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Environmental control and life support

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ABSTRACT

ESA PSS-03-40 contains top level definitions applicable to ECLS (environmental control and life support) terminology, a comprehensive breakdown of the functional requirements of ECLS subsystems, and guidelines to the ECLS design philosophy on atmosphere, water, food, hygiene and waste. It also includes symbols for ECLS schematics.

DOCUMENT HISTORY

Issue	Date	Sections affected	Remarks
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Figure A-1 The ESA ECLS document tree I

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SCOPE AND APPLICABILITY

ESA PSS-03-40 contains top-level definitions applicable to ECLS (environmental control and life support) terminology, a comprehensive breakdown of the functional requirements of ECLS subsystems, and guidelines to the ECLS design philosophy on atmosphere, water, food, hygiene and waste.

ESA PSS-03-40 constitutes a framework which should support the documentation of ECLS specifications for manned space projects. Therefore, all designers are encouraged to use its terminology, the ECLS functional breakdown, the given symbols, and so on.

Appendices detail the ECLS specification tree, symbols, a verification method for the requirements, related documents, and acronyms and definitions.

ESA PSS-03-40 shall not be applicable for spacesuits and payloads.

ESA PSS-03-40 shall apply as "recommended practices".

HOW TO USE THIS DOCUMENT

For definitions of acronyms and technical terms, see Appendix E.

All functional requirements are given an identification number **[xxx]** for verification by means of a matrix. (See Appendix C: "Recommended verification method").

All functional requirements marked with **[xxx, c]** are not requirements as such, but rather are comments to support ECLSS design.

All functional requirements numbered **[xxx, p]** are project dependent.

UPDATES AND CHANGES

ESA PSS-03-40 is intended to be updated on a regular basis.

Users are invited to take part in this process, by making use of the change request form enclosed at the end of the document.

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1. INTRODUCTION

Human beings can survive in a relatively narrow range of environmental conditions only, and conditions in space do not fall in this range.

Therefore, for humans to travel, to live, and to work in space, and to return safely to Earth, it is necessary for them to be surrounded by an environment in which conditions are compatible with human physiology.

The goal of ECLS hardware is to create a suitable environment for the human being, by providing all needed consumables, discarding and/or recycling generated waste products, (see Table 1-1) and adequately managing all environmental parameters.

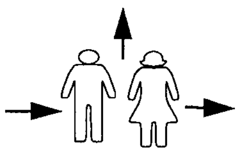
Consumables	latent/sensible heat	Waste products
Oxygen Food Potable water Hygiene water		Carbon dioxide Water vapour (Perspiration, expiration) Gaseous contaminants Particles Microbes Waste water Human waste

Table 1-1 Human life support needs

ECLS is defined as the sum of all the physical, chemical, and biological processes that, by creating a "shirt sleeve" environment, keep the crew healthy and productive.

Processes that are based on expendables or consumables are generally referred to as "open loop" ECLS systems (e.g. subsystems of Mercury, Gemini, Apollo, US orbiters, Vostok, Voskhod, Soyuz).

ECLS processes that recycle, regenerate, or recover materials or needed elements are referred to as "closed loop" ECLS systems. This also implies that these processes do not use significant quantities of expendables.

ECLS systems shall consist of the following nine functional subsystems: **[1]**

- Air revitalisation subsystem ARS
- Atmosphere control and supply subsystem ACSS
- Temperature and humidity control subsystem THCS

• Water recovery and management subsystem	WRMS
• Hygiene management subsystem	HMS
• Solid waste processing subsystem	SWPS
• Food management subsystem	FMS
• Fire detection and suppression subsystem	FDSS
• Instrumentation monitoring and control subsystem	IMCS

2. GENERAL REQUIREMENTS

2.1 General engineering requirements

2.1.1 Physical requirements

For details of mass, see Table 2-2 on page 6. **[2, c]**

For details of volume, see Table 2-2. **[3, c]**

For details of power, see Table 2-2. **[4, c]**

2.1.2 Materials for construction

Building materials used for habitable volumes shall be selected to minimise:

- offgassing of trace contaminants into the cabin atmosphere **[5, c]**
- leaching of contaminants into the ECLS process flow streams **[6, c]**
- rough surfaces, porosity, and stagnation points: these can cause scale build up, and can harbour microbes and other biological contaminants **[7, c]**

Refer to ESA PSS-01-70 for further details on materials. **[8, c]**

2.1.3 Configuration

The operational ECLS configuration shall not impose rigid design constraints on the structural architecture. **[9, c]**

Refer to specification ESA PSS-03-70, Human factors, chapter 11, for details of controls, fasteners, connectors, markings, instrumentation, access ports, handling, fixtures and general engineering design features. **[10, c]**

2.1.4 Commonality

ECLS shall be designed to minimise the complexity and maximise the commonality of components. Stores inventory shall be reduced, and commonality of controls shall be maximised for ease of training, check-out and operation. **[11, c]**

2.1.5 Inheritability

[TBD]

2.1.6 Adaptability

ECLS designs shall provide for standard component interfaces, with built-in flexibility to accommodate system evolution. A modular approach to ECLS architecture and subsystem design shall be employed as a general rule. This shall facilitate the incorporation of new components, processors, and subsystems with improved performance, increased operating life and reliability, and increased process capacities. This shall accommodate growth in crew size, and other changes. **[12, c]**

2.1.7 Ease of transportation

All components and materials shall meet applicable safety standards (refer to ESA PSS-01-40 and ESA PSS-01-402) for transport between and across all ground and space transportation nodes, and shall withstand transient forces and conditions imposed by transportation vehicles and the environment. **[13, c]**

2.1.8 Ease of assembly

[TBD]

2.1.9 Ability to be palletised

[TBD]

2.1.10 Service life

ECLS components, subsystems and systems shall be designed for a minimum number of years of operational life cycle, to be specified by project. **[14, p]**

2.1.11 Sizing and dimensioning

Sizing of ECLS consumables shall be based on the maximum of the average range of physiological daily consumption. **[15, c]**

For the sizing of ECLS consumables, timetabling of crew activities (sleep; light, moderate, heavy physical exercise) shall be considered. Refer to ESA PSS-03-401 for the design requirements. **[16, c]**

For equipment dimensioning, the level of activity of the crew, depending on the mission phase, shall be considered. See also Table 5-1: "ECLS operating modes according to mission phase". **[17, c]**

2.2 Human requirements

2.2.1 Gender

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

2.2.2 Metabolism

Refer to ESA PSS-03-401 for details of mean oxygen consumption, pulmonary ventilation, and expenditure of energy. **[18, c]**

Refer to ESA PSS-03-70 for details of overall intake of gas, water and food, and elimination of gas, liquids, and solids, according to a 24-hour standardised level of activity. **[19, c]**

2.3 Mission scenarios

2.3.1 Basic mission features

The basic requirements to be considered for ECLS designs for various mission scenarios are detailed in Table 2-1.

Basic requirements	LEO transportation mission	Lunar transportation mission	LEO mission	Lunar outposts	Mars mission
Duration	3 days	few days	28 to 90 days, to permanent	28 to 90 days, to permanent	1 to 3 years
Volume	30 m^3	30 m^3	100 - 500 m^3	100 - 500 m^3	150 m^3
Crew size [TBC]	3 to 6	3	3 to 8	3	4 or 6
ECLS type	open loop	open loop	partially closed	partially closed closed	partially closed [TBC]
EVA	no	no	yes	yes	yes
Return time	< 24 hours	few days	< 24 hours	TBD	≥ 0.5 years
Safe haven	IVA suits oxygen masks	IVA suits oxygen masks lunar space station LEO space station	return vehicle	TBD	TBD
Maintenance workstation	no	no	yes	yes	no

Table 2-1 Mission scenarios to be considered for ECLS design

Basic requirements	LEO transportation mission	Lunar transportation mission	LEO mission	Lunar outposts	Mars mission
Crew health system [TBC]	first aid kit	first aid kit	capability for: - prevention - diagnosis - treatment	capability for: - prevention - diagnosis - treatment	capability for: - prevention - diagnosis - treatment
Habitability	sleeping instant foods low leisure low personal hygiene	sleeping instant foods low leisure low personal hygiene	sleeping various foods leisure extended personal hygiene	sleeping various foods leisure extended personal hygiene	sleeping various foods leisure extended personal hygiene

Table 2-1 **(Continued)** Mission scenarios to be considered for ECLS design

2.3.2 Impact of mission scenarios on physical requirements

The impact of various mission scenarios on physical requirements is detailed in Table 2-2.

