ECSS-E-30 Part 4A

5 August 2005

EUROPEAN COOPERATION

ECSS

FOR SPACE STANDARDIZATION

# Space engineering

## Mechanical – Part 4: Environmental control and life support

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ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

Published by: ESA Publications Division
ESTEC, P.O. Box 299,
2200 AG Noordwijk,
The Netherlands

ISSN: 1028-396X

Price: € 20

Printed in: The Netherlands

# 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 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 standard.

The formulation of this Standard takes into account the existing ISO 9000 family of documents.

This Standard has been prepared by the ECSS-E-30 Part 4 Working Group, reviewed by the ECSS Engineering Panel and approved by the ECSS Steering Board.

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# Contents

## Tables

# 1

# Scope

This Standard is the Part 4 of ECSS-E-30 (Space engineering – Mechanical). It 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 as defined in ECSS-E-00, and
- any other form of life to be maintained on board.

When viewed from the perspective of a specific project context, the requirements defined in this standard should be tailored to match the genuine requirements of a particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements or specifications, standards and related documents are evaluated and made applicable to a specific project, by selection and, in some exceptional cases, modification of existing or addition of new requirements.

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# 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 revisions 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 most recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

| | |
|---|---|
| ECSS-P-001B | Glossary of terms |
| ECSS-E-10 Part 2B [1)] | Space engineering — System engineering — Part 2: Verification |
| ECSS-E-10 Part 17A [1)] | Space engineering — System engineering — Part 17: System engineering DRDs |
| ECSS-E-10-03A | Space engineering – Testing |
| ECSS-E-70B [1)] | Space engineering – Ground systems and operations |
| ECSS-Q-20B | Space product assurance – Quality assurance |

1) To be published.

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# 3

# Terms, definitions and abbreviated terms

## 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ECSS-P-001 and the following apply.

### 3.1.1
**anoxic**

gas or atmosphere containing no oxygen

### 3.1.2
**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.

### 3.1.3
**compression**

EVA related action to increase total pressure

### 3.1.4
**decompression**

EVA related action to reduce the total pressure

### 3.1.5
**depressurization**

action to reduce the total pressure

### 3.1.6
**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.

**3.1.7**
**environmental control and life support system (ECLSS)**
system that includes the hardware and software to perform ECLS functions

**3.1.8**
**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

**3.1.9**
**open-loop ECLSS**
ECLSS based on external resupply of resources

**3.1.10**
**partial pressure**
participation of one of the constituents of a gas mixture or an atmosphere in the total pressure

NOTE 1 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:
$PO_2 = 0{,}21 \times 1{,}013 \times 10^6$ Pa = $0.213 \times 10^6$ Pa.

NOTE 2 Abbreviation for partial pressure is P followed by the chemical formula of the constituent.

EXAMPLE 1 $PCO_2$, stands for partial pressure of carbon dioxide,

EXAMPLE 2 $PH_2O$, stands for water vapour partial pressure.

**3.1.11**
**pressurization**
action to increase the total pressure

**3.1.12**
**re-compression**
<EVA> EVA related action to restore the total pressure after decompression or to treat decompression illness

**3.1.13**
**re-compression**
<Other than EVA> action to restore the total pressure after depressurization

**3.1.14**
**re-pressurization**
action to restore the total pressure after depressurization

**3.1.15**
**safe haven**
facility capable of sustaining human life under emergency conditions as a minimum, in the case of a life threatening situation

## 3.2 Abbreviated terms

The following abbreviated terms are defined and used in this document:

| 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 |

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# 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.

Relevant DRDs are listed in subclause 4.9.2.

## 4.2 Mission and system

### 4.2.1 General

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

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

NOTE For project phases and planning, see ECSS-M-30.

#### 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

The following requirements 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):

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

When a vehicle is used for several missions, the following issues shall be addressed during the design phase (project Phase B):

a. standby, storage and parking conditions between missions;

b. 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-10 Part 11.

#### 4.3.1.2 Forms of life other than humans

a. Metabolism

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).

b. Environmental conditions

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

For forms of life other than human, requirements shall

a. define the environment suitable for the forms of life to be supported, and

b. take into account the potential interference with the human mission requirements.

### 4.3.3 Environmental condition

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 subclause 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

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 1.

