procedure specified in 4.4.4.2.1d.
- f. Oxygen shall be provided to make up for atmosphere leakage.
- g. Oxygen shall be provided to make up for airlock losses during EVA exit and reentry.
- h. Oxygen shall be provided to restore the accessible volume atmosphere in the event of loss of pressure.
- i. Oxygen shall be provided to support portable and umbilical supplied emergency oxygen breathing equipment.

4.4.4.2.2 Supply oxygen

- a. Oxygen shall be supplied to points of use in conformance with the interface specifications for gas temperature, pressure and flow rate.

4.4.4.2.3 Store oxygen

- a. Oxygen usage and contingency needs, including the accessible volume's atmosphere restoration, shall be specified.
- b. Storage of oxygen or oxygen generating resources shall be provided with the capacity to meet the usage and contingency needs specified in 4.4.4.2.3a.

4.4.4.2.4 Generate or recycle oxygen

- a. Oxygen shall be generated and recycled at a rate capable of maintaining at least the specified minimum oxygen storage specified in 4.4.4.2.3b.

NOTE Oxygen generation and recycling can include plant or algae photosynthesis and water electrolysis.

4.4.4.2.5 Monitor oxygen consumption and oxygen storage

- a. The quantity of stored oxygen shall be monitored.

4.4.4.2.6 Accept external oxygen

- a. Resupplied oxygen shall be accepted in conformance with the interface specifications.

4.4.4.3 Provide breathing gases for specific situations

4.4.4.3.1 Overview

Requirements on supply of specified breathing gases (e.g. composition, quality, and quantities) are intended to support nominal or degraded situations (e.g. breathing on masks, safe haven, and treatment of decompression illness).

4.4.4.3.2 Requirements

- a. Breathing gases shall be supplied to points of use in conformance with the applicable interface specifications for gas temperature, pressure and flow rate.
- b. Storage breathing gases capacity shall be specified.
- c. When mixing or recycling of gases takes place onboard, the quality of the produced gases shall be specified.
- d. The quantity of stored breathing gases shall be monitored.
- e. Resupplied external breathing gases shall be accepted in conformance with the interface specifications.

4.4.4.4 Provide water

4.4.4.4.1 Water needs

- a. Potable water needs, including water for drinking, oral hygiene, and food preparation (e.g. rehydration), shall be specified.
- b. Hygiene water needs, including water for personal hygiene, laundry and dishwashing, shall be specified.
- c. Water needs for medical purposes (e.g. sterile water and medicine reconstitution) shall be specified.
- d. Water to meet the water needs specified in 4.4.4.4.1a, b and c shall be provided.

NOTE Other needs can include housekeeping, preparation of hydroponic solutions, food processing, and water quality sampling.

4.4.4.4.2 Water quality

- a. For each use, the water quality shall be specified using the following criteria:
 1. Organoleptic parameters, such as colour, turbidity and taste.
 2. Physical parameters, such as temperature, conductivity and particle size.
 3. Chemical parameters, such as pH, dissolved gases, minerals, total hardness and undesirable substances.
 4. Toxic substances.
 5. Microbiological parameters, such as bacteria, viruses, yeast and moulds.
 6. Radiological parameters.

4.4.4.4.3 Supply water

- a. Water shall be supplied to points of use in conformance with the interface specifications for water temperature, pressure, flow rate and quality.

4.4.4.4.4 Store water

- a. The water peak usage and contingency needs shall be specified.
- b. Storage of water shall be provided with the capacity and flow rate to meet the peak usage demand specified in 4.4.4.4.4a.
- c. The quantity of stored potable water shall meet the contingency needs specified in 4.4.4.4.4a.

4.4.4.4.5 Monitor water in storage

- a. The quantity of stored potable and hygiene water shall be monitored.

4.4.4.4.6 Generate and regenerate water

- a. Water shall be regenerated at a rate capable of maintaining at least the minimum water storage specified in 4.4.4.4.5a.
- b. The conditions to use generated water shall be specified.

NOTE Water regeneration can include waste water purification and water recovering from combustion of hydrocarbon wastes.

4.4.4.4.7 Accept external water

- a. Resupplied water shall be accepted in conformance with the interface specifications.

NOTE Resupply can include water obtained from in situ resources.

4.4.4.5 Provide food

4.4.4.5.1 Supply food and food ingredients

- a. Nutritional requirements shall be specified.
- b. Food shall be provided for human consumption in conformance with the nutritional requirements specified in 4.4.4.5.1a.
- c. The food provided shall take into account the physiological changes in the human being in his adaptation to a new gravitational environment and his return to a 1-g environment, and the extra needs related to eventual EVA.
- d. Prior to consumption, food shall meet specified food safety requirements.
- e. The choice of food shall meet food related psychological needs, that is:
 1. The choice of food accommodates foods for special events.
 2. The fraction of mass and calories of recreational foods to be included in the choice of food is specified.
 3. The variety of foods to be included in the choice of food is specified.
 4. The diet is composed of palatable food and shall be made of similar ingredients to those used by the crew members on Earth.
 5. The meals take into account ethnic and cultural food pattern differences between crew members.

NOTE Requirements in this clause 4.4.4.5.1 are provided in order to supply food according to a daily individual diet of a crew-member consistent with human physiological requirements.

4.4.4.5.2 Store food

- a. Food usage and contingency needs shall be specified.
- b. Storage of food and food ingredients shall be provided with the capacity to meet the usage and contingency needs specified in 4.4.4.5.2a.
- c. The storage conditions to keep the nutritional and palatability characteristics of the food intact and to prevent any contamination or degradation, either of physicochemical or biological origin, shall be specified.

4.4.4.5.3 Produce food

1. When food production is specified, it shall be produced in conformance with crew needs, following food requirements specified in 4.4.4.5.1.
2. Produced food quality shall be controlled.
3. The food production expendable by products shall be specified.

4.4.4.5.4 Monitor food

1. Food quality, quantity and palatability shall be monitored.
2. The diet and food intake of each individual shall be monitored.

