Geophysical Research Abstracts
Vol. 18, EGU2016-17163, 2016
EGU General Assembly 2016

Towards a Moon Village: Young Lunar Explorers Report

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Introduction: The Moon Village Workshop at ESTEC on the 14th December 2015 was organized by ILEWG/ESTEC in conjunction with the Moon 2020-2030 Symposium. It gathered a multi-disciplinary group of professionals from all around the world to discuss their ideas about the concept of a Moon Village, the vision of ESA's Director General (DG) Jan Woerner of a permanent lunar base within the next decades [1]. The workshop participants split in three working groups focusing on Moon Habitat Design, science and technology potentials of the Moon Village, and engaging stakeholders [2-3]. Their results and recommendations are presented in this abstract.

The Moon Habitat Design group identified that the lunar base design is strongly driven by the lunar environment, which is characterized by high radiation, meteoroids, abrasive dust particles, low gravity and vacu-um. The base location is recommended to be near the poles to provide optimized illumination conditions for power generation, permanent communication to Earth, moderate temperature gradients at the surface and interesting subjects to scientific investigations. The abundance of nearby available resources, especially ice at the dark bottoms of craters, can be exploited in terms of In-Situ Resources Utilization (ISRU).

The identified infrastructural requirements include a navigation, data- & commlink network, storage facilities and sustainable use of resources. This involves a high degree of recycling, closed-loop life support and use of 3D-printing technology, which are all technologies with great potential for terrestrial spin-off applications. For the site planning of the Moon Village, proven ideas from urban planning on Earth should be taken into account. A couple of principles, which could improve the quality of a long-term living milieu on the Moon, are creating spacious environments, visibility between interior and exterior spaces, areas with flora, such as gardens and greenhouses, establishing a sustainable community and creating social places for astronauts to interact and relax.

The proposed establishment of the lunar base can be divided into 4 steps. First the primary base infrastructure is laid out through robotic missions, assisted by human tele-operations from Earth, from the lunar orbit, or via a human-tended gateway station in one of the Earth-Moon Lagrange points (EML-1/2). During the second phase, the first manned habitation module will be deployed. This module contains a bare minimum of functionality to support a small crew for a couple of months. During the third phase, additional modules with more dedicated functions will be sent to the Moon, in order to enhance functionality and to provide astronauts with more space and comfort for long-term missions. In the final phase of the lunar village, a new set of modules will be sent to the base in order to accommodate new arriving crew members.

To ensure crew safety, the landing site for supply vessels shall be located in safe distance to the base. Extensive utilization of autonomous or tele-operated robots further minimizes the risk for the crew. From the very beginning, quickly accessible emergency escape vehicles, as well as a heavily shielded 'safe haven' module to protect the crew from solar flares, shall be available.

Sustainable moon village development would require explorers to fully utilize and process in-situ resources, in order to manufacture necessary equipment and create new infrastructure. Mining activities would be performed by autonomous robotic systems and managed by colonists from the command center. Building upon the heritage of commercial mining activities on Earth the production would be divided into six stages: geological exploration and mapping, mine preparation, extraction of raw resources, processing of raw resources, separation of minerals, storage and utilization. Additional manufacturing techniques, such as forging, would also need to be explored so as not to limit the production capabilities. To facilitate the progress of the Moon Village initiative it is necessary to attract private industry investments. Potential sources range from technology testing in the moon environment and private R&D funding from science and academia fields, to space tourism, and more ambitious endeavors such as building a prototype launcher site as a ground segment for debris de-orbiting and satellite recycling activities.

The Science and Technology team has identified key technologies and possible major scientific disciplines for a Moon Village and ranked them by importance and by Technology Readiness Level (TRL). In terms of basic technologies and objectives, rover exploration, life support systems, navigation and surveying technologies resulted to have the highest importance and readiness. Technologies for the development of the habitats (materials, modules connections, power supply, alternative energy technologies and energy storage) ended up on having high importance with medium-low technology readiness. Technologies intended to help the astronauts or improve techniques had low-medium importance together with low-medium TRL (e.g. space lift to transfer resources, bio cybernetic augmentation “Exoskeleton”, jumping rover, telescope).