	LEO transportation mission	Lunar transportation mission	LEO mission	Lunar outposts	Mars mission
Mass constraints	high	high	medium	medium	medium
Volume constraints	high	high	medium	medium	medium
Power constraints	high	high	medium	medium	medium
Crew spare time	low	low	medium	medium	medium
Availability of consumables	medium	low	medium	medium	low
Reliability requirements	low	medium	high	high	high

Table 2-2 Impact of mission on physical requirements

2.4 Miscellaneous storage and handling requirements

The ECLSS shall include:

- appropriate storage and handling **[20, c]**
- environment conditioning for containment of inventories **[21, c]**
- preservation of, and ready access to, all crew consumables, and all ECLS related servicing and maintenance inventories, tools and equipment **[22, c]**

Refer also to ESA PSS-03-70, sections 10.11: Trash management facility, 10.12: Stowage facility, 11: Hardware and equipment, and 12: Design for maintainability. **[23, c]**

3. ECLS FUNCTIONAL REQUIREMENTS

3.1 Air revitalisation subsystem (ARS)

The ARS continuously regenerates the breathable atmosphere in the pressurised volumes, to maintain crew health and comfort, and working conditions for all operational activities. It replaces oxygen consumed, and eliminates or reduces carbon dioxide produced by crew activity within the pressurised volumes. Continuous trace contaminant monitoring and control shall be provided for the atmosphere in the habitable volumes and attached airlocks [TBC], with the capability for testing, and ensuring safe storage and transfer of, consumable gases for EVA (extra vehicular activity) and manned vehicle systems. The ARS shall provide revitalised atmosphere to the IVA (intra vehicular activity) safety suits when nominally [TBD] used. The ARS shall also support contingency hyperbaric treatment facilities, provided for the treatment of decompression sickness.

The ARS functions are as follows:

- carbon dioxide removal and concentration **[24]**
- carbon dioxide reduction **[25]**
- oxygen generation **[26]**
- monitoring of trace contamination **[27]**
- control of airborne particles and microbes **[28]**
- control of trace contamination and odour **[29]**

3.2 Atmosphere control and supply subsystem (ACSS)

The ACSS regulates the composition and pressure of the breathable atmosphere within the pressurised volumes. It has the capability for emergency repressurisation following contingent air loss (depressurisation, decompression), fire, or purging of contaminated air in any compartment. It also supports EVA pre-breathe, airlock, and hyperbaric chamber operation, as required.

The ACSS functions are as follows:

- pressure monitoring and control (total pressure, oxygen partial pressure) **[30]**
- oxygen supply **[31]**
- nitrogen supply **[32]**

3.3 Temperature and humidity control subsystem (THCS)

The THCS controls the temperature and humidity of the atmosphere in the pressurised volumes to provide a safe, comfortable environment for the crew, and to remove excess heat generated by activities carried out, and equipment operating, within pressurised volumes. It also provides chilled storage for food and other perishable commodities. Water separated by the humidity control process is recovered for processing by the water recovery and management subsystem.

The THCS functions are as follows:

- air temperature monitoring and control [33]
- humidity monitoring and control [34]
- ventilation air flow [35]
- thermally controlled stowage [36]

3.4 Water recovery and management subsystem (WRMS)

The WRMS stores, conditions, and distributes all the water required by the crew for potable and hygiene purposes, and for other water uses within and external to the habitable volumes. (Habitable volumes are those which are pressurised, accessible, and normally occupied. For definitions of the different volume types, see Appendix E.) All water is recovered for processing and reuse, with continuous monitoring of quality and microbial content. The WRMS provides a means of buffering peaks of consumption and supply with normal input/output flow streams, and maintains a secure emergency water supply for contingency situations.

The WRMS functions are as follows:

- water storage and distribution [37]
- water temperature control [38]
- urine and flush collection and processing [39]
- hygiene water processing [40]
- potable water processing [41]
- end use utility water processing
  (i.e. laundry, dishwashing, maintenance) [42]
- water quality monitoring [43]
- contingency water supply [44]

3.5 Hygiene management subsystem (HMS)

The HMS provides the crew with appropriate items and/or facilities to carry out personal and environmental hygiene functions, to promote sanitary working conditions, and to support crew activities within a healthy living environment.

The personal hygiene functions are as follows:

- whole body cleaning [45]
- partial body cleaning [46]
- hair care [47]
- shaving [48]
- oral care [49]
- skin care [50]
- nail care [51]
- body odour control [52]
- cosmetics supply [53]
- clothes supply [54]

The environmental hygiene functions are as follows:

- surface cleaning and/or disinfection [55]
- utensil cleaning [56]

3.6 Solid waste processing subsystem (SWPS)

The SWPS provides safe collection, segregation, stabilisation, and processing of all solid waste products, including metabolic, reusable, and non-reusable materials. By-product materials determined to be currently non-reusable shall be separated, compacted, stabilised and stored, for eventual disposal at an appropriate site, or for potential use in future missions incorporating advanced solid waste recovery processes.

The SWPS functions are as follows:

- solid human waste collection, storage and stabilisation [57]
- recoverable waste processing [58]
- trash collection, storage, and stabilisation [59]

3.7 Food management subsystem (FMS)

The FMS functions are as follows:

- food supply (controlling food quality, quantity and palatability) **[60]**
- food storage **[61]**
- food inventory management **[62]**
- food preparation **[63]**
- food quality monitoring **[64]**
- supply of food serving utensils and containers **[65]**
- monitoring the diet of individual crew members **[66]**
- restraints and mobility aids **[67]**
- food trash management **[68]**

3.8 Fire detection and suppression subsystem (FDSS)

The FDSS consists of sensors for monitoring the pressurised volumes for the unintentional presence of combustion products, detecting conditions indicative of fire hazard, and alerting the crew. It also provides a means of automatic and manual delivery of fire-suppression materials.

The FDSS functions are as follows:

- fire detection **[69]**
- crew alert **[70]**
- fire suppression **[71]**
- post-fire decontamination **[72]**

3.9 Instrumentation monitoring and control subsystem (IMCS)

The IMCS includes all sensors and control components required for monitoring and control of all the ECLSS processors and subsystem functions.

The IMCS functions are as follows:

- monitoring and control of the ECLSS **[73]**
- interface with the data-management system **[74]**
- visual and acoustic crew-alert indication **[75]**
- manual control override **[76]**

4. ECLS DESIGN PHILOSOPHY REQUIREMENTS

All ECLS graphics shall use the symbols listed in Appendix B. **[77]**

For further details concerning the hardware and technologies appropriate to the various subsystems, refer to ESA PSS-03-406. **[78, c]**

4.1 Air revitalisation subsystem

4.1.1 General

No venting of atmospheric gases to the external environment shall be allowed, except for emergency purging of contaminated atmospheres. **[79]**

All design requirements regarding ARS functions or parameters are detailed in ESA PSS-03-401. **[80, c]**

The ARS design shall provide the maximum possible regeneration of the atmosphere constituents of the habitable volumes. **[81, p]**

4.1.2 Carbon dioxide removal and concentration

The facility to remove, and to regulate partial pressure of, carbon dioxide shall be 100% functional during periods of crew occupancy. **[82]**

Carbon dioxide levels shall be monitored and controlled in all pressurised volumes, during all periods of crew occupancy. **[83]**

4.1.3 Carbon dioxide reduction

The ARS shall provide the capability, if required, for recovering oxygen from carbon dioxide for recycling into the atmosphere of the habitable volumes (e.g. on long-duration missions). **[84, p]**

4.1.4 Oxygen generation

[TBD]

4.1.5 Monitoring of trace contamination

The ARS shall include sensors for continuous monitoring of volatile organics throughout the pressurised volumes. **[85]**

The capability shall be provided for regularly identifying and quantifying any undesirable organic compounds. **[86]**

Air samples shall be regularly monitored for the presence of bacteria, yeast, and moulds. **[87]**

The ARS shall be capable of collecting and transmitting atmospheric monitoring data to the IMCS, for analysis and determination of necessary action. **[88]**

Crew alert signals shall be provided for any condition exceeding allowable contamination levels, together with appropriate information on fault diagnosis, fault tracing, and remedial action. **[89]**

Automatic testing of all monitoring equipment at reasonable intervals shall be provided, to ensure continuous functioning and early detection of failure or degraded sensitivity levels. **[90]**

Airborne particles within the pressurised volumes shall be filtered and removed. **[91]**

The maximum particle mass concentration and maximum number of particles shall meet crew health requirements. Refer to ESA PSS-03-401 for further details. **[92, c]**

The ARS shall provide the capability for rapid detection and containment of contingent contamination events, e.g. fire, toxic spill, etc. **[93, c]**

4.1.5.1 Control of airborne particles and microbes

[TBD]

4.1.5.2 Control of trace contamination and odour

The ARS shall provide the capability for controlling trace contaminants and odours. **[94]**

The subsystem for trace contaminant monitoring shall be 100% functional during all periods of crew occupancy of the habitable volumes. **[95]**

Decontamination procedures, materials, and supporting equipment shall be provided for counteracting all contamination events, and for manual verification of restoration to acceptable levels. On-site/on-board means shall be provided for safe disposal or containment of decontamination materials and contaminated components, with clear, unambiguous identification to prevent unintentional return of these items to materials or spares inventories. **[96, c]**

Facilities and equipment shall be designed to limit, and contain at the source, all odours originating from hygiene, food preparation, waste processing, and operational activities. **[97, c]**