**Table 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<br>Crew quarter | Behind racks, panels, floor or ceiling which can be removed |

#### 4.4.2.2 Control atmosphere total pressure

a. Total atmospheric pressure

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

b. Monitor atmosphere total pressure

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

c. Means for adjusting pressure

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.

d. Prevent over-pressurization

Over-pressurization shall be prevented.

e. Equalize atmosphere pressure

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

f. Add inert diluent gas to atmosphere

1. 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.

2. 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.
3. 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.
4. The limits for pressure adjustments, decompression, compression and re-compression shall be specified.
5. Means to manage pressure change rates within the specified limits shall be provided.

g. Add oxygen to atmosphere

1. 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.
2. 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.
3. Addition of oxygen shall not create risk of fire.

#### 4.4.2.3 Control thermal nominal condition

a. Maintain thermal nominal condition

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.

b. Maintain temperature

1. The atmosphere dry bulb temperature in the habitable volume shall be selectable within the operational range.
2. The accuracy for the stabilized dry bulb temperature in the habitable volume shall be specified.
3. 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.
4. The points of measurement for the dry bulb temperature shall be representative for the habitable volume situation.

c. Maintain atmosphere humidity

1. The range for the atmosphere relative humidity in the habitable volume shall be specified.
2. 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.

d. Monitor atmosphere humidity

1. The range and the accuracy to monitor the atmosphere relative humidity in the habitable volumes shall be specified.
2. The range and accuracy of the atmosphere dew point temperature to be monitored in the pressurized volumes shall be specified.

3. Water vapour shall be removed from or added to the pressurized volume atmosphere at a rate capable of maintaining the specified range.

e. Circulate atmosphere

As atmosphere circulation in the habitable volume is intended to maintain thermal nominal condition and atmospheric composition, control of atmosphere circulation includes the following:

1. Ventilate habitable volume

Atmosphere velocities in the habitable volume shall be maintained within the specified air velocity ranges, adapted to total atmospheric pressure situation.

NOTE Gas velocity ranges can differ between habitable and non-habitable volume.

2. Exchange of atmosphere between pressurized volumes

Atmosphere exchange between connected pressurized volumes shall be specified.

3. Monitor ventilation and atmosphere exchange

Location of ventilation and atmosphere exchange monitoring shall be specified.

#### 4.4.2.4 Control oxygen partial pressure

a. Maintain oxygen partial pressure

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

b. Monitor oxygen partial pressure

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

c. Add oxygen into the atmosphere

Requirements in 4.4.2.2 g. shall apply.

#### 4.4.2.5 Control carbon dioxide partial pressure

a. Maintain low carbon dioxide partial pressure

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

b. Remove carbon dioxide from atmosphere

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.

c. Monitor carbon dioxide partial pressure

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

a. Maintain low carbon monoxide partial pressure

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

b. Remove carbon monoxide from atmosphere

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.

c. Monitor carbon monoxide partial pressure

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

a. Maintain low trace gases partial pressures and odour

1. 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.
2. The threshold values for the odour in the atmosphere shall be specified.

b. Remove trace gas and odour from atmosphere

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.

c. Monitor trace gases in atmosphere

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 airborn particles

a. Maintain low level of airborne particles

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

b. Remove airborne particles from atmosphere

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

c. Monitor airborne particles in atmosphere

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

#### 4.4.2.9 Control microorganisms

a. Maintain low level of airborne microorganisms

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

b. Remove airborne microorganisms from atmosphere

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

c. Monitor airborne microorganisms in atmosphere

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

d. Monitor surface microorganisms

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

#### 4.4.2.10 Support ionizing radiation control

a. Monitoring

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

b. Shielding

1. Ionizing radiation limits shall be specified.
2. 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

Non-ionizing radiation limits should be specified.

