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Concept of Mechanical Interfaces for Planetary Space Suit to Airlock and Rover

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ABSTRACT

Advanced projects envisage multiple EVAs on the planetary surface and great distances to be covered by EVA astronauts during manned Mars missions. Astronauts' egress with special Martian EVA space suits on can be provided only through the landing module/spacecraft airlock. To move over the planet, astronauts are expected both to walk and use a planetary rover (Martian rover).

To make EVA activities on the planetary surface successful, an optimized concept for space suit attachment both to the airlock and Martian rover should be developed. The paper considers concept options of the planetary space suit (PSS)/airlock and PSS/Martian rover mechanical interfaces based on patent information study and analysis of development, test and operation data for the EVA space suits. The paper proposes an option of the concept that, in the authors' viewpoint, fulfills in the best way the following tasks: astronauts' unassisted capability to fulfill all airlock procedures, space vehicle ingress/egress, Martian rover ingress/egress and control of driving.

The selected interface concept is based on the space suit design with a hard upper torso (HUT) and a rear entry hatch. The concept provides for HUT-mounted attachment points and their mating fasteners located on the airlock wall and on the Martian rover. Using the same interfaces, the suited astronaut can be attached to the Martian rover working station and to the airlock. There are no usual seats on the Martian rover, consequently, there is no need to sit and stand in the rover. Ingress to and egress from the Martian rover become comfortable. To have a rest, an astronaut can "sit" inside the suit. This paper presents interfaces' design concepts and application method.

INTRODUCTION

While developing a planetary space suit and selecting means for manned EVAs on the Martian surface as well as means for travelling across the planet, one should bear in mind that a method and design of the PSS attachment to these means and interfaces between them are of great importance.

The mechanical interfaces are mainly designed to:

- secure the suited crewmember during airlocking
- secure the suited crewmember while rover driving
- secure the PSS during maintenance between EVAs
- secure the PSS during its donning/doffing

Taking into account the Martian operating conditions, the mechanical interfaces can provide for a rigid attachment of the PSS to the mating fasteners. The cause is a need both to reduce a PSS-induced load on the crewmember due to gravity on Mars and to exclude adverse effect of possible G-loads on the crewmember/PSS system, e.g. while rover driving. The orbital environment did not oblige to meet this requirement. The experience gained in the space suit operation under weightlessness conditions has shown that sometimes the space suits were secured with safety tethers only.

The authors believe that a selected concept of the mechanical interfaces must ensure that the suited crewmember is capable of unassisted attaching to/detaching from the mating parts of interfaces. This requirement is crucial in case of emergency activities of a single suited crewmember on the Martian surface. This is also the point in case of a two-crewmember EVA to provide assistance to each other.

Based on the RD&PE Zvezda's experience and available literature analysis, the authors consider three options for mechanical securing of the PSS to mating fasteners:

1) Russian Orlan EVA space suit type of attachment (by the waist portion of the hard upper torso),

2) US EMU space suit/Space Shuttle type of attachment (by the rear portion); or

3) Use of the PSS as a mini-airlock.

As the onboard systems and units are likely to provide life support of the suited crewmember during airlock and, probably, rover driving, the onboard systems-to-PSS interfaces are also briefly discussed.

CONCEPT OF MECHANICAL THREE-POINT PSS-TO-VEHICLE INTERFACES

As is known, the Russian Orlan-type EVA space suit, which has been used many times onboard the Salyut and Mir space stations and is currently being used onboard the International Space Station (ISS), features a metal HUT with a rear entry hatch. The arms and lower torso assembly are made of soft goods.