The ARS shall back up these capabilities with a means of deodorising the atmosphere of the habitable volumes, to maintain aesthetically acceptable conditions. **[98, c]**

4.2 Atmosphere control and supply subsystem

4.2.1 General

The ACSS shall provide the means to supply the atmosphere in the pressurised volumes. **[99]**

The ACSS may use ARS equipment to perform functions such as pressure equalisation between adjacent pressurised volumes. **[100]**

At any time, it shall be possible to identify the quantity of gas remaining in the ACSS tanks. **[101]**

During re-entry, the ACSS shall provide a positive differential pressure in the pressurised volumes with respect to the external environment, to avoid external contamination entering the space vehicle. **[102]**

The following parameters shall be monitored in habitable volumes:

- total pressure **[103, c]**
- oxygen partial pressure **[104, c]**
- pressure change rates **[105, c]**

All design requirements regarding ACSS functions and/or parameters shall be detailed in ESA PSS-03-401. **[106, c]**

The atmosphere supplied to the habitable volumes shall be made of oxygen and nitrogen. The required percentages are specified in ESA PSS-03-401. **[107, p]**

The ACSS shall support airlock operation. See also Subsection 5.8.4: "Airlock supporting mode". **[108, p]**

In the case of an accidental depressurisation (sudden decompression) due to a hole of [TBD] mm diameter, the ACSS shall maintain pressurisation of the habitable volumes at not lower than [TBD] hPa for a minimum period of [TBD] seconds. **[109, p]**

4.2.2 Pressure monitoring and control

The ACSS shall provide the means for controlling the total pressure, and the oxygen partial pressure, in the pressurised volumes, during all the mission phases. **[110]**

The pressure control subsystem shall be 100% functional during all periods of crew occupancy of the habitable volumes. **[111]**

The ACSS shall provide a leak detection capability in all pressurised volumes. **[112]**

The ACSS shall provide the means for depressurising/repressurising the different pressurised volumes. **[113]**

The ACSS shall be capable of pressure equalisation throughout the pressurised volumes, with minimum pressure differences between compartments, at any time. **[114, c]**

Where feasible, excess pressure conditions shall be corrected by methods other than venting to the external environment. **[115, p]**

4.2.3 Oxygen supply

The oxygen storage and partial pressure regulation in all pressurised volumes shall be 100% functional during all periods of crew occupancy. **[116]**

Oxygen storage facilities shall include off-line emergency supplies, which shall be regularly tested and replenished. **[117, p]**

4.2.4 Nitrogen supply

The ACSS shall provide nitrogen as necessary to maintain total air pressure. **[118, p]**

Nitrogen storage facilities shall include off-line emergency supplies that shall be regularly tested and replenished. **[119, p]**

4.3 Temperature and humidity control subsystem

4.3.1 General

The THCS shall provide the quantity, type, and location of sensors required to ensure accurate temperature and humidity readings within each pressurised volume. **[120]**

The temperature and humidity of the atmosphere shall be monitored in all habitable volumes. **[121]**

For design requirements regarding THCS functions or parameters, refer to ESA PSS-03-401. **[122, c]**

4.3.2 Air temperature monitoring and control

All compartments shall have controls to allow the crew to make temperature adjustments. These shall be maintainable within ±1°C [TBC] throughout the allowable temperature range. **[123, p]**

The required response time for automatic or manual temperature adjustments is [TBD]. **[124, p]**

4.3.3 Humidity monitoring and control

Water condensation on any surface shall be avoided. **[125, c]**

4.3.3.1 Load model

[TBD]

4.3.3.2 Control requirements

Adequate controls shall be provided for the crew to select humidity values, within the allowable range, for all habitable volumes. **[126]**

The ventilation of any habitable volume shall be possible with all internal doors closed. **[127, p]**

The response time for automatic or manual humidity adjustments is [TBD]. **[128, p]**

4.3.4 Ventilation air flow

Ventilation shall be provided throughout the habitable volumes. **[129]**

Adequate controls (refer to ESA PSS-03-70 Section 9.3) shall be provided for crew selectable ventilation rates within the allowable ranges (refer to ESA PSS-03-401) for all habitable volumes. **[130, c]**

Any activities or workstations which are isolated from the main air circulation system shall be serviced with portable fans. **[131, p]**

4.3.5 Thermally controlled stowage

The THCS shall support storage volumes with separately controlled temperature and humidity atmospheres as required, including chilled areas for storing food and perishable items. **[132, p]**

4.4 Water recovery and management subsystem

4.4.1 General

The WRMS shall include a means of safe, effective, on-site disinfection and sanitisation. **[133]**

The WRMS shall also include a means of isolating and containing any contaminated components, either under the direction of the control executive, or by manual override. **[134]**

4.4.2 Source

4.4.2.1 Human body waste liquids

Human body waste liquids shall include:

- urine

- evaporation water (expiration and perspiration on towels and/or condensed water from the ACSS)
- faecal water

In determining the overall waste liquid budget, the following shall be assumed:

total body waste liquid = water intake + metabolic water production

The water intake shall include:

- beverages
- food rehydration water
- food water content

4.4.2.1.1 Urine

The quantity of urine water shall be calculated from the equation defined in Subsection 4.4.2.1, all other quantities being assumed known. **[135, c]**

The production rate of metabolic water is defined in ESA PSS [TBD]. **[136, c]**

4.4.2.1.2 Evaporation water

It shall be considered that all perspired water is evaporated into the cabin air. **[137, c]**

The quantity of evaporation water shall be a function of metabolic heat load and of cabin air temperature, as defined in ESA PSS-03-70, Chapter 4. **[138, c]**

4.4.2.1.3 Condensed water

[TBD]

4.4.2.1.4 Faecal water

The quantity of faecal water is defined in ESA PSS-03-70, Chapter 4. **[139, c]**

4.4.2.2 Brine

[TBD]

4.4.2.3 Hygiene

[TBD]

4.4.2.4 Washing and maintenance

[TBD]

4.4.3 Supply

4.4.3.1 Potable water

Potable water shall be available to the crew at any time. **[140]**

The following life support parameters shall be monitored:

- temperature of water delivered to the crew **[141]**
- pressure of water delivered to the crew **[142]**
- pH and/or electrical conductivity of water delivered to the crew **[143]**
- potable water tank level **[144]**
- levels of waste liquid tanks **[145]**

The WRMS shall process and supply potable water. **[146]**

Refer to ESA PSS-03-402 for potable water quality requirements. **[147, c]**

Water dispensing capabilities shall be provided for food and drink reconstitution. **[148, p]**

Off-line potable water reserves shall be maintained, and regularly tested and changed out, to allow for periods of WRMS maintenance, emergency shutdown, or sustained operation at degraded/discomfort performance levels. **[149, p]**

4.4.3.2 Hygiene

The WRMS shall provide the crew with water for personal hygiene. **[150]**

Hygiene functions shall be carried out with hygiene water. Refer to ESA PSS-03-402 for the quality requirements for hygiene water. **[151, c]**

The WRMS shall process and supply recycled hygiene water. **[152, p]**

4.4.3.3 Washing and maintenance

The WRMS shall process and supply water for washing of clothes [TBC], dishwashing [TBC], maintenance of habitable volumes, and operations such as cleaning. **[153]**

Washing and maintenance shall be carried out with hygiene water. Refer to ESA PSS-03-402 for the quality requirements for hygiene water. **[154, c]**

4.5 Hygiene management subsystem

The urine receiver shall be so located that any male crew member may urinate in the standing position without removing lower clothing. **[155, c]**

Any waste collector shall provide adequate crew interfaces to avoid spills. **[156, c]**

4.6 Solid waste processing subsystem

4.6.1 General

The SWPS shall process solid waste and trash, including collection, storage, compaction whenever necessary, and stabilisation. Solid waste sources are: **[157]**

- the human body (faeces, vomitus, hair, nails ...)
- hygiene operations (wrapping tissue, wet tissue ...)
- nutrition functions (food and drink packages)
- the EVA suit
- the IVA suit

Waste liquid extracted from or produced by the above trash shall be routed towards the WRMS. **[158]**

Appropriate restraints shall be provided. Refer to ESA PSS-03-70, Section 11.7. **[159]**

Solid waste shall be stored (and processed if necessary) in such a way as to avoid any type of contamination (e.g. bacterial contamination), either through direct contact or through the atmosphere. **[160, c]**

Waste which can be piled up (e.g. food packages) shall not be compacted, but stored (after piling up) in garbage bays. **[161, c]**

A means shall be provided to control noise and odour, as specified in ESA PSS-03-70 and ESA PSS-03-401 respectively, during and between operations of SWPS equipment. **[162, c]**

4.6.2 Solid human waste

The body waste function shall have a back-up/contingency system. **[163]**

The capability shall be provided for a crew member to obtain samples of his body waste products. **[164]**

The capability shall be provided for a crew member to visually inspect his body waste products. **[165]**

The body waste equipment and facility shall be easy to clean and disinfect. **[166, c]**

