International Environmental Control and Life Support System Interoperability Standards (IECLSSIS)

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REVISION AND HISTORY

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PREFACE

INTERNATIONAL ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM INTEROPERABILITY STANDARDS (IECLSSIS)

This International Environmental Control and Life Support System Interoperability Standards (IECLSSIS) document establishes standards to develop the necessary ECLSS technical solutions to enable collaborative endeavors in deep space.

Configuration control of this document is the responsibility of the Multilateral Coordination Board (MCB). The National Aeronautics and Space Administration (NASA) will maintain the IECLSSIS under Human Exploration and Operations Mission Directorate (HEOMD) Configuration Management. Any revisions to this document will be approved by the MCB.

INTERNATIONAL ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM INTEROPERABILITY STANDARDS (IECLSSIS)

CONCURRENCE

MARCH 2019

/s/ William H. Gerstenmaier Associate Administrator for Human Exploration and Operations National Aeronautics and Space Administration	9 May 2019 Date
Signature Pending Executive Director of Human Space Programs State Space Corporation Roscosmos	 Date
/s/ David Parker Director of Human and Robotic Exploration European Space Agency	4 July 2019 Date
/s/ Gilles Leclerc Director General, Space Exploration Canadian Space Agency	2019.07.10 Date
/s/ Ryuichiro Shirama Deputy Director General Research and Development Bureau Ministry of Education, Culture, Sports, Science, and Technology	19 July 2019 Date

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1.0 INTRODUCTION

This International Environmental Control and Life Support System Interoperability Standards (IECLSSIS) is the result of a collaboration by the International Space Station (ISS) membership to establish interoperable interfaces, terminology, techniques, and environments to facilitate collaborative space exploration endeavors in cislunar and deep space environments. These standards are available for international and commercial partnerships.

Standards that are established and internationally recognized have been selected where possible to enable a variety of providers. Increasing commonality among providers while decreasing unique configurations has the potential to reduce the traditional barriers in space exploration: overall mass and volume required to execute a mission. Standardizing interfaces can reduce the scope of the development efforts.

The information within this document represents a set of parameters, which if accommodated in the system architecture support greater efficiencies, promote cost savings, and increase the probability of mission success. These standards are not intended to specify all system details needed for implementation nor do they dictate design features behind the interface. Specific requirements will be defined in unique specification documents for future vehicles or modules.

1.1 PURPOSE AND SCOPE

The purpose of the IECLSSIS is to provide common basic performance parameters based on applicable, internationally recognized standards to allow developers to independently develop Environmental Control and Life Support System (ECLSS) technology solutions which can be easily compared and seamlessly integrated. They address areas covering cabin atmospheric conditions, potable water supply, urine stabilization, and special technical areas associated with ECLSS process technology or component compatibility. The focus of this version of the document is on cislunar space missions, including cislunar space platforms and their interfaces, with content that is also relevant to future missions. Extensibility to other deep space missions has also been considered and where practicable the documents include content that is also relevant to future missions. Future revisions of the document will incorporate additional deep space missions.

For technical areas associated with ECLSS process technology or component compatibility, standards are provided to define appropriate constraints and/or guidance necessary to comply with the specific compatibility issue. In some cases, there are specific constraining technical solutions that are expected to be applied to new cislunar space platform modules and future deep space modules to enable interoperability based on current data available. These solutions are described in the rationale and would be implemented in future specification documents and verification methods.

Standards for other technical areas that are necessary to develop a suitable exploration ECLSS and require evaluation by the ECLSS technical community are identified. Additional performance and design specification requirements will be necessary to achieve a detailed system design implementation and will be defined in future vehicle or module requirements documents. Some of these have been identified in the document as “Placeholders” for future research, discussion, and negotiation and are listed in Section 5. Content in these technical areas will be added to this document or requirements documents as appropriate.

1.2 RESPONSIBILITY AND CHANGE AUTHORITY

Any proposed changes to this standard by the participating partners of this agreement shall be brought forward to the IECLSSIS working group for review.

Configuration control of this document is the responsibility of the Multilateral Coordination Board (MCB). The National Aeronautics and Space Administration (NASA) will maintain the IECLSSIS under the Human Exploration and Operations Mission Directorate (HEOMD) Configuration Management. Any revisions to this document will be approved by the MCB.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, or other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

None

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document. These reference documents may or may not be specifically cited within the text of this document.

AIAA 2009-01-2592	A Design Basis for Spacecraft Cabin Trace Contaminant Control
GOST P 50804-95 Group D10	State Standard of the Russian Federation Cosmonaut's Habitable Environments on Board of Manned Spacecraft: General Medicotechnical Requirements (GOST) The GOST will be an applicable document for Roscosmos modules and systems, levied by the appropriate program.
JSC 20584	Spacecraft Maximum Allowable Concentrations for Airborne Contaminants, Latest Revision September 2017
JSC 63414	Spacecraft Water Exposure Guidelines, Latest Revision July 2017
NASA/SP-2010-3407/REV1	Human Integration Design Handbook Revision 1
NASA-STD-3001, Vol 2	NASA Space Flight Human-System Standard, Vol. 2: Human Factors, Habitability, and Environmental Health Volume 2 of NASA-STD-3001 is undergoing revision, and will soon be released as Revision A. The existing version may not yet capture all of the relevant information needed for future missions. When there are discrepancies between the existing NASA-STD-3001 and the IECLSSIS, the content in the IECLSSIS is intended to have early information or lead to changes in these documents that are more suitable for future deep space missions, and discrepancies will be resolved over time when they appear.
NASA TM-2013-217377	Effects of the 8 psia / 32% O_2 Atmosphere on the Human in the Spaceflight Environment

NASA TP-2010-216134	Recommendations for Exploration Spacecraft Internal Atmospheres: The Final Report of the NASA Exploration Atmospheres Working Group
Working Document Reference Numbers: ISO/DIS 16726, ISO/DIS 16157, ISO/DIS 17763	Draft ISO Standards for Human-Medical Requirements

3.0 INTERNATIONAL ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM INTEROPERABILITY STANDARD

3.1 GENERAL

The purpose of the IECLSSIS is to provide common basic performance parameters based on relevant, internationally recognized standards to allow developers to independently develop ECLSS technology solutions which can be easily compared and seamlessly integrated. Use of standard assumptions makes technology development more efficient, especially when multiple partners are involved in a joint venture.

For technical areas that have inconsistencies or conflicts between the applicable individual national standard documents, the inconsistency or conflict is resolved by evaluating overlaps between the applicable standards to create reasonable technical compromise. This tailoring enables the international standard to meet the requirements from multiple international partners.

This document focuses on system performance parameters and technical areas that most directly affect interoperability between systems in different modules and ECLSS technology developer solutions.

The following subsections describe the key exploration ECLSS system interfaces and performance parameters that are pertinent to cislunar and deep space missions.

3.1.1 ENGINEERING UNITS OF MEASURE

All dimensions are in International System of Units (SI units) (metric).

Alternate units may be provided in addition to metric units.

3.2 INTERFACES AND SYSTEM COMPATIBILITY

This section describes constraints created by fluids that flow between systems, and will be expanded to include mechanical connections or other interfaces in future updates. Other interoperability standards documents cover interfaces such as power, command and data avionics, and thermal control. Unless otherwise stated, the features called out in this section and its subsections shall be implemented by Environmental Control and Life Support (ECLS) systems to ensure compatibility between and within ECLS systems. For ECLSS components, this interface may also be between the ECLSS component and the human crewmembers. Other interfaces are the result of technology and system choices or the result of allocation of requirements and resources between systems. Each standard is specified only once with its required value and tolerance, if relevant. For some standards, a minimum success requirement for crew health and safety and a goal value for optimal crew comfort and performance may both be specified. For physical connections, deviations from these dimensions may be possible.