There are interfaces located on a special load-bearing frame around the lower edge of the HUT (for the first versions of a semi-rigid suit) or on the flange to connect the lower torso assembly (for the latest versions). These interfaces are

designed to secure the space suit onboard the station during the launch and in-flight service (suit adjustment for crewmember's height, checks and replacement of the life support system components, pre-EVA suit checkouts and preventive repair, if needed, etc.) Originally, the suit was supposed to be also secured for its donning/doffing (ingress/egress). However, as years of operation have shown, weightlessness does not require this type of attachment. The semi-rigid suit design has a lot of advantages, which have been highlighted in papers presented at international conferences [1-3] and the main pluses are ease and rapidness of the suit donning/doffing.
The above-mentioned securing system (interfaces between space suit and onboard the station) retains these benefits. It ensures that a crewmember in the pressurized suit is capable of unassisted attaching/detaching while onboard the station or other device. The securing system includes three attachment points. The front one is a pin located perpendicular to the front center of the HUT The side ones are V-shaped catchers, with the widest part of V facing forward (**Fig.1, 3**), located on both sides of the HUT, close to the ingress hatch embedding. There are mating interfaces of the securing system onboard the spacecraft for the space suit to be connected to. They are a central lock to secure the central pin of the suit and two side pins to engage with the suit catchers.

Thus, reliable and strong securing of the space suit is ensured. The central attachment point is located in the area of good vision and can be reached by any arm of a suited crewmember, i.e. engagement with the mating attachment point of the airlock and handling with the locking unit are under crewmember's control.
Under gravity, if any, (Earth, Moon - gravity is 1/6 g or Mars - gravity is about 1/3 g), a good attachment system is critical for the space suit operation, because the suit weight can vary from 100 to 130 kg on the Earth. (For Mars, designers expect to reduce the suit weight down to 40-60 kg). Under ground operating conditions, the above securing system is used to attach the suit to the assembling trolley - cart (**Fig. 2**). The cart is intended for suit maintenance, donning/doffing, and sizing adjustment. The cart can be adjusted for height and angle of its frame with attachment points.
After a crewmember enters the space suit, the suit is pressurized and then the crewmember can get out of the cart and again get on and attach to it unassisted.

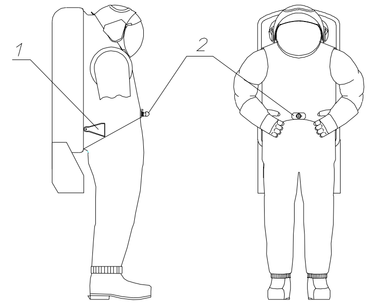

Figure 1. The Orlan-M SS mechanical interfaces
1 – Side catcher, 2 – Front pin

As the cart "relieves" the suit weight from the crewmember, he/she can stay within the suit for a long time to conduct tests, training, etc.
As the authors propose, the above-listed advantages of the three-point attachment system for a semi-rigid suit, in waist portion, can be successfully used in planetary projects for mechanical interfaces of the PSS to the airlock or rover.