The body waste equipment and facility shall prevent cross contamination among crew members, and prevent contamination within pressurised volumes. **[167, c]**

The body waste function shall provide the maximum possible visual and acoustic privacy. **[168, c]**

4.6.3 Recoverable waste processing

Reusable materials and components shall be saved and conditioned for recycling or other operational uses. A means shall be provided for on-site/on-board reconditioning of reusable items. **[169, p]**

The inedible biomass produced by plant growth chambers shall be processed by the SWPS. **[170, p]**

4.6.4 Trash collection, storage, and stabilisation

Consideration shall be given to long-term storage of materials which may be used on future missions. **[171, p]**

Materials and components that cannot be reconditioned on-site or on-board shall be saved, and conditioned for containment external to the habitable volumes, pending an appropriate means of disposal. **[172, p]**

Long-term trash-storage volumes shall be provided, external to the habitable volumes. **[173, p]**

4.7 Food management subsystem

4.7.1 General

The FMS shall be 100% functional during all periods of crew occupancy of the habitable volumes. **[174]**

Refer to ESA PSS-03-403 for food and galley design requirements. **[175, c]**

4.7.2 Supply

The FMS function shall provide the crew with palatable food, according to a daily diet which meets the human physiological requirements. **[176, c]**

The diet shall take into account the physiological changes of the human being in his adaptation to 0-g, any foreseeable extra calorie expenditure related to EVA, and preparation before return from a 0-g to a 1-g environment. **[177, c]**

The meals shall be made of ingredients as similar as possible to those used by the crew on Earth. **[178, c]**

The meals shall take into account ethnic and cultural food pattern differences within the crew. **[179, c]**

During a space mission, at least one warm meal per day shall be provided for the crew. **[180, c]**

4.7.3 Storage

[TBD]

4.7.4 Inventory management

The FMS function shall provide immediate status data for on-board/on-site food availability and localisation. **[181]**

4.7.5 Preparation

[TBD]

4.7.6 Quality monitoring

[TBD]

4.7.7 Serving utensils and containers

[TBD]

4.7.8 Crew member individual diet monitoring

[TBD]

4.7.9 Restraints and mobility aids

Refer to ESA PSS-03-70 (Sections 11.7, 11.8) for the design requirements for restraints and mobility aids. **[182, c]**

4.7.10 Food trash management

Food trash shall be kept to the strict minimum in terms of mass and volume (after compaction and/or processing). **[183, c]**

Food trash, including packaging, shall be made as far as possible from recyclable/biodegradable materials. **[184, p]**

4.8 Fire detection and suppression subsystem

4.8.1 General

Refer to ESA PSS-03-401 for design requirements regarding fire prevention. **[185, c]**

Depressurisation scenarios concerning the habitable volumes after a fire and/or a contamination shall be [TBD]. **[186, c]**

4.8.2 Fire detection

The FDSS shall, at a minimum, consist of: **[187]**

- smoke, thermal, and flame sensors for detecting and locating fire within all the pressurised volumes;
- crew alert devices; and
- a means of automatic and manual fire control and suppression.

The FDSS shall provide continuous status data to the control executive resident in the IMCS. **[188]**

The IMCS shall integrate status data on smoke, toxic gas, temperature, and radiation, with other information, and activate an appropriate response. **[189]**

All sensors shall be accessible for servicing and replacement, and shall include reset and self-test capabilities. **[190]**

Refer to ESA PSS-01-40 for further details. **[191, c]**

4.8.3 Crew alert

Crew alert signals shall include information about the fire location, type, and magnitude, plus the procedural action to be taken by the crew. **[192]**

Cautionary alarms shall be issued on determination of threat conditions, to enable timely action by the crew to prevent fire occurrence. **[193]**

Refer to ESA PSS-01-40 for further details. **[194, c]**

4.8.4 Fire suppression

The FDSS shall provide the capability for extinguishing any fire condition by automatic or manual means. **[195]**

The FDSS shall be capable of automatic isolation of a fire area, shutdown of power and airflow to the affected area, and/or venting of air loaded with combustible or toxic products to the external environment. These functions shall have manual overrides. **[196]**

Provision shall be made for disabling the automatic fire control and suppression components, to prevent inadvertent activation during servicing. **[197]**

The FDSS shall be capable of rapid restoration to active status following activation. **[198, c]**

All fire suppression agents shall be compatible with safety, corrosion, and toxicity requirements. Refer to ESA PSS-01-40 for further details. **[199, c]**

The FDSS shall use non-toxic suppressant agents for fire suppression. **[200, c]**

The FDSS shall include a remotely activated fire extinguishing system and portable fire extinguishers. **[201, c]**

4.8.5 Post-fire decontamination

Capability shall be provided for rapid and safe removal of expended fire suppression materials during recovery and clean-up. **[202]**

4.9 Instrumentation monitoring and control subsystem

The IMCS automatic control executive, and the expert system advisory capability as appropriate, shall communicate with the data management system (DMS), in order to integrate information processing and control functions for the pressurised volumes. **[203]**

The DMS shall provide for Earth-based, or on-site, supervision of the pressurised volume functions, in any combination that may be required. **[204]**

Advisory messages shall notify the crew of any automatic process initiated by the control executive, to allow for manual intervention if necessary. **[205]**

The ECLS shall include sensors with the capability for indicating status conditions in real time. **[206]**

The functional processors of life-critical subsystems shall incorporate duplicate sensors for critical measurements. This is to enable the IMCS control executive to poll the instruments, in the event of anomalous readouts or detection of a sensor failure. **[207]**

Appropriate types and quantities of sensors shall be located to enable the IMCS to detect, diagnose, and correct fault situations or anomalous conditions, or to alert the crew. **[208, c]**

5. OPERATIONAL REQUIREMENTS

5.1 Operating modes

5.1.1 Situation definitions

Environment conditions (or operating modes) shall be defined according to crew physiological requirements. **[209, c]**

5.1.1.1 Comfort

"Comfort" corresponds to the optimal environment, in which astronauts can work in shirtsleeves with the maximum efficiency. **[210, p]**

5.1.1.2 Discomfort

"Discomfort" corresponds to an environment which has been altered, due to an ECLS subsystem failure. As a consequence, the astronauts' well-being and performance may be slightly decreased. The mission is continued. **[211, p]**

5.1.1.3 Survival

A "survival" situation corresponds to an environment being potentially life threatening if immediate corrective actions are not undertaken. As the first step, astronauts shall have to protect themselves, before initiating any corrective actions to restore either a discomfort or a comfort situation. If this is not possible, the mission is then aborted. **[212, p]**

5.1.1.4 Stand-by status

This mode corresponds to the uninhabited mode of a space system (e.g. between two visits by crew, in the case of a man-tended configuration). **[213, p]**

5.1.2 Operational impacts

During some mission phases (to be specified by project), a discomfort situation shall possibly be considered as the baseline. Various mission phases are summarised in Table 5-1.

Phase	Possible ECLS mode	Crew activity
Pre-launch	C	light
Abort launch	S	moderate
Ascent	C, D	light
Orbital transfer	C, D	moderate
Rendezvous and docking	C, D	moderate
Docked	C	high
De-docking	C, D	moderate
De-orbit	C, D	light/moderate
Re-enter orbital arc	C, D, S*	light/moderate
Re-enter atmosphere flight	C	light
Landing	C, D	light
Post-landing	C	moderate

Notes:
C = comfort
D = discomfort
S = survival
* after a THCS failure, fire, atmosphere contamination

Table 5-1 ECLS operating modes according to mission phase

Table 5-2, below, summarises the main impacts of these different situations.

	Environmental conditions	Crew's health	Performance	Safety	Maximum duration	Effect on mission
Comfort	Optimal	Good	Maximum	Maximum	The whole mission	Mission as planned
Discomfort	Acceptable	Good	Maximum or slightly decreased	Crew alert, automatic safing	The whole mission	Continued
Survival	Altered (but not life threatening)	Possibly altered	Decreased or null	Crew alert, crew safing	Maximum 12 hours [TBC]	Must return to comfort or discomfort mode, otherwise mission aborted

Table 5-2 Impact of operating modes

5.1.2.1 Comfort

[TBD]

5.1.2.2 Discomfort

Discomfort conditions may be acceptable during certain transitional (scheduled or contingency) operations. Refer to Table 5-2 for further details. **[214, p]**

5.1.2.3 Survival

No conditions shall lead to any physical injury or life-threatening situation. **[215]**

Survival conditions are to be specified by project. **[216, p]**

5.1.2.4 Stand-by status

Survival and discomfort situations shall be acceptable in pressurised volumes during an unattended period of a space element. **[217, p]**

5.2 Management

ECLS management covers activation and deactivation, maintenance, control, and monitoring.