3.2.1 POTABLE WATER BIOCIDE COMPATIBILITY

Potable water may be supplied by different logistics providers, visiting vehicles with crewmembers, or closed-loop recycling systems. Ground supplied water and water processor system design concepts may vary, but the water provided should be able to be used across the modules for the cislunar and deep space missions for a robust logistics plan and maximum flexibility and evolvability of the systems. Residual biocides are used in many potable water systems to maintain water quality and prevent microbial growth, but are not always compatible with other biocides or certain materials of construction.

To be compatible, mixing water sources with residual biocides:

- should not inactivate the antimicrobial properties of the residual biocide;
- should not produce any byproducts that could be unacceptable for crew consumption or create a crew health risk;
- should not create problems in the systems used to store, distribute, or process potable water such as particulate or free gas generation;
- should not cause any other damaging effects to vehicle or module systems.

Future verification details will require detailed definitions of each type of potable water. The current assumed definition of potable water with biocide will include silver with a concentration up to 0.4 milligrams per liter (mg/L). This is because potable water with silver ion residual biocide will be included in the Orion water system design, and is therefore the first example of potable water that must be compatible with other water supply. The form of silver and detailed test methods will be defined later.

ECLSS-01: Biocides used in vehicle or module potable water systems shall be compatible with any other biocides used in the other potable water systems.

Rationale: When potable water is supplied to a distribution or delivery system, such as a galley, it will be mixed with water and any residual biocide already present in the system.

ECLSS-02: Biocides in the water transferred to ECLSS from other systems or vehicles, generated in the modules, or otherwise used in a vehicle or module potable water system shall be compatible with potable water system hardware and materials of construction.

Rationale: Systems for water storage, distribution, and delivery to crewmembers may be present in multiple modules, and could be provided by a variety of suppliers or partners. Potable water from all sources should be able to be used in all potable water systems.

ECLSS-03: Biocides used in the vehicle or module potable water systems shall be compatible with potable water that includes any contaminant identified in water quality specifications at levels up to human health limits.

Rationale: In potable water, contaminants are maintained below required levels, but it is not free of contaminants or other added species, such as minerals sometimes added for taste. The potable water biocide should *not create any byproducts that would be a threat to crew health when used in water with these contaminants.*

ECLSS-04: Potable water biocides and byproducts from combining biocides will be evaluated for toxicity by agency health and medical experts.

Rationale: The Spacecraft Water Exposure Guidelines (SWEG), JSC 63414, *are not an exhaustive list of all contaminants that may have negative effects on human health. They include contaminants that have been considered risks in previous human spaceflight missions based on those systems and operations. The limits are not necessarily identical to other public health standards. Introduction of a new species in spacecraft potable water will require evaluation to set a SWEG level.*

3.2.2 EMERGENCY AND FIRE SUPPRESSION SYSTEM COMMONALITY AND COMPATIBILITY

Responding to emergencies should be as simple and consistent as possible to minimize the opportunity for confusion or human error while making decisions in a challenging environment. Unfortunately, varying design standards and choices between the United States (U.S.) and Russian segments of the ISS have resulted in having two separate systems for fire suppression, and two sets of protective equipment for the crew, such as breathing masks, for use while fighting the fires. For cislunar and deep space missions, the goal is to have one common system that can be used in all spacecraft to simplify crew training and minimize resupply.

Handheld fire suppression devices will be expected to meet requirements for operation in microgravity. Shelf life requirements may depend on logistics delivery plans, but for Mars transit missions would be at least 1200 days **<TBR 3-8>**, and likely > 4 years to accommodate logistics plans to deliver supplies a substantial period of time before the crew mission to Mars begins.

ECLSS-05: A common design for portable, crew operated fire suppression systems shall be used across the vehicles.

Rationale: Using common emergency systems across the crew vehicle will simplify crew training and improve emergency response speed.

ECLSS-06: The fire suppression system (including fire suppressant, provided personal protective equipment, and any other necessary systems) shall not create a toxic environment for the crew.

Rationale: Vehicles and modules for cislunar missions, such as in-space cislunar platforms or a human lunar lander, and deep space missions, such as a transit vehicle to Mars, are expected to have smaller volumes than the ISS. Therefore, fire suppressants will not be diluted across as large a volume. Fire suppressants that cause health hazards for the crew create challenges for protective equipment while fighting the fire and a hazardous environment while recovering the vehicle or module status after the fire.

ECLSS-07: The vehicle fire suppression systems shall be compatible with vehicle systems.

Rationale: Extinguishing a fire should not create additional hazards for the crew when the fire suppressant comes into contact with vehicle systems, such as power and avionics systems. Fire suppressants should not damage systems so that they cannot be used after the fire is put out. Trace Contaminant Control Systems (TCCS) are another key system which needs to be considered for compatibility with the fire suppressant fluids. The extinguishing agents should not react in the TCCS to create toxic byproducts. The extinguishing fluids also should not poison or damage the TCCS.

ECLSS-08: The fire suppression system extinguishing agents shall be able to be removed from the cabin environment to return to nominal conditions after an emergency event.

Rationale: Vehicles and modules for cislunar and deep space missions will be located farther from Earth than ISS and resupply of consumables will be more difficult. Also, depressurizing and repressurizing a large transit habitat volume may require a prohibitively large quantity of consumables. Thus, there should be an option to recover after a fire.

ECLSS-09: ECLSS shall provide fire suppression methods that can be used while the crew is not present.

Rationale: Mission concepts for cislunar platforms and for reusable transit vehicles for Mars missions will have periods of time in which the crew is not present, but some systems are powered on. Handheld, deployable fire extinguishers are an important part of an integrated fire suppression system design, especially when the crew uses equipment like laptops out in the cabin. But handheld systems will not be sufficient when the crew is not present. The options for suppressing a fire when the crew is not present may be broader, as long as vehicle environment can be returned to normal before the crew returns. Systems such as diluent nitrogen, carbon dioxide, or cabin depressurization could be used during periods when no crew is present on the spacecraft since there is time to recover to a habitable atmosphere before the crew returns.

3.2.3 DESIGNING COMMON TECHNOLOGY FOR MULTIPLE MISSION OXYGEN ENVIRONMENTS

ECLSS-10: ECLSS technologies and components intended to be extensible to future missions utilizing Exploration atmospheres should be designed to operate in atmospheres with pressures as low 55 kilopascal (kPa) (8.0 pounds per square inch absolute (psia)), and oxygen concentrations as high as 36%.

Rationale: For maximum forward compatibility to Exploration missions, components that are expected to be common with surface systems that *utilize lower nitrogen atmospheres recommended in NASA TP-2010-216134 and NASA TM-2013-217377 for high-frequency extravehicular activity (EVA) should be designed to operate in this environment.*

3.3 PERFORMANCE

In addition to the physical interface requirements, a set of common design parameters and conditions is provided. Many of the ECLSS performance standards define the environment that needs to be maintained in the spacecraft for the crewmembers. Other common design parameters, if accommodated in the ECLSS design, increase the probability of successful collaboration by having systems from multiple providers that could be functionally interchangeable.

