05/2202 Oxygen extraction from lunar regolith

Type of activity: Medium Study (4 months, 25 KEUR)

Background

ESA plans for the exploration of the solar system, developed in the frame of the Aurora Programme, envisage robotic and human exploration of Mars, the Moon and the asteroids, human exploration of Mars being the ultimate target around 2025-2030.
The exploration of the Moon is considered as an important base for scientific research, as strategic station for further travel and as intermediate test-bed for processes and technologies to be applied on Mars.
Extended manned missions require large quantities of propellants for surface and space vehicles.
The costs for supplying the propellants from Earth is extremely high, therefore research is focused on the investigation of available natural resources and on appropriate technologies to convert them into propellants on site.

Lunar and Martian regoliths are particularly rich in oxygen bound in metal oxides. Oxygen is largely employed as oxidiser both in propellants and in fuel cells for electric power generation.

Several processes have been proposed to extract oxygen from the lunar soil and rocks. Among the investigated reactions the reduction of ilmenite ($FeTiO_3$) and iron oxide (FeO), under hydrogen flow at high temperature, were individuated as the most feasible. The reactions result in the extraction of oxygen in the form of water, which in a second step is decomposed into oxygen and hydrogen gas via electrolysis. Oxygen is liquefied and stored and hydrogen is recycled as reducing agent.

A detailed analysis of the process steps and the estimation of the efficiency and of the mass and energy balances is required to determine the technical and economical feasibility of the processes.

The investigation will focus on the construction and operation of an oxygen extraction plant on the Moon. The possibility to adapt the process to Martian conditions will be explored.

Study Objectives

The investigation shall provide:

- A review of lunar resources comprising new data provided by the lunar orbiter Smart-1.
- An analysis of ilmenite and iron oxide reduction conditions and required infrastructure.
- An assessment of the processing steps and infrastructure required to provide ilmenite and iron oxide in the proper form (e.g. mining, grinding, sieving).
- An estimation of the quantity of hydrogen to be supplied from Earth.

- An estimation of the efficiency of the overall processes including water electrolysis and hydrogen recycling.
- An estimation of the energy balances.
- An estimation of the dimensions and mass of the plants.
- Assessment of the technical feasibility and cost effectiveness of the processes.