Apollo Ground Evaluation Portable Life Support Systems

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The “backpack” of the Apollo spacesuit was named the Portable Life Support System (PLSS). The PLSS supplied pressure and oxygen, removed carbon-dioxide, particulates and odors, provided cooling, and controlled humidity within safe and comfortable parameters. Apollo flight PLSSs were fully autonomous systems as the life support and communications required no connection to a supporting spacecraft. However to support development of Apollo vehicles and to improve the quality of Earthly pre-flight training, another series of PLSSs were also developed for Apollo. These were ground-training PLSSs that were key to the overall Apollo program development.

To accomplish Apollo, the space suits and the vehicles had to operate as one system. To aid develop of the Apollo Space Suit Assembly (SSA, later re-named the Extravehicular Mobility Unit or EMU) and Lunar Excursion Module (LEM), later re-named the Lunar Module, the Hamilton Standard Division (HSD) of the United Aircraft Corporation proactively developed a fully autonomous ground-evaluation PLSS (Figure 1) on internal funding as part of an unsolicited proposal for a fleet of training “backpacks.”

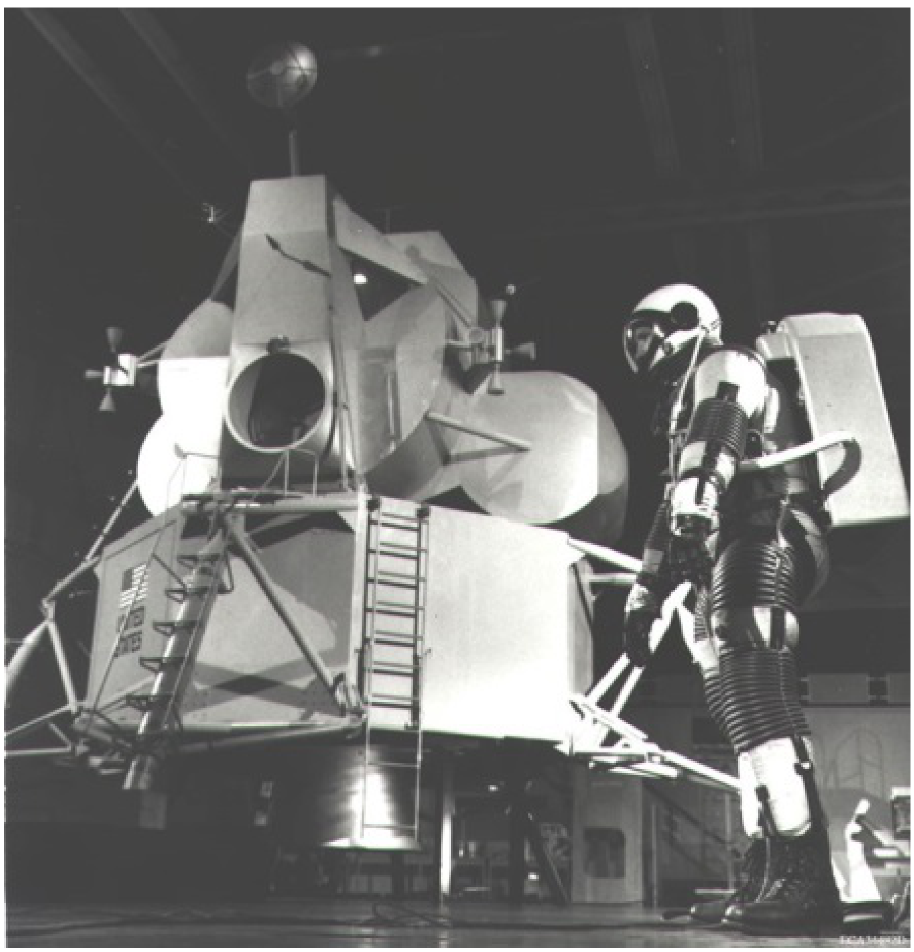

Figure 1 An Early Apollo Training Suit With HSD Ground-Evaluation PLSS
(Courtesy United Technologies Aerospace Systems)

This unit featured a fiberglass shell which represented the maximum Apollo PLSS envelope allowed under the Apollo SSA contract as the flight PLSS was being developed in parallel and its final size and shape were unknown. This “ground-training” PLSS was essentially a simple shell containing a compressed air bottle and gage. It supplied a purge-flow to remove carbon dioxide (CO_2) and humidity while providing modest cooling sufficient and oxygen enriched air for adequate comfort and safety during testing. While the proposal included an option to provide radio communications, the prototype relied on a cable when communications were necessary. The autonomous ability of this system, without communications, proved a significant aid to the manned LEM prototype evaluations conducted at Grumman in early 1963 (Figure 1). This unit was also used in conjunction with prototype thermal over-garments to aid in suit-system development. However, the proposed fleet of training units never received funding. Instead, NASA elected to fund occasional volumetric mockups representing the current state of PLSS and SSA development.