3.3.1 INTERNAL ATMOSPHERE PRESSURE

Achieving different oxygen and pressure control points is not usually a substantial challenge for the ECLSS design, but it drives the design and materials of the other spacecraft systems and must be identified early in the design process since integrated modules share atmosphere.

Figure 3.3.2-1, Oxygen and Total Pressure Conditions, illustrates how the combination of oxygen and total pressure requirements in Sections 3.3.1 and 3.3.2 create the nominal operation zone. This does not define control bands around a particular set point, but only describes possible allowable conditions within the vehicle or module.

The airlock will have additional requirements for total pressure limits to allow complete depressurization. Special tailoring may also be necessary for certain vehicles, such as human landers or pressurized rovers which also support high-frequency EVA.

ECLSS-11: The nominal internal atmosphere pressure for vehicles and modules will be approximately 101 kPa (14.7 psia).

Rationale: The vehicles covered by the IECLSSIS are expected to support crews for long duration, and have minimal EVA. An Earth-normal atmosphere is most appropriate for crew health in this type of mission. The control band around this setpoint has not yet been defined.

ECLSS-12: Vehicles and modules shall be designed to operate at internal atmosphere pressures from 65 kPa (9.5 psia) to 105 kPa (15.2 psia).

Rationale: This operational range provides interoperability across multiple use cases and is consistent with the orbiting and transport modules range recommended by the Exploration Atmospheres Working Group in NASA TP-2010-216134. The high end matches that of the ISS, providing and some structural margin above the nominal human shirt-sleeve environment defined in ECLSS-11 to support limited air save operations. The low end of this range allows the crew to acclimate to lower nitrogen levels to reduce decompression sickness risk ahead of suited operations, to manage off-nominal scenarios, to dock with other vehicles that operate at reduced pressure, and allows for reduced pressure operations during *uncrewed mission phases to save leakage makeup. The active control range is defined in ECLSS-13.*

ECLSS-13: The ECLSS shall control internal atmosphere pressures from 65 kPa (9.5 psia) to 102 kPa (14.9 psia).

Rationale: The ECLSS is responsible for controlling the vehicle atmosphere so that it does not exceed design limits. An ECLSS component or assembly will often be the prime system controlling atmosphere across many docked pressurized modules with hatches open. This range is the same control range adopted by the Orion spacecraft offering interoperability to support integrated operations.

ECLSS-14: The ECLSS shall not automatically relieve internal pressure overboard at a pressure lower than 103 kPa (15.0 psia).

Rationale: This requirement ensures that a pressure is not relieved below the maximum operational pressure as defined in ECLSS-12. Each exploration module must establish pressure relief in accordance with its own structural capabilities and operational requirements.

ECLSS-15: Vehicles and modules intended for human exploration missions with high frequency EVA shall be designed to operate at internal pressures as low as 55 kPa (8.0 psia) **<TBR 3-1>**.

Rationale: The Exploration Atmosphere of 57 kPa (8.2 psia) and 34% oxygen was recommended by NASA TM-2013-217377. Current mission concepts for the cislunar space platforms and deep space microgravity missions do not include high frequency EVA. Forward work is needed to validate this operational mode ahead of potential application to planetary surface exploration missions with high frequency EVA, including testing in a hypo-gravity environment. Testing in cislunar space has been requested in two separate Human System Candidate Test Objectives (CTOs) to support this validation effort (HS-22, HS-23). For maximum forward compatibility to Exploration missions, components that are expected to test or be common with surface systems should be designed to operate in this environment.

ECLSS-16: Vehicles and modules that will operate at 57 kPa (8.2 psia) shall be designed to operate in conditions up to 36% oxygen.

Rationale: The Exploration Atmosphere of 8.2 psia and 34% oxygen was recommended by NASA TM-2013-217377 as a nominal environment for future human exploration missions. The recommended control band at this pressure is expected to be between 33% and 35% oxygen. The Oxygen (O_2) concentration in this requirement provides some margin for the actual control band to ensure minimum oxygen level for human life is maintained.

ECLSS-17: The ECLSS shall be capable of controlling internal atmospheres from 55 kPa (8.0 psia) to 58 kPa (8.4 psia) within modules that will operate at 57 kPa (8.2 psia).

Rationale: This pressure range has been identified a viable atmosphere for future exploration missions. The ECLSS must be capable of controlling the atmosphere for the operational ranges selected.

3.3.2 ATMOSPHERE OXYGEN

Achieving different oxygen and pressure control points is not usually a substantial challenge for the ECLSS design, but it drives the design and materials of the other spacecraft systems and must be identified early in the design process since vehicles and modules share atmosphere. The partial pressure of oxygen is driven by crew health requirements. Oxygen concentration is important for controlling risk of fire in the vehicle.

Figure 3.3.2-1, Oxygen and Total Pressure Conditions, illustrates how the combination of oxygen and total pressure requirements in Sections 3.3.1 and 3.3.2 create the nominal operation zone. This does not define control bands around a particular set point, but only describes possible allowable conditions within the vehicle or module. It is not expected that the vehicle would operate at the highest allowable pressure setpoints at the same time as allowing the highest oxygen concentrations.

Modules designed for unique operations, such as high-frequency EVA, require expanded capabilities. Airlocks will also have additional requirements, such as nominal exposure to vacuum during depressurization and high oxygen conditions that may occur due to prebreathe or suit purging.

ECLSS-18: The nominal atmosphere oxygen partial pressure will be approximately 21 kPa (3.1 psia) when the total atmosphere pressure is approximately 101 kPa (14.7 psia).

Rationale: The vehicles covered by the ECLSS Standard are expected to support crews for long duration and have minimal EVA. An Earth-normal atmosphere is most appropriate for crew health in this type of mission.

ECLSS-19: The ECLSS shall control oxygen partial pressures to a selected set point within a range from 18.7 kPa (2.7 psia) to 23.4 kPa (3.4 psia).

Rationale: Controlling oxygen partial pressure within a medically acceptable range to avoid hypoxia or hyperoxia is required to protect crew health. Allowable oxygen levels for NASA spacecraft are found in NASA-STD-3001, Volume 2A, Section 6.2. The proposed range exceeds the range in NASA-STD-3001, but is within the range acceptable for indefinite exposure without measurable impairments per NASA/SP-2010-3407/Rev1. NASA-STD-3001 is expected to be updated in the future to include lower oxygen levels that are acceptable after acclimatization for reduced pressure atmospheres.

ECLSS-20: The ECLSS shall control oxygen concentration below 25.9% oxygen with nominal operating functions at pressures above 80 kPa (11.8 psia).

Rationale: High oxygen concentration increases flammability risk. High oxygen concentrations should not be necessary at higher cabin pressures to provide sufficient oxygen partial pressures for the crew.

ECLSS-21: The vehicles and modules shall be designed to operate in conditions up to 25.9% oxygen with nominal operating functions above 80 kPa (11.8 psia).

Rationale: Vehicle systems should be designed for the possible nominal operating environments that the ECLSS is designed to provide.

ECLSS-22: The ECLSS shall maintain oxygen partial pressure at or below 21 kPa (3.1 psia) when transitioning between atmosphere set points between 70 kPa (10.2 psia) and 80 kPa (11.8 psia).

Rationale: The ECLSS system needs intermediate control bounds when transitioning from 101 kPa (14.7 psia) atmospheres to lower pressure setpoints at 70 kPa. ECLSS-21 applies until the pressure reaches 80 kPa, then ECLSS-22 applies between 70 and 80 kPa.