5.2.1 Activation/deactivation

[TBD]

5.2.2 Maintenance

[TBD]

5.2.3 Control

Control encompasses the effective means to command, regulate, or restrain a given ECLS parameter. **[218, c]**

5.2.4 Monitoring

Monitoring encompasses the effective means to keep watch over, record, or test a given ECLS parameter. **[219, c]**

Monitoring encompasses the following functions:

- crew alert **[220]**
- operational status checks (OS) **[221]**

- system autonomy (SA) **[222]**
- trend analysis (TA) **[223]**
- fault detection (FD), fault isolation, management, and correction **[224]**

5.3 Availability

The ECLS shall operate continuously during any period of manned occupancy. **[225]**

Capability shall be provided for a planned shutdown, or for switch over to the lower stand-by status, during unoccupied periods. **[226]**

On re-occupancy, the ECLS shall have the residual capability for rapid check-out and return to full operational condition. **[227]**

The capability for controlling power-up and check-out shall be provided for both Earth based and on-site supervisors. **[228]**

Life-critical subsystems [TBD] shall be 100% functional during all periods of crew occupancy of the habitat. **[229]**

Refer to ESA PSS-01-30 for further details. **[230, c]**

5.4 Reliability

Refer to ESA PSS-01-30 for requirements on reliability. **[231, c]**

5.5 Maintainability

Refer to ESA PSS-01-50 for requirements on maintainability. **[232, c]**

Components and interfaces shall be engineered to minimise the need for preventive and corrective maintenance. **[233, c]**

5.6 Operability

5.6.1 Autonomous operation

The ECLS shall be designed for minimal intervention by the crew, except for routine scheduled servicing and unscheduled maintenance. This may require redundant components to be provided (such as stand-by bypass filters) for IMCS directed switch over, in the event of a premature servicing demand. **[234, c]**

Integrated ECLS performance between the regularly scheduled service and preventive maintenance intervals must be sustained. **[235, c]**

5.6.2 Earth-based supervision

Earth-based ECLS support shall include parallel monitoring and supervision of all critical ECLS functions, with a data trend analysis capability. **[236, c]**

Remotely controlled robotic servicing of ECLS components shall be provided, if technically feasible [TBC]. **[237, p]**

5.6.3 Crew intervention

All remote automatic control functions shall have a manual override capability. **[238]**

The ECLS shall provide clear, unambiguous, on-site/on-board indications of the operational, servicing, and maintenance status at all times. **[239]**

System controls and access ports shall be operable by following instructions and advice contained in standard operating manuals and/or the IMCS. Therefore, crew members shall not require extensive training or frequent refresher training in ECLS management. **[240]**

5.7 Servicing and maintenance

[TBD]

5.8 Specific supporting modes

5.8.1 EVA supporting mode

The ECLS subsystems shall support EVA as follows:

ACSS:

- supply of pre-breathe oxygen **[241, p]**
- suit oxygen:
  - supply
  - pressure [TBD] hPa
  - maximum flow rate [TBD] kg/s
  - temperature [TBD] °C **[242, p]**
- supply of suit purge oxygen **[243, p]**
- supply of tank recharge oxygen **[244, p]**

THCS:

- drying of the EVA suits **[245, p]**

HMS:

- cleaning of the EVA suits **[246, p]**

WRMS:

- drinking water supply **[247, p]**
- condensate return **[248, p]**
- urine return **[249, p]**
- sublimator water supply **[250, p]**

5.8.2 IVA supporting mode

The ACSS shall supply gaseous oxygen to IVA suits, via connectors and umbilicals, for the management of certain emergency scenarios. The supplied oxygen shall be used for the pressurisation of the suit and the anti-g device. **[251, p]**

The IVA interface functions with ECLS shall encompass:

- oxygen supply:
  - flow rate [TBD] g/s/suit
  - pressure [TBD] hPa
  - temperature: + 5°C to +30°C
  - purity [TBD]
  - maximum duration [TBD] s **[252, p]**
- number of connections and locations [TBD] **[253, p]**
- quick disconnects **[254, p]**

5.8.3 Safe-haven supporting mode

A safe-haven configuration is designed to protect the crew against unexpected dangerous situations for a duration of [TBD] hours.

The safe-haven support-mode functions are as follows:

ARS:	carbon dioxide removal	**[255, p]**
ACSS:	oxygen storage and supply	**[256, p]**
THCS:	pressurised volumes air and humidity control, ventilation air flow	**[257, p]**
WRMS:	water storage and distribution, urine collection	**[258, p]**
HMS:	partial body cleaning, surface cleaning	**[259, p]**
SWPS:	faecal waste containment	**[260, p]**

FMS: food supply **[261, p]**

5.8.4 Airlock supporting mode

Control and monitoring of the airlock depressurisation and repressurisation shall be possible from the airlock. **[262, p]**

Airlock operations shall include airlock evacuation and recovery of compartment air to the maximum practical extent, with no more than 10% loss [TBC] of airlock atmosphere per cycle for unavoidable leakages and ullage residuals. **[263, p]**

5.8.5 Hyperbaric supporting mode

[TBD]

5.8.6 Portable equipment supporting mode

The portable equipment includes:

- extra clothes for low temperatures **[264, p]**
- oxygen masks (oxygen leakage, depressurisation, contamination, fire) **[265, p]**
- smoke hoods (fire, contamination) **[266, p]**
- portable extinguishers **[267, p]**
- others TBD

6. SAFETY REQUIREMENTS

The safety aspects of any design are particularly important, due to the direct reliance of the crew member on the ECLS system for his survival.

ECLS shall contribute to crew safety for all phases, from before launch to after landing. **[268, c]**

The technical safety requirements contained in ESA PSS-01-40, chapters II-1 and II-2, are applicable to manned space systems. Consequently the design and operation of the ECLS of a given space system shall ensure the system (design and operation) meets the above-quoted ESA PSS-01-40 requirements. **[269, c]**

All relevant safety aspects concerning ECLS shall be taken into account at the earliest phase of the design. **[270, p]**

7. INTERFACES

7.1 Subsystem internal interfaces

All the requirements in this document have been given identification numbers. These can be broken down as follows:

- numbers [1] to [23, c] are general system requirements
- numbers [24] to [76] are the functional requirements specific to the ECLS subsystems. These are summarised below for cross-reference with the following tables.
- numbers [77] to [208, c] are design philosophy requirements
- numbers [209, c] to [267, p] are operational requirements
- numbers [268, c] to [270, p] are safety requirements

ARS	[24]	Carbon dioxide removal & concentration	[51]	Nail care	HMS (Cont)
ARS	[25]	Carbon dioxide reduction	[52]	Body odour control	HMS (Cont)
ARS	[26]	Oxygen generation	[53]	Cosmetics supply	HMS (Cont)
ARS	[27]	Monitoring of trace contamination	[54]	Clothes supply	HMS (Cont)
ARS	[28]	Control of airborne particles and microbes	[55]	Surface cleaning and/or disinfection	HMS (Cont)
ARS	[29]	Control of trace contamination and odour	[56]	Utensil cleaning	HMS (Cont)
ACSS	[30]	Pressure monitoring and control	[57]	Solid human waste collection, storage and stabilisation	SWPS
ACSS	[31]	Oxygen supply	[58]	Recoverable waste processing	SWPS
ACSS	[32]	Nitrogen supply	[59]	Trash collection, storage and stabilisation	SWPS
THCS	[33]	Air temperature monitoring and control	[60]	Food supply	FMS
THCS	[34]	Humidity monitoring and control	[61]	Food storage	FMS
THCS	[35]	Ventilation air flow	[62]	Food inventory management	FMS
THCS	[36]	Thermally controlled stowage	[63]	Food preparation	FMS
WRMS	[37]	Water storage and distribution	[64]	Food quality monitoring	FMS
WRMS	[38]	Water temperature control	[65]	Supply of food serving utensils and containers	FMS
WRMS	[39]	Urine and flush collection and processing	[66]	Monitoring the diet of individual crew members	FMS
WRMS	[40]	Hygiene water processing	[67]	Restraints for food & crew members	FMS
WRMS	[41]	Potable water processing	[68]	Food trash management	FMS
WRMS	[42]	End use utility water processing	[69]	Fire detection	FDSS
WRMS	[43]	Water quality monitoring	[70]	Crew alert	FDSS
WRMS	[44]	Contingency water supply	[71]	Fire suppression	FDSS
HMS	[45]	Whole body cleaning	[72]	Post-fire decontamination	FDSS
HMS	[46]	Partial body cleaning	[73]	Monitoring and control of ECLSS	IMCS
HMS	[47]	Hair care	[74]	Interface with the DMS	IMCS
HMS	[48]	Shaving	[75]	Visual & acoustic crew alert indication	IMCS
HMS	[49]	Oral care	[76]	Manual control override	IMCS
HMS	[50]	Skin care			

The ECLS subsystem internal interfaces are summarised in Table 7-1 to Table 7-9.