The volumetric mockup PLSSs supplied encumbrance but no life support or communications to the suited subject. Those functions were provided through umbilicals. An early volumetric mockup was used in 1963 SSA evaluations conducted by NASA at the Argonne National Laboratories in Illinois (Figure 2) in mid to late 1963. However, the volumetric mockups proved to have limitations. In 1964, NASA funded HSD for an updated version of its Ground-Evaluation PLSS (Figure 3).

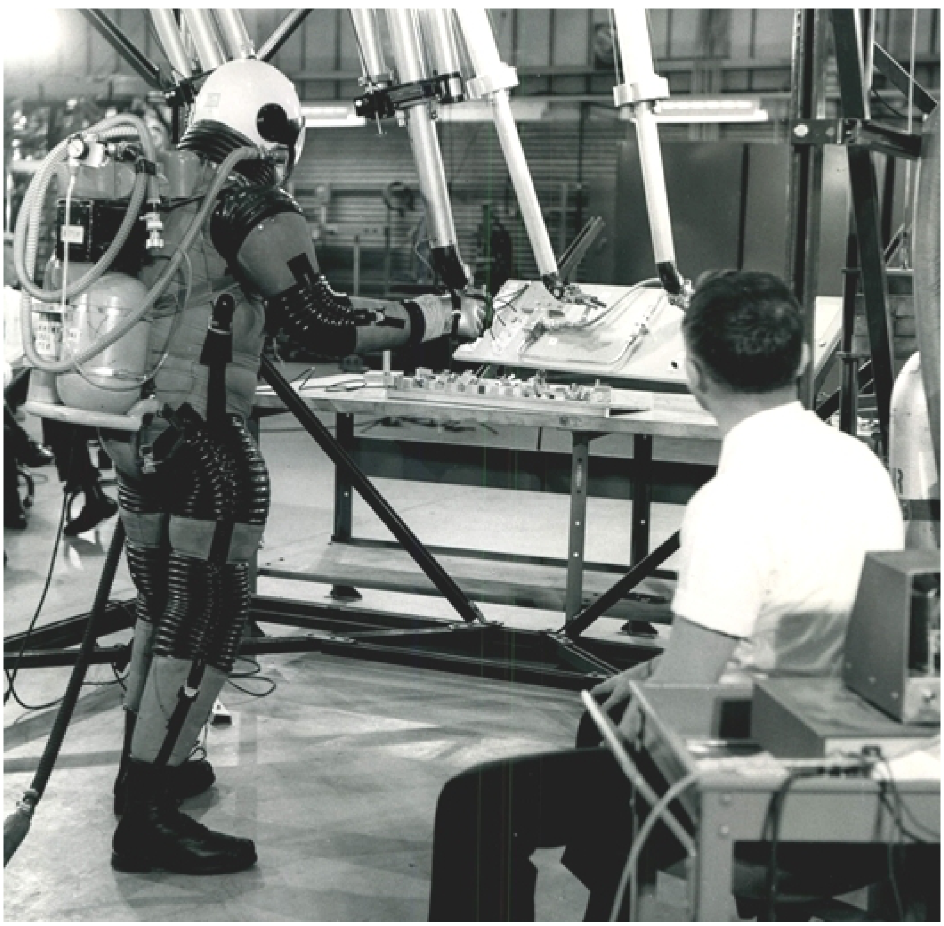

Figure 2 A 1963 Apollo SSA in Performance Evaluations
(Courtesy Gary Harris)