ECLSS-23: The ECLSS shall control oxygen concentration below 30% under nominal operations for nominal atmosphere pressures up to 70 kPa (10.2 psia).

Rationale: Atmospheres with lower nitrogen content are needed before EVA operations to reduce risk of decompression sickness and make EVA operations more efficient. While this atmosphere is applicable to nominal EVA preparation, there are also contingency scenarios the atmosphere is applicable to, such as unpressurized, suited crew transfer in a Launch, Entry and Abort (LEA) suit to a vehicle that cannot hold atmosphere pressure.

NASA has collected material flammability data at 70 kPa (10.2 psia) and 30% oxygen for the Space Shuttle and Orion vehicles and made that data publically available through the Materials and Processes Technical Information System (MAPTIS).

During severe failures and emergencies, higher concentrations could occur, and the ideal ECLSS system should be able to manage and minimize or reduce oxygen concentrations in off-nominal scenarios, or it may be necessary to temporarily create higher oxygen concentrations to create levels the crew can survive.

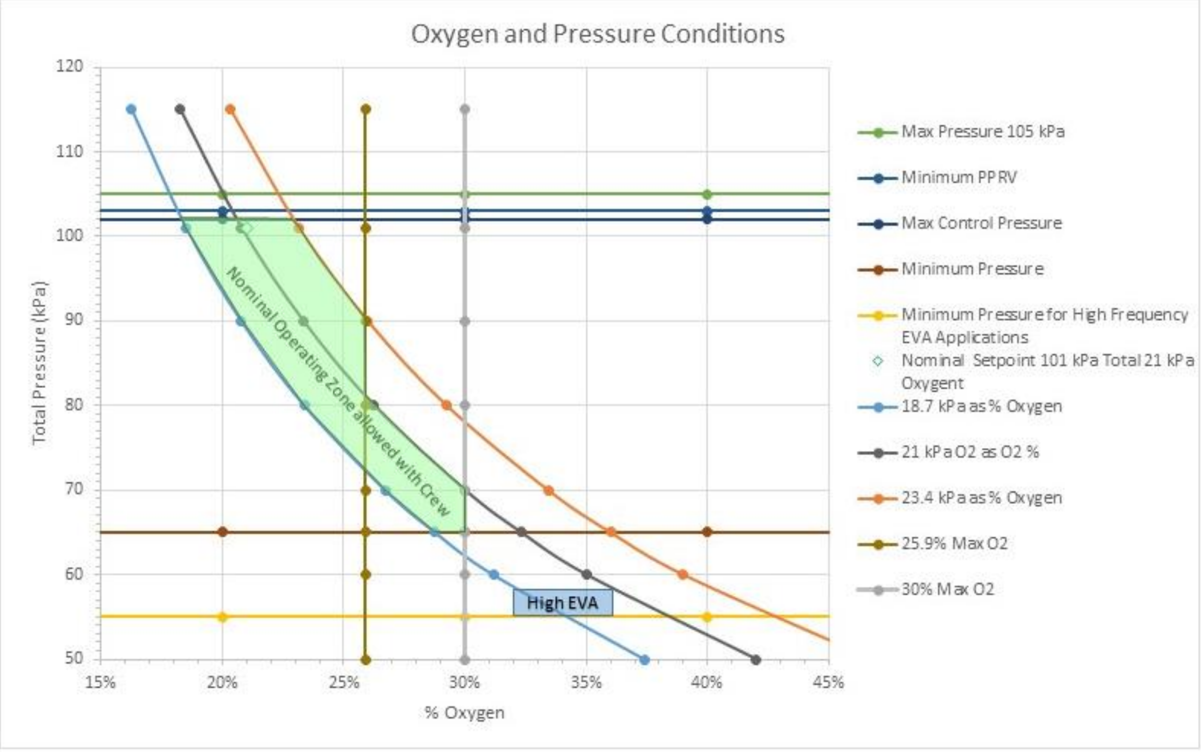
ECLSS-24: The vehicles shall be designed to operate in conditions up to 30% oxygen with nominal operating functions for atmosphere pressures up to 70 kPa (10.2 psia).

Rationale: Vehicle systems should be designed for the possible nominal operating environments that the ECLSS is designed to provide. Vehicle designers should still consider that failure scenarios could induce off-

nominal conditions. Individual vehicle designs will have to assess what contingencies to include in the unique specifications, such as the ability to dilute with nitrogen to control to 30%, or accepting and certifying to higher oxygen concentrations, or expecting somewhat higher oxygen concentrations (such as 40%) but minimizing risk to some acceptable level by controlling ignition sources or setting higher certification standards for sensitive or necessary components, such as avionics.

ECLSS-25: ECLSS shall control atmospheric oxygen concentration to below 36% oxygen within crewed modules that will operate at 57 kPa (8.2 psia).

Rationale: This oxygen concentration has been identified as an Exploration Atmosphere. The ECLSS must be capable of controlling the atmosphere for the operational ranges elected. This higher oxygen concentration increases flammability risk, and therefore must only be allowed at the low Exploration Atmosphere to the extent necessary to avoid hypoxia.



NOTE: This Figure does not describe the control box around any set point.

FIGURE 3.3.2-1 OXYGEN AND TOTAL PRESSURE CONDITIONS

3.3.3 ATMOSPHERE CARBON DIOXIDE LEVELS

Carbon dioxide (CO_2) is produced as a waste product by crew metabolism and must be removed to maintain a safe and healthy environment for the crew. Typically, not every pressurized volume in a group of docked modules has a CO_2 removal system, so ventilation is required to move CO_2 to the system that removes it from the atmosphere. CO_2 concentration in the atmosphere determines whether a certain flow rate of air is sufficient for maintaining CO_2 levels with intermodule ventilation. The performance and design of the CO_2 removal systems also depend on the CO_2 levels in the atmosphere.

ECLSS-26: The ECLSS shall control the 24-hour average cabin CO_2 partial pressure to a goal of 267 Pascal (Pa) (2 millimeter of Mercury (mmHg)) (2600 parts per million (ppm)) **<TBR 3-2>**

Rationale: Some evidence from long-term ISS missions suggests that microgravity increases crewmembers' susceptibility to CO_2-related symptoms, such as headache, lethargy, malaise, listlessness, and fatigue. Therefore, as a technical goal, CO_2 levels should be as low as possible in order to reduce or prevent crew symptoms. NASA medical experts recommend 267 Pa (2 mmHg) (2600 ppm) as the design level to minimize crew symptoms. This new standard is expected to be levied in a future update of NASA-STD-3001.

3.3.4 ATMOSPHERE TEMPERATURE

Atmosphere temperature control is important for crew comfort and health. Atmosphere temperatures, especially at high and low extremes, may also be important for the design of vehicle systems inside the pressurized volumes. The combination of atmosphere and humidity must be maintained within a "comfort zone". Figure 3.3.5-1, Environmental Comfort Zone, illustrates the interactions between temperature and moisture content of the air that impact crew comfort and define at what temperatures 100% relative humidity is reached and condensation will occur.

ECLSS-27: The ECLSS, utilizing life support and thermal control system functions, shall control the internal atmosphere temperature between 20° Celsius (C) (70°Farenheit (F)) and 27°C (81°F) when the crew is present.

Rationale: "Maintaining proper atmospheric temperature is important for maintaining a safe body core temperature, and is also important for comfort" per NASA/SP-2010-3407/Rev1.