		ARS					
		[24]	[25]	[26]	[27]	[28]	[29]
ACSS	[30]						
	[31]						
	[32]						
THCS	[33]						
	[34]						
	[35]						
	[36]						
WRMS	[37]						
	[38]						
	[39]						
	[40]			+			
	[41]						
	[42]			+			
	[43]						
	[44]						
HMS	[45]					+	
	[46]					+	
	[47]					+	
	[48]					+	
	[49]					+	
	[50]					+	
	[51]					+	
	[52]				+	+	+
	[53]				+	+	+
	[54]					+	
	[55]					+	
	[56]					+	
SWPS	[57]						
	[58]						
	[59]				+	+	+
FMS	[60]						
	[61]				+		+
	[62]						
	[63]				+	+	+
	[64]						
	[65]						
	[66]						
	[67]						
	[68]						
FDSS	[69]						
	[70]						
	[71]						
	[72]				+	+	+
IMCS	[73]	+	+	+	+	+	+
	[74]						
	[75]	+	+	+	+	+	+
	[76]						

Table 7-1 ARS interfaces [TBC]

		ACSS		
		[30]	[31]	[32]
ARS	[24]			
	[25]			
	[26]			
	[27]			
	[28]			
	[29]			
THCS	[33]			
	[34]			
	[35]			
	[36]			
WRMS	[37]			
	[38]			
	[39]			
	[40]			
	[41]			
	[42]			
	[43]			
	[44]			
HMS	[45]			
	[46]			
	[47]			
	[48]			
	[49]			
	[50]			
	[51]			
	[52]			
	[53]			
	[54]			
	[55]			
	[56]			
SWPS	[57]			
	[58]			
	[59]			
FMS	[60]			
	[61]			
	[62]			
	[63]			
	[64]			
	[65]			
	[66]			
	[67]			
	[68]			
FDSS	[69]		+	
	[70]	+	+	
	[71]	+	+	+
	[72]			
IMCS	[73]	+	+	+
	[74]			
	[75]		+	+
	[76]	+	+	+

Table 7-2 ACSS interfaces [TBC]

		THCS			
		[33]	[34]	[35]	[36]
ARS	[24]				
	[25]				
	[26]				
	[27]				
	[28]				
	[29]				
ACSS	[30]				
	[31]				
	[32]				
WRMS	[37]				
	[38]				
	[39]				
	[40]				
	[41]				
	[42]				
	[43]				
	[44]				
HMS	[45]				
	[46]				
	[47]				
	[48]				
	[49]				
	[50]				
	[51]				
	[52]				
	[53]				
	[54]				
	[55]				
	[56]				
SWPS	[57]				
	[58]				
	[59]	+	+		
FMS	[60]				
	[61]				+
	[62]				
	[63]			+	
	[64]				
	[65]				
	[66]				
	[67]				
	[68]				
FDSS	[69]				
	[70]				
	[71]				
	[72]				
IMCS	[73]	+	+	+	+
	[74]				
	[75]	+	+	+	+
	[76]	+	+		+

Table 7-3 THCS interfaces [TBC]

		WRMS							
		[37]	[38]	[39]	[40]	[41]	[42]	[43]	[44]
ARS	[24]								
	[25]								
	[26]				+		+		
	[27]								
	[28]								
	[29]								
ACSS	[30]								
	[31]								
	[32]								
THCS	[33]								
	[34]								
	[35]								
	[36]								
HMS	[45]	+	+		+				
	[46]	+	+		+				+
	[47]	+	+		+				
	[48]	+	+		+				
	[49]	+	+		+				
	[50]	+	+		+				
	[51]	+	+		+				
	[52]	+	+		+				
	[53]	+	+		+				
	[54]	+	+		+				
	[55]	+	+		+				+
	[56]	+	+		+				
SWPS	[57]								
	[58]								
	[59]								
FMS	[60]								
	[61]								
	[62]								
	[63]	+	+						
	[64]								
	[65]								
	[66]								
	[67]								
	[68]								
FDSS	[69]								
	[70]								
	[71]								
	[72]								
IMCS	[73]	+	+	+	+	+	+	+	+
	[74]								
	[75]	+	+	+	+	+	+	+	+
	[76]	+	+	+				+	+

Table 7-4 WRMS interfaces [TBC]

		HMS											
		[45]	[46]	[47]	[48]	[49]	[50]	[51]	[52]	[53]	[54]	[55]	[56]
ARS	[24]												
	[25]												
	[26]												
	[27]								+	+			
	[28]	+	+	+	+	+	+	+	+	+	+	+	+
	[29]								+	+			
ACSS	[30]												
	[31]												
	[32]												
THCS	[33]												
	[34]												
	[35]												
	[36]												
WRMS	[37]	+	+	+	+	+	+	+	+	+	+	+	+
	[38]	+	+	+	+	+	+	+	+	+	+	+	+
	[39]												
	[40]	+	+	+	+	+	+	+	+	+	+	+	+
	[41]												
	[42]												
	[43]												
	[44]		+									+	
SWPS	[57]												
	[58]		+	+	+	+	+				+		
	[59]		+	+	+	+	+				+		
FMS	[60]												
	[61]												
	[62]												
	[63]		+									+	
	[64]												
	[65]												
	[66]												
	[67]												
	[68]												
FDSS	[69]												
	[70]												
	[71]												
	[72]												
IMCS	[73]												
	[74]												
	[75]												
	[76]												

Table 7-5 HMS interfaces [TBC]

		SWPS		
		[57]	[58]	[59]
ARS	[24]			
	[25]			
	[26]			
	[27]			+
	[28]			+
	[29]			+
ACSS	[30]			
	[31]			
	[32]			
THCS	[33]			+
	[34]			+
	[35]			
	[36]			
WRMS	[37]			
	[38]			
	[39]			
	[40]			
	[41]			
	[42]			
	[43]			
	[44]			
HMS	[45]			
	[46]		+	+
	[47]		+	+
	[48]		+	+
	[49]		+	+
	[50]		+	+
	[51]			
	[52]			
	[53]			
	[54]		+	+
	[55]			
	[56]			
FMS	[60]			
	[61]			
	[62]			
	[63]		+	+
	[64]			
	[65]			
	[66]			
	[67]			
	[68]			+
FDSS	[69]			
	[70]			
	[71]			
	[72]			
IMCS	[73]	+	+	+
	[74]			
	[75]	+	+	+
	[76]			

Table 7-6 SWPS interfaces [TBC]

		FMS								
		[60]	[61]	[62]	[63]	[64]	[65]	[66]	[67]	[68]
ARS	[24]									
	[25]									
	[26]									
	[27]		+		+					
	[28]				+					
	[29]		+		+					
ACSS	[30]									
	[31]									
	[32]									
THCS	[33]									
	[34]									
	[35]				+					
	[36]		+							
WRMS	[37]				+					
	[38]				+					
	[39]									
	[40]									
	[41]									
	[42]									
	[43]									
	[44]									
HMS	[45]									
	[46]				+					
	[47]									
	[48]									
	[49]									
	[50]									
	[51]									
	[52]									
	[53]									
	[54]									
	[55]				+					
	[56]									
SWPS	[57]									
	[58]				+					
	[59]				+					+
FDSS	[69]									
	[70]									
	[71]									
	[72]									
IMCS	[73]		+	+	+	+		+		
	[74]									
	[75]		+	+	+	+		+		
	[76]		+	+	+	+		+		

Table 7-7 FMS interfaces [TBC]

		FDSS			
		[69]	[70]	[71]	[72]
ARS	[24]				
	[25]				
	[26]				
	[27]				+
	[28]				+
	[29]				+
ACSS	[30]		+	+	
	[31]	+	+	+	
	[32]			+	
THCS	[33]				
	[34]				
	[35]				
	[36]				
WRMS	[37]				
	[38]				
	[39]				
	[40]				
	[41]				
	[42]				
	[43]				
	[44]				
HMS	[45]				
	[46]				
	[47]				
	[48]				
	[49]				
	[50]				
	[51]				
	[52]				
	[53]				
	[54]				
	[55]				
	[56]				
SWPS	[57]				
	[58]				
	[59]				
FMS	[60]				
	[61]				
	[62]				
	[63]				
	[64]				
	[65]				
	[66]				
	[67]				
	[68]				
IMCS	[73]	+	+	+	+
	[74]				
	[75]	+	+	+	+
	[76]			+	+

Table 7-8 FDSS interfaces [TBC]

		IMCS			
		[73]	[74]	[75]	[76]
ARS	[24]	+		+	
	[25]	+		+	
	[26]	+		+	
	[27]	+		+	
	[28]	+		+	
	[29]	+		+	
ACSS	[30]	+			+
	[31]	+		+	+
	[32]	+		+	+
THCS	[33]	+		+	+
	[34]	+		+	+
	[35]	+		+	
	[36]	+		+	
WRMS	[37]	+		+	+
	[38]	+		+	+
	[39]	+		+	+
	[40]	+		+	
	[41]	+		+	
	[42]	+		+	
	[43]	+		+	+
	[44]	+		+	+
HMS	[45]				
	[46]				
	[47]				
	[48]				
	[49]				
	[50]				
	[51]				
	[52]				
	[53]				
	[54]				
	[55]				
	[56]				
SWPS	[57]	+		+	
	[58]	+		+	
	[59]	+		+	
FMS	[60]				
	[61]	+		+	+
	[62]	+		+	+
	[63]	+		+	+
	[64]	+		+	+
	[65]				
	[66]	+		+	+
	[67]				
	[68]				
FDSS	[69]	+		+	
	[70]	+		+	
	[71]	+		+	+
	[72]	+		+	+

Table 7-9 IMCS interfaces [TBC]

7.2 Subsystem external interfaces

Table 7-10 shows the interfaces of various external facilities and functions with each ECLS subsystem.

