

A Comparison of the Apollo and Early Orion Environmental Control, Life Support and Active Thermal Control System's Driving Requirements and System Mass

Cynthia Cross, John F. Lewis and George C. Tuan
NASA/Johnson Space Center

ABSTRACT

The Orion Crew and Service Modules are often compared to the Apollo Command and Service Modules due to their similarity in basic mission objective: both were dedicated to getting a crew to lunar orbit and safely returning them to Earth. Both spacecraft rely on the environmental control, life support and active thermal control systems (ECLS/ATCS) for the basic functions of providing and maintaining a breathable atmosphere, supplying adequate amount of potable water and maintaining the crew and avionics equipment within certified thermal limits. This assessment will evaluate the driving requirements for both programs and highlight similarities and differences. Further, a short comparison of the two system architectures will be examined including a side by side assessment of some selected system's hardware mass. This evaluation provides a top level assessment of the efficacy of the Orion ECLS/ATCS, as well as identifies areas that could benefit from a more careful examination as the Orion project approaches the preliminary design review milestone.

INTRODUCTION

In 1969, Neil Armstrong's famous leap marked a milestone in American history – Man's first visit to the surface of the moon. Today, the National Aeronautics and Space Administration (NASA) has established a new program called Constellation, with the goal of returning man to the lunar surface.

In 1969, Armstrong, Aldrin and Collins flew to the moon using the Apollo Command and Service Module. Crews of the future will travel in the Orion Crew and Service Module. As both programs have the same ultimate goal, it is not surprising that many comparisons of the two spacecraft have been and will continue to be made. Recently, these comparisons have centered around mass and whether the Orion vehicle compares favorably

to the Apollo system. One area that has received much of this scrutiny is the Environmental Control, Life Support and Active Thermal Control System (ECLS/ATCS).

The primary objectives of the Orion ECLS/ATCS, as well as the Apollo Environmental Control System (ECS), are to provide and maintain a breathable atmosphere, supply adequate potable water to the crew, and keep avionics hardware and the crew within specified temperature limits. While the objectives for both spacecraft are similar, many of the driving requirements for the systems are different. This assessment will evaluate the similarities and differences between the top-level requirements for the two systems, briefly describe the top level system architecture put in place to meet those requirements and finally evaluate the mass of key subsystem areas. This assessment can then be used to evaluate the mass efficacy of the Orion system and highlight areas where technology has improved upon total mass to orbit. It will also identify areas where more emphasis may be needed to minimize the mass of the Orion ECLS/ATCS as it approaches its preliminary design review (PDR) milestone currently planned in the late summer of 2008.

DRIVING REQUIREMENTS

Before any discussion can be had on the choice of system architecture, it is essential to understand the requirements that drive the technology selection and hence overall system design. This is true for both the Apollo ECS as well as the Orion ECLS/ATCS. A summary of the primary driving requirements for both the Apollo and Orion systems is included in Table 1.

Immediately it can be noted that there are significant differences between the two systems in terms of crew size and mission duration. Typically referred to as the number of crew days (mission duration multiplied by the number of crew), Apollo, with a crew size of three people

Table 1: Comparison of Apollo and Orion Driving Requirements

Apollo	Requirement	Orion
36	Crew Days	84.4 (+6 month Quiescent)
1640 W in Low Lunar Orbit	Heat Load to Radiators	3954 W in Low Lunar Orbit Reentry cooling below 30.5 km
3 Male	Peak Crew Compliment	6 Male and Female Lunar exercise
34.4 kPa (5 psia) 100% O ₂ 7.6 mmHg CO ₂	Cabin Atmosphere	62 – 101.3 kPa (9 – 14.7 psia) 21-30% O ₂ 5.0 mmHg CO ₂
26.9 kPad (3.9 psid) No Liquid Cooling Garment	Suit Parameters	29.6 – 55.2 kPad (4.3-8.0 psid) Liquid Cooling Garment
Fuel Cells	Power System	Solar Arrays

and a mission length of 12 days, was required to support 36 crew days. Orion, however, must accommodate a crew of four for 21.1 days for a total requirement of 84.4 crew days – an approximate increase of 134%. This value is important to a number of hardware sizing calculations including the amount of consumables – oxygen, nitrogen and water to name a few - required for the entire mission.

In addition to total crew days, the Orion system is required to provide more cooling capability than the Apollo ECS. This is due not only to advances in electronics, but also due to the fact that the Apollo ECS was not required to cool the power system's fuel cells; there was a separate thermal control system for the electrical power system. For Orion, the active thermal control system (ATCS) is required to cool the power system electronics boxes and batteries. Further, the Orion ATCS is required to provide cooling throughout the re-entry profile up until a specified period, currently 15 minutes, post-landing (analysis is on going to increase this to 2 hours). The Apollo ECS did not have provisions for cooling below approximately 30.5 km (100,000 ft).

Finally, it should be noted that the Apollo vehicle, after launch, maintained the 9.0 m³ (320 ft³) cabin volume at 34.5 kPa (5 psia) and 100% oxygen concentration. Orion, however, is driven to maintain its much larger cabin volume of approximately 17 m³ (600 ft³) to as low as 62 kPa (9 psia) when completing lunar operations and as high as 101.4 kPa (14.7 psia) when attached to the International Space Station (ISS) with oxygen concentrations ranging from 21% to 30%. These conditions drive the necessity of a mixed gas system made up of oxygen and nitrogen.