ECLSS-28: The ECLSS shall provide crew selectable set points for internal atmosphere temperature in step sizes no greater than 1°C increments.

Rationale: Temperature preferences vary between crewmembers, and may vary depending on the workload and activity being performed at the time, such as sleep or exercise.

ECLSS-29: The ECLSS, utilizing life support and thermal control system functions, shall control the internal atmosphere temperature to within +/- 1.5°C (+/- 2.7°F) of the temperature set point.

Rationale: Per NASA/SP-2010-3407/Rev1, +/- 1.5°C (+/- 2.7°F) is sufficient precision to maintain crew comfort.

ECLSS-30: The ECLSS should provide crew selectable set points for atmosphere temperature in step sizes of 0.5°C (0.9°F) increments for crew comfort.

Rationale: More set points will provide more options for the crew to select the optimal temperature for crew comfort.

ECLSS-31: The ECLSS, utilizing life support and thermal control system functions, should design to control the atmosphere temperatures to increments +/- 0.5°C (+/- 0.9°F) of the temperature set point for crew comfort.

Rationale: Tighter control bands and less temperature variation would allow control closer to the desired temperature selected by the crew.

ECLSS-32: The vehicles systems inside the pressurized volume shall be designed to survive, or operate if needed during dormant phases, in temperatures as low as 4°C (39°F) **<TBR 3-3>** during periods when crew is not present.

Rationale: During uncrewed periods, there is no need to maintain systems for crew health. Lower temperatures could aid in reducing growth of microbial contamination in wetted systems or on vehicle surfaces, if there is no other reason to maintain temperature at nominal levels. The temperature should be maintained high enough that liquid water will not freeze and expand, which would damage systems. This requirement does not define the functional allocation or concept of operation that would describe what functions must operate during this uncrewed dormant phase. All systems onboard the spacecraft may be exposed to dormant conditions, unless functionality is included in part of the system to actively condition them. Other systems may be required to perform their functions, possibly in a modified mode, depending on the concept of operations of the mission, while other systems are dormant and the vehicle is controlling the environment to conditions that are different from conditions when the crew is present.

3.3.5 ATMOSPHERE RELATIVE HUMIDITY

Water content in the atmosphere can be described as a partial pressure or concentration, but relative humidity is more directly connected to crew comfort, and to the risk of condensation on vehicle surfaces. Figure 3.3.5-1, Environmental Comfort Zone, illustrates the interactions between temperature and moisture content of the air that impact crew comfort and define at what temperature 100% relative humidity is reached and condensation will occur.

ECLSS-33: The ECLSS, utilizing life support and thermal control system functions, shall nominally control relative humidity of the pressurized volumes (vehicles and habitable modules) atmosphere from 40% to 75% when the crew is present.

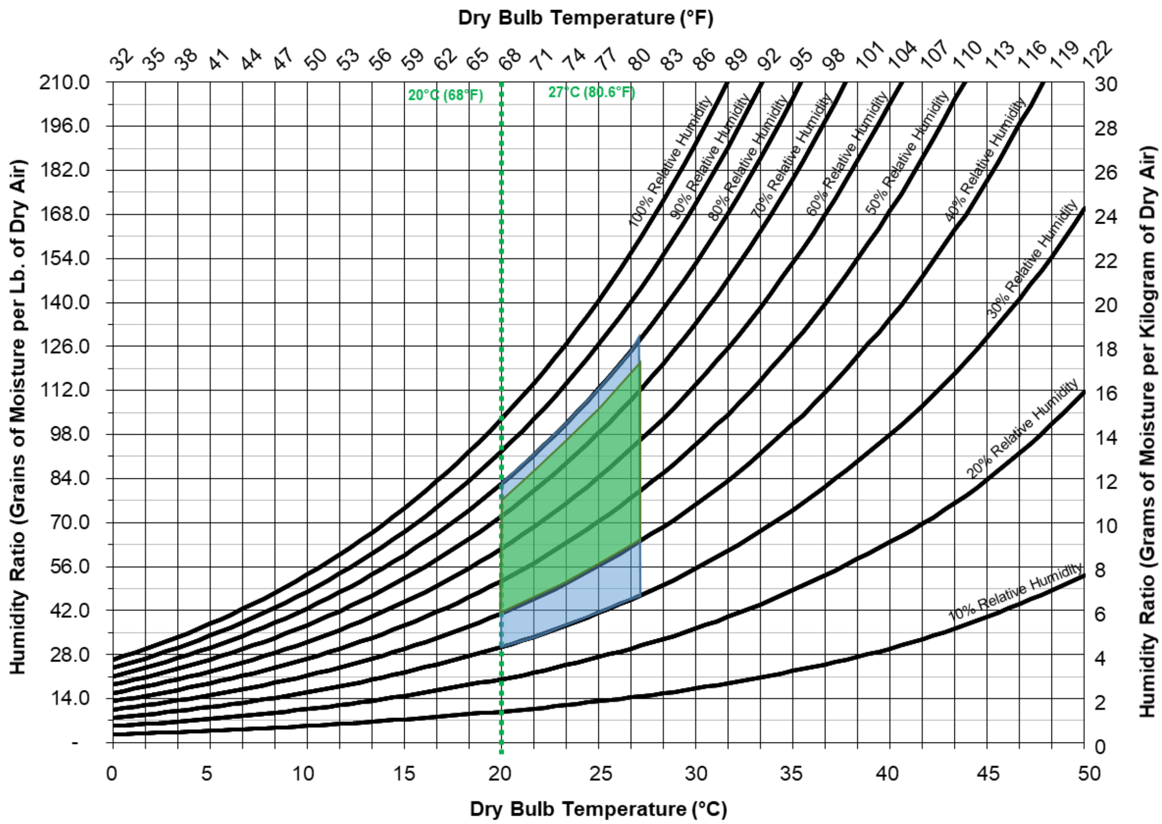
Rationale: Relative humidity is controlled for crew comfort, and is a function of dew point temperature in the atmosphere and atmosphere temperature. NASA recommendations for the tolerable range for relative humidity are provided in NASA-STD-3001, Vol 2 Rev A, in Section 6.2.3.1, and in Section 6.2.3.2 of NASA/SP-2010-3407/Rev1 as 25%-75% relative humidity. The GOST P 50804-95 Group D10 document recommends a minimum of 40% relative humidity for crew comfort.

ECLSS-34: For short durations less than 24 continuous hours, the vehicles, the ECLSS, utilizing life support and thermal control system functions, can allow the relative humidity of the atmosphere to be lower or higher than the nominal range, from 30% to 80% when the crew is present.

Rationale: Humans can tolerate a wide range of humidity for short periods of time. High humidity may make it difficult to control core body temperature if sweat does not evaporate well. Low humidity causes drying of the eyes, skin, and mucous membranes of the nose and throat.

ECLSS-35: The ECLSS shall control the dew point temperature of the atmosphere below the pressurized volumes (vehicles and habitable modules) internal wall or surface temperatures to prevent condensation at all times.

Rationale: Liquid water on surfaces is conducive to microbial growth, and can be damaging to system hardware. Local condensation can be created when the atmosphere dew point temperature is at or above the surface temperature in any location. When power is available to condition vehicle walls to higher temperatures, higher dew points can be permitted to achieve higher relative humidity if it is more comfortable for the crew.



NOTE: Illustrates relationships between Dew Point, Temperature, and Relative Humidity Standards to maintain crew comfort.