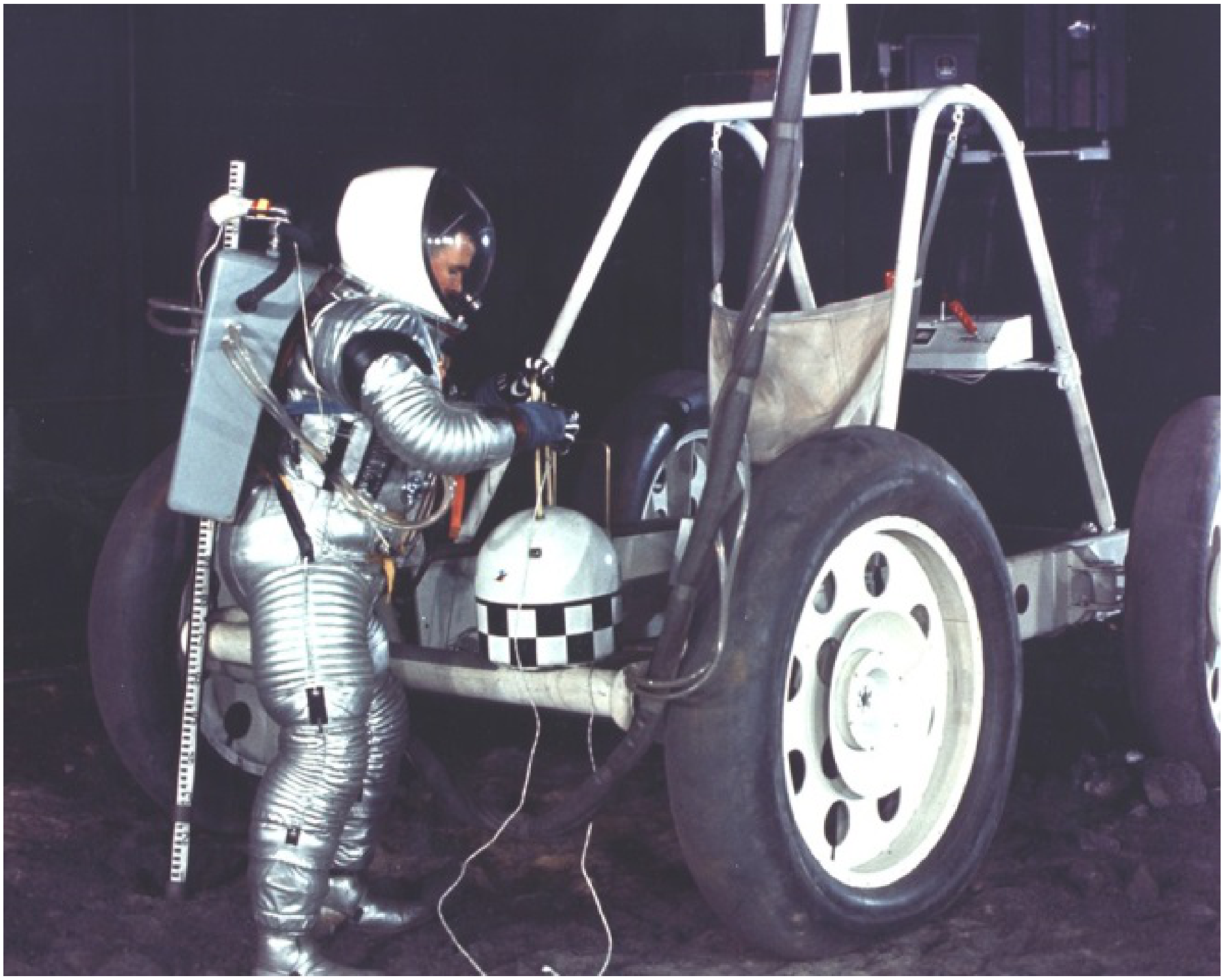

Figure 3 An Early 1965 Apollo Training EMU In NASA Human Factors Testing
(Courtesy United Technologies Aerospace Systems)

In the trade studies that supported to the Apollo SSA contract win of 1962, HSD had conducted research into the possibility of using a cryogenic oxygen system with an ejector drive as the basis of a possible flight PLSS. The potential advantages of such a system were that the demand for oxygen paralleled the need for cooling. Cryogenic oxygen could support both functions. The use of an ejector drive powered by the oxygen flow eliminated the need for a fan assembly and a larger, heavier battery, thus simplifying the system and reducing mass and volume. HSD had produced a test version of the system in 1961 under internal funding. However, there were challenges to using cryogenic oxygen in zero gravity, which was an Apollo requirement that made the approach unfeasible. In 1964, HSD under internal funding repackaged the prototype into a shell that represented the volume of the current flight PLSS and named it the Cryo-Pack (Figures 4 and 5). This system provided cooling, pressurization, ventilation, CO2 removal, communication, and up to 3.5 psi suit pressure for up to 1.5 hours to simulate suited EVA conditions without the risk or expense of a staffed vacuum chamber. The CO_2 level and pressure were controlled by dumping a portion of the vent flow overboard. Cooling from the ventilation gas provided heat removal up to 930 btu/hour.