APOLLO ARCHITECTURE

The Apollo ECS was an open loop life support system and a full system schematic is shown in Figure 1. A comprehensive overview of the Apollo ECS can be found in the NASA Technical Note D-6718, "Apollo

Experience Report – Command and Service Module Environmental Control System" by Samonski and Tucker (1). A short summary of the system architecture is presented here in order to set a foundation for the mass comparisons included later.

The Apollo ECS can be divided into 3 distinct functions: air revitalization, water management and active thermal control.

The air revitalization system (ARS) used oxygen that had been boiled off of the cryogenic supply tanks for the fuel cell system to feed 100% oxygen to the cabin or suit loop depending on phase of flight.

Carbon dioxide was removed through the use of lithium hydroxide (LiOH) canisters to maintain the partial pressure of carbon dioxide below 7.6 torr. A condensing heat exchanger was used to maintain the air temperature and humidity to 18.3°C +/- 2.3°C (65°F +/- 5°F) and 40 to 70% relative humidity, respectively. A small charcoal cartridge was included in the LiOH canisters to provide trace contaminant control (TCC). TCC is required to remove contaminants in the air stream such as ammonia and carbon monoxide.

Water from the condensing heat exchanger was fed into a waste water tank and stored until used for cooling in the ATCS evaporator. Potable water was fed into water tanks from the fuel cell system and subsequently chlorinated to maintain microbial content to the required levels. Excess water from the fuel cell system was routinely dumped overboard as the water tanks were filled.

The ATCS used an ethylene glycol and water coolant mixture to pick up heat from the cabin air or suit loop heat exchangers and cold plated hardware. The coolant would then flow out to a series of body mounted radiators on the exterior of the service module (SM). An evaporative heat sink was used to evaporate water when the radiators were unavailable or in environments where radiation cooling was not sufficient. This included

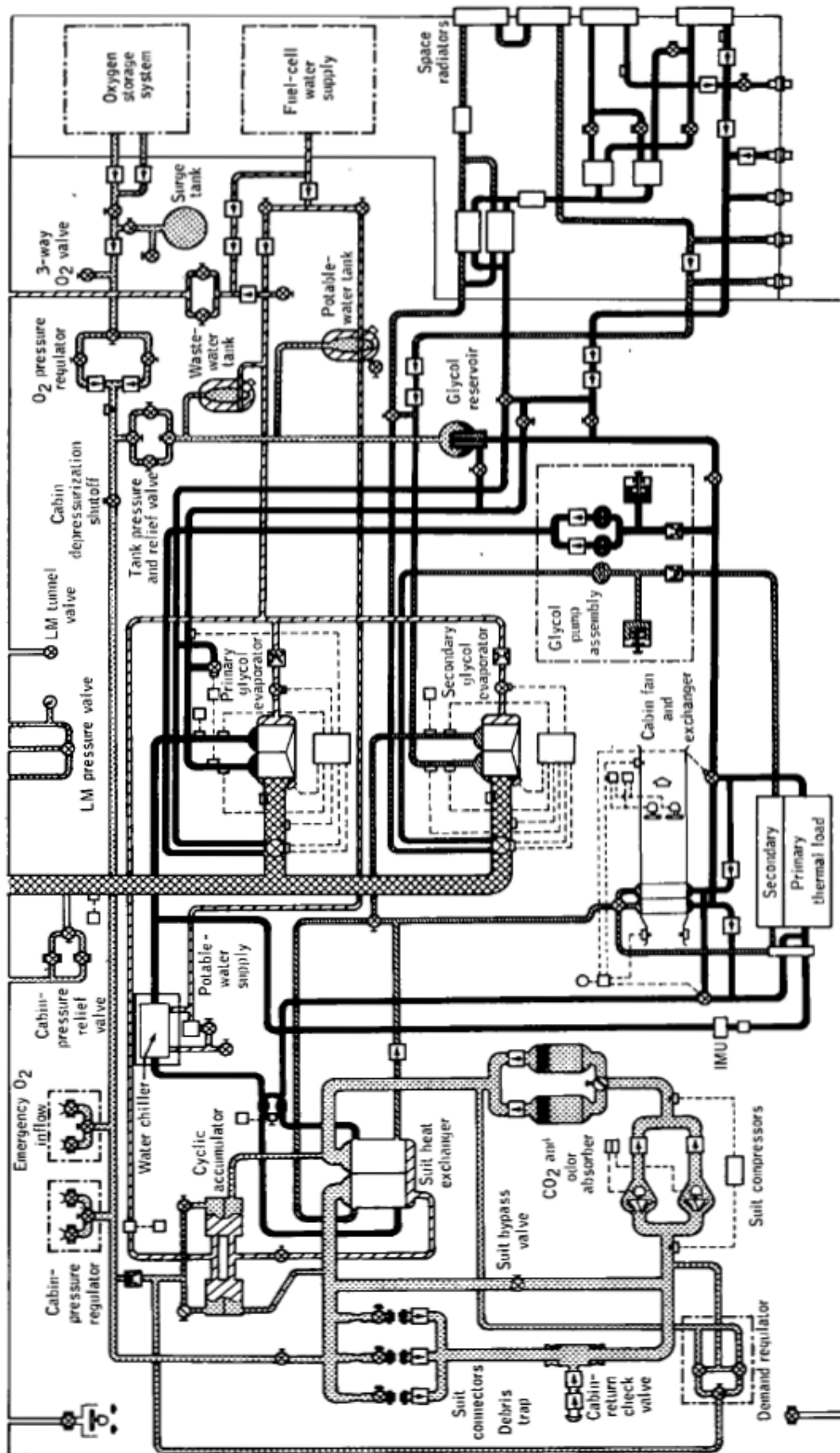


Figure 1.- Apollo environmental control system.