FIGURE 3.3.5-1 ENVIRONMENTAL COMFORT ZONE

3.3.6 POTABLE WATER QUALITY

Potable water quality must be defined so that water provided by any partner will be accepted for crew consumption by medical experts. Potable water quality limits are defined by crew health and medical experts. Several changes to existing standards are expected for future missions, and the requirements below highlight these expected changes.

ECLSS-36: The ECLSS shall provide potable water within standards for chemical and microbial contamination, and within acceptable aesthetic limits for crew consumption.

Rationale: Potable water quality limits are specifically set to be appropriately protective of the health and performance of spaceflight crews in consideration of the types of chemical/microbial risks relevant to this unique population. Definitions for acceptable water quality must be agreed upon for all potable water suppliers or recycling systems to be viable for consumption by all crewmembers.

TABLE 3.3.6-1 KEY WATER QUALITY STANDARDS

Property	Limit or Range	Notes
Total Organic Carbon	< 5 mg/L **<TBR 3-4>** uncharacterized < 25 mg/L **<TBR 3-5>** characterized	Value has changed compared to previous version of NASA SWEG in JSC 63414 in place prior to 2017
Ammonia	< 3 mg/L	Value expected to change in future updates to JSC 63414
Silver	< 0.4 mg/L	Expected to be used at concentrations near the maximum allowable for biocide control
pH	5.5-9	Selected as a range that meets both NASA and GOST standards.
Free and Dissolved Gas	< 0.1%	Only appears as a health standard in NASA standards, not in GOST standards

NOTE: Values for these particular parameters are provided in Table 3.3.6-1, Key Water Quality Standards, because they have either recently changed, or are likely to be updated by the time new modules are developed, or they have differences between U.S. and Russian standards documents.

ECLSS-37: The ECLSS shall maintain individual chemical contaminants below toxicity limits defined by health and medical standards in potable water.

Rationale: Potable water quality limits are specifically set to be appropriately protective of the health and performance of spaceflight crews in consideration of the types of chemical/microbial risks relevant to this unique population. A current list of toxicity limits in NASA's SWEGs can be found in JSC 63414. A final list of critical contaminants will need to be reviewed after vehicle systems are selected. New limits could be added to those standards if new materials or operations introduce risks beyond what is currently managed for the International Space Station.

ECLSS-38: Microbial control shall maintain cleanliness equivalent to 50 colony forming units per milliliter (cfu/mL) counts **<TBR 3-6>**, with non-detectable per 100 milliliter (mL) coliform bacteria, non-detectable per 100 mL fungus, and 0 parasitic protozoa in potable water.

Rationale: Potable water quality limits are specifically set to be appropriately protective of the health and performance of spaceflight crews in consideration of the types of chemical/microbial risks relevant to this unique population. These limits are what is set by NASA-STD-3001-Volume 2. The method of measuring and validating microbial control may change based on new monitoring technology, and cfu/mL may not ultimately be the units used for reporting microbial content of spacecraft potable water.

3.3.7 POTABLE WATER QUALITY AND MICROBIAL CONTROL PERFORMANCE

The compatibility of biocides in potable water is an important issue for system interoperability, and is described in Section 3.2.2. Performance requirements for the biocide in the potable water system must be met at the same time as the compatibility requirements.

ECLSS-39: The vehicles ECLSS shall maintain the quality, including chemical and microbial, of stored potable water within defined limits for at least 4 years **<TBR 3-7>** in open-loop systems.

Rationale: Water storage duration includes time between ground processing and launch, and storage on orbit before use. Long storage durations are important for the early cislunar space platform missions before closed-loop life support is delivered and will also be useful for long duration missions, especially in reusable modules. The final scenario to define the mission operations concept that drive duration will be captured in official program documents. Until then, this assumes that one crew launch per year occurs for cislunar or deep space missions, and that not every major launch would be able to include water delivery. A robust system should also be designed for contingencies like delayed launches or lost resupply missions that could add another year of storage for the on-orbit assets before the crew returns. Some analysis cases may choose not to put water on logistics missions, especially if more perishable items like food are needed, or items specific to a particular crew (e.g. clothing and spacesuits) need to be delivered. ***<TBR 3-7>*** *starts with 4 years as a life target based on time for ground processing, at least two years of nominal mission storage, plus margin for contingencies or providing flexibility for logistics choices.*

For long duration missions with closed-loop water recycling, expired water can be processed to return to potable status. Therefore, transit to Mars, or dormancy in Mars orbit on the Mars surface are not driving durations for storage life. However, this would drive a requirement to supply ascent vehicles or predeployed landers with recently processed potable water before use, or water stored for contingencies.

3.3.8 URINE PRETREATMENT PERFORMANCE

Crew urine is a resource that can be recycled into useful water or oxygen when closed-loop recycling systems are provided as part of the ECLSS. In a system with many contributing partners, the provider of the waste collection system may not be the provider of the urine recycling system. Waste collection systems are likely provided earlier than water recycling systems. Defining performance requirements for these systems early will make it possible to compare technical solutions for future modules, test viable systems for compatibility with closed-loop urine recycling systems.

This is not intended to define the functional allocations in the cislunar or deep-space elements and mission architectures, nor does it require that every vehicle or module must have a waste collection system with urine pretreatment. But if they do have a waste collection system, the urine pretreatment should meet these standards.

ECLSS-40: The waste collection system(s) shall provide a urine pretreatment that protects the waste collection system.

Rationale: Pretreatment is initially used to protect the urine collection system components. Current systems assumptions include a spin-separator in the urine collection system that cannot accept particulate (e.g. precipitation of solids from urine), and bellows tank storage that cannot accept evolution of free gas (e.g. CO_2 or Ammonia (NH_3)) or biological fouling. Free gas would cause tank pressurization, and biomass from biological fouling can cause failures in pumps, filters or other components.

ECLSS-41: The waste collection system(s) shall provide a urine pretreatment that maintains effective microbial (bacterial and fungal) control in the pretreated urine for at least 3 months of storage.

Rationale: Urine pretreatment controls prevent microbial growth that would clog the urine recycling systems or fluid lines and tanks in the system. ISS experience shows that urine may need to be stored during maintenance and troubleshooting of water processing systems. The three-month requirement allows time for systems to store urine during startup of ECLSS systems, and during maintenance, and still be able to recover water. This does not create a requirement to store urine through dormancy between crewed missions to process in the next mission.

ECLSS-42: The waste collection system(s) shall provide a urine pretreatment that maintains the urine within specifications for processing by the water recovery system after 3 months of storage.

Rationale: In long duration missions, pretreating urine also allows water recovery from stored urine by making sure that it is still compatible with the water recovery system. The urine recycling system may have unique requirements such as free gas, particulate, or other constraints on what can successfully be processed by the system. ISS experience shows that urine may need to be stored during maintenance and troubleshooting of water processing systems. The three-month requirement allows time for systems to store urine during startup of ECLSS systems, and during maintenance, and still be able to recover water. This does not create a requirement to store urine through dormancy between crewed missions to process in the next mission.

ECLSS-43: Urine pretreatment chemicals shall have stable shelf life of greater than 3 **<TBR 3-8>** years.

Rationale: Waste collection systems for initial cislunar space platforms are expected to be common with future deep space missions to simplify *crew training and maximize common spares, especially since the waste collection system often has disposable components for cleanliness. For technologies used that are intended to be used for future Mars missions, stable shelf life should be greater than 5 years for pre-emplaced cargo delivery scenarios. Operation of initial systems, such as at the cislunar space platform will build experience with the system to be used in future deep space modules and missions, and thus should be designed to meet those future long duration mission requirements.*

ECLSS-44: Urine pretreatments used in vehicle or module waste systems shall be compatible with any other pretreatment used in the other waste systems.

