

Minimizing EVA Airlock Time and Depress Gas Losses

Luis A. Trevino and Sharon A. Lafuse
NASA Johnson Space Center

ABSTRACT

This paper describes the need and solution for minimizing EVA airlock time and depress gas losses using a new method that minimizes EVA out-the-door time for a suited astronaut and reclaims most of the airlock depress gas. This method consists of one or more related concepts that use an evacuated reservoir tank to store and reclaim the airlock depress gas. The evacuated tank can be an inflatable tank, a spent fuel tank from a lunar lander descent stage, or a backup airlock. During EVA airlock operations, the airlock and reservoir would be equalized at some low pressure, and through proper selection of reservoir size, most of the depress gas would be stored in the reservoir for later reclamation. The benefit of this method is directly applicable to long duration lunar and Mars missions that require multiple EVA missions (up to 100, two-person lunar EVAs) and conservation of consumables, including depress pump power and depress gas. The current ISS airlock gas reclamation method requires approximately 45 minutes of the astronaut's time in the airlock and 1 KW in electrical power. The proposed method would decrease the astronaut's time in the airlock because the depress gas is being temporarily stored in a reservoir tank for later recovery. Once the EVA crew is conducting the EVA, the volume in the reservoir would be pumped back to the cabin at a slow rate.

Various trades were conducted to analyze this method, which include time to equalize the airlock with the evacuated reservoir versus reservoir size, pump power to reclaim depress gas versus time allotted, inflatable reservoir pros and cons (weight, volume, complexity), and feasibility of spent lunar nitrogen and oxygen tanks as reservoirs.

INTRODUCTION

Current airlock procedures for EVA operations from the Shuttle Orbiter allow for venting of the airlock gas to vacuum during airlock depress because there is no on-board equipment to recover that gas. For the International Space Station (ISS) airlock, a gas recovery technique is provided by using an on-board pump to transfer up to 90 percent of the airlock gas to the pressurized cabin for re-use in subsequent airlock operations. While the ISS procedure saves oxygen and nitrogen gases and reduces the need to replenish them in resupply ships, the efficiency of this recovery in terms of time, power, and total gas recovered needs to be improved for long duration planetary missions. In order to describe the efficiency gaps for long duration missions, an abbreviated description of current ISS and Shuttle airlock design and operations is presented in this section. The efficiency needs are addressed in subsequent sections.

The current study is a conceptual study with a potential solution. It is also an intermediate step between an idea and a thorough design study. The idea was presented numerous times and received well during initial Constellation mission planning at NASA. This study provides the beginnings of realistic data, including airlock gas depressurization and repressurization simulations with a proven software tool, whose results are intended to motivate engineers and program planners to continue investigating because of its potential merits. The final goal is to optimize the airlock procedures coupled with savings in airlock gas mass.

General Description of ISS Airlock Operations

The ISS Joint Airlock, which supports EVA capability for both Shuttle EMUs and Orlan space suits, incorporates a depress pump procedure to recover airlock depress gas. It is comprised of two distinct modules: the Equipment Lock and the Crew Lock, as shown in Figure 1 [1].

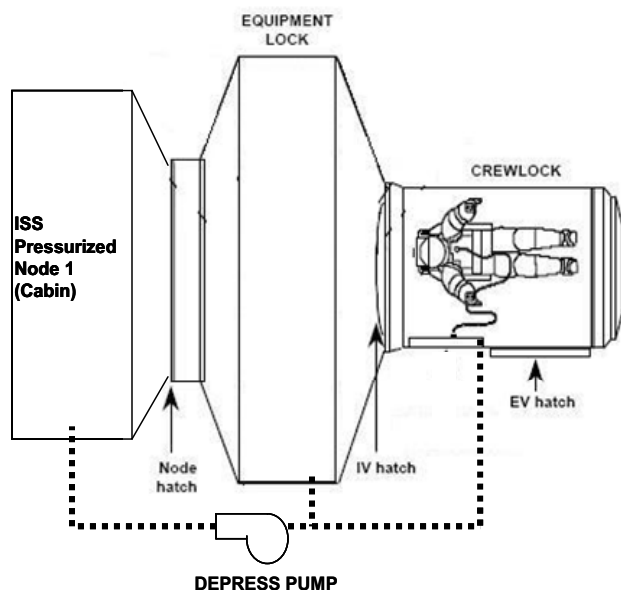


Figure 1: ISS Joint Airlock and Depress Pump Configuration

The Equipment Lock is connected to Node 1 (Unity) for crew access to and from the ISS cabin volumes. The Equipment Lock can be depressured to 70 kPa (10.2 psia) from the nominal 101 kPa (14.7 psia) cabin pressure to accommodate the EMU EVA prebreathe protocol. During the depressurization process, a Russian-supplied depressurization pump located in the Equipment Lock returns the gas to Node 1. Airlock gas can be evacuated from either the Crew Lock or the Equipment Lock to Node 1 by using the depress pump. For the Crew Lock depressurization during EVA preparation, pumpdown from 101 to 35 kPa (14.7 to 5 psia) takes approximately 13 minutes. At 35 kPa, the depress is paused for a suit leak check. Although the depress pump can continue the depress from 35 kPa down to 7 kPa (1 psia), which takes about 6 minutes, venting of the last 35 kPa is done directly to vacuum to simplify procedures and because the remaining

consumables are not a significant loss to ISS. The depress pump has an average power consumption of 1.38 kW and a minimum operational life of 1250 hours.