4.4.4.5.5 Process food

1. Raw materials and ingredients shall be processed into ready-to-eat foods and food ingredients at a rate capable to meet current usage needs and storage requirements specified in 4.4.4.5.2.
2. Means for food processing, serving as well as utensil and restraints and mobility aids, shall be provided.
3. Food trash shall be avoided in term of mass and volume.

4.4.4.5.6 Monitor food and food ingredients in stock

1. Stored food and food ingredients shall be listed in an explicit inventory providing its quantity, status data, its availability, localisation and its end of date limit.
2. The quantity of food in production shall be monitored.
3. The requirements for monitoring the quality of food and food ingredients shall be specified .

4.4.4.5.7 Generate food and food ingredients

- a. Food and food ingredients shall be produced at a rate capable to maintain at least the minimum food storage requirements specified in 4.4.4.5.2.

NOTE Food regeneration can include for example growth of food crops, harvesting, plants, animal growth, eggs, aquaculture and chemical food production.

4.4.4.5.8 Accept external food and food ingredients

- a. Resupplied food and food ingredients shall be accepted in conformance with the interface specifications.

4.4.5 Manage waste

4.4.5.1 Manage carbon dioxide

4.4.5.1.1 Accept carbon dioxide

- a. Carbon dioxide shall be accepted from points of collection in conformance with interface specifications.

NOTE Carbon dioxide includes metabolically produced carbon dioxide and carbon dioxide produced by combustion of wastes.

4.4.5.1.2 Store carbon dioxide

- a. Carbon dioxide peak recovery rate and storage contingencies shall be specified.

NOTE Storage contingencies include temporary loss of downstream processing capability.

- b. Storage of carbon dioxide shall be provided with the capacity to meet the peak recovery rate and storage contingencies specified in 4.4.5.1.2a.

4.4.5.1.3 Monitor carbon dioxide waste

- a. The requirements for monitoring the quantity and quality of stored carbon dioxide shall be specified.

4.4.5.1.4 Process carbon dioxide

- a. For long duration missions the capability for recovering oxygen or any product from carbon dioxide shall be specified.

4.4.5.1.5 Dispose excess carbon dioxide

- a. The capability to dispose excess carbon dioxide shall be provided.

4.4.5.2 Manage waste water

4.4.5.2.1 Collect and accept waste water

- a. Waste water shall be collected and accepted in conformance with the interface specifications.

4.4.5.2.2 Store waste water

- a. Storage of waste water shall be provided taking into account the capacity to meet peak recovery rate and storage contingency needs.

NOTE Storage contingencies include temporary loss of downstream processing capability.

4.4.5.2.3 Monitor waste water

- a. The requirements for monitoring the quality and quantity of waste water shall be specified.

4.4.5.2.4 Process waste water

- a. Waste water shall be processed to recover potable and hygiene water .

NOTE Processing can include chemical stabilization and water recovery.

- b. Processed waste water shall meet specified quality requirements for further use.

NOTE Other uses can include hydroponic solutions preparation.

4.4.5.2.5 Dispose excess waste water

- a. The capability to dispose excess water shall be provided.

NOTE Disposal includes overboard dumping and transfer to a returning vehicle. This requirement is mission or design dependent.

4.4.5.3 Manage gas, solid and concentrated liquid wastes

4.4.5.3.1 Collect and accept gas, solid and concentrated liquid wastes

- a. Gas, solid and concentrated liquid wastes shall be accepted from points of collection in conformance with the interface specifications.
- b. To prevent atmosphere contamination, the gas from breathing systems, including the collection of expired gas from breathing masks (e.g. pre-breathing for EVA and medical treatment gases), shall not be released into the atmosphere.

NOTE 1 Waste gas originates mainly from breathing systems and experiments.

NOTE 2 Concentrated liquid waste is mainly the residuals of waste water processing but not only water soluble liquids (oil and organic liquids can be present).

Waste water includes biological and used hygiene water.

Biological waste water includes:

- urine,
- condensate from human and plants expiration and perspiration,
- faecal water,
- vomit, and
- menses.

Waste water from general hygiene processes include:

- shower water and condensate from shower,
- water from washing and maintenance, and
- food preparation water.

NOTE 3 Solid waste is mainly composed of solid elements which are not usable in their chemical or physical form by humans.

Source of solid waste are of biological and physicochemical nature and originate from the general hygiene processes and food trash.

Biological solid waste includes:

- faeces,
- non-consumable solids from food production storage management systems,
- solid residues from food preparation (cooking),
- solid residue from non eaten food, and
- medical waste.

Non-biological solid waste includes all the degraded, non-usable solid elements used on board, as

- in hygiene,
- food production and preparation,
- clothes,
- maintenance by-products,
- disposable parts and conditioning materials, and
- waste water processor residual.

4.4.5.3.2 Store gas, solid and concentrated liquid wastes

- a. Peak and contingency needs for unprocessed gas, solid and concentrated liquid waste shall be specified.

NOTE Contingencies include temporary loss of downstream processing capability.

- b. Temporary storage of unprocessed gas, solid and concentrated liquid wastes shall be provided with the capacity to meet the peak and contingency needs specified in 4.4.5.3.2a.
- c. Long-term storage shall be provided for residuals and non-recycled wastes.

NOTE Residuals are wastes from which no further useful resources can be recovered. Non-recycled wastes are wastes that can contain useful resources, but for which processing is not attempted.

- d. Long term storage of waste shall not increase the risk of biological, chemical or particulate contamination.

4.4.5.3.3 Monitor gas, solid and concentrated liquid wastes

- a. Waste management shall keep records of the stored wastes status.
- b. The quantity of stored wastes shall be monitored.
- c. The requirements for monitoring of the physical, chemical and biological quality of wastes shall be specified.

4.4.5.3.4 Process gas, solid and concentrated liquid wastes

- a. Solid and concentrated liquid wastes shall be processed to recover water, carbon dioxide, and other useful products such as nitrogen, methane, nutrients.

4.4.5.3.5 Dispose gas, solid and concentrated liquid wastes

- a. The capability to dispose of non-recovered wastes and process residuals in conformity with the specified safety and environmental standards shall be provided.