Rationale: If multiple waste collection systems are present, urine pretreatment from each system may be mixed in shared venting systems or when the urine is recycled in a water processor.

4.0 VERIFICATION AND TESTING

It is the responsibility of the spacecraft developer to perform verification and validation. The majority of the standards will be verified using a combination of interface/compatibility testing, integrated end-to-end testing and analysis at the subsystem and system level.

The following provides guidance on early test methods for verification.

4.1 EARLY DISCUSSIONS ON TESTING STANDARDS

For some topic areas, early discussions on test methods are required for technology development, as well as for the final vehicle design. This section provides information or discussion on topics that would be implemented in the lower level verification requirements, but may be useful background to guide technology development.

4.1.1 AUGMENTED URINE TO REPRESENT SPACEFLIGHT CONDITIONS

Wastewater systems and water processors which process urine should perform testing with wastewater streams that represent urine from crewmembers during spaceflight. This is especially true for systems which add additional chemical species (such as a pretreatment), or are sensitive to particulates, or concentrate wastewater, or otherwise utilize phase change (such as distillation, evaporation, freeze-drying, precipitation). ISS operations history and failures have identified several lessons learned that demonstrate that ground testing did not sufficiently replicate spacecraft conditions. One example is increased concentration of key minerals such as calcium. The document CTSD-ADV-1324 “Collection, Augmentation, Stabilization, and Disposal of Urine” describes methods to augment human urine collected on Earth to represent key spacecraft urine properties, such as Calcium concentration of 230 mg/L. It also describes current available spacecraft methods for pretreating urine with added chemicals for stability and microbial control.

4.1.2 INOCULATION OF URINE FOR URINE PRETREATMENT TESTS

New pretreatment formulations shall be tested to see if they achieve the same levels of microbial and fungal control as state of the art pretreatment, using inoculated, augmented, human urine. A pretreatment that does not perform the same as the state of the art pretreatment could still be selected. If other pretreatments have different performance, they must be thoroughly tested with an integrated waste collection system, wastewater transport and storage, and water processing system to show successful operation.

Inoculation with fungus and bacteria is based on microbial load that has been found on ISS in the waste system. Testing in a lab is likely to have a cleaner environment than ISS and would not provide a consistent or sufficient challenge.

4.1.3 TECHNOLOGY VALIDATION TESTING

NASA and international partners need to agree on expectations for technology demonstration before systems can be considered ready for inclusion in new modules or vehicles for cislunar or deep space missions.

NOTE: Carbon dioxide removal is one of the first systems where discussions have begun. For example, European Space Agency (ESA) has negotiated a 1 year cumulative demonstration for the Advanced Closed Loop System (ACLS) on ISS. One possible agreement could be that CO_2 removal systems must be tested on orbit for at least one year cumulative time to verify their reliable performance in microgravity. On-orbit tests should be compared to ground tests that replicate ISS inlet conditions to validate that the system performs the same way in microgravity as it does on Earth. If on-orbit and ground tests are shown to have equivalent results, ground tests can be used to demonstrate system performance with different inlet CO_2 and flow conditions. These topics should be part of international contribution discussions.

5.0 FUTURE TOPICS FOR POSSIBLE STANDARDIZATION

Several topics are partially defined, or have been identified for work, to lead to future standards.

The topics identified as forward work include waste management, waste processing and resource recovery, physical connections (in addition to the quick disconnect connections identified below), design standards related to repairability and system refurbishment and maintainability, any tailoring of human system interaction standards, requirements that enable joint spares tracking and management.

In the areas listed below, some technical discussion has already begun, but there is forward work needed before a requirements structure and values can be proposed.

5.1.1 URINE PRETREATMENT FORMULATION AND DOSING

The document CTSD-ADV-1324, "Collection, Augmentation, Stabilization, and Disposal of Urine", describes methods to augment human urine collected on Earth to represent key spacecraft urine properties. It also describes current available spacecraft methods for pretreating urine with added chemicals for stability and microbial control with phosphochromic and sulfochromic pretreatment formulations.

Additional updates may be required if technology development results in new, feasible formulations.

5.1.2 POTABLE WATER BIOCIDE FORMULATION AND MAINTENANCE

The primary residual biocide used in the vehicle will be silver based. Concentrations must meet requirements for potable water when it is consumed by humans. Specifics of the silver formulation or generation method are undefined at this time.

Additional updates may be required if technology development results in new, feasible methods.

5.1.3 LIQUID QUICK DISCONNECT CONNECTIONS

Placeholder for future content. Trade studies may be required and must take into account safety requirements, such as minimizing leakage of hazardous fluids during mating and demating.

5.1.4 GAS QUICK DISCONNECT CONNECTIONS

Placeholder for future content. Trade studies may be required and must take into account safety requirements, such as leaking hazardous gases into the habitable volume.

5.1.5 EMERGENCY EQUIPMENT

Emergency systems, such as masks, should be standardized to simplify crew training and improve crew response in contingencies.

5.1.6 CREWMEMBER METABOLIC RATES

Placeholder for future standard.

Rationale: Crew metabolic rates define the oxygen use, carbon dioxide production, sensible heat production, water vapor production (respiration and latent heat through perspiration) of a crewmember as a result of metabolic activity and individual crewmember size. These values are a reasonable maximum to be used for system design, but will vary significantly during actual missions for individual crewmembers. Total metabolic rate is expected to be higher for exploration missions than what is described in NASA/SP-2010-3407/Rev1 due to longer exercise periods.

5.1.7 CREWMEMBER TRACE GAS GENERATION RATE

Placeholder for future standard.

Rationale: Trace gas generation rates are needed to design trace contaminant control systems. Trace gas generation includes both crewmember and materials off-gassing. Reference AIAA 2009-01-2592 for preliminary values.

5.1.8 VEHICLE TRACE GAS GENERATION RATE

Placeholder for future standard.

Rationale: Trace gas generation rates are needed to design trace contaminant control systems. Trace gas generation includes both crewmember and materials off-gassing. Reference AIAA 2009-01-2592 for preliminary values.

5.1.9 PLANT GROWTH SYSTEM GAS EXCHANGE RATES

Placeholder for future standard.

Rationale: Growing plants for food will introduce oxygen, carbon dioxide, and humidity production and consumption rates that will impact the design of pressure control, CO_2 removal, and especially humidity control systems. Plants will also create and destroy trace gas contaminants, but those rates are likely to be low and not substantially impact designs. Limited plant growth is expected as part of early cislunar missions with a negligible effect on CO_2 and O_2. Transpiration of water into atmosphere humidity could have a detectable impact on the system even with small amounts of plant growth.

5.1.10 CREWMEMBER WASTE GENERATION RATES

Placeholder for maximum single events for design for urine, feces, and emesis.

Placeholder for average planning rate for urine, feces, and emesis.

> *Rationale: Crewmember urine and feces generation rates will drive waste collection system design, logistics supply planning (based on frequency of toilet use), and waste management and disposal planning.*

5.1.11 WATER COMPATIBILITY WITH OTHER VEHICLE SYSTEMS

Placeholder for water interface with spacesuits, which may have specific constraints for biocides in the water.

Placeholder for water interface with oxygen generation systems, which likely cannot accept biocides in the water.