ISS and Shuttle Airlock Work Efficiencies

Total EVA preparation time in the Joint Airlock for a typical EVA is described in "Lunar Architecture Update" [2]. Actual ISS airlock depress times take 30 to 40 minutes as compared to 10 to 15 minutes for the Shuttle airlock (max time allows for pause time for EMU systems check). The additional depress time decreases the EVA Work Efficiency Index (WEI), a measure of the total EVA overhead (EVA time divided by total prep and post-EVA time). The WEIs reported are 0.51 for the Shuttle airlock at 70 kPa, 0.39 for ISS 4-hour in suit protocol, and 0.43 for ISS exercise protocol. Target WEIs are >3.0, which compare to those obtained in the commercial saturation diving industry.

Gas Loss Penalties Without Reclamation

Unlike the ISS airlock, the Shuttle airlock has no airlock gas reclamation, resulting in the entire airlock depress gas being lost to vacuum for every EVA. This limitation precludes the use of this procedure for long duration lunar and Mars missions that must conserve the on-board resources. An estimate of the amount of gas lost for every airlock depress is as follows: using the ideal gas law and for the current lunar missions planned at 55 kPa (8 psia) cabin and airlock pressures, the airlock gas lost for an 55 kPa airlock is calculated to be approximately 0.65 kg per cubic meter (4.06 lbm per 100 cubic feet) of vented volume. This equates to 2.39 kg (5.27 lbs) air lost for an airlock the size of the Shuttle airlock with the free air volume of 3.68 cubic meters (130 cu ft) and two crewmembers inside (each crewmember is approximately 0.283 cubic m.). For 100 EVAs, the proposed number for a 6-month outpost lunar mission, the airlock gas penalty is 239 kg (527) lbs of air. A goal for lunar missions is to save 90 percent of the gas, reducing the airlock gas lost from 239 kg to approximately 24 kg for 100 EVAs.

Overall Impacts of Current Airlocks to Future Missions

From the above discussion, it is concluded that the limitations of the ISS airlock depress techniques are additional crew time required during the depress due to the pump-down time of 30 to 40 minutes and pump power penalties required for the pumping of airlock gas to the

ISS cabin. Because of the additional time and pump power required to conserve 90 percent of the airlock gas, the current ISS procedures in use conserve only 70 percent of the airlock gas. For the Shuttle airlock, its limitation is that all the airlock gas is vented.

The proposed lunar architecture currently being studied and the frequency of EVAs proposed also demonstrate the need for reducing airlock impacts. NASA architecture studies have shown that habitats will be needed earlier than first thought [2].



Figure 2: Lunar Architecture Options

Several architecture options are being studied for habitats and airlocks as shown in Figure 2, but all options will need airlocks to enable humans to conduct both shirtsleeve and vacuum operations. In addition, the number of EVAs, or “mountain of EVAs” required for lunar operations are expected to be more than the combined EVAs of past programs, as shown in Figure 3.

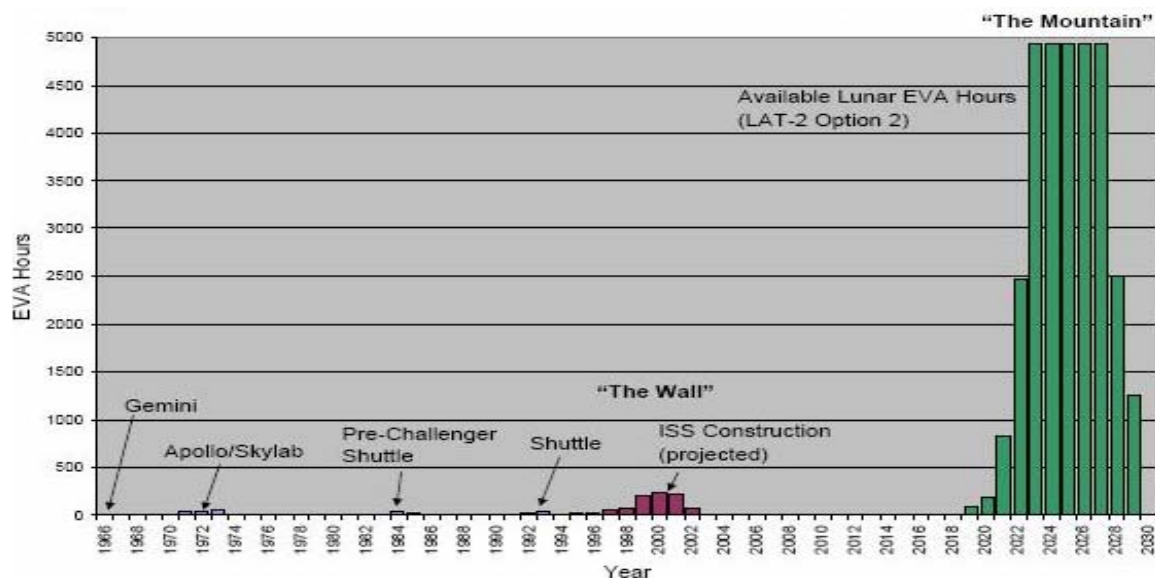


Figure 3: Mountain of Lunar EVAs Compared to Previous Programs

The expected EVA frequency imposes higher EVA systems consumable penalties, including airlock operational support and consumables.

AIRLOCK GAS RECLAMATION METHOD USING RESERVOIR TANKS

Basic Airlock Gas Reclamation Method

The airlock gas reclamation method described in this paper minimizes EVA out-the-door time for a suited astronaut and reclaims most of the airlock depress gas. This method consists of one or more related concepts that use an evacuated reservoir tank to store and reclaim the airlock depress gas. The benefit of this method is directly applicable to long duration lunar and Mars missions that require multiple EVA missions (up to 100, two-person lunar EVAs) and conservation of consumables, including depress pump power and depress gas makeup. The evacuated tank or reservoir can be an inflatable tank, a spent fuel tank from a lunar lander descent stage, or a backup airlock, as shown in Figure 4.