

International Space Station Water System Architecture and Operational Plan

David A. Yeoman

ARES Corporation, Program Integration and Control Contract

Brienne Shkedi

NASA Lyndon B. Johnson Space Center

Barry Tobias

United Space Alliance, Space Program Operation Contract

ABSTRACT

The International Space Station (ISS) is gaining many new capabilities in 2008. The delivery of the United States Operation Segment (USOS) Regenerative Environmental Control and Life Support (ECLS) Systems allow for the ISS crew expansion from 3 to 6 members. The ability to process recovered condensate and produce oxygen from water has been available on the Russian Segment (RS) since the astronauts and cosmonauts have been living on the ISS. The U.S. systems introduce the ability to process urine in addition to condensate greatly reducing the amount of water needed from the ground each year while also reducing the amount of time astronauts need to spend maintaining the systems. However, the interconnectedness of these systems may create operational difficulties and cause the loss of otherwise recoverable water.

This paper outlines the current and future USOS and Russian system architectures, system interdependencies and the inter-segment relationships. The current and future resupply needs are also discussed, as well as the expected ISS program savings that will be gained with the operation of the USOS Water Recovery Systems (WRS).

INTRODUCTION

The USOS Regenerative ECLS Systems recover water from condensate and urine, provide potable water and oxygen for the crew, and supply water to other water using systems. These new systems include the Urine Processor Assembly (UPA), Water Processor Assembly (WPA), Potable Water Dispenser (PWD) and Waste and Hygiene Compartment (WHC) which are all interdependent. The Oxygen Generation Assembly

(OGA) is also part of the Regenerative ECLS systems, and is already on orbit undergoing operational testing. These systems are all designed to work together without daily crew interaction.

The Russian Segment currently has similar systems and capabilities. These include the SRV-K water processor to recover condensate that can be used in the galley for crew consumption, the Elektron oxygen generator, and toilet. These systems, however, are all designed to operate independently and the crew is responsible for refilling the water containers when necessary.

Systems with the least amount of crew interaction are preferable, but have their downside. If one of the systems fails, the other interdependent systems are affected. In order to describe these affects, it is required to understand the different water types and their storage containers, how each system operates and their interdependencies, how the U.S. Operating Segment and Russian Segments interact, and finally, how the water is used and resupplied.

ISS Water Types and Storage

There are currently 4 types of usable water on ISS. This section describes these different types and explains how each is used and stored on-orbit.

Iodinated Water

The USOS life support systems all use water with iodine biocide. Currently all of the iodinated water on ISS actually comes from the Orbiter, generated on-orbit by the vehicle's fuel cells as a byproduct of Shuttle power generation. This water, stored in two of the Shuttle's four supply water tanks, is iodinated for microbial control (the remaining two tanks have no biocide, and are used

for the Shuttle's Flash Evaporator System). The stored water is transferred into small portable containers called Payload Water Reservoirs (PWR), which are filled from the Orbiter galley and transferred to ISS. The PWR is certified to hold iodinated water for up to 1080 days. Presently, the PWRs are used to supply iodinated water to the Oxygen Generation System (OGS) and the EMU. In the future, the Regenerative ECLSS Water Recovery System (WRS) racks will also produce iodinated water for use by these USOS life support systems.

Technical Water in Contingency Water Containers

The RS life support systems all use water with silver biocide. Since most of the ISS life support systems are located in the RS, it is necessary to remove the iodine from the Shuttle fuel cell water and add silver biocide in its place. Water is transferred to Contingency Water Containers (CWC) from the Orbiter using the Galley Iodine Removal Assembly (GIRA). Iodine is removed using the ACTEX (an activated carbon/ion exchange cartridge), and silver biocide is added by injecting a syringe of silver fluoride into the flow path. This water, which has only silver biocide added, is called technical CWC water because it is used primarily in the RS Elektron for oxygen generation and the RS ASU as flush water rather than for crew consumption. This water type has no shelf life limit.

Potable Water in Contingency Water Containers

Similar to the Technical CWC water, potable CWC water also comes from the Shuttle fuel cells and is transferred from the Shuttle galley using the GIRA. In addition to silver biocide, potable CWC water also has minerals (organic salts containing calcium and magnesium) added during the CWC filling process. This water has a 64 week shelf life. This water is nominally consumed by the crew through the Russian SVO-ZV, a stored water distribution system where the crew can fill drink bags.

Russian Ground Supplied Water

This water is supplied by the Russian Progress vehicles. It is naturally mineralized water, with added silver ions to prevent development of microbial contamination. The water is processed and loaded into the Progress vehicles on the ground and can be launched in either Progress Rodnik tanks or in water containers (EDV). Upon arrival and docking of a Progress to the ISS, this water is nominally transferred to the empty and compressed Service Module (SM) Rodnik tanks and EDV for long-term storage. This type of water can be stored in the SM Rodnik tanks for up to three years or in EDVs for two years. The Russian ground supplied water can be used to supply crewmember water needs for drinking and food preparation, as well as in the toilet and Elektron. Once transferred to the SM Rodnik tanks, due to its long shelf life, lack of impact on ISS stowage capacity, and versatile capability, Rodnik water serves as the main reserve on ISS. Generally, Rodnik water is

used after all the potable or technical CWCs and EDVs have been used.

European Ground Supplied Water

In 2008, the European Space Agency (ESA) will launch the first Automated Transfer Vehicle (ATV). Like the Progress, this vehicle will have the capability to launch large quantities of water from the ground. The ATV is certified to launch either iodinated water for the USOS or Russian type water (naturally mineralized water with silver ions) for use in the RS. If iodinated water is flown, it will be transferred to iodine compatible water containers (ICWCs). These new containers are currently in development, and will combine features from both the PWR and the CWC. Iodinated water in these containers will be certified for a minimum of 1 year storage, though testing is on-going to extend this shelf life. If Russian type water is flown, it will be transferred to EDVs for storage and use in the Russian life support systems.