### 4.4.3 Respond to environmental contingencies

#### 4.4.3.1 Respond to uncontrolled depressurization

The functionality to detect and recover from uncontrolled depressurization events covers:

a. Detect uncontrolled depressurization

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.

b. Recover from uncontrolled depressurization

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

#### 4.4.3.2 Respond to uncontrolled pressurization

The functionality to detect and recover from uncontrolled pressurization covers:

a. Detect uncontrolled pressurization

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

b. Recover from uncontrolled pressurization

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

#### 4.4.3.3 Respond to fire

The functionality to detect, suppress, and recover from fire events in the pressurized volume to be provided includes:

a. Detect fire, smoke, smouldering

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

b. Isolate fire

Fire events shall be isolated in the affected location.

c. Suppress fire

The capability to suppress a fire shall be provided.

d. Recover from fire

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

The functionality to detect and protect from hazardous radiation conditions to be provided includes:

a. Detect hazardous radiation levels

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

b. Provide human protection from radiation

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

c. Detect radiation level normalization

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

d. Inform humans that they can move out from protection

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

#### 4.4.3.5 Respond to hazardous atmosphere

The functionality to detect and recover from a hazardous atmosphere to be provided includes:

a. Detect hazardous atmosphere

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

b. Provide human protection

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

c. Restore an acceptable atmosphere

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

d. Recover from hazardous atmosphere

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

The supply of inert diluent gases (for example nitrogen) to support the diluent gases needs includes:

a. Supply inert diluent gases

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

b. Store inert diluent gas

1. Inert diluent gas usage and contingency needs, including pressurized volumes re-pressurization, shall be specified.
2. Storage of inert diluent gas shall be provided with the capacity to meet usage and contingency needs specified in 1. above.

c. Monitor inert diluent gas storage

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

d. Accept external inert diluent gas

Resupply of inert diluent gas shall be accepted in accordance with the interface specifications.

#### 4.4.4.2 Provide oxygen

Requirements on supply of oxygen includes:

a. Oxygen needs

1. The amount of oxygen to support human metabolic needs shall be specified.
2. Oxygen shall be provided to support human metabolic needs specified in 1. above.
3. Oxygen shall be provided for EMU recharging to support nominal human metabolic needs, as specified in 1. above.
4. An EVA suit flush procedure shall be specified.
5. Oxygen shall be provided for breathing during de-nitrogenation process and the EVA suit flush procedure specified in 4. above.
6. Oxygen shall be provided to make up for atmosphere leakage.
7. Oxygen shall be provided to make up for airlock losses during EVA exit and reentry.
8. Oxygen shall be provided to restore the accessible volume atmosphere in the event of loss of pressure.
9. Oxygen shall be provided to support portable and umbilical supplied emergency oxygen breathing equipment.

b. Supply oxygen

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

c. Store oxygen

1. Oxygen usage and contingency needs, including the accessible volume's atmosphere restoration, shall be specified.

2. Storage of oxygen or oxygen generating resources shall be provided with the capacity to meet the usage and contingency needs specified in 1. above.

d. Generate or recycle oxygen

Oxygen shall be generated and recycled at a rate capable of maintaining at least the specified minimum oxygen storage specified in c. 2.

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

e. Monitor oxygen consumption and oxygen storage

The quantity of stored oxygen shall be monitored.

f. Accept external oxygen

Resupplied oxygen shall be accepted in accordance with the interface specifications.

#### 4.4.4.3 Provide breathing gases for specific situations

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

a. Supply breathing gases

Breathing gases shall be supplied to points of use in accordance with the applicable interface specifications for gas temperature, pressure and flow rate.

b. Store breathing gases

Storage breathing gases capacity shall be specified.

c. Mix or recycle breathing gases

When mixing or recycling of gases takes place onboard, the quality of the produced gases shall be specified.

d. Monitor breathing gases consumption and gases in stock

The quantity of stored breathing gases shall be monitored.

e. Accept external gases

Resupplied external breathing gases shall be accepted in accordance with the interface specifications.

#### 4.4.4.4 Provide water

Requirements on the supply of water to support the various needs include:

a. Water needs

1. Potable water needs, including water for drinking, oral hygiene, and food preparation (e.g. rehydration), shall be specified.
2. Hygiene water needs, including water for personal hygiene, laundry and dishwashing, shall be specified.
3. Water needs for medical purposes (e.g. sterile water and medicine reconstitution) shall be specified.
4. Water to meet the water needs specified in 1., 2. and 3. above shall be provided.

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

b. Water quality

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.

c. Supply water

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

d. Store water

1. The water peak usage and contingency needs shall be specified.
2. Storage of water shall be provided with the capacity and flow rate to meet the peak usage demand specified in 1. above.
3. The quantity of stored potable water shall meet the contingency needs specified in 1. above.

e. Monitor water in storage

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

f. Generate and regenerate water

1. Water shall be regenerated at a rate capable of maintaining at least the minimum water storage specified in d.
2. 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.

g. Accept external water

Resupplied water shall be accepted in accordance with the interface specifications.