NOTE Disposal includes overboard dumping and transfer to a returning vehicle. This requirement is mission and design dependent.

- b. When recovery cannot be performed, storage and stabilization of wastes shall specify means for safe and effective disinfection, sanitization and containment.

4.4.6 Support EVA operations

4.4.6.1.1 Support EMU servicing and check out

- a. Oxygen, consumable filtering material and potable water shall be provided for EMU servicing.
- b. Removal of waste water from EMU shall be implemented.

NOTE Some projects also specify the removal of waste carbon dioxide.

- c. Cleaning and drying procedures of the spacesuit shall be established and corresponding equipment specified.

4.4.6.1.2 Support de-nitrogenation procedure

- a. Pre-breathe procedures shall be established and corresponding equipment specified.

NOTE This requirement is equivalent to the ISS requirement.

4.4.6.1.3 Support decompression for egress

- a. Decompression of the airlock from the habitable volume pressure to the external pressure shall be supported at a specified rate.
- b. The minimum percentage of the airlock atmosphere to be recovered during decompression under nominal (non-emergency) EVA operations shall be specified.

4.4.6.1.4 Support re-compression for ingress

- a. Re-compression procedure of the airlock for a crew member from the external ambient pressure to the habitable volume pressure shall be supported at a specified nominal rate.

4.4.6.1.5 Support contaminant detection and decontamination

- a. Contaminant detection and decontamination of the EVA equipment and of the person shall be supported following an EVA.
- b. The decontamination levels shall be specified.

4.4.6.1.6 Support decompression illness management

- a. Procedure and corresponding equipment for managing DCI cases by treatment or evacuation shall be provided.

4.4.6.1.7 Support EVA radiation monitoring

- a. Real-time monitoring of the ionizing radiation environment of the space suit, and of the accumulated total doses inside the spacesuit, shall be supported during an EVA.

4.4.6.1.8 Support IVA

- a. IVA operations shall be supported.

4.4.6.1.9 Support rover operations

- a. Rover operations shall be supported.

4.4.6.1.10 Safe haven operation

- a. Safe haven operations shall be supported.

4.4.7 Provide health related services

4.4.7.1 Provide health monitoring

- a. Requirements for providing health monitoring shall be specified.

4.4.7.2 Provide medical assistance on board

4.4.7.2.1 Support first aid

- a. Requirements on support of first aid shall be specified.

4.4.7.2.2 Provide medical equipment for diagnostic and treatment purposes

- a. Requirements for providing medical equipment for diagnostic and treatment purposes shall be specified.

NOTE This can include means to treat cases of decompression illness.

4.4.7.2.3 Provide drugs

- a. Requirements shall be specified to
 1. store drugs,
 2. monitor quantity and quality of drugs,
 3. dispose drug waste, and
 4. dispose drugs.

4.4.7.2.4 Provide access to tele-medicine services

- a. Requirements to provide access to tele-medicine services shall be specified.

4.4.7.2.5 Provide means of sanitary evacuation

- a. Requirements to provide means of sanitary evacuation shall be specified.

NOTE Depending on the mission, evacuation can be a scenario in case of medical problem.

4.4.7.3 Support time (day and night) control

- a. Requirements on supporting time (day and night) control shall be specified.

4.4.7.4 Support gravity counter measures

- a. The requirements to support reduced gravity counter measures shall be specified.
- b. The requirements to support increased gravity counter measures (launch and reentry) shall be specified.

4.5 Design

4.5.1 Overview

4.5.1.1 Introduction

Design requirements cover the requirements on ECLSS hardware and software to ensure that the flight system fulfils the objectives of the ECLSS in terms of mission requirements (see clause 4.2) and functional requirements (see clause 4.4)

ECLSS is not a stand-alone subsystem, and therefore is designed to conform to interface requirements with other subsystems (see clause 4.6) aiming to minimize constraints on other subsystems or systems.

4.5.1.2 Structural and mechanical

For structural and mechanical requirements, see ECSS-E-ST-32, ECSS-E-ST-33-01, and ECSS-E-ST-32-08.

4.5.1.3 Thermal

For thermal requirements applicable to ECLSS, see ECSS-E-ST-31.

4.5.1.4 Electrical and electromagnetic compatibility (EMC)

For electrical and electromagnetic compatibility requirements applicable to ECLSS, see ECSS-E-ST-20.

4.5.1.5 Operations and logistics

For operations and logistics requirements applicable to ECLSS, see ECSS-E-ST-70 and ECSS-E-TM-10-10.

4.5.1.6 Failure detection, isolation and recovery

For requirements on FDIR applicable to ECLSS, see ECSS-Q-ST-30-02.

4.5.1.7 Human factors

The design of all ECLS hardware and their mounting inside the pressurized volume cannot be done without taking into consideration that hardware is functioning with, for and under the control of humans. That implies the complete apprehension and application of ergonomics, psychological and cognitive factors and constraints.

For requirements on human factors, see ECSS-E-ST-10-11.

4.5.2 Data management control

- a. The ECLSS shall include:
 1. the sensors and control components for monitoring each ECLSS process and subsystem functions;
 2. interface with the on-board data management system, and with ground base support;
 3. visual and acoustic warning and alarm indications;
 4. manual override control system.

4.6 Interface

4.6.1 General

- a. The ECLSS design shall take into account the ECLSS hardware and software functional interfaces with:
 1. other ECLSS in multiple ECLSS missions;
 2. non-ECLSS hardware and software;
 3. the humans for direct control in normal operation or override in case of emergency.

4.6.2 Ground support equipment (GSE)

- a. Interfaces of the ECLSS with ground support shall be provided.
- b. The GSE requirements shall be specified.

4.6.3 Mission interfaces

4.6.3.1 Flight system

- a. Requirements on mission interfaces for flight system shall be specified.

4.6.3.2 Software, data systems, interface

- a. The ECLSS shall conform to the specified data handling and software.

4.6.3.3 Thermal control interface

- a. Being part of the overall environmental control system (ECS) of the vehicle, ECLSS design shall conform to interface requirements with TCS.

NOTE The objective of this requirement is to reduce to a minimum the constraints on TCS subsystem.

