REQUIREMENT ANALYSIS AND NIGHT SURVIVAL CONCEPT FOR Z-01 LANDING MISSION USING FUEL CELL

Satishchandra C Wani[1], Udit Shah[2], Adithya Kothandapani[1], Prateek Garg[1], Mrigank Sahai[1], Mannika Garg[1], Sunish Nair[1]
[1]TeamIndus - Axiom Research Labs Pvt Ltd (adithya.kothandhapani@teamindus.in, Bangalore, KA-560092, India)
[2]StarLiner Engineering Inc. (udit.shah@starliner.com, 1279 Washington Valley Rd, Bridgewater, NJ 08807, USA)

Introduction: Space exploration missions have ramped up with improvements in technology. Where it was previously impossible to access certain bodies in the Solar System, advances in material science, power systems and communication, to name a few, have enabled longer and more productive scientific lunar missions. Of many lunar missions only few were intended to land. Solar-powered missions today are limited to short durations (max 14 days), due to availability of sun light on Lunar surface. In addition to harsh surface temperatures during the day, lunar night is even more challenging due to duration of night (14 Earth days near equatorial sites, higher near poles). In absence of any planetary or sun heating during night, the spacecraft experience cold environment viz. Lunar soil reaching -170C (Equator) and space at -269C [1]. Only three missions were able to survive lunar night, but using Radioisotope Thermo-Electric Generators and Radioisotope Heating Units. This paper presents an fuel cell based concept to extend life of existing mission Z-01 by surviving Lunar night.

Challenges to energy methods: Nuclear energy has advantage of high energy density hence needs less mass, but there are many disadvantages viz. difficult to source hence costly, transport, handle & storage. In such situation it is evident to explore non-nuclear energy sources for generating energy not only for single but many lunar nights. With present limitations in energy density from non-nuclear methods, the spacecraft should hibernate during lunar night and maintain at storage temperatures using survival heaters. After night it should function again as nominal during lunar day. This strategy reduces the cost of landed lunar missions to a large extent. To survive lunar night, one must minimize heat lost to space, enhance low temperature survival of spacecraft components and use heater power to maintain components at storage temperature limits.

Case study and proposed concept: To quantify the requirement of energy, present mission i.e. Z-01 is used. Z-01 is thermally designed to survive lunar day, hence energy requirements are expected to be higher. Thermal simulation compute the requirement as 90W heater power to maintain components at storage temperatures. This energy has to be supplied for 350 hours or net energy requirement is 31.5KW-hr. On comparison of available options viz. Mechanical (Flywheel) Electro-chemical (Battery), Electrical (Super capacitor), Thermal (PCB, Wadis), Chemical energy methods using parameters viz. Energy Capacity, Density, Discharge time & Maturity of Technology (Space qualified), Fuel cell is a potential energy method.

Figure 1 describes one such concept of using Fuel Cell as energy storage system to survive lunar night.

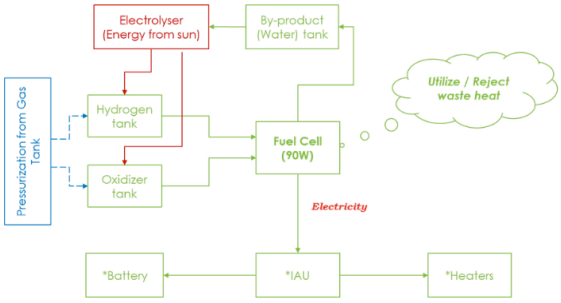

Figure 1: Energy Storage System using Fuel Cell

The fuel cell (PEM) powered by hydrogen and oxygen, is used to generate electricity and waste heat is tapped using heat pipes. The by-product i.e. water is collected in separate tank. During the day, electrolyser or reversible fuel cell is used to generate hydrogen and oxygen. Power for electrolyser is used from existing solar panels. The reactants are stored in separate tanks and be used in night for energy generation. Hence this concept can supply power for many lunar nights. The overall mass of the system to generate 90W for 350 hours is 50.3 kg, that is 25% of Z-01 dry mass.

Other technologies viz. Internal PCB Heater, Lunar Soil heating and Variable Conductance Loop Heat Pipe that help to reduce overall energy requirement are also presented.

Conclusion: Overall the paper presents historic missions that survived lunar night, overall challenges to survive lunar night, computation of energy requirement on actual project using thermal simulations. Due to disadvantages of nuclear energy method, alternative energy storage system using fuel cell is conceptualized. Due to its space heritage, simplicity of operation and regenerative capability, Fuel cell is most promising of all energy methods available

References: [1] Ashwin R. Vasavada, David A. Paige, Stephen E. Wood (1999), "Near-Surface Temperatures on Mercury and the Moon", *Icarus 141,* Page 179-193