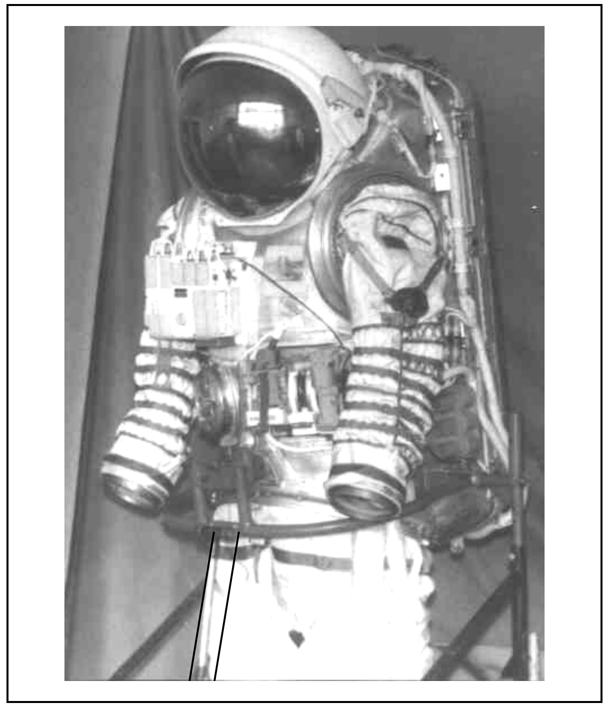

Figure 2. The Orlan SS attachment to the cart

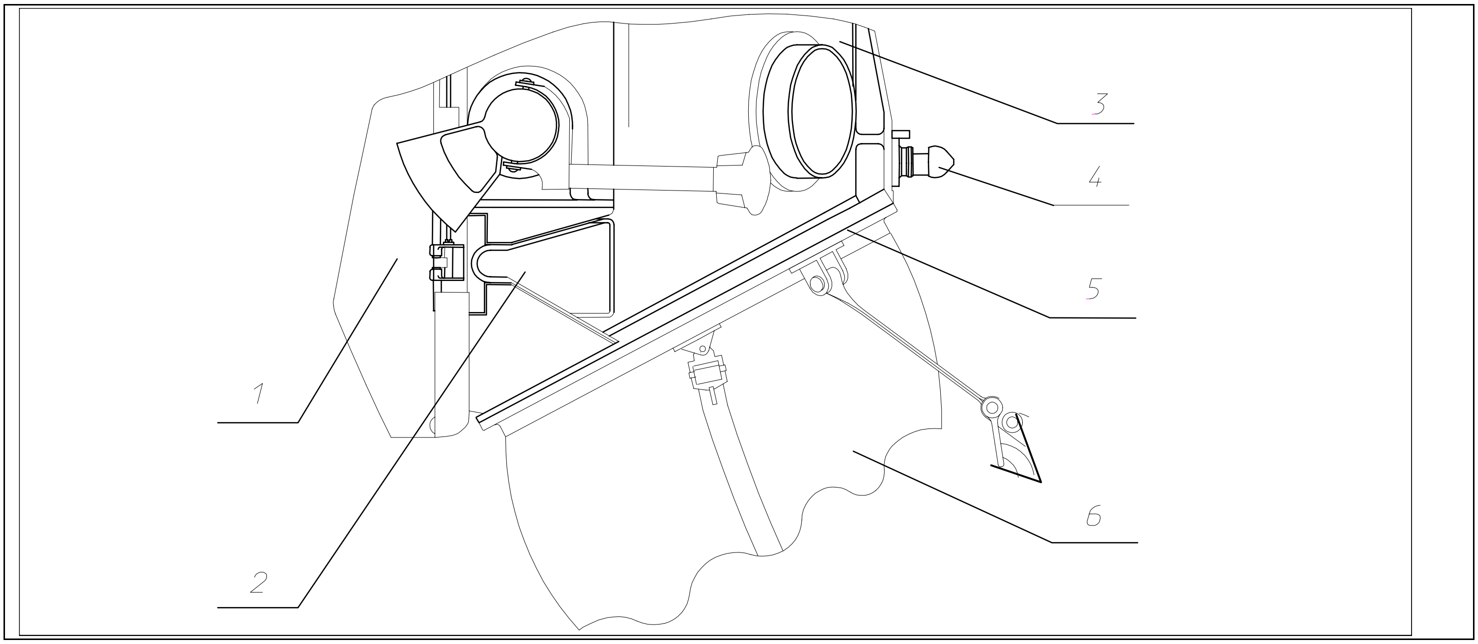

Figure 3. Side view of the Orlan space suit (waist portion)
1. Backpack portion, 2. Side catcher,
3. HUT, 4. Front pin, 5. Waist flange, 6. LTA