4.6.3.4 Biological interface

- a. As non-wanted forms of life can be present onboard, for example microbiological species, the ECLSS shall, as part of their functional requirements:
 1. monitor potential unwanted forms of life,
 2. prevent dissemination of such form of life from ECLSS, and
 3. control any unwanted form live developing on board.

4.6.3.5 Mechanical and structural interface

4.6.3.5.1 Pressurized volume configuration and layout

- a. ECLSS shall take into account the overall configuration and layout, together with the following information provided for each item from the applicable ICD:
 1. dimension and mass;
 2. fixation and mounting techniques;
 3. contact area;
 4. surface characteristics, e.g. treatment, and roughness;
 5. alignment requirements;
 6. connectors locations;
 7. available area for fixation of ECLSS hardware;
 8. spacecraft harness;
 9. accessibility.

4.6.3.5.2 Mechanical load

- a. The ECLSS shall conform to the mechanical load during the mission phases.
- b. The internal-to-external differential pressure in the pressurized volume shall be prevented from exceeding the maximum design pressure.

4.6.3.5.3 Stability requirements

- a. Exported vibrations from ECLSS shall be specified.
- b. microgravity disturbances shall be specified.

4.6.3.5.4 Hardware configuration

- a. ECLSS design shall define the ECLSS hardware configuration and layout and provide the inputs for the ICD.

4.6.3.5.5 Forbidden zones

- a. The requirements on ECLSS specific forbidden zones shall be specified at project Phase C (ECLSS design phase).

NOTE Forbidden zones include outside FOV, and operational range of mechanisms.

4.6.3.5.6 Fracture control

- a. Fracture control procedures shall be applied to ECLSS.

NOTE For requirements on fracture control, see ECSS-E-ST-32-01.

4.6.3.6 Electric power

- a. The requirements for electric power supply to ECLSS shall be specified.

NOTE For example, peak and average electric power, duty cycles, and backup electric power.

4.6.3.7 Environment for on-board equipment

- a. The requirements for payload in the pressurized volume shall be specified.

4.6.3.8 Human interface

- a. The dedicated human time allocation for operation and maintenance on ground and on board shall:
 1. be specified (in man-year per mission), and
 2. not exceed the value specified in conformance with 1. above.

NOTE To prevent too frequent human interventions on board and actions from the personnel on the ground in order to replace consumable or dispose waste, maintainability issues are given a particular importance in ECLS design.

- b. The need for direct human actions for the operation and maintenance of ECLSS shall be traded-off against automatic systems.
- c. ECLSS specification shall define the training, qualification of the human for operation, maintenance, and control of ECLSS for:
 1. nominal modes of operation, and
 2. degraded modes of operation.

4.7 Verification

4.7.1 General

- a. Verification shall demonstrate that the ECLSS design conforms to specified performance requirements.

NOTE For verification, refer to ECSS-E-ST-10-02.

- b. A verification programme shall be established and submitted to the customer for approval.
- c. Conformance of the ECLSS design to its requirements shall be demonstrated by satisfactory completion of the ECLSS verification programme specified in 4.7.1b.
- d. Verification activities shall be carried out on each level, i.e. component, sub-assembly and assembly.
- e. Verification activities related to inspection and testing shall be performed under product assurance (PA) control.

NOTE Requirements on PA can be found in ECSS-Q-ST-20.

- f. During project Phase A, a complete and coherent verification plan and matrix shall be established clearly indicating for each item and level the intended verification approach.

4.7.2 Verification by similarity

- a. When verification by similarity is performed, similarity between the two items shall exist with respect to:
 1. functional design,
 2. hardware used,
 3. mission requirements, and
 4. life time.

4.7.3 Verification by inspection

- a. No physical contact with the hardware shall take place during an inspection.
- b. If 4.7.3a is not met, the physical contact shall be planned and approved as part of the verification plan and inspection procedure in conformance with ECSS-E-ST-10-02.

4.7.4 Verification by analysis

- a. Verification by analysis shall be performed for all cases where representative testing cannot be carried out, such as limitation of test facilities (e.g. environmental, dimensional and behaviour of ECLSS items under reduced or increased gravity).

4.8 Product assurance and safety

- a. Product assurance and safety provisions shall apply to design, production manufacturing testing and utilization of ECLSS.

NOTE For product assurance and safety, refer to the Q-branch of the ECSS Standards.

- b. Automated safety functions shall be implemented.

NOTE In case of failure, the very capability of the humans can be directly degraded from the resulting environmental conditions, and therefore they can be unable to access or to operate any of the recommended safety actions.

- c. Product assurance and safety provisions shall apply to ECLS ground support equipment.

4.9 Deliverables

4.9.1 Hardware

- a. The hardware to be delivered in the course of a project shall be specified during project Phase A.
- b. Since the ECLSS can consist of several functional sub-units, for each sub-unit integration procedures and interfaces shall be defined during project Phase B.

NOTE Examples of the hardware to be delivered include

- ECLSS hardware for different models (e.g. EM, QM and FM),
- hardware for sample test,
- spare, tools and repair hardware, and
- integration and support hardware.

4.9.2 Documentation

- a. The organization responsible for the ECLSS shall issue the specification to lower-level suppliers for the procurement of ECLSS sub-units.

Annex A (informative)

Parameters specification and monitoring

A.1 Specification of parameters

Table A-1 lists the parameters to be specified, and refers to the provisions where these parameters are specified.