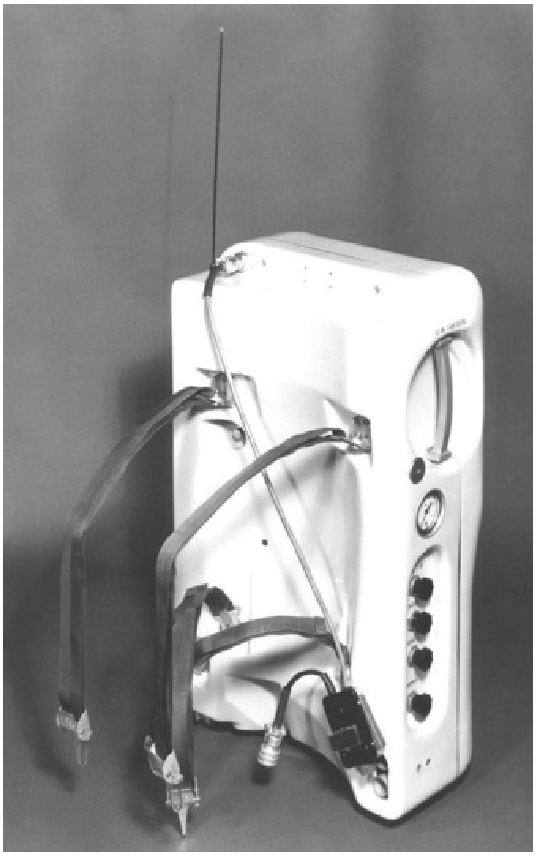

Figure 4 Cryo-Pack 1-G Training
(Courtesy United Technologies
Aerospace Systems)

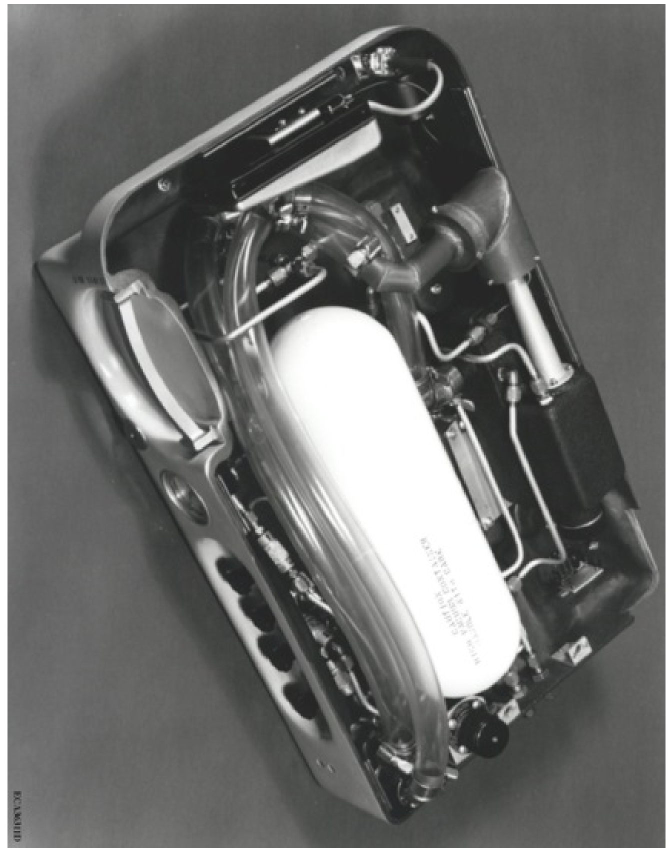

Figure 5 Cryo-Pack System Details
(Courtesy United Technologies
Aerospace Systems)

The Cryo-Pack not only permitted 1-G pressurized training without umbilicals, but also offered practice operating the flight PLSS controls expected to be used for Apollo. Prior to 1966, there was no provision for a chest mounted Remote Control Unit as was used in the Lunar missions. In 1964, the controls were located on the bottom right corner of the PLSS (ref. Figure 6), which were out of the Astronaut's line of vision. Control adjustments were performed by feel and experience. Optimum PLSS operation required practice.

The one issue from NASA testing was oxygen level increases during use due to suit leakage. In response, HSD internally funded the development of a second prototype named the Liquid Air Pack.