NOTE Resupply can include water obtained from in situ resources.

#### 4.4.4.5 Provide food

Requirements on the supply of food provided to support humans, and availability in the habitable volume during all phases of the mission, include:

a. Supply food and food ingredients

Requirements on supply of food according to a daily individual diet of a crew-member consistent with human physiological requirements include:

1. Nutritional requirements shall be specified.
2. Food shall be provided for human consumption in accordance with the nutritional requirements specified in 1. above.
3. 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.
4. Prior to consumption, food shall meet specified food safety requirements.
5. The choice of food shall meet food related psychological needs, that is:
   (a) The choice of food shall accommodate foods for special events.

(b) The fraction of mass and calories of recreational foods to be included in the choice of food shall be specified.

(c) The variety of foods to be included in the choice of food shall be specified.

(d) The diet shall be composed of palatable food and shall be made of similar ingredients to those used by the crew members on Earth.

(e) The meals shall take into account ethnic and cultural food pattern differences between crew members.

b. Store food

1. Food usage and contingency needs shall be specified.
2. Storage of food and food ingredients shall be provided with the capacity to meet the usage and contingency needs specified in 1. above.
3. 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.

c. Produce food

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

d. Monitor food

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

e. 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 b. above.
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.

f. 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 .

g. Generate food and food ingredients

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

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

h. Accept external food and food ingredients

Resupplied food and food ingredients shall be accepted in accordance with the interface specifications.

### 4.4.5 Manage waste

#### 4.4.5.1 Manage carbon dioxide

Requirements on management of carbon dioxide for resource recovery, storage or disposal are specified in a. to e. below.

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

a. Accept carbon dioxide

Carbon dioxide shall be accepted from points of collection in accordance with interface specifications.

b. Store carbon dioxide

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

NOTE Storage contingencies include temporary loss of downstream processing capability.

2. Storage of carbon dioxide shall be provided with the capacity to meet the peak recovery rate and storage contingencies specified in 1. above.

c. Monitor carbon dioxide waste

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

d. Process carbon dioxide

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

e. Dispose excess carbon dioxide

The capability to dispose excess carbon dioxide shall be provided.

#### 4.4.5.2 Manage waste water

Requirements on management of waste water for recovery, storage or disposal include:

a. Collect and accept waste water

Waste water shall be collected and accepted in accordance with the interface specifications.

b. Store waste water

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.

c. Monitor waste water

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

d. Process waste water

1. Waste water shall be processed to recover potable and hygiene water .

NOTE Processing can include chemical stabilization and water recovery.

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

NOTE Other uses can include hydroponic solutions preparation.

e. Dispose excess waste water

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

Requirements for the processing of gas, solid and concentrated liquid wastes for resource recovery, storage or disposal include:

a. Collect and accept gas, solid and concentrated liquid wastes

1. Gas, solid and concentrated liquid wastes shall be accepted from points of collection in accordance with the interface specifications.
2. 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,
- fecal 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:

- feces,
- 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.

b. Store gas, solid and concentrated liquid wastes

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

   NOTE Contingencies include temporary loss of downstream processing capability.

2. 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 1. above.

3. 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.

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

c. Monitor gas, solid and concentrated liquid wastes

1. Waste management shall keep records of the stored wastes status.
2. The quantity of stored wastes shall be monitored.
3. The requirements for monitoring of the physical, chemical and biological quality of wastes shall be specified.

d. Process gas, solid and concentrated liquid wastes

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

e. Dispose gas, solid and concentrated liquid wastes

1. 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.

2. 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

a. Support EMU servicing and check out

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

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

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

b. Support de-nitrogenation procedure

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

NOTE This requirement is equivalent to the ISS requirement.

c. Support decompression for egress

1. Decompression of the airlock from the habitable volume pressure to the external pressure shall be supported at a specified rate.