Table A-1: List of parameters to be specified

Clause	Parameter
4.2.2.2 Identification of requirements, and	For each mission phase, specific ECLS requirements Transport and storage condition of supplies
4.2.2.3 Mission phases	
4.4.2.2 Control atmosphere total pressure	Nominal and limit values for total atmospheric pressure Range and accuracy of total pressure monitoring Limits of anoxic and hypoxic zones in accessible volumes Limits for pressure change rates for pressure adjustments Range of PO ₂ in accessible volumes
4.4.2.3 Control thermal nominal condition	Limits for effective temperature in habitable volumes Accuracy of stabilized dry bulb temperature Range of relative humidity in habitable volumes Range of dew point temperature in pressurized volumes Range and accuracy of relative humidity monitoring Range and accuracy of dew point monitoring Air velocity range in habitable volumes Atmosphere exchange between connected pressurized volumes. Localization of ventilation and atmosphere exchange monitoring
4.4.2.4 Control oxygen partial pressure	Limits for PO ₂ in habitable volumes Range and accuracy for PO ₂ monitoring
4.4.2.5 Control carbon dioxide partial pressure	Limits for PCO ₂ value in habitable volumes Range of monitoring of PCO ₂
4.4.2.6 Control carbon monoxide partial pressure	Maximum PCO value in habitable volumes Range of monitoring of PCO

Clause	Parameter
4.4.2.7 Control trace gases and odour	Threshold values for odours in habitable volumes
4.4.2.8 Control airborne particles	Threshold limit values for air borne particles
4.4.2.9 Control microorganisms	Threshold limit values for air born microorganisms
4.4.2.10 Support ionizing radiation control	Ionizing radiations limits
4.4.2.11 Support non-ionizing radiation control	Non-ionizing radiation limits
4.4.3.11 Respond to uncontrolled depressurization	Maximum depressurization rate Time limits for recovery from depressurization
4.4.3.2 Respond to uncontrolled pressurization	Time limits for recovery from depressurization Time limits for decompression back to nominal pressure
4.4.3.5 Respond to hazardous atmosphere	Hazardous airborne contaminants detection criteria
4.4.4.1 Provide inert diluent gas	Inert diluent gas usage and contingency needs, including pressurized volumes re-pressurization
4.4.4.2 Provide oxygen	Amount of oxygen to support human metabolic needs EVA suit flush procedure Minimum oxygen storage quantity
4.4.4.3 Provide breathing gases for specific situations	Composition, quality and quantity of breathing gases
4.4.4.4 Provide water	Water qualities for each usage Minimum water storage quantities Water peak usage demand
4.4.4.5 Provide food	Nutritional requirements Food safety criteria Fraction of recreational food Variety of food Food usage and contingency needs Food storage conditions Food production expendable by-products Food monitoring requirements
4.4.5.1 Manage carbon dioxide	Carbon dioxide peak recovery rate and storage contingencies Monitoring quantity and quality of stored carbon dioxide requirements Requirements for stored CO ₂ monitoring For long duration missions the capability for recovering oxygen or any product from carbon dioxide

Clause	Parameter
4.4.5.2 Manage waste water	Stored waste water monitoring requirements Processed waste water quality Waste water disposal safety and environmental guidelines Recovery rate of waste water
4.4.5.3 Manage gas, solid and concentrated liquid wastes	Monitoring of physical, chemical and biological wastes requirements Non-recovered waste disposal safety and environmental guidelines Recovery rate of gas, solid and concentrated liquids
4.4.6 Support EVA operations	Equipment to clean and dry space suits Equipment and consumables supporting pre-breathe procedure Nominal rate of decompression for EVA egress Minimum % of airlock atmosphere to be recovered Nominal rate of re-compression after EVA
4.6.2 Ground support equipment (GSE)	GSE requirements
4.6.3.2 Software, data systems, interface	ECLSS data handling and software requirements
4.6.3.5 Mechanical and structural interface	Stability requirements
4.6.3.6 Electric power	Electric power requirements
4.8 Product assurance and safety	PA and safety policy
4.9.1 Hardware	All products for delivery

A.2 Monitoring of parameters

Table A-2 lists the parameters to be monitored, and refers to the provisions where these parameters are specified.

Table A-2: List of parameters to be monitored

Clause	Parameter
4.4.2 Maintain environment	Total pressure Differential pressure (over-pressure, under-pressure) Temperature (Dry bulb) Humidity (Wet bulb, relative humidity) Ventilation and air flow Oxygen partial pressure Carbon dioxide partial pressure Carbon monoxide partial pressure Trace gases to be monitored (list is project dependent) Airborne particles microorganisms Ionizing radiation
4.4.4 Provide resources	Nitrogen or other inert gas Oxygen Other breathable gases Water (quality and quantity) Food (quality, quantity, individual diet)
4.4.5 Manage waste	Carbon dioxide Water Gas, solid and concentrated liquids
4.4.7 Provide health related services	Drugs

Annex B (informative)

Reference information for parameters

B.1 Previous flight data

In order to provide the designers with basic information on the values which can be used for dimensioning the systems, the data from previous flights and the reference values of ISS are listed in Table B-1 to Table B-5.

Table B-1: Previous flight data

Parameter	Earth ^a	Skylab (1973-4) ^b	MIR (1986-) ^c	SSF (1992) ^d	STD-3000 (1995) ^e	ISS (1996) ^f
-	-	84 day max. stay	365 day max. stay	90+ day design stay	-	90+ day design stay
Total pressure, kPa	101,3	34,5	88,0-114,7	100,0-102,7	100,0-102,7	97,9-102,7
O ₂ partial pressure, kPa	21,0	22,8-26,9	20,0-26,7	19,5-23,1	19,5-23,1	19,5-23,1
CO ₂ partial pressure, Pa	31-100	670 (nominal)	≤ 800	≤ 400	≤ 400	Average < 707, peak < 1 013
Diluent gas	N ₂ /Ar	N ₂	N ₂	N ₂	N ₂	N ₂
Temperature, °K	292,5-300,5	285,9-305,4	291,1-301,1	291,5-299,8	291,5-299,8	291,5-302,6
Dew point, °K	274,9-289,9	280,9-288,7	-	277,6-288,7	277,6-288,7	277,6-288,7
Relative humidity, %	20-85	25-85	30-70 ^g	25-70	25-70	25-70
Ventilation, m/s	< 0,1	-	0,2-0,5	0,076-0,203	0,076-0,203	0,051-0,203
Particles (> 0,5 µm), particles/m ³	-	-	-	< 3,5E6	≤ 3,5E6	Average < 3,5E6, peak < 7,1E7
Particles (> 0,5 µm), µg/m ³	8-9 (nominal)	-	-	-	-	Average < 50, peak < 1000
Microorganisms ^h , CFU/m ³	200-600	-	-	≤ 1000	≤ 500	Average < 1000
Trace contaminants	Variable	-	see ref. (c)	≤ SMAC ⁱ	≤ SMAC ⁱ	≤ SMAC ⁱ