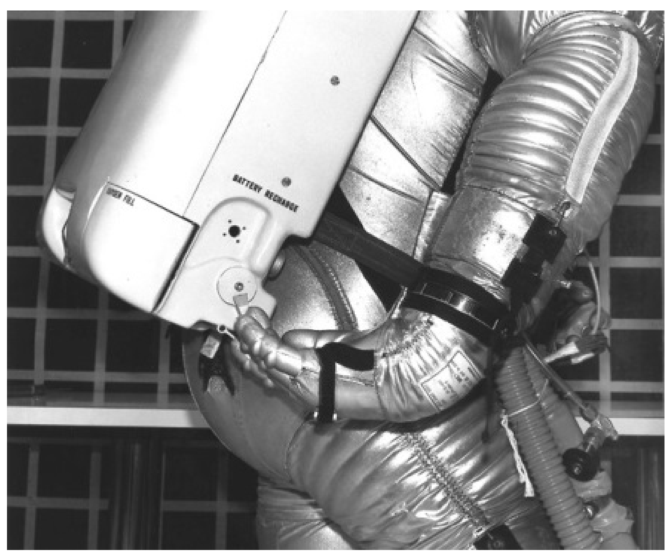

Figure 6 Demo Of Early Apollo PLSS Controls
(Courtesy United Technologies
Aerospace Systems)

With the beginning of 1965, HSD funded the creation of a new cryogenic ground test portable life support system. This effort was named the “Liquid Air Pack” to reflect the use of cryogenic air rather than oxygen. Like the “Cryo-Pack” Prototype of 1964, this system provided cooling, pressurization, ventilation, CO2 removal, communication, and up to 3.5 psi suit pressure for up to 1.5 hours. The 1965 design was a refinement in gas flow and cooling rates based on the manned test experience of the 1964 system. In an interview some thirty-five years later, the NASA test subject Jack Mays (pictured in Figure 7) vividly remembered how well the Liquid Cooling Air Pack worked.

Figure 7 The HSD Liquid Air Pack In A 1965 Advanced Suit Test (Courtesy NASA)

The Liquid Air Pack design was subsequently put into production. However, NASA elected to award the production contract to the AiResearch Manufacturing Division of the then Garrett Corporation due to NASA concern that HSD lacked the capacity to produce both a new version of the flight PLSS, engage in Pressure Suit Assembly development, and produce the training production units of the Liquid Air Pack. The subsequent ground training PLSSs provided the Astronaut Corps with a training tool that allowed hundreds of manned pressurized hours to be logged at minimum expense. However, the development of the Cryo-Pack and Liquid Air Pack had paralleled the increase of flight PLSS thermal requirements and the introduction of the Apollo Liquid Cooling Garment (LCG). The Liquid Air Packs did not include a radio or provisions for LCG use. To provide communications and liquid cooling, umbilicals had to be used. While this detracted from mission simulations to some degree, it was an accepted inconvenience until NASA was faced with the development of the Lunar Rover Vehicle.

The introduction of the Rover affected training requirements as well as those for flight. Vacuum chambers were too restricting and expensive to permit realistic training with Rover (1-G) training replicas. In 1970, HSD was contracted by NASA to re-design the Liquid Air Pack to provide cooling through the Liquid Cooling Garments as well as greater, flight PLSS cooling capacity. This was to be done while retaining the same envelope as the flight PLSS and not significantly increasing weight of the Liquid Air Pack. The resulting ground training PLSS named the Improved Cryo-Pack (Figure 8).

Figure 8 The Improved Cryo-Pack
(Courtesy United Technologies Aerospace Systems)

For this effort, HSD used components from the original design Cryo-pack where possible. The Improved Cryo-Pack used cryogenic (liquid) air to provide ventilation, oxygen, CO_2 removal to levels below 7.6 mm Hg, suit pressure to 3.5 psi, and cooling for up to 2000 btu per hour for 1.5 hours. Ventilation circulation was driven by an ejector which powered the expanding gas from the cryo tank. The CO_2 level was controlled by dumping a portion of the vent flow overboard. Astronaut cooling was accomplished by circulating 3.5 lb/min of H_20 through the Liquid Cooled Garment by a battery-powered pump. This system rejected heat by vaporizing the liquid air and melting ice. HSD designed a liquid air-to-water heat exchanger to interface with a liquid cooled garment as well as the ventilation system. This heat exchanger performed the heat rejection function of the porous plate sublimator on the Apollo flight PLSS that was used on the lunar surface. The unique aspect of this heat exchanger was its ability to store cooling capacity by freezing water. This provided longer duration and higher cooling capability. NASA reserved the Oxygen Purge System volume, the module mounted atop the PLSS for the battery and radio that they provided. This fully autonomous system served in preparations for the Apollo 15 to 17 mission tool use (Figure 9) and Lunar Rover training (Figure 10).