Water storage containers

There are several different types of water storage containers on ISS as noted in the preceding paragraphs. All of the USOS portable containers are made of soft materials, and are intended to be folded when stowed empty. Table 1 summarizes the primary characteristics of the USOS containers. The PWR and CWC are described in further detail in reference 1.

On the RS, there are two main types of storage containers. The Rodnik system is designed for long-term storage of Russian ground supplied water. Water is stored in two Rodnik system tanks located in an unpressurized SM Assembly Compartment. Each tank can hold up to 210 L (463 lbm), and is certified for up to 15 fill and drain cycles. The tanks are connected to the water-dispensing panel in the SM with metal pipes. To use water from one Rodnik tank, a holding tank, EDV, is filled using a water pump or air compressor unit. The EDV is a small portable water storage container. It can hold up to 22 L (48.5 lbm), and consists of a soft bladder inside of a hard metal shell. In order to maximize storage space, the metal shells are designed to stack inside one-another when not in use.

Table 1: Fluid Storage Container Specifications¹

Parameter	Payload Water Reservoir (EMU)	Payload Water Reservoir (OGS)	Contingency Water Container	Iodine Compatible Water Container*
Part number	SEG46117689-301	SEG46117689-302	SEG33113140-305	SEG33120607-301
Capacity, nom (L)	10	10	44	44
Empty mass (kg)	0.6	1.8	1.4	1.4
Empty length (cm)	61	63.5	63.5	69.9
Empty width (cm)	34	35.6	50.8	58.4
Empty height (cm)	2.54	2.54	10.2	5.1
Nom full volume (cm ³)	5190	N/A	50450	56 x 79 x TBD
Max fill/drain cycles on-orbit	12	12	49	100 mate/demate events
Primary Applications	USOS EMU Fluid Recharge Launch of IATCS Coolant	USOS OGS Water Supply	STS water transfer RS water storage (potable, technical water) USOS Lab condensate storage	USOS water storage (iodinated water)

* The ICWC is currently in development; Information provided is preliminary.

USOS Systems Architecture

Currently the USOS is only capable of collecting condensate and storing the various types of water in CWCs and PWRs, as described. The USOS, unlike the Russian segment, does not have the capability to process condensate or deliver water for crew consumption, however, the US water systems interface with two US systems, the Extravehicular Mobility Unit (EMU) and the Oxygen Generator Assembly (OGA).

The USOS collects condensate via Condensing Heat Exchangers (CHX) which divert water, via the use of a water/gas separator, through a series of waste water bus lines into the Lab condensate tank. The condensate tank consists of bellows within a surrounding cylindrical tank. The tank has a total capacity of 75 L (165 lbm), however, operationally the tank is limited to a 45.5 L (100 lbm) capacity in order to protect against fatigue cycling on the tank bellows. When the tank is full, a compression force of 13.8 kilopascals (2 psig) exists. This compression force allows the tank to be offloaded without the need of a pump or compressor.

There are two methods to offload the condensate tank. The first method is to vent the tank's contents overboard. Water flows from the condensate tank through waste water lines, through a 100 micron filter, past two solenoid valves, in series, and exits the Lab module water vent. The water vent outside the LAB shell has a heated waste water line that extends from the Lab module shell to the micrometeor orbital debris (MMOD) shield where a heated nozzle facilitates water venting to space vacuum. The line between the Lab shell and MMOD shield and nozzle are heated to ensure condensate water does not freeze during the venting process.

The second, and most common, method used to offload the condensate tank is to offload the condensate into a CWC. The CWC is connected via a hose to the waste water bus at which point the condensate is pushed into

the CWC by the condensate metal bellows' compression force. The condensate metal bellows' neutral point is ~6 L (~13 lbm), thereby preventing an empty CWC from being overfilled provided the condensate tank is kept at its operational capacity limit.

Offloading the condensate to a CWC is preferable because the condensate can be transferred to the RS for processing in the SRV-K. This allows condensate water to be recycled and reduces the need for resupply water.

The CWCs are also used to offload EMU wastewater. Before and after every spacewalk, in addition to routine maintenance, the EMU water tanks are filled with iodinated water from PWRs. In order to create ullage that allows for thermal expansion of the EMU water tanks, the tanks are filled full and then 0.45 L (~1 lbm) is removed. Due to the fact that the Russian SRV-K is not certified to process water with iodine, the EMU water can not be offloaded into the Lab condensate tank. Therefore, a CWC is used to collect the EMU ullage. This CWC is vented via the Shuttle when it begins to reach its upper limits.

The OGA is the most recent U.S. system to be interfaced to the U.S. water system. The OGA uses iodinated water and, via electrolysis, creates O₂ that is vented into the cabin for crew metabolic as well as H₂ which is vented overboard. Currently, the OGA source water is fed from OGA PWRs filled by the Shuttle. The PWR connects to a water delivery system that consists of a pump and accumulator and pressurizes the water to the OGA's required inlet pressure. In the event that the OGA detects an air bubble in the water it diverts the water to the waste water bus. This is performed in order to avoid a potential explosion event. The diverted water passes through an ACTEX filter to remove the residual iodine and then flows into the waste water bus, eventually collecting in the Lab condensate tank.

In the near future, a collection of systems will be flown on the ULF-2 Shuttle flight and will be installed in the