The distance from the onboard attachment points to the floor can be adjusted either by shifting the attachment points themselves or by shifting up/down the platform (with the crewmember in standing position) so that crewmembers of various heights are capable of using the securing system.
However, the permanently positioned attachment points also can be used by a wide range of crewmembers' heights through extending or partial flexing of the legs.
“RD&PE Zvezda” JSC in cooperation with ENERGIA RSC, for the first time, developed and successfully tested the above discussed three-point attachment system as an interface between the Krechet semi-rigid lunar space suit and the landing module cabin of the lunar spacecraft within the Soviet lunar project N1-L3 in 1965-1969.
An onboard part of this interface functioned as a shock-absorbing/securing system. It was designed not only to secure the suit to the working station near the control panel, but also to ensure cosmonauts' tolerance to G-loads during lunar landing and takeoff. The cosmonaut got into the lunar spacecraft and secured himself to the working station unassisted. It should be noted the Krechet lunar space suit had a horizontal axle instead of the above mentioned front pin. The axle was located on a special bracket and oriented in parallel to the upper torso. The axle provided for more comfortable suit connection with the onboard shock-absorbing/securing system under gravity. The cosmonaut came first in the side attachment points and then engaged with the central lock by "nodding" forward.
Later modifications of the Orlan space suits were shifted to a pin because of peculiar attachment in weightlessness.
The prototype shock-absorbing/securing system together with the Krechet space suit underwent comprehensive multiple tests such as fitchecks in a lunar spacecraft mockup; drop tests (lunar landing G-load simulation); and flying lab tests under lunar gravity.
The tests proved that the selected concept of the shock-absorbing/securing system was correct and unassisted cosmonaut's use of the securing system with the suit pressurized to an operating pressure, was feasible.
Later on, this system modification was applied to the Orlan-type space suits onboard the Salyut and Mir space stations.
One of the N1-L3 projects envisaged also that the unmanned lunar rover, which had ‘traveled’ over the Moon in 1970-1973, (E series Lunokhod), could be adapted for cosmonaut's trips [4]. The front part of the lunar rover was to have a platform for the cosmonaut to step on and drive the vehicle in the same way as an electrocar. To do this, a control console was to be mounted in front of the cosmonaut. Although, there were no specific designs, obviously, the suited cosmonaut could be securely fixed at the working station of the lunar rover by means of a device similar to the shock-absorbing/securing system.
The above-mentioned mechanical interface system can be successfully used for future manned Mars missions, which projects are now under discussion. The proposed concept, in the author's viewpoint, optimally enables, the following tasks: crewmember's capability to accomplish all airlock procedures unassisted, space suit donning/doffing, Martian rover ingress/attachment/egress, Martian rover driving, long duration of the crewmember within the space suit while rover driving.
Moreover, the proposed concept simplifies and simultaneously improves the suit design in regard to its mobility for walking and working on the Martian surface because the suit does not need to be adjusted for sitting down in the rover seat.
The crewmember using the attachment system will be able to stand at the working station of the planetary rover, so the motion control will be more comfortable and the environment's vision will be enlarged. The options of the suited crewmember-to-rover attachments are presented in

Fig 4. To have a rest, the crewmember can "sit" inside the “standing” suit, by using a soft lower torso assembly (LTA) as a bike saddle.
The authors believe that a standing position also simplifies the planetary rover design, makes rover ingress/egress more comfortable and there is no need to have seats on the rover.

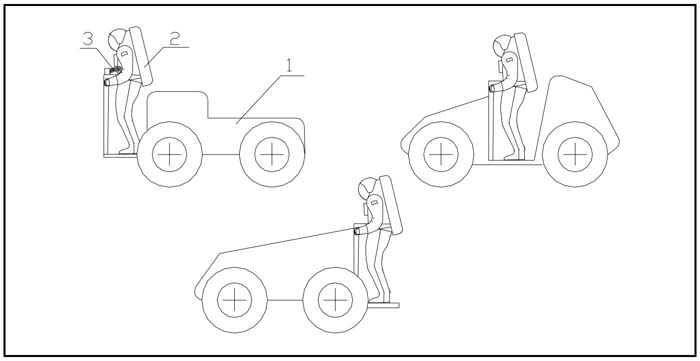

Figure 4. Attachment options of the suited crewmember to the rover
1 –Rover, 2 – Suited crewmember, 3 - Interfaces

