A SPACESUIT FOR TITAN

Jonah Dijoux[1,2] and Pascal Lee[1,3,4,5]
[1]SETI Institute, [2]Butte College, [3]Mars Institute; [4]Kepler Space University, [5]NASA Ames Research Center.
E-mails: jonah3734@gmail.com, pascal.lee@marsinstitute.net

Summary: A first Extra-Vehicular Activity (EVA) spacesuit concept for the human exploration of Saturn's moon, Titan, is presented.

Titan: Titan, Saturn's largest moon and the second largest moon in the Solar System, has a surface gravity of 1.352 $m.s^{-2}$ or 0.138 G (< 0.166 G on the Moon), and an atmosphere denser than Earth's, with a surface pressure of 146.7 kPa or 1.45 atm. The surface temperature is 93.7 K (-179.5°C or -291.1°F). The atmosphere at the surface is made of 97% nitrogen (N_2), 2.7% methane (CH_4), and 0.2% hydrogen (H_2) by volume, with trace amounts of other gases, some toxic including ethane (C_2H_6), diacetylene (C_4H_2), methylacetylene (C_3H_4), acetylene (C_2H_2), propane (C_3H_8), cyanoacetylene (C_3HN), hydrogen cyanide (HCN), carbon dioxide (CO_2), carbon monoxide (CO), cyanogen $(CN)_2$, some non-toxic including argon (Ar) and helium (He) [1]. The surface is dominated by land, made mostly of a porous H_2O ice crust with hydrocarbon precipitates and dunes, but also presents large lakes, made of liquid hydrocarbons (C_2H_6, CH_4) and dissolved nitrogen (N).

Titan Exploration. Titan is an important destination for science and exploration, in particular for planetary science and astrobiology, as it represents a frigid cauldron of prebiotic chemistry that may inform us about the origin(s) of life on Earth and the possibility of extraterrestrial life. Titan was explored in-situ via the entry, descent, and landing of the NASA/ESA *Cassini* mission's *Huygens* probe, and will be explored in-situ again with NASA's *Dragonfly* drone mission scheduled for launch in 2028 and arrival in 2034. As Saturn is 9.58 times farther than the Earth from the Sun, Hohmann transfer times from Earth to Titan are 6 to 7 years. With nuclear thermal propulsion, transfer times may be reduced to 4 to 5 years. Titan is thus within plausible reach for human exploration.

Humans On Titan. Because Titan's atmosphere is slightly thicker than Earth's, humans would not need a pressure suit to explore Titan. From that perspective, Titan is more forgiving to explore than the Moon or Mars. A suit would still be required to keep astronauts warm, with a slight overpressure to fend off toxic gases and a portable life support system (PLSS) to provide breathable oxygen (O_2). We present here the first concept design of an EVA spacesuit for Titan.

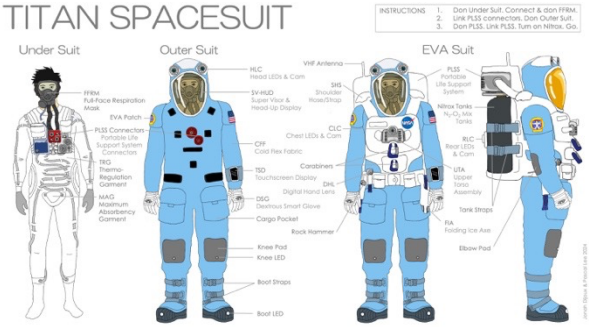

Figure 1. Titan EVA Spacesuit. *L to R, in donning sequence: Under Suit, Outer Suit, and Portable Life Support System (PLSS) (Artwork by J. Dijoux).*

Titan EVA Spacesuit. The design of the Titan EVA Spacesuit (TES) is derived from terrestrial Level-A (maximum protection) hazmat suits with self-contained breathing apparatus (SCBA), but evolved further due to Titan's low surface temperatures and the suit's exploration application. The TES presents 3 main components:

Under Suit System (USS). The USS includes a *thermo-regulation garment (TRG)*, a *full-face respiration mask (FFRM)* with PLSS Nitrox hoses and connectors forming a chemical barrier, and a *maximum absorbency garment* (MAG) for body waste.

Outer Suit System (OSS). The OSS is a single-piece, full-body, thermal and chemical barrier garment, with a blue outer (complementary color to orange, for max visibility against Titan's orange-colored landscape) *Cold Flex Fabric (CFF)* shell that remains supple under Titan's frigid temperatures, integrated *Super Visor and Head-Up Display (SV-HUD)*, and *Dextrous Smart Glove(s) (DSG)* evolved from the *Astronaut Smart Glove (ASG)* [2].

Portable Life Support System (PLSS). The PLSS is designed as an easy-don/doff backpack, with *shoulder hose straps (SHS)* and PLSS connectors, *Upper Torso Assembly (UTA)*, *EVA tool belt*, and large, external, swappable Nitrox (N_2+O_2 mix) tanks taking advantage of Titan's low gravity, N_2-rich atmosphere, and low temperatures.

References: [1] Sofou & Lee. Titan: Surface environmental conditions, chemical toxicity, and implications for future human exploration. *In prep.*; [2] Lee et al. 2020. Astronaut smart glove: A human-machine interface for the exploration of the Moon, Mars, and beyond. ICES-2020-428.