	ARS	ACSS	THCS	WRMS	HMS	SWPS	FMS	FDSS	IMCS
Thermal control			+	+	+				+
Electrical power	+	+	+	+	+	+	+	+	+
Structure, mechanisms, and material	+	+	+	+	+	+	+	+	+
EVA		+		+	+	+		+	+
IVA		+	+	+					
Safe haven	+	+	+	+	+	+	+	+	+
Portable equipment		+							
Propulsion		+							
DMS								+	

Table 7-10 ECLS external interfaces

Appendix A: THE ECLS PSS DOCUMENT TREE

The ECLS document tree as currently planned is shown in Figure A-1. Further documents may be added in the future.

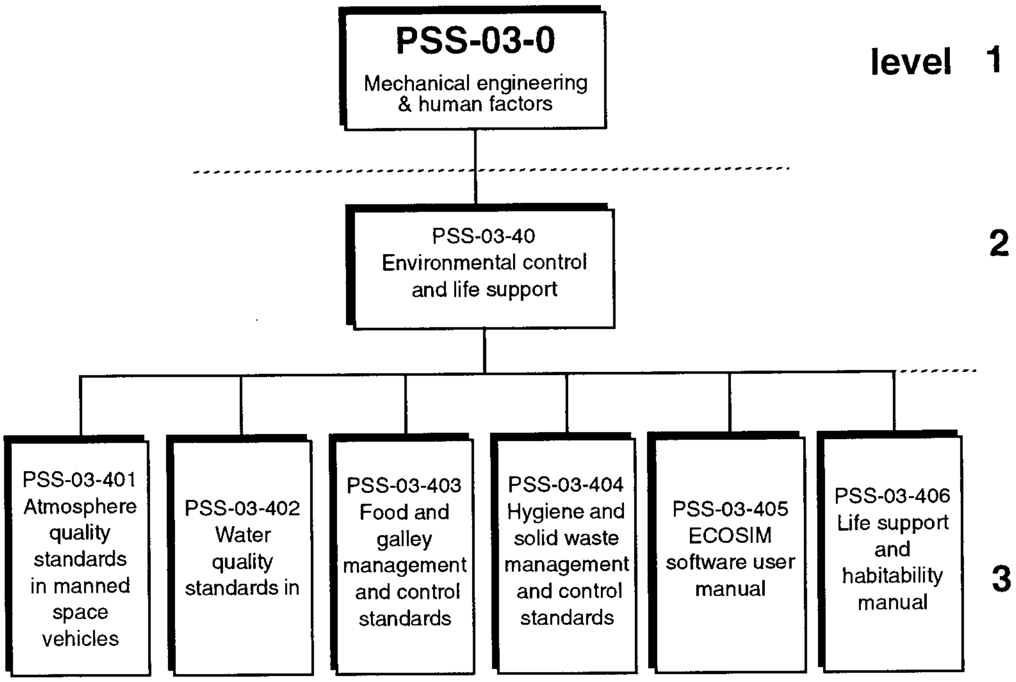


Figure A-1 The ESA ECLS document tree

A.1 The document identifier

Each ESA PSS document is given an identifier: for example, ESA PSS-03-401. “PSS” stands for procedures, specifications and standards.

The first field, 03, identifies all mechanical engineering & human factors documents. The second field, starting with “40”, identifies all ECLS related documents.

The number of ciphers in the second field indicates the level of the document in the document tree:

- ESA PSS-03-0 is a level 1 document.
- ESA PSS-03-40 is a level 2 document.
- ESA PSS-03-401, ESA PSS-03-402 etc. are level 3 documents.

All ECLS PSS documents are level 2 and 3 documents.

A.2 The structure of the document tree

A.2.1 The level 1 document

There is currently no document planned for PSS-03-0.

A.2.2 The level 2 document

ESA PSS-03-40 covers Environmental control and life support system (ECLSS) functional requirements as well as guidelines for the ECLSS design philosophy on atmosphere, water, food and hygiene.

A.2.3 The level 3 documents

The level 3 documents shall define requirements according to crew health requirements, and not subsystem performance. Therefore, requirements shall be given for *comfort*, *discomfort*, and *survival* situations (and not for nominal, degraded, and emergency modes).

ESA PSS-03-401/402/403/404 provide engineers and designers, working in the field of manned spacecraft programmes, with design requirements for atmosphere, water, food and galley, and hygiene and solid waste, respectively. Each of these documents consists of two parts, one dedicated to the design considerations (definitions, terminology, general data, peculiarities of the 0-g environment, etc.) and the other giving the requirements (including the range of permissible values).

ESA PSS-03-405 is the user's manual of ECOSIM (Environmental COntrol SIMulation software).

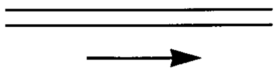
ESA PSS-03-406 is the Life support and habitability manual. It is designed to serve life support and habitability engineers and designers working in the field of manned space programmes. The complete document includes 12 chapters and a number of appendices, covering various aspects of life support and habitability. Specific technologies are presented in each chapter, and are detailed by a series of data sheets which follow a standard format.

A.3 Applicability

All ECLS PSS documents shall be applicable as "*recommended practices*".

Appendix B: SYMBOLS

Air lines
(flow direction)



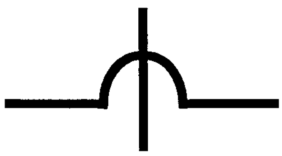
Gas lines (O_2, N_2, etc.)

Liquid lines (water, freon, ...)

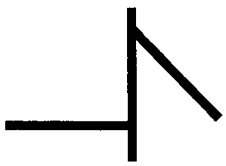
Signal lines, power lines

Enclosures for several components assembled in one unit

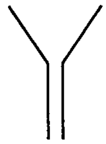
Lines crossing



Lines joining

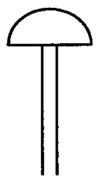


Overboard vent for air

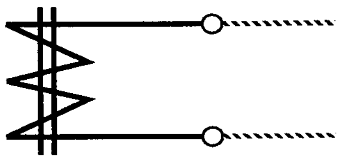


Overboard vent for gas or liquid

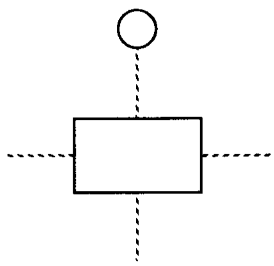
Overboard dump nozzle



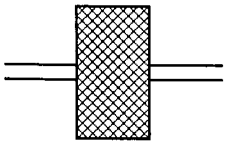
Nozzle heater



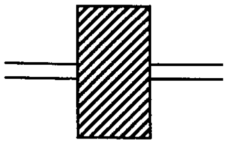
Selector controller (electrical)



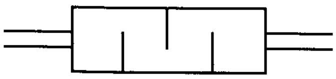
Filter



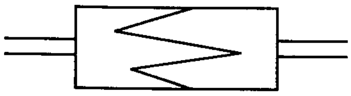
Debris trap



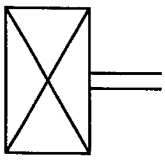
Silencer



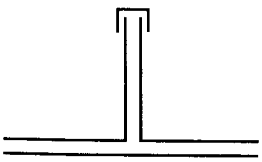
Burst disc



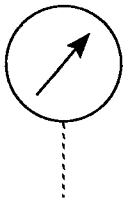
Disconnect



Test port

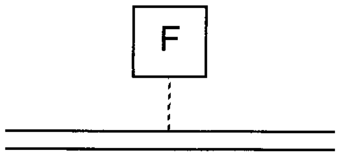


Gauge

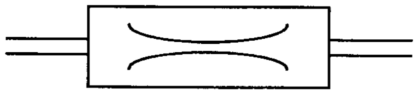


Transducers:

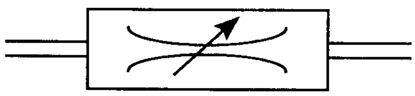
F	(flow)
T	(temperature)
P	(pressure)
ΔP	(differential pressure)
PCO_2	(partial pressure CO_2)
PO_2	(partial pressure O_2)
Q	(volume)
VPI	(valve position indicator)
S	(speed)
FS	(fire/smoke sensor)



