



# Isru taskforce in Toulouse toward in situ autonomous electrochemical and additive manufacturing processes of lunar

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**ISRU TASKFORCE IN TOULOUSE TOWARD IN SITU AUTONOMOUS ELECTROCHEMICAL AND ADDITIVE MANUFACTURING PROCESSES OF LUNAR REGOLITH.** M. Gibilaro<sup>1</sup>, L. Massot<sup>1</sup>, C. Chiron<sup>1</sup>, P. Chamelot<sup>1</sup>, J.J. Favier<sup>2</sup>, T. Cutard<sup>3</sup>, Y. Le Maoult<sup>3</sup>, T. Sentenac<sup>3</sup>, P.C. Pinet<sup>4</sup> and S. Chevrel<sup>4</sup>, <sup>1</sup>IMT Mines Albi; Campus Jarlard, F-81013 Albi, France, <sup>3</sup>Institut Clément Ader (ICA); Université de Toulouse; CNRS, IMT Mines Albi, INSA, ISAE-SUPAERO, UPS ; Campus Jarlard, F-81013 Albi, France, <sup>4</sup>Institut de Recherche en Astrophysique et Planétologie (IRAP), CNRS/CNES, Observatoire Midi-Pyrénées, Université de Toulouse, France.

**Introduction:** Long-duration missions with permanent lunar bases to sustain technical and scientific activities suppose the incorporation of In-Situ Resources Utilization (ISRU) to produce life support consumables and everyday life [1]. The ISRU concept considers the resources at the exploration site with the use of lunar regolith (rocks, soils) as raw material and essentially the energy from the sun. The lunar regolith is composed of various metallic oxides [2], with variable composition and abundances, which calls for the use of controlled simulants.

**Objectives:** Our multidisciplinary consortium recently created in Toulouse, France, focuses on autonomous electrochemical and additive manufacturing processes to be implemented on appropriate Moon sites (regolith, energy) with 3 goals:

- 1- Characterization and production of new lunar simulants.
- 2- Electrochemical processes of regolith simulant for metals/alloys and O<sub>2</sub> production
- 3- Objects and tools with predefined geometries from regolith simulant by additive manufacturing .

The **1<sup>st</sup> objective** is to deliver a lunar simulant which can be used as a basis for ISRU applications involving both electrochemical and additive fabrication processes. A terrestrial basaltic material [3], already used for laboratory studies on the lunar regolith optical and spectrophotometric behavior, is being evaluated and characterized for this purpose. This fresh basalt comes from a lava flow of Pic d'Ysson (Massif Central, France), containing some phenocrysts of olivine, pyroxene and plagioclase, and has been mechanically ground and sieved. The largest grains are composite polycrystalline regular blocks with a rough aspect and some visible shiny facets of phenocrysts. Their shapes become more irregular with more smooth isolated translucent monocrystals as grain size decreases.

The **2<sup>nd</sup> objective** is to select a molten solvent composition for simulant dissolution and then extraction of oxygen and metals from the lunar soil by electrolysis. In a close loop system, our process should fulfill the following requirements: a maximum temperature of 1000°C, a high solubility of regolith metallic oxides, a recyclable solvent and a non-consumable anode.

*The first step* is the simulant dissolution into the molten salt, leading to metallic and oxide ions, where oxygen gas and metals will be produced by electrolysis.

*The 2<sup>nd</sup> step* is the oxygen extraction from the simulant, where the need of resistant materials used under severe conditions (O<sub>2</sub>, 1000°C) leads to the selection of noble metals, conductive oxides and cermets. Then, these materials will be tested to detect O<sub>2</sub>.

*The last step* concerns the metal deposition; the goal is to obtain metals/alloys of spatial interest. Tests will be performed on inert/reactive cathodes for pure metal and alloys depositions.

The **3<sup>rd</sup> objective** is to develop an in-situ lunar additive manufacturing process using lunar soil simulants. Topics deal with fabricating and repairing objects and tools with limited dimensions, high geometrical accuracy and mechanical properties. The approach couple experiment and modeling for the process, material transformations and final properties. *The first step* consider a laser based SLM machine and *in the 2<sup>nd</sup> step* a new specific additive manufacturing process is developed using halogen lamps as heat sources. Optical [4] and thermal characterizations have to be performed on the new simulant based on Pic d'Ysson basalt to provide the database that will be used for predictive computations for light-matter interactions. It should lead to optimized processing conditions in order to ensure the good quality of the parts, quality that will be tested through  $\mu$ -structure characterization and mechanical testing [5].

#### References:

- [1] P. D. Spudis, 1996, "The once and future moon", Smithsonian Institution Press, Washington, DC.
- [2] D. Stoesser et al., NASA, Marshall Space Flight Center, Report no. NASA/TM-2010-216438 (2010).
- [3] A. L. Souchon et al., Icarus, 215, 313–331, (2011).
- [4] A. El Bakali et al., Rev. Sci. Instrum., 90 (2019).
- [5] D. Mauduit et al., Materials Design, 95, 414–421, (2016).