Concept of combined mechanical interfaces.
The paper [5] considers the space suit with a HUT and a rear entry hatch as a mini-airlock for usage on the Mars. To do this, the space suit shall be mated (by its “back”) directly to the spacecraft habitat ingress/egress hatch or to the pressurized rover hatch, if there is one on the rover. The USA patents [6 and 7] and the USSR papers on mating of the space suit (by its “back”) to the habitat hatch are known. However, there are no any recommendations for implementation of this process.
The suited astronaut does not see the interface, mating (by the “back”) to the spacecraft wall or to the rover. That is why; it will be very difficult for the astronaut to perform all the mating procedures unassisted.
In that case, the concept of the combined mechanical interfaces can be used. The waist part of the space suit has three attachment point analogous to those described in the previous section, while the mating fasteners shall be arranged on the mating rotary frame of the airlock or rover. The frame shall be equidistant to the space suit HUT. Moreover, it shall rotate on hinges about the spacecraft wall.
For the first time, such an attachment procedure was used on the Russian manned maneuvering unit (MMU) to transfer the MIR space station cosmonaut in free space. With the face “forward”, the suited cosmonaut enters the turned structural frame (as in case of the shock-absorbing/securing system), secures to it and turns the frame in the initial position **(Fig.5)**. Then he attaches the frame free end to the MMU frame using the locking device.
It should be noted that this paper does not consider the advantages and shortcomings of the procedure to mate the space suit “back” to the habitat; it considers only the space suit interfaces design arrangement for its realization.

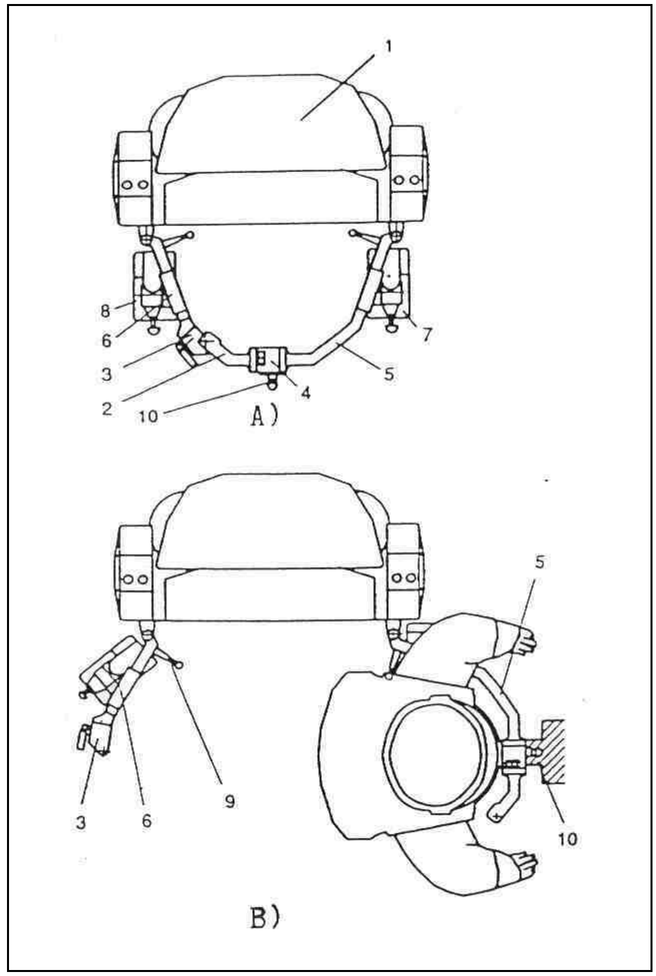

Figure 5. Attachment of the Orlan space suit to the MMU
A – plan view, B – view with a turned frame
1. MMU back portion, 2. Frame, 3. Side lock, 4. Central lock, 5. Frame left portion, 6. Frame right portion, 7,8. MMU control panels, 9. Pin for the space suit attachment, 10. Interface to mate the MMU to the airlock