After brainstorming for required technologies, the fo-cus was shifted to what kinds of science can be ex-pected to be performed, once a functional and usable habitat would be available. The group has categorized studies of planetary formation and the Solar System as a highly important scientific discipline with a medi-um-high TRL. Scientific areas with high-medium im-portance, but low technological readiness, were found to be ISRU, psychological effects, adaptations of life to low gravity and plant cultivation. The physiological effects of low-gravity on the body were considered of medium importance and readiness.

The Engaging Stakeholders working group started by identifying the main stakeholders and groups that play a role or that could play a role towards the Moon Village project. These stakeholders were classified on their influence towards the program and their attitude towards it. Complex system innovations like the Moon Village initiative often encounter stiff resistance from intended beneficiaries and stakeholders, because they disrupt existing behaviors, organizational structures and business models. However, if this large-scale change is rather approached as two simultaneous and parallel challenges — the design of the artifact in ques-tion and the design of the intervention that brings it to life — the chances that it will take hold will increase. Finally, the group recommended actions to be taken by the ESA DG to engage the most direct stakeholders: The general public should be addressed on an emotional level, human centered design thinking and social movement design should be used to engage the civic society. When engaging with the Moon Village stakeholders, the emotional resonance of Moon Village’s value proposition should be taken into account as much as its scientific and technical requirements. This involves (social) media, art and humanities and, for the long term, also investments on education. In this way, a social excitement similar as for the Apollo program might be triggered, which can be used by the member states to engage with their national politicians and convince their taxpayers of the Moon Village’s benefits. ESA should invest on the creation of a European new Space industry (similar to the one in the U.S.) and therefore simplify their processes in order to make it easier for the industry to invest and work with ESA with less bureaucracy. In order to succeed in this large-scale international collaboration, a political & legal framework needs to be established. It is recommended to push for an International Moon Village Treaty agreement at the U.N. and to start a conversation about the Moon Village at the UNCOPUOS, so the delegations and member states can start providing ESA with their political and legal inputs. The aim should be to present a sound concept already at the ESA ministerial 2016.

Conclusion: Since a long-term human presence in the cis-lunar and lunar surface environment is envisaged, human factors become an even more crucial element in defining the success of the missions. Therefore, it is very important that not only a set of technical problems is solved to survive the harsh environment on the Moon. It is also necessary that psychological and physiological factors will be considered in the design of the systems, equipment and habitats. In that light, the Moon Habitat Design group noticed a missing link between the currently developed space technologies and the actual long-term usability by astronauts. It is therefore critical that ESA would collaborate more with urban planners, architects and industrial designers who provide the expertise in creating suitable environments and products, which are not only technically sound and functional, but also easy to use, comfortable and aesthetically pleasing.

The Science and Technology group has in general analyzed the key challenges, technologies, objectives and issues related to the development of a manned colony on the moon, classifying them from an importance vs. Technology Readiness Level (TRL) point of view.

The Engaging Stakeholders working group has identified the main stakeholders and groups that could play a role towards the Moon Village project. These stake-holders were classified on their influence towards the program, and their attitude towards it. One clear conclusion was that most of the stakeholders showed a positive view towards the Moon Village program, and that the most important step within a short term strategy should focus on the actions to be taken to engage stakeholders for th next ESA Ministerial to support the program. Finally, the group came up with some recommendations on which actions should be taken by the ESA DG to invite partners and to engage the most direct stakeholders: ESA delegations, media, national governments, citizens and taxpayers.

References: [1] http://sci.esa.int/ilewg/ and https://ildwg.wordpress.com/ [2] Foing B. Moon explora-tion highlights and Moon Village introduction. [3] Young Lunar Explorers Report ESTEC Moon village sessions with community and young professionals.

*Organisation: Bernard Foing, ESA/ESTEC & ILEWG, ESTEC Moon Village workshop WGs co-conveners: Peter Batenburg, Andrea Jaime, Abigail Calzada, Angeliki Kapoglou, Chris Welch, Susanne Pieterse, Daniel Esser, Audrey Berquand, Daniel Winter, Hanna Läkk, Dmitri Ivanov, S Paternostro, Matias Hazadi, Oscar Kamps