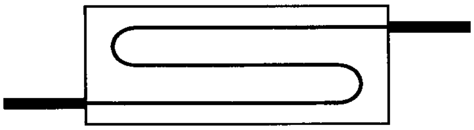
Flow restrictor



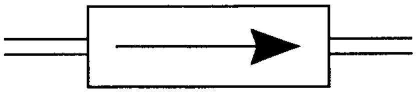
Adjustable flow restrictor



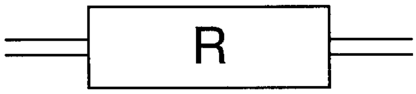
Radiator



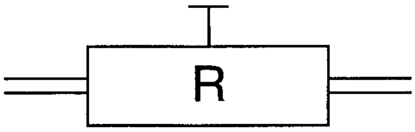
Check valve



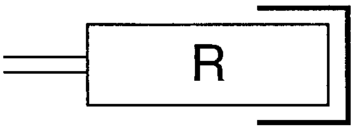
Relief valve



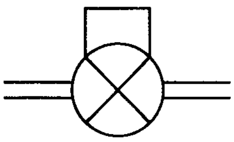
Relief valve
(spring loaded with manual override)



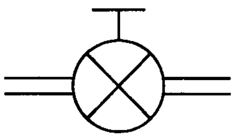
Relief valve with redundant cover



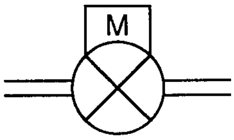
2-way shut-off valve
(solenoid operated)



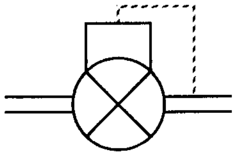
2-way shut-off valve
(manually operated)



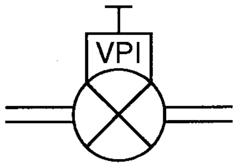
2-way shut-off valve
(motor driven)



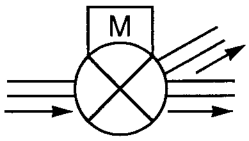
2-way shut-off valve
(pressure operated)



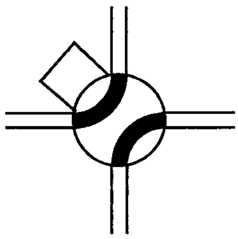
2-way shut-off valve
(solenoid operated with manual override and valve position indicator)



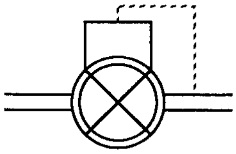
Modulating valve
(motor operated)



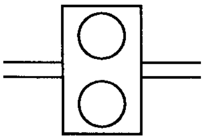
Multi way flow directional valve
(solenoid operated)



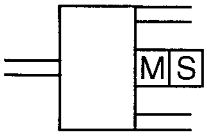
Pressure regulator



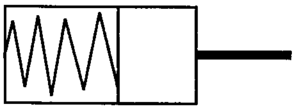
Fan or pump



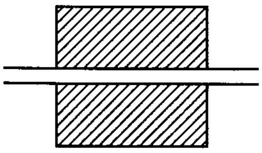
Water separator
(motor driven with speed sensor)



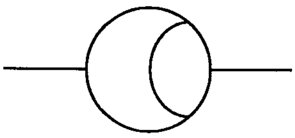
Accumulator



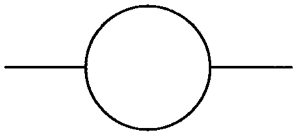
LiOH cartridge



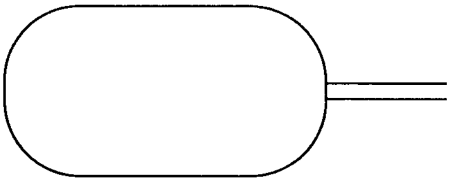
Bladder tank



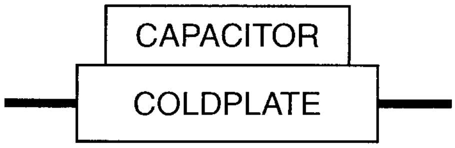
Gas tank



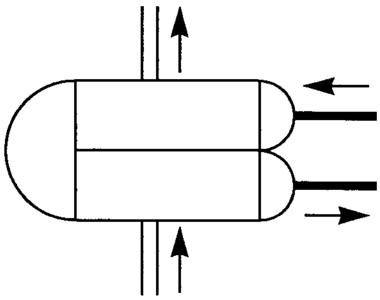
Tank (e.g. FSS bottle)



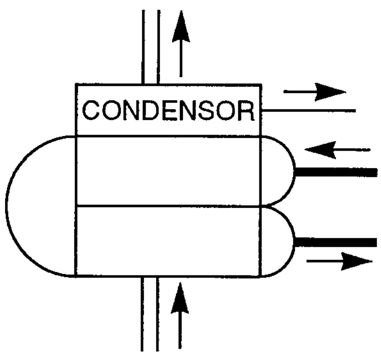
Thermal capacitor element



Cross counter flow heat exchanger



Condensing heat exchanger



Appendix C: RECOMMENDED VERIFICATION METHOD

Requirement number	Analysis	Inspection	Review of design	Qualification tests			Acceptance tests		
				Equipment	Subsystem	System	Equipment	Subsystem	System

Explanatory notes:

Analysis	An analytical method such as calculation, or any logical processing of information, for the purpose of determining parameters or performances, or checking correctness and completeness of the information in relation to the scope of verification.
Inspection	A method of verification involving physical checking such as form, fit and function of equipment, or availability of proper documentation and procedures, or checking on implementation of methods/procedure etc.
Review of design	[TBD]
Qualification tests	A test which demonstrates that the qualification model meets the performance requirements during exposure to the anticipated environmental conditions, with adequate margins.
Acceptance tests	Formal tests conducted to determine whether or not a system satisfies its acceptance criteria, and to enable the customer to determine whether or not to accept the system or the subsystem.

Appendix D: RELATED DOCUMENTS

ESA PSS-01-30	Reliability assurance requirements for ESA space systems
ESA PSS-01-40	System safety requirements for ESA space systems
ESA PSS-01-401	ESA fracture control requirements*
ESA PSS-01-50	Maintainability requirements for ESA space systems
ESA PSS-01-70	Materials and process selection and quality control for ESA space systems and associated equipment
ESA PSS-03-401	Atmosphere quality standards in manned space vehicles
ESA PSS-03-402	Water quality standards in manned space vehicles†
ESA PSS-03-403	Food and galley management and control standards†
ESA PSS-03-404	Hygiene and solid waste management and control standards†
ESA PSS-03-70	Human factors†

* This document is not referred to in the text. However, all ECLSS subsystems must meet this standard.

† At the time of writing, these documents have not been issued.

Appendix E: ACRONYMS AND DEFINITIONS

ACSS	Atmosphere control and supply subsystem
ARS	Air revitalisation subsystem
Closed loop ECLS systems	ECLS processes which recycle, regenerate, or recover materials or needed elements. This implies that significant expendables are not used in these processes.
Control	The action required to achieve a certain goal or stay within certain limits
Crew alert	A crew alert advises of the existence of a hazardous situation (e.g. out of the comfort mode).
Data management system	This consists of a distributed information management system which provides an overall environment for all on-board information management and data processing functions.
DMS	Data management system
ECLS	Environmental control and life support
ECLSS	The environmental control and life support system
ECOSIM	Environmental control simulation software
Environmental control and life support system	All the physical, chemical and biological processes which keep the crew healthy and productive in hostile environments, by creating a "shirt sleeve" environment
ESA	European Space Agency
EVA	Extravehicular activity
FD	Fault detection
FDSS	Fire detection and suppression subsystem
FMS	Food management subsystem
FSS	Fire suppression system
HMS	Hygiene management subsystem
IMCS	Instrumentation monitoring and control subsystem
IVA	Intravehicular activity

Latent heat loss	Heat loss related to water evaporation from the skin and respiratory tract
LEO	Low earth orbit
Monitoring	The supervision or observation of a process or an activity, either directly by a human being or indirectly by means of software
Open loop ECLS systems	Processes which are based on expendables or consumables
OS	Operational status
PBC	Partial body cleaning
PSS	Procedures, specifications and standards
SA	System autonomy
Safe haven	A facility on a space vehicle or on the ground which is capable of sustaining crew life until escape or rescue can be accomplished or the situation is rectified
Safing	The capability to render safe an occurring or imminent hazard. The priority is the safety of the crew.
Sensible heat loss	Heat loss resulting from direct heat transfer between the body and the environment
SMAC	Spacecraft maximum allowable concentration
SWPS	Solid waste processing subsystem
TA	Trend analysis
TBC	To be confirmed
TBD	To be defined
TCS	Thermal control system
THCS	Temperature and humidity control subsystem

Volumes definitions: (see table below)

Pressurised volumes		
Inaccessible volumes	**Accessible volumes**	
Inside racks and equipment	Normally occupied	Not normally occupied
	Habitable volumes	Behind racks, panels, floor or ceiling Interconnecting volumes and tunnels Storage volumes

VPI Valve position indicator

WRMS Water recovery and management subsystem

End of document

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PSS change request form

Document number:	PSS-	Issue/ date:		Volume/section/part:	
Paragraph number:		Type of change (tick one):		Modification ❑ Addition ❑ Deletion ❑	

Existing text:

Recommended text:

Justification for change (please provide documentation to support your request):

THIS SECTION MUST BE COMPLETED

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