a Total pressure, O₂ partial pressure and lower bound on CO₂ partial pressure are based on ambient, sea-level conditions (Lide, 1995). Upper bound on CO₂ partial pressure is considered a nominal-to-high indoor value based on the ASHRAE standard for indoor-outdoor air exchange (ASHRAE, 1989) (indoor values as high as 300 Pa are reported). Temperature, dew point, relative humidity, and ventilation ranges are based on bounds of the ASHRAE indoor comfort zones (ASHRAE, 1989). Particulate levels are indoor values (for particulates > 2,5 µm) reported by Liu, et al. (1991). Microorganism levels are indoor values (for manufacturing areas) reported in the ISS ECLS requirements document (D684-10508-1-4, 1996).
 b Ref: Wieland, 1994.
 c Ref: D684-10508-2-3, 1996.
 d Ref: JSC-31000, 1992; SSP-30000, 1992; NASA-STD-3000, 1991.
 e Ref: NASA-STD-3000, 1995. Based on values reported in customary units.
 f Ref: D684-10508-1-1, 1996; D684-10508-1-2, 1996; D684-10508-1-4, 1996, D684-10508-2-1, 1996.
 g At 293,1 K. Water vapour partial pressure is reported to be 1,3 @ 0,7 kPa.
 h CFU = Colony forming units.
 i SMAC = Spacecraft maximum allowable concentration.

NOTE: For additional references, see Annex C .

Table B-2: American programmes - Requirements

Programme	MERCURY	GEMINI	APOLLO COMMAND MODULE	APOLLO LUNAR MODULE	SKYLAB	ORBITER (baseline)	SPACELAB ^a (baseline)
Operational period	1961 – 1963	1965 – 1966	1968 - 1972	1968 - 1972	1973 - 1974	1980's	1983
Mission duration, days	< 1 to 1,5	< 1 to 14	6 to 13	1 to 4	28 to 84	7	Cf orbiter
Crew size (men)	1	2	3	2	3	4 to 7	0 – 4
Power : generation type	battery	fuel cells + battery	fuel cells	1.1.1.1	solar power	fuel cells	1.1.1.2
Output, kW	1.1.1.3	1.1.1.4	4	1.1.1.5	23	21	from orbiter
Atmosphere type	oxygen	oxygen	oxygen	oxygen	oxygen and nitrogen	oxygen and nitrogen	oxygen and nitrogen
Total cabin Pressure, hPa	345	345	345	345	345	1013	1013
O ₂ partial pressure, hPa	345	345	345	345	250	220	220
CO ₂ partial pressure (max), hPa	10,6	10,1	10,1	1.1.1.6	7,3	6,6 - 10,1	6,6 – 10,1
Temperature, °C	15 - 22	15 - 22	25	1.1.1.7	18 – 24	21	18 – 27
Humidity, %	1.1.1.8	1.1.1.9	1.1.1.10	1.1.1.11	1.1.1.12	1.1.1.13	50
^a European contribution							
NOTE: For references see Annex C .							

Table B-3: American programmes - Functions

Programme	MERCURY	GEMINI	APOLLO COMMAND MODULE	APOLLO LUNAR MODULE	SKYLAB	ORBITER (baseline)	SPACELAB ^a (baseline)
Operational period	1961 – 1963	1965 – 1966	1968 - 1972	1968 - 1972	1973 - 1974	1980's	1983
Oxygen supply	Stored	Stored	Stored (cryo)	Stored + cryo	Stored (cryo)	Stored + cryo	From orbiter
Nitrogen supply	N/A	N/A	N/A	N/A	Stored	Stored	Stored
CO ₂ control	LiOH	LiOH	LiOH	LiOH	R	LiOH	LiOH
CO control	none	none	none	none	None	none	none
Humidity control	CHX	CHX	CHX	Suit cooling	CHX	CHX	CHX
Trace contaminant monitoring	1.1.1.14	1.1.1.15	no	no	No	1.1.1.16	no
Trace contaminant control	Charcoal + leak	Charcoal + leak	Charcoal + leak	Charcoal + leak	Charcoal + leak	Charcoal + leak	Charcoal + leak
Gas recovery / Regeneration	none	none	none	none	none	none	none
Gas storage	O ₂ (500 bar)	O ₂ cryo	O ₂ cryo	O ₂ 186 b cryo	O ₂ N ₂ (200 b)	O ₂ N ₂ (230 b)	N ₂ (230 b)
Fire detection	Crew sense	Crew sense	Crew sense	Crew sense	UV detector	Ionis. smoke	Ionis. smoke
Fire suppressant	Water spray Manual, venting	Water spray venting	Water gel venting	Water gel venting	Water gel Venting	Halon venting	Halon venting
^a European contribution							
NOTE: For references see Annex C .							

Table B-4: Russian programmes - Requirements

Programme	VOSTOCK	VOSKHOD	SOYUZ, T and TM	SALYUT	MIR
Operational period	1961 – 1963	1964 – 1965	Soyuz 1967 – 1981 T 1980 – 1986 T M ? - 1987	1971 – 1986	1986 - 2002
Mission duration, days	1 to 5	1	1 to 17	Max. 236	Max. 366
Crew size (men)	1	2 (V2) and 3 (V1)	1 to 3	2 to 6	2 to 6
Atmosphere type	Air	Air	O ₂ / N ₂ (N ₂ : 70-80 %)	O ₂ / N ₂	O ₂ / N ₂ Max 78 % N ₂
Total cabin pressure, hPa	1013	1013	1013 (3)	1013	600 - 1280
O ₂ partial pressure, hPa	1.1.1.17	1.1.1.18	Max. 304	210 - 317	Max. 470
CO ₂ partial pressure (max.), hPa	1.1.1.19	1.1.1.20	1.1.1.21	1.1.1.22	Max. 30
Temperature, °C	12 - 25	12 - 25	12 – 25	12 - 25	20 comfort (18-28)
Humidity, %	30 - 70	30 - 70	30 – 70	1.1.1.23	20 – 70 (for T = 20 °C)
NOTE: For references see Annex C .					

