

21st IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM (A5)  
Human Exploration of the Moon and Cislunar Space (1)

Author: Mr. Paolo Guardabasso  
Politecnico di Torino, Italy

Mr. Giovanni Artuso  
Politecnico di Torino, Italy

Mr. Gabriele Bigi  
Politecnico di Torino, Italy

Mr. Antoine Carré

SUPAERO- Ecole Nationale Supérieure de l'Aéronautique et de l'Espace, France

Mr. Augustin Colonna Walewski

Politecnico di Torino - Thales Alenia Space Italia - ISAE Supaero Toulouse, France

Mr. Matteo Crema

Politecnico di Torino, Italy

Mr. Matteo Dragoni

Politecnico di Torino - Thales Alenia Space Italia - ISAE Supaero Toulouse, Italy

Mr. David Gaudin

ISAE - Institut Supérieur de l'Aéronautique et de l'Espace, France

Mr. Nicholas Gollins

University of Leicester, United Kingdom

Mr. Giuseppe Governale

Politecnico di Torino, Italy

Mr. Karim Hacene Lhadj

Politecnico di Torino, Italy

Mr. Luca Kiewiet

Politecnico di Torino, The Netherlands

Mr. Daniel Luque Arriero

Politecnico di Torino, Italy

Mr. Daniel Martínez Díez

ISAE-Supaero University of Toulouse, France

Mr. Thibault Magnin

ISAE-Supaero University of Toulouse, France

Ms. Laura Miquel Parra

Politecnico di Torino, Spain

Ms. Roberta Pascale

Politecnico di Torino, Italy

Mr. Fabio Pino

Politecnico di Torino, Italy

Mr. Daniel Robson

University of Leicester, United Kingdom

Mr. Maximilian Scherer

Politecnico di Torino - Thales Alenia Space Italia - ISAE Supaero Toulouse, United Kingdom

Mr. Pietro Maria Vernicari

Politecnico di Torino, Italy  
Mr. Joshua Wilde  
University of Leicester, United Kingdom  
Mr. William Zhang  
ISAE - Institut Supérieur de l'Aéronautique et de l'Espace, France  
Mr. Corentin Buti  
ISAE - Institut Supérieur de l'Aéronautique et de l'Espace, France  
Mrs. Pauline Delande  
ISAE - Institut Supérieur de l'Aéronautique et de l'Espace, France  
Mr. Guillaume du Roy  
ISAE-Supaero University of Toulouse, Belgium  
Ms. Noelia Fariñas Álvarez  
University of Leicester, Spain  
Mr. Cristian Hipwell  
University of Leicester, United Kingdom  
Mr. Callum Huggins  
University of Leicester, United Kingdom  
Mr. Jack Kemp  
University of Leicester, United Kingdom  
Ms. Gaargi Jain  
University of Leicester, United Kingdom  
Mr. Tse Lin  
University of Leicester, United Kingdom  
Mr. Maxime MAILLY  
ISAE-Supaero University of Toulouse, France  
Ms. Charlotte Morrison  
University of Leicester, United Kingdom  
Mr. Matthew Pain  
University of Leicester, United Kingdom  
Mr. Aaron Shaw  
University of Leicester, United Kingdom  
Mr. Daniel Tanner  
University of Leicester, United Kingdom  
Ms. Veronica Trivino Herrero  
University of Leicester, Spain  
Mr. Pierrick Vivares  
SUPAERO- Ecole Nationale Supérieure de l'Aéronautique et de l'Espace, France

## LUNAR OUTPOST SUSTAINING HUMAN SPACE EXPLORATION BY UTILIZING IN-SITU RESOURCES WITH A FOCUS ON PROPELLANT PRODUCTION

### **Abstract**

Space exploration has recently witnessed a surge of renewed interest, in particular, the concept of a human mission to the Moon is increasingly being discussed by national agencies and private enterprises alike. A lunar base is commonly regarded as a good first step for humanity's expansion beyond Earth.

This paper proposes a pre-phase A study about infrastructure on the Moon surface with the capability of sustaining future human space exploration. The outpost will be relying on In-Situ Resources Utilization (ISRU) and on the support of the orbiting Deep Space Gateway (DSG), in line with the current ISECG exploration roadmap. In this context, precursor robotic missions, such as the concept proposed in the ESA-led Heracles study, and related activities on the Moon surface are considered as sources of insight

and technology validation. The incremental steps necessary for setting up the Lunar outpost are discussed and analysed, both for surface and on-orbit missions. A feasibility and sustainability study is carried out for a propellant production plant, the primary purpose of which is to provide the capability of refuelling space vehicles. The design of the overall mission revolves around four main building blocks, which are analysed in detail: crew habitats, a large pressurized crew rover, ISRU facilities and a lunar spaceport. The overall mission scenario has been derived from a set of trade-off analyses that have been performed to choose the mission architecture and operations that satisfy the stakeholder expectations: the most important features of these analyses and their results are described within the paper. Regarding the timeframe, the analysed mission is expected to take place after robotic precursor expeditions, which are scheduled to launch in the 2020s. The first manned mission shall follow before 2030 with the purpose of setting up the propellant production facility, which shall be operational by 2035.

The study is carried out by the 10th edition of the Specializing Master programme in Space Exploration and Development Systems (SEEDS) of 2017/18 at Politecnico di Torino (Italy). This work was performed in cooperation with students from ISAE-Supaero (France) and University of Leicester (UK). The project is supported by Thales Alenia Space Italy, the European Space Agency, and the Italian Space Agency.