

1-g Suit Port Concept Evaluator 2008 Test Results

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ABSTRACT

The Lunar Electric Rover (LER), which was formerly called the Small Pressurized Rover (SPR), is currently being carried as an integral part of the lunar surface architectures that are under consideration in the Constellation Program. One element of the LER is the suit port, which is the means by which crew members perform Extravehicular Activities (EVAs). Two suit port deliverables were produced in fiscal year 2008: a 1-g suit port concept evaluator for functional integrated testing with the LER 1-g concept vehicle and a functional and pressurizable Engineering Unit (EU). This paper focuses on the 1-g suit port concept evaluator test results from the Desert Research and Technology Studies (D-RATS) October 2008 testing at Black Point Lava Flow (BPLF), Arizona.

The 1-g suit port concept evaluator was integrated with the 1-g LER cabin and chassis concepts. It is located on the aft bulkhead of the LER cabin structure and includes hatches, a locking mechanism, seals, interior and exterior suit don/doff aids, and exterior platforms to accommodate different crew member heights. A light-weight mockup of the Mark III suit was tested with the 1-g suit port concept evaluator. There are several limitations to the suit port and mockup suits, and results of the suit port evaluation are presented and interpreted within the context of these limitations in this paper.

INTRODUCTION

The LER is intended to optimize human safety and performance in planetary exploration by combining a comfortable shirtsleeve, sensor-augmented environment for gross translations and geological observations with the ability to rapidly place suited astronauts on a planetary surface via the suit port. Each LER incorporates two suit ports that enable rapid egress to the planetary surface to take full advantage of human perception, judgment, and dexterity in an EVA suit and rapid ingress to the shelter of the LER in response to Solar Particle Events (SPEs), suit malfunctions, or medical emergencies. Suit ports also enable one-person EVA operations [1]. Figure 1 shows the 1-g LER concept vehicle.



Figure 1 (jsc2008e138757): The 1-g LER Concept Vehicle

Two suit port deliverables were funded in fiscal year 2008: 1-g suit port concept evaluator for functional integrated testing with the 1-g LER concept vehicle and a functional and pressurizable EU. The Johnson Space Center (JSC) Crew and Thermal Systems Division (EC) led the development effort for both of the deliverables, with support from Ames Research Center (ARC), for initial suit port concepts and fabrication and testing of the EU, and Langley Research Center (LaRC), for fabrication of the honeycomb aft bulkhead structure.

Refer to 39th International Conference on Environmental Systems (ICES) paper number 2009-01-2586 "Preliminary Development of a Suit Port for Planetary Surface EVA – Design Studies" for background information on the suit port design down selection.

TEST HARDWARE DESCRIPTIONS

LER

The National Aeronautics and Space Administration (NASA) JSC Automation, Robotics, and Simulation Division (ER), which is in the Engineering Directorate (EA), provided the Chariot chassis, or lunar truck, for the LER.

The Chariot chassis has active suspension, a six-wheel drive with independent steering for each wheel, and crab steering that allows each wheel to pivot individually in any direction, regardless of where any other wheel points. It can also raise or lower individual wheels to keep the vehicle level when driving on uneven ground or to lower the belly to the ground. The Chariot chassis is a concept vehicle that was designed to provide a mobile platform to develop and test advanced rover technologies, and to enable the development and demonstration of mission operations and concepts that are applicable to future planetary rover vehicle development activities. Figure 2 shows the Chariot chassis [2].



Figure 2: Chariot Chassis, or Lunar Truck

The LER configuration (Figure 1) adds a cabin, including an aft bulkhead with suit ports, to the Chariot chassis. The LER cabin was developed as a collaborative effort among JSC, LaRC, ARC, and Glenn Research Center (GRC). The concept vehicle cabin, which is not pressurized, incorporates functional suit ports including alignment guides and clamping mechanisms - all of the necessary crew accommodations to support a 3-day traverse - and it is fully integrated with the Chariot chassis, all of which is consistent with current Constellation Lunar Architecture Team (CxAT_Lunar) architectural assumptions. The LER cabin also incorporates interior cameras and microphones that are used by the JSC Usability, Testing, and Analysis Facility (UTAF) to collect human factors data [1].

1-G SUIT PORT CONCEPT EVALUATOR

The suit port is an element of the LER by which the crew performs EVAs. The suit port concept evaluator, which is located on the aft bulkhead of the LER cabin structure, includes hatches, a locking (marman) mechanism, seals, interior and exterior suit don/doff aids, and exterior platforms to accommodate different crew member heights [3]. Figure 3 shows the suit port concept evaluator on LER with Mark III mockup suits. The test subject is disconnecting from the suit port on the port side of the LER. Figure 4 shows an interior view of the aft bulkhead and suit ports.



Figure 3 (jsc2008e139052): Suit Port Concept Evaluator on LER with Mark III Mockup Suits and the Port Side Test Subject Disconnecting from the Suit Port



Figure 4 (jsc2008e125494): LER Interior View of Aft Bulkhead and Suit Ports

MARK III MOCKUP SUIT

A lightweight mockup of the Mark III suit was tested with the suit port concept evaluator.

The Mark III suit, which is also called the H-suit, represents a hybrid space suit configuration in that it is composed of hard elements such as a Hard Upper Torso (HUT) and brief, and soft components, such as single-axis fabric elbows, knees, and ankle joints. Key features of the suit are its use of a rolling convolute waist joint and of bearings in multi-axis mobility joint systems. The Mark III suit has bearings at the shoulder, upper arm, waist, upper hip, mid-hip, upper leg (3-bearing hip), and ankle joints. The suit is donned through a rear entry hatch on the HUT. Suit subjects are integrated to the suit by a waist belt weight relief system and shoulder straps. The boots of the Mark III suit, which are designed for traverses over rough terrain, were derived from a military flight-style boot. The Mark III suit weighs approximately 45.4 kg (100 lbs). Figure 5 shows the front of the Mark III suit as tested at the D-RATS 2007 remote field test [4].



Figure 5 (jsc2007e049514): Mark III Advanced Space Suit Technology Demonstrator

The D-RATS testing of the LER that was performed this year required a suit that is lighter-weight than the Mark III but that looks similar (cosmetically), and that has similar mobility limitation features, such as the 3-bearing hip. Using lightweight suits minimizes injury risk and more closely represents the suit weights that will be experienced by astronauts on the lunar surface [1].

Approximately 4 years ago, Global Effects Inc. designed and fabricated eight lightweight suits that were modeled after the Mark III suit to use in the movie industry. The company then fabricated a ninth suit for NASA Headquarters to use as a Public Affairs Office (PAO) display model. In April 2008, Global Effects Inc. delivered four Mark III mockup suits to JSC EC [1].

The Mark III mockup suits weigh approximately 28 kg (62 lbs), are cosmetic representations of the Mark III suit, and have similar mobility limitations as the Mark III suit (e.g. waist bearing, hip bearings, shoulder convolutes, etc.). While the mockup suits have mobility limitations that are similar to those of the real Mark III suit, it should be noted that there are several limitations to the mockup suits, as will be discussed later in this report [1].

Two of the four suits were modified to interface with the LER suit port. Changes include, but are not limited to, the addition of an interface plate to the rear entry hatch; increasing the Portable Life Support System (PLSS) volume; and adding a communication system, a Global Positioning System (GPS) data logger, helmet lights, and an EVA camera. Figure 6 illustrates the Mark III mockup suit configuration for interfacing with the suit port concept evaluator.



Figure 6 (jsc2008e138835): Mark III Mockup Suit Configuration for Interfacing with the Suit Port Concept Evaluator