Table B-5: Russian programmes - Functions

Programme	VOSTOCK	VOSKHOD	SOYUZ, T, and TM	SALYUT	MIR
Operational period	1961 – 1963	1964 - 1965	Soyuz 1967 – 1981 T 1980 – 1986; TM ? - 1987	1971 - 1986	1986 - 2002
Oxygen supply	KO ₂	KO ₂	KO ₂	KO ₂	KO ₂
Nitrogen supply	Air storage	Air storage		Air storage	Air storage
CO ₂ control	KO ₂	KO ₂	KO ₂	KO ₂ + LiOH	KO ₂ + LiOH
CO control					
Humidity control	KO ₂ + Silicagel + LiCl	KO ₂ + charcoal	KO ₂ + charcoal		
Trace contaminant monitoring					
Air flow, m/s	fan	fan	fan	adjust. 0,1 – 0,8	fan + air ducts
Gas monitoring	O ₂ CO ₂ only	O ₂ CO ₂ only	O ₂ CO ₂ only	O ₂ CO ₂ only	O ₂ CO ₂ only
Trace contaminant control	KO ₂ + charcoal	KO ₂ + charcoal	KO ₂ + charcoal	KO ₂ + charcoal	KO ₂ + charcoal
Gas recovery / Regeneration					Electrolysis
Gas storage	Comp. air + KO ₂	Comp. air + KO ₂	KO ₂	Comp. air + KO ₂	Compressed air + KO ₂
Fire detection	none			CO ₂ detectors	
Fire suppressant					
NOTE: For references see Annex C .					

B.2 ISS data

B.2.1 Atmosphere

Table B-6 lists the atmosphere data from existing programs.

Table B-6: Atmosphere data

Parameter	US ECLS Requirements	Russian ECLS requirements
	Range	Range
Total pressure	97,9 kPa to 102,7 kPa (95,8 min)	79,9 kPa to 114,4 kPa (93,0 normal min)
Total pressure monitoring	0 to 110,6 kPa	1 kPa to 131,58 kPa
PCO ₂ ^a	0,705 kPa to 1,011 kPa (0,705 kPa normal 24 h average)	0,69 kPa up to 3 people 1,0 kPa up to 5 people 0,59 kPa average
PCO ₂ Monitoring	0 to 2,0 kPa	0 to 3,33 kPa
PO ₂	19,5 kPa to 23,1 kPa	19,5 kPa to 23,1 kPa
PO ₂ monitoring	0 to 40 kPa	-
PN ₂	< 80 kPa	< 80 kPa
Relative humidity	25 % to 70 %	30 % to 70 %
Relative humidity monitoring	Not monitored	1 kPa to 4,6 kPa (± 0,2 kPa accuracy)
Atmospheric temperature ^b	17,8 °C to 26,7 °C	18 °C to 28 °C
Atmospheric temperature Monitoring	15,6 °C to 32,2 °C (± 1,8 °C)	-
Dew point temperature	4,4 °C to 15,6 °C	4,4 °C to 15,6 °C
Intramodule air circulation	0,051 m/s to 0,20 m/s (0,036 m/s to 1,02 m/s lower and upper limits)	0,05 m/s to 2,0 m/s
Intramodule air flow	(66 ± 2,4) l/s	(60 to 70) l/s
Fire suppression PO ₂ level	10,5 %	-
Particulate concentration (0,5 to 100) mm diameter	Average < 0,05 mg/m ³	< 0,15 mg/m ³
Temperature of surfaces	4 °C < Touch temperature < 45 °C 46 °C to 49 °C for momentary contact	> dew point
Atmospheric leakage ^c per module	Max. of 0,23 kg/day at 101,3 kPa	< 0,02 kg/day (Pressure not specified; assume 101,3 kPa)

^a During crew ex changes the maximum daily average PCO₂ is 1,01 kPa, with a peak of up to 1,33 kPa.

^b For Node 1, the cupola, and the MPLM; the requirement is (18,8 to 29,4) °C since these modules do not have a CCAA.

^c Total atmospheric leakage is less than 0,68 kg/day, although the ability to accommodate 2,04 kg/day leakage is present.

NOTE: For references see Annex C .

B.2.2 ECLS loads

Table B-7 lists the metabolic loads from existing programs.

Table B-7: Metabolic loads

Parameter	U.S. ECLS loads		Russian ERCLS loads	
	Standard value	Range	Standard value	Range
Crew O ₂ consumption (kg/person/day)	0,84	0,49 to 1,25	0,86	
Experiment O ₂ consumption (g/day)	120	-		
Animal O ₂ consumption (kg/day)	1,08			
Crew heat loads (W/person)	137	-		
Experimental animals heat loads ^a (W)	6	-		
Animal-generated moisture	136 g	TBD	2,5 l/day/animal	
Crew water consumption (kg/day/person)	2,8	Up to 5,15		
Crew hygiene water usage (kg/day/person)	6,8	Up to 7,3	1,1 (ISS service module only) 4,43 (ISS service module and Life Support Module)	
Crew urine production (kg/day/person)	1,56	Up to 2,0	1,2	
Microbial generation rate (CFU/person/day)	3,0	N/A		
Particles generation rate (pcs/person/day)	1 × 10 ⁹	N/A		
Crew CO ₂ generation rate ^b (kg/person/day)	1,00	0,52 to 1,50	1,00	
Animal CO ₂ generation rate (g/day)	136	-		
^a These values are for rodents. Up to 72 rodents (or an equivalent metabolic load) can be accommodated.				
^b The CO ₂ generation rate is based on CO ₂ releases of 13,5 l/hr during sleep, 18,7 l/hr during light work, and 72 l/hr during exercise.				
NOTE: For references see Annex C .				

B.2.3 Water quality

Table B-8 lists the water quality specifications from existing programs.