2. The minimum percentage of the airlock atmosphere to be recovered during decompression under nominal (non-emergency) EVA operations shall be specified.

d. Support re-compression for ingress

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.

e. Support contaminant detection and decontamination

1. Contaminant detection and decontamination of the EVA equipment and of the person shall be supported following an EVA.

2. The decontamination levels shall be specified.

f. Support decompression illness management

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

g. Support EVA radiation monitoring

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.

h. Support IVA

IVA operations shall be supported.

i. Support rover operations

Rover operations shall be supported.

j. Safe haven operation

Safe haven operations shall be supported.

### 4.4.7 Provide health related services

#### 4.4.7.1 Provide health monitoring

Requirements for providing health monitoring shall be specified.

#### 4.4.7.2 Provide medical assistance on board

a. Support first aid

Requirements on support of first aid shall be specified.

b. Provide medical equipment for diagnostic and treatment purposes

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

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

c. Provide drugs

Requirements shall be specified to

1. store drugs,

2. monitor quantity and quality of drugs,

3. dispose drug waste, and
4. dispose drugs.

d. Provide access to tele-medicine services

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

e. Provide means of sanitary evacuation

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

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

#### 4.4.7.4 Support gravity counter measures

The following requirements shall be specified:

a. requirements to support reduced gravity counter measures;

b. requirements to support increased gravity counter measures (launch and reentry).

## 4.5 Design

### 4.5.1 General

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 subclause 4.2) and functional requirements (see subclause 4.4)

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

### 4.5.2 Structural and mechanical

For structural and mechanical requirements, see ECSS-E-30 Parts 2, 3, 7 and 8.

### 4.5.3 Thermal

For thermal requirements applicable to ECLSS, see ECSS-E-30 Part 1.

### 4.5.4 Electrical and electromagnetic compatibility (EMC)

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

### 4.5.5 Operations and logistics

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

### 4.5.6 Failure detection, isolation and recovery

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

### 4.5.7 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-10 Part 11.

### 4.5.8 Data management control

The ECLSS shall include:

a. the sensors and control components for monitoring each ECLSS process and subsystem functions;

b. interface with the on-board data management system, and with ground base support;

c. visual and acoustic warning and alarm indications;

d. manual override control system.

## 4.6 Interface

### 4.6.1 General

The ECLSS design shall take into account the ECLSS hardware and software functional interfaces with:

a. other ECLSS in multiple ECLSS missions;

b. non-ECLSS hardware and software;

c. 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

Requirements on mission interfaces for flight system shall be specified.

#### 4.6.3.2 Software, data systems, interface

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

#### 4.6.3.3 Thermal control interface

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

As non-wanted forms of life can be present onboard, for example microbiological species, the ECLSS shall, as part of their functional requirements

a. monitor potential unwanted forms of life,

b. prevent dissemination of such form of life from ECLSS, and

c. control any unwanted form live developing on board.

#### 4.6.3.5 Mechanical and structural interface

a. Pressurized volume configuration and layout

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.

b. Mechanical load

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

c. Stability requirements

The following stability requirement shall be specified:

1. exported vibrations from ECLSS;
2. microgravity disturbances.

d. Hardware configuration

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

e. Forbidden zones

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.

f. Fracture control

Fracture control procedures shall be applied to ECLSS.

NOTE For requirements on fracture control, see ECSS-E-30-01.

#### 4.6.3.6 Electric power

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

EXAMPLE Peak and average electric power, duty cycles, and backup electric power.

#### 4.6.3.7 Environment for on-board equipment

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 accordance 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‐10 Part 2.

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 b.

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‐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

When verification by similarity is performed, similarity between the two items shall exist with respect to

a. functional design,

b. hardware used,

c. mission requirements, and

d. life time.

### 4.7.3 Verification by inspection

a. No physical contact with the hardware shall take place during an inspection.

b. if a. above is not met, the physical contact shall be planned and approved in accordance with ECSS‐E‐10 Part 2B subclause 5.8.

### 4.7.4 Verification by analysis

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).

### 4.7.5 Verification by test

The testing programme shall be established in accordance with ECSS-E-10 Part 2B subclause 5.5.

NOTE For requirements on testing, see ECSS-E-10-03.

## 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.

EXAMPLE 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 ECLSS shall be documented in accordance with the space engineering document requirements as specified in Table 2.

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

c. Since the ECLSS consist of several functional sub-units, for each sub-unit the specified documents shall be provided.