Placeholder for other future standards.

> *Rationale: Water supply to spacesuits, oxygen generation, monitoring systems, medical systems, or supplying experiments may have unique interface requirements. This water does not necessarily also have to meet the potable water standard.*

5.1.12 VEHICLE TEMPERATURES AND HUMIDITY DURING DORMANCY

Placeholder for maximum temperature during dormancy if analysis shows it is higher than nominal temperatures.

> *Rationale: A close approach to the moon could induce a high temperature that would need to be defined if thermal control systems are in a dormant state. If analysis shows that high temperatures are possible during dormancy, internal vehicle temperature control analysis needs to be performed to examine what temperatures would actually be experienced, and where the limits of operation are for electronic components or others that might be sensitive at higher temperatures. High temperatures would drive higher rates of materials off gassing during this period.*

Placeholder for controlling vehicle internal temperature during dormancy if payloads require it.

> *Rationale: It may also be necessary to define local temperatures for science payloads that are maintained separately from the overall vehicle temperature.*

Placeholder for minimum humidity during dormancy if electrostatic hazards are not defined elsewhere.

> *Rationale: ECLSS will want to lower humidity during dormancy to control microbial growth, but there may be a minimum threshold.*

5.1.13 AIRLOCK OXYGEN

The airlock will have unique oxygen requirements.

5.1.14 AIRLOCK PRESSURE

The airlock will have unique pressure requirements.

5.1.15 CO_2 SHORT DURATION EXPOSURE LIMITS

Limits for contingencies or short duration exposure will need to be defined.

5.1.16 PARTICULATE GENERATION RATES

Particulate generation rates are needed to design systems to meet particulate limits. Assumptions may be needed for lunar dust transferred from lunar landers or sample transfer.

5.1.17 PLANETARY PROTECTION

Future exploration missions may need limits on quantity or composition of wastes vented to the environment, or new limits to prevent transfer of materials from another planetary surface back to Earth.

APPENDIX A - ACRONYMS AND ABBREVIATIONS

AIAA	American Institute of Aeronautics and Astronautics
ACLS	Advanced Closed Loop System
C	Celsius
cfu/mL	colony forming unit per milliliter
CO_2	Carbon Dioxide
CTO	Candidate Test Objectives
CTSD	Crew and Thermal Systems Division
ECLS	Environmental Control and Life Support
ECLSS	Environmental Control and Life Support System
ESA	European Space Agency
EVA	Extravehicular Activity
F	Farenheit
GOST	Transliteration of Russian acronym for State Union Standard
HEOMD	Human Exploration and Operations Mission Directorate
HS	Holding Structure
IECLSSIS	International Environmental Control and Life Support System Interoperability Standards
ISO	International Organization for Standardization
ISS	International Space Station
ISCEWG	
JSC	Johnson Space Center
kPa	kilopascal
LEA	Launch Entry and Abort
MAPTIS	Materials and Processes Technical Information System
MCB	Multilateral Coordination Board
mg/L	milligrams per Liter
mL	Milliliter
mmHg	Millimeter of Mercury
MMOP	Multilateral Medical Operations Panel
NASA	National Aeronautics and Space Administration
NH_3	Ammonia
O_2	Oxygen
Pa	Pascal
ppm	parts per million

psia	pounds per square inch absolute
SI	International System of Units
SMAC	Spacecraft Maximum Allowable Concentration
SWEG	Spacecraft Water Exposure Guidelines
TBD	To Be Determined
TBR	To Be Resolved
TCCS	Trace Contaminant Control System
U.S.	United States

APPENDIX B GLOSSARY

CREW

The term "crew" is used throughout to refer to the entire flight crew onboard the vehicle or assembled modules.

EXPLORATION ATMOSPHERES

The set of oxygen and pressure setpoints recommended to support classes of human space exploration missions based on the planned activities, such as long duration habitation or high frequency EVA.

MODULE

A major individual piece of flight hardware for cislunar or deep space missions. For example, a habitat that delivers cargo are all unique individual modules.

SYSTEM

The term "system" refers to the vehicle and hardware developed by NASA, International Partners, or commercial companies.

VEHICLE

A spacecraft delivering crew or cargo from Earth to a cislunar or deep space location, or between cislunar or deep space locations.

APPENDIX C OPEN WORK

Table C-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. As each TBD is solved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

The IECLSSIS contains many placeholder topics for which future standards need to be created. However, since the best structure for listing the various values for each topic has not been created, they are not included as TBDs at this point.

TABLE C-1 TO BE DETERMINED ITEMS

TBD	Section	Description

Table C-2 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. As each TBR is resolved, the updated text is inserted in place of the original value, and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

TABLE C-2 TO BE RESOLVED ISSUES

TBR	Section	Description
3-1	3.3.1	Further testing and analysis of prebreathe protocols will validate what the ideal lower pressure bound for exploration atmospheres should be.
3-2	3.3.3	There is a known disagreement on this standard. Roscosmos/Energia does not concur with the 2 mmHg (2600 ppm) CO_2 level, and recommends 6 mmHg daily average. The ECLSS team recommends authorizing a Multilateral Medical Operations Panel (MMOP) to begin including exploration content to set a single, shared “Design Goal” for future missions, for nominal long duration, long-term exposure levels for CO_2. This approach could be similar to the “design safety factor” that is applied to trace contaminant control levels. This allows a design goal for nominal operation that is lower than the maximum allowable level based on functional margin. (Functional margins may need to be greater for missions farther from Earth that do not have abort options or logistics resupply options.) This would apply to CO_2 removal systems across all international partners to prepare for long-duration exploration missions. Additionally, the panel can also discuss what medical research is necessary to set a final requirement in the future. NASA has removed CO_2 from the Spacecraft Maximum Allowable Concentration (SMACs) in JSC 20584, and will be implementing a new value in NASA-STD-3001.
3-3	3.3.4	Low temperatures are desired to slow microbial growth during dormancy. Analysis and testing has not been performed to determine what temperature is sufficiently low to inhibit microbial growth. Additionally, analysis has not been done to determine if any systems or payloads will be unable to operate at this low temperature and constrain the lower limit. 4°C was selected as a reasonable starting point for a dormancy temperature to control microbial growth based on public health recommendations to control bacteria growth in refrigerators.

Baseline

TBR	Section	Description
3-4	3.3.6	Based on ISS experience, NASA has updated requirements to allow higher total organic carbon levels in potable water. This change has been updated in the new version of the SMACs in JSC 20584 for 100 day or less durations. Specific limits for 1000 day missions have not yet been set.
3-5	3.3.6	Based on ISS experience, NASA expects to update requirements to allow higher total organic carbon levels in potable water. These changes have not yet been included in the applicable parent documents.
3-6	3.3.6	Microbial quality standards for potable water are expected to maintain a similar intent for future spacecraft, but a revision of the applicable parent documents may change the way viability, enumeration, or identification of microbial contamination is discussed.
3-7	3.3.7	Potable water shelf life is based on logistics delivery assumptions from ISCEWG Phase 1 analysis. More detail on ground processing time, risk tolerance for skip cycles, or updated logistics analysis could change the maximum time water is stored before it is consumed or a closed-loop water recycling system is provided to reprocess it.
3-8	3.2.2, 3.3.8	Fire extinguisher and urine pretreatment shelf life is based on concepts for 1000-1200 day human Mars missions. If urine pretreatment must be delivered much earlier for habitat outfitting logistics, or ground processing time is very long, this minimum required number could increase.