Table B-8: Water quality specifications

Parameters ^b	Potable water specifications	Parameters ^b	Potable water specifications
Physical		Inorganic constituents	
- Total solids	100 mg/l	- Ammonia	0,5
- Colour true	15 pt/Co Units	- Arsenic	0,01
- Taste	3 TTN	- Barium	1,0
- Odour	3 TON	- Cadmium	0,005
- Particles	40 µ max. size	- Calcium	30
- pH	6 to 8,5	- Chlorine (Total includes chloride)	200
- Turbidity	1 NTU	- Chromium	0,05
- Dissolved gases ^a	(free at 37 °C)	- Copper	1,0
- Free gas ^a	(STP)	- Iodine (Total includes organic iodine)	15
Aesthetics		- Iron	0,3
- CO ₂	15 mg/l	- Lead	0,05
Microbial		- Magnesium	50
- Bacteria/fungi	100 CFM/100 ml	- Manganese	0,05
- Total coliform	< 1 CFU/100 ml	- Mercury	0,002
- Virus	< 1 CFU/100 ml	- Nickel	0,05
		- Nitrate (NO ₃ -N)	10
		- Potassium	340
		- Selenium	0,01
		- Silver	0,05
		- Sulphate	250
		- Sulphide	0,05
		- Zinc	5
Organic parameters		Bactericide	
- Total acids	500 µg/l	- Residual iodine (minimum)	1
- Cyanide	200 µg/l	- Residual iodine (maximum)	4
- Halogenated hydrocarbons	1 µg/l		
- Total phenols	500 µg/l		
- Total alcohols	500 µg/l		
- Total organic carbon (TOC) ^c	100 µg/l		
- Uncharacterized TOC (UTOC) ^c			
<p>a No detectable gas using a volumetric gas versus fluid measurement system-excludes CO₂ used for aesthetic purposes.</p> <p>b Each parameter-constituent maximum contamination level (MCL) is considered individually and independently of others.</p> <p>c UTOC equals TOC minus the sum of analysed organic constituents expressed in equivalent TOC.</p>			
NOTE: For references see Annex C .			

B.2.4 Radiation doses

The limit dose values for the ISS crew exposure are given in the following tables:

- Consensus dose limits for the international partners of the ISS are listed in Table B-9 and Table B-10.

Crew exposures are managed in conformance with the ALARA (as low as reasonably achievable) principle. Current career limits for each agency are documented in the AMERD (JSC 24834).

If nuclear generator systems are employed, the effects of radiation from them on crew and systems are carefully assessed.

Table B-9 and Table B-10 show the current US astronaut exposure limits based on recommendations by the National Council on Radiological Protection and Measurements (NCRP). Exposure to large solar flares or long-term exposure to cosmic rays can exceed these limits. Note that these limits are considerably above those for non-space workers.

- Table B-11 shows the current career exposure limits.

These limits are expressed in effective dose. The career depth equivalent dose limit is based upon a maximum 3% lifetime excess risk of cancer mortality and has additional components of detriment associated with it, namely the risk of heritable effects (0,6%) and of non-fatal cancer (also 0,6%) for a total detriment of 4,2%. These nominal risks are as given in ICRP (1991a) and NCRP (1993a). The total equivalent dose yielding this risk depends on sex and age at the start of exposure.

Table B-9: Current ionizing radiation equivalent dose limits

Organ specific equivalent dose limits	
Exposure interval	BFO (Sv)
30 days	0,25
Annual	0,50
For references, see Annex C .	

Table B-10: Organ dose limits for deterministic effects (all ages)

Exposure interval	Bone marrow (Sv)	Eye (Sv)	Skin (Sv)
30 days	0,25	1,0	1,5
Annual	0,50	2,0	3,0
Career	-	4,0	6,0
For references, see Annex C .			

Table B-11: Current career exposure limits

Sex	Age of exposure			
	25	35	45	55
Male	0,7	1,0	1,5	3,0
Female	0,4	0,6	0,9	1,7

NOTE 1: Based on 3% excess lifetime risk on fatal cancer in Sv.
NOTE 2: For references, see Annex C .

Annex C (informative) References

Additional data for ECLS can be found in the following documents:

- [1] ESA-PSS-03-40 Issue 1, 1992: Environmental control and life support
- [2] ESA-PSS-03-401 Issue 1, 1992: Atmosphere quality standards in manned space vehicles
- [3] ESA-PSS-03-402 Issue 1, 1994: Water quality standards in manned space vehicles
- [4] ESA-PSS-03-70 Issue 1, 1994: Human factors Volume 1 and 2
- [5] NASA STD 3000 Man-Systems Integration Standards, 2002 : Volumes I and II - JSC-ARD-OHAB\SF-INTRA\MSIS-Review\DOC files
- [6] NASA/TM-1998-206956/Vol1: Living together in Space : The design and operation of the Life Support System on the ISS.
- [7] NASA/CTSD-ADV-245 (REV A) 1998: Advanced Life Support Program – Requirements Definition and Design Considerations. JSC 38571.
- [8] NASA/CTSD-ADV-371 1999: Advanced Life Support – Systems Modeling and Analysis Project Baseline and Assumptions Document. JSC 39317.

Bibliography

The publications listed below were used in the preparation of this standard, and contain background information relating to the subject addressed.

ECSS-S-ST-00	ECSS System – Description , implementation and general requirements
ECSS-E-ST-10-03	Space engineering – Testing
ECSS-E-ST-10-11	Space engineering – Human factors engineering
ECSS-E-ST-20	Space engineering – Electrical and electronic
ECSS-E-ST-31	Space engineering – Thermal control general requirements
ECSS-E-ST-32	Space engineering – Structural general requirements
ECSS-E-ST-32-01	Space engineering – Fracture control
ECSS-E-ST-32-08	Space engineering – Materials
ECSS-E-ST-33-01	Space engineering – Mechanisms
ECSS-E-TM-10-10	Space engineering – Logistics engineering
ECSS-M-ST-10	Space project management – Project planning and implementation
ECSS-Q-ST-20	Space product assurance – Quality assurance
ECSS-Q-ST-30-02	Space product assurance – Failure modes, effects (and criticality) analysis (FMEA/FMECA)