**Table 2: ECLSS references for DRD**

| Reference in table of contents | Controlling DRD Reference |
|---|---|
| 4.2 Mission and system | ECSS-E-10 Part 17A: System engineering DRDs:<br>Annex C: Mission description document<br>Annex D: System concept report<br>Annex E: System engineering plan |
| 4.3 General | ECSS-E-10 Part 6A: System engineering - Functional and technical specification<br>Annex A: Functional specification |
| 4.4 Functional | ECSS-E-10 Part 6A: System engineering - Functional and technical specification<br>Annex A: Functional specification<br>Annex B: Technical specification<br>Annex C: Interface requirement document<br>Annex D: Requirements traceability matrix<br>Annex E: Requirements justification file |
| 4.5 Design | ECSS-E-10 Part 17A System engineering DRDs<br>Annex H: Design definition file<br>Annex L: Design justification file |
| 4.6 Interface | ECSS-E-10 Part 4A:System engineering - Interface control<br>Annex A: Interface control document |
| 4.7 Verification | ECSS-E-10 Part 2B: System engineering - Verification<br>Annex B: Verification matrix<br>Annex C: Verification plan<br>Annex D: Assembly, integration and test plan<br>Annex E: Assembly, integration and verification plan<br>Annex F: Verification control document<br>Annex G: Test specification<br>Annex H: Test procedure<br>Annex I: Test report<br>Annex J: Analysis report<br>Annex K: Review-of-design report<br>Annex L: Inspection report<br>Annex M: Verification report<br>ECSS-E-10-03A: System engineering - Testing<br>Annex A: Test support specification |
| 4.8 Product assurance and safety | ECSS-Q-20B: Quality assurance<br>Annex B: Logbook<br>Annex C: End item data package<br>Annex D: Certificate of conformity |
| 4.9 Deliverables | ECSS-E-70B Ground system and operations<br>Installation manual<br>Installation plan<br>Accommodation handbook<br>User manual |

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# 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**

| Subclause | Parameter |
|---|---|
| 4.2.2.2 Identification of requirements, and<br>4.2.2.3 Mission phases | For each mission phase, specific ECLS requirements<br>Transport and storage condition of supplies |
| 4.4.2.2 Control atmosphere total pressure | Nominal and limit values for total atmospheric pressure<br>Range and accuracy of total pressure monitoring<br>Limits of anoxic and hypoxic zones in accessible volumes<br>Limits for pressure change rates for pressure adjustments<br>Range of PO2 in accessible volumes |
| 4.4.2.3 Control thermal nominal condition | Limits for effective temperature in habitable volumes<br>Accuracy of stabilized dry bulb temperature<br>Range of relative humidity in habitable volumes<br>Range of dew point temperature in pressurized volumes<br>Range and accuracy of relative humidity monitoring<br>Range and accuracy of dew point monitoring<br>Air velocity range in habitable volumes<br>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<br>Range and accuracy for $PO_2$ monitoring |
| 4.4.2.5 Control carbon dioxide partial pressure | Limits for $PCO_2$ value in habitable volumes<br>Range of monitoring of $PCO_2$ |

**Table A-1: List of parameters to be specified** *(continued)*

| Subclause | Parameter |
|---|---|
| 4.4.2.6 Control carbon monoxide partial pressure | Maximum PCO value in habitable volumes<br>Range of monitoring of PCO |
| 4.4.2.7 Control trace gases and odour | Threshold values for odours in habitable volumes |
| 4.4.2.8 Control airborn 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 |
| 4.4.3.1 Respond to uncontrolled depressurization | Maximum depressurization rate<br>Time limits for recovery from depressurization |
| 4.4.3.2 Respond to uncontrolled pressurization | Time limits for recovery from depressurization<br>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<br>EVA suit flush procedure<br>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<br>Minimum water storage quantities<br>Water peak usage demand |
| 4.4.4.5 Provide food | Nutricional requirements<br>Food safety criteria<br>Fraction of recreational food<br>Variety of food<br>Food usage and contingency needs<br>Food storage conditions<br>Food production expendable by-products<br>Food monitoring requirements |
| 4.4.5.1 Manage carbon dioxide | Carbon dioxide peak recovery rate and storage contingencies<br>Monitoring quantity and quality of stored carbon dioxide requirements<br>Requirements for stored $CO_2$ monitoring<br>For long duration missions the capability for recovering oxygen or any product from carbon dioxide |