Concept of the interfaces for space suit life support system lines
In order to supply oxygen/electric power to the crewmember during airlock operations and, probably, rover driving, the space suit can be connected to the onboard systems by interfaces. The number of such interfaces and procedure of their connection considerably depend on the selected life support designs of both the space suit proper and onboard systems.

The procedure for the space suit connection to the onboard life support and electric/radio equipment systems depends to a great extent on the selected type of the space suit attachment.
In case of attachment of the suited crewmember (with his face “forward”), the interfaces can be used to connect the space suit with the onboard systems via the flexible umbilical of hoses with an electric cable. If this is the case, the umbilical can comprise some separate hoses and an electric cable can be terminated with a combined connector **(Fig.6)** or some disconnects.

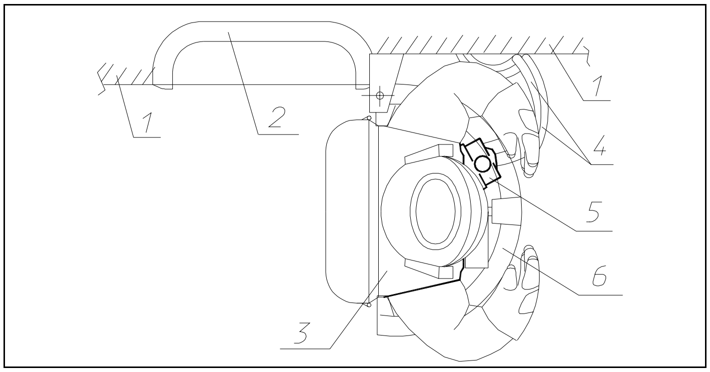

Figure 6. The planetary space suit connection to the onboard support systems (plan view)

1. Wall of habitat, 2. Habitat hatch, 3. Space suit, 4. Umbilical, 5. Combined connector, 6. Frame with interfaces

CONCLUSIONS

In authors' opinion, the proposed concept three-point attachment system for securing the planetary space suit (in its waist portion) to the airlock or rover is the optimum one for the semi-rigid-type suit design concept.

This concept has certain advantages, which provide:
- Crewmember ability to fulfill unassisted all the procedures on mating of the space suit to the airlock board or to the rover,
- Utilization of the combined attachment system to mate the space suit back to the habitat entrance hatch,
- Ease of access to the space suit for maintenance prior to EVA sortie,
- The crewmember "standing" position onboard the rover that simplifies its structure and provides comfortable accommodation of the suited crewmember in the rover during its driving.

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ACRONYMS

EMU - EVA Mobility Unit
EVA - Extra Vehicular Activity
HUT - Hard Upper Torso
ISS - International Space Station
MMU - Manned Maneuvering Unit
PSS - Planetary Space Suit
"RD&PE Zvezda" JSC -Research, Development and Production Enterprise Zvezda Joint Stock Company
ENERGIA RSC - ENERGIA Rocket Space Corporation
LTA - Lower Torso Assembly

DEFINITIONS

Krechet – Soviet space suit for EVA on the Moon surface, this suit was developed and certified at Zvezda in 60's
L3 – Luna-3, spacecraft for Soviet Moon expedition
Lunokhod – Rover (eng.) for Moon exploration
N1 – rocket for Soviet Moon expedition
Orlan – Soviet/Russian space suits for EVA on a lower earth orbit
Zvezda – leading Russian company in development and production of portable life support systems for pilots and cosmonauts, emergency escape and survival means for passengers and crews of flying vehicles.