Figure 9 Practicing Sample Drilling (Courtesy NASA)

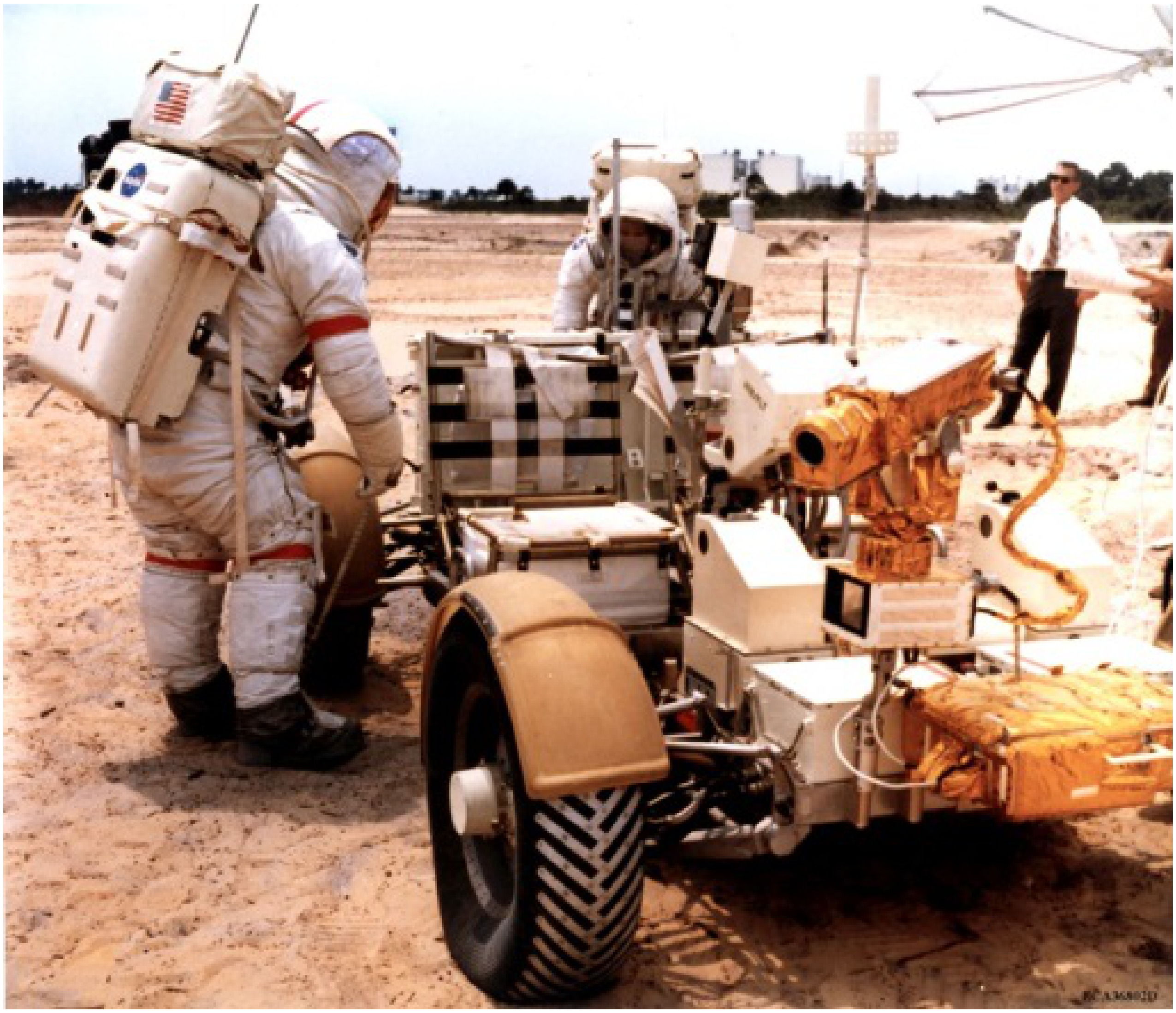

Figure 10 Earthy Rover Mission Simulations (Courtesy NASA)

Note: The author wishes to thank Earl Bahl and the numerous other veterans of the Apollo Space Suit Assembly and Portable Life Support System programs with whom the author had the privilege of working with for their contributions to this and other efforts of historical preservation.