**Table A-1: List of parameters to be specified** *(continued)*

| Subclause | Parameter |
|---|---|
| 4.4.5.2 Manage waste water | Stored waste water monitoring requirements<br>Processed waste water quality<br>Waste water disposal safety and environmental guidelines<br>Recovery rate of waste water |
| 4.4.5.3 Manage gas, solid and concentrated liquid wastes | Monitoring of physical, chemical and biological wastes requirements<br>Non-recovered waste disposal safety and environmental guidelines<br>Recovery rate of gas, solid and concentrated liquids |
| 4.4.6 Support EVA operations | Equipment to clean and dry space suits<br>Equipment and consumables supporting pre-breathe procedure<br>Nominal rate of decompression for EVA egress<br>Minimum % of airlock atmosphere to be recovered<br>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**

| Subclause | | Parameter |
|---|---|---|
| 4.4.2 | Maintain environment | Total pressure<br>Differential pressure (over-pressure, under-pressure)<br>Temperature (Dry bulb)<br>Humidity (Wet bulb, relative humidity)<br>Ventilation and air flow<br>Oxygen partial pressure<br>Carbon dioxide partial pressure<br>Carbon monoxide partial pressure<br>Trace gases to be monitored (list is project dependent)<br>Airborne particles<br>microorganisms<br>Ionizing radiation |
| 4.4.4 | Provide resources | Nitrogen or other inert gas<br>Oxygen<br>Other breathable gases<br>Water (quality and quantity)<br>Food (quality, quantity, individual diet) |
| 4.4.5 | Manage waste | Carbon dioxide<br>Water<br>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 tables B-1 to 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 < 1 000 |

**Table B-1: Previous flight data** *(continued)*

| Parameter | Earth [a] | Skylab (1973-4) [b] | MIR (1986-) [c] | SSF (1992) [d] | STD-3000 (1995) [e] | ISS (1996) [f] |
|---|---|---|---|---|---|---|
| Microorganisms [h], CFU/$m^3$ | 200-600 | - | - | ≤ 1 000 | ≤ 500 | Average < 1 000 |
| Trace contaminants | Variable | - | see ref. (c) | ≤ SMAC [i] | ≤ SMAC [i] | ≤ SMAC [i] |

[a] Total pressure, $O_2$ partial pressure and lower bound on $CO_2$ partial pressure are based on ambient, sea-level conditions (Lide, 1995). Upper bound on $CO_2$ 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 B.2.5.

## 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 | | solar power | fuel cells | |
| Output, kW | | | 4 | | 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 | 1 013 | 1 013 |
| $O_2$ partial pressure, hPa | 345 | 345 | 345 | 345 | 250 | 220 | 220 |
| $CO_2$ partial pressure (max), hPa | 10,6 | 10,1 | 10,1 | | 7,3 | 6,6 - 10,1 | 6,6 – 10,1 |
| Temperature, °C | 15 - 22 | 15 - 22 | 25 | | 18 – 24 | 21 | 18 – 27 |
| Humidity, % | | | | | | | 50 |

[a] European contribution

NOTE: For references see B.2.5.

## 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 | | | no | no | No | | 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 B.2.5.

### Table B-4: Russian programmes - Requirements

| Programme | VOSTOCK | VOSKHOD | SOYUZ, T and TM | SALYUT | MIR |
|---|---|---|---|---|---|
| **Operational period** | **1961 – 1963** | **1964 – 1965** | **Soyuz 1967 – 1981<br>T 1980 – 1986<br>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 | 1 013 | 1 013 | 1013 (3) | 1013 | 600 - 1280 |
| $O_2$ partial pressure, hPa | | | Max. 304 | 210 - 317 | Max. 470 |
| $CO_2$ partial pressure (max.), hPa | | | | | Max. 30 |
| Temperature, °C | 12 - 25 | 12 - 25 | 12 – 25 | 12 - 25 | 20 comfort (18-28) |
| Humidity, % | 30 - 70 | 30 - 70 | 30 – 70 | | 20 – 70 (for T = 20 °C) |

NOTE: For references see B.2.5.

## Table B-5: Russian programmes - Functions

| **Programme** | **VOSTOCK** | **VOSKHOD** | **SOYUZ, T, and TM** | **SALYUT** | **MIR** |
|---|---|---|---|---|---|
| **Operational period** | **1961 – 1963** | **1964 - 1965** | **Soyuz 1967 – 1981<br>T 1980 – 1986;<br>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 B.2.5.

## 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<br>(95,8 min) | 79,9 kPa to 114,4 kPa<br>(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<br>(0,705 kPa normal 24 h average) | 0,69 kPa up to 3 people<br>1,0 kPa up to 5 people<br>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<br>(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<br>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<br>(Pressure not specified; assume 101,3 kPa) |

[a] During crew ex changes the maximum daily average $PCO_2$ 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 B.2.5.

### 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)<br>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) | $1 \times 10^9$ | 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 CO2 generation rate is based on CO2 releases of 13,5 l/hr during sleep, 18,7 l/hr during light work, and 72 l/hr during exercise.

For references see B.2.5.

### 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 $\mu$ 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 |
| | | - Iron | 0,3 |
| Aesthetics | | - Lead | 0,05 |
| - $CO_2$ | 15 mg/l | - Magnesium | 50 |
| | | - Manganese | 0,05 |
| | | - Mercury | 0,002 |
| | | - Nickel | 0,05 |
| Microbial | | - Nitrate ($NO_3$ –N) | 10 |
| - Bacteria/fungi | 100 CFM/100 ml | - Potassium | 340 |
| - Total coliform | < 1 CFU/100 ml | - Selenium | 0,01 |
| - Virus | < 1 CFU/100 ml | - Silver | 0,05 |
| | | - Sulphate | 250 |
| | | - Sulphide | 0,05 |
| | | - Zinc | 5 |
| Organic parameters | | Bactericide | |
| - Total acids | 500 $\mu$g/l | - Residual iodine (minimum) | 1 |
| - Cyanide | 200 $\mu$g/l | - Residual iodine (maximum) | 4 |
| - Halogenated hydrocarbons | 10 $\mu$g/l | | |
| - Total phenols | 1 $\mu$g/l | | |
| - Total alcohols | 500 $\mu$g/l | | |
| - Total organic carbon (TOC) [c] | 500 $\mu$g/l | | |
| - Uncharacterized TOC (UTOC) [c] | 100 $\mu$g/l | | |

[a] No detectable gas using a volumetric gas versus fluid measurement system-excludes $CO_2$ used for aesthetic purposes.

[b] Each parameter-constituent maximum contamination level (MCL) is considered individually and independently of others.

[c] UTOC equals TOC minus the sum of analysed organic constituents expressed in equivalent TOC.

NOTE: For references see B.2.5.

### 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 B-10.

  Crew exposures are managed in accordance 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 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 B.2.5. | |

**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 B.2.5. | | | |

**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.<br>NOTE 2: For references, see B.2.5. | | | | |

### B.2.5 Other sources of information

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

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

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# Bibliography

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


| | |
|---|---|
| ECSS-E-00 | Space engineering – Policy and principles |
| ECSS-E-10 Part 10 [2)] | Space engineering – System engineering – Part 10: Logistics engineering |
| ECSS-E-10 Part 11 [2)] | Space engineering – System engineering – Part 11: Human factors engineering |
| ECSS-E-20 | Space engineering – Electrical and electronic |
| ECSS-E-30 Part 1 | Space engineering – Mechanical – Part 1: Thermal control |
| ECSS-E-30 Part 2 | Space engineering – Mechanical – Part 2: Structural |
| ECSS-E-30 Part 3 | Space engineering – Mechanical – Part 3: Mechanisms |
| ECSS-E-30 Part 7 | Space engineering – Mechanical – Part 7: Mechanical parts |
| ECSS-E-30 Part 8 | Space engineering – Mechanical – Part 8: Materials |
| ECSS-E-30-01 | Space engineering – Fracture control |
| ECSS-M-30 | Space project management – Project phases and planning |
| ECSS-Q-00 | Space product assurance – Policy and principles |
| ECSS-Q-20 | Space product assurance – Quality assurance |
| ECSS-Q-30-02 | Space product assurance – Failure modes, effects and criticality analysis (FMECA) |
| ISO 128: 1982 | Technical drawings - General principles of presentation |


[2)] To be published.

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