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PROMOMOON INITIATIVE FOR MOON VILLAGE GENERATION IN HONOR OF DR. ALEXANDER DEGTYAREV

Moon Village Association, together with Yuzhnoye State Design Office, created and implemented the Mentorship Program "PromoMoon Initiative for Moon Village Generation in honor of Dr. Alexander Degtyarev". The main goal of the Program is to build the capacity of new participants in the space market. The Mentorship Program allows the winners of the competition to receive expert assessment through online B2B mentorship sessions provided by MVA members and specialists from Yuzhnoye State Design Office. This year marks the 4th PromoMoon Initiative. 19 projects are presented by participants from 16 countries. Most of the projects are dedicated to the creation of lunar base infrastructure and technologies for extracting useful resources on the Moon. The main focus of the proposed projects is on the use of local resources, cost-effectiveness and reliability. Seven projects are dedicated to various residential module designs: with an inflatable chamber and high-strength shells; with small 3D-printed panels and their assembly in a module; modular habitats created and serviced by autonomous microrobots; modules using biomimetic principles of adaptation found in Earth's natural systems. The modules are made of terrestrial materials, lunar regolith, and a building material based on radiation-absorbing fungi, as well as "PotatoCrete" material derived from potato raw materials. The Lunar-Based Solar Power Station with Microwave Power Transmission from a Satellite Orbiter was developed by the Lunar Energizers team, and the Lunar Regolith-Based Thermal Energy Storage for Moon Village Generation, in the project of the same name. The Tochtli system for regolith extraction and processing was proposed by the Torres Orbital Mining team, the RegOne system for regolith extraction and transportation was proposed by the MoonAixperts e.V. team. Anodes for direct molten regolith electrolysis were developed by a team of Ukrainian scientists. The Sand to Green team developed a lunar agroforestry system. Two launch complexes, the Lunar Electrostatic Dust Removal Station, a lunar rescue sled and a centralized cloud platform with open access for storing, analyzing and exchanging lunar mission data were proposed.

Keywords: lunar modules, local resources, extraction of useful resources.

Асоціація місячного поселення спільно з ДП «КБ «Південне» створили й реалізували Менторську програму «Ініціатива PromoMoon для покоління Moon Village на честь Олександра Дегтярева», головна мета якої – нарощування потенціалу нових учасників космічного ринку. Менторська програма дає можливість переможцям конкурсу отримати оцінку експертів за допомогою онлайн B2B менторських сесій, яку надають члени асоціації та спеціалісти ДП «КБ «Південне». Цього року проведено вже IV Ініціативу PromoMoon. Представлено 19 проєктів, що подали учасники з 16 країн. Більшість проєктів присвячено створенню інфраструктури місячної бази та технологіям видобування корисних ресурсів на Місяці. Основну увагу в проєктах приділено використанню місцевих ресурсів та економічності й надійності запропонованих розробок. Сім проєктів присвячено створенню житлових модулів різного дизайну: з надувною камерою та високоміцними оболонками; з використанням невеликих 3D-друкованих панелей та складанням їх у модулі; модульні житла, які створюють та обслуговують автономні мікроботи; модулі, в яких використано біоміметичні принципи адаптації природних систем Землі. Модулі створюють із земних матеріалів, з місячного реголіту, а також із будівельного матеріалу на основі грибів, які поглинають радіацію, і навіть з матеріалу PotatoCrete з картопляної сировини. Місячну станцію сонячної енергії з передаванням енергії із супутника мікрохвилями розробила команда Lunar Energizers, а також сховище теплової енергії на базі реголіту для створення місячного поселення в однойменному проєкті. Систему Tochtli для виймання та обробляння реголіту запропонувала команда Torres Orbital Mining, систему RegOne для вилучення та транспортування реголіту – команда MoonAixperts e.V. Аноди для прямого електролізу розплаву реголіту розробили українські вчені. Команда Sand to Green розробила систему місячного агролісівництва. Запропоновано також два стартових комплекси, місячну електростатичну станцію для видалення пилу, місячні рятувальні сани та централізовану хмарну платформу з відкритим доступом для зберігання, аналізування даних місячних місій та обміну ними.

Ключові слова: місячні модулі, місцеві ресурси, видобуток корисних ресурсів.

Introduction

Establishing a human settlement on the Moon and implementing interplanetary missions stood as the most cherished visions of General Designer and General Director of Yuzhnoye State Design Office, Alexander Degtyarev. These ambitions shaped the trajectory of technological advancement within our organization. Our own concept of creating a lunar industrial and research base was developed and a number of related studies were conducted under direct leadership of Alexander Degtyarev, even before this topic became the main trend worldwide. He was a consistent supporter and member of the Advisory Board of the international Moon Village Association (MVA), which encourages cooperation between government space agencies, commercial space organizations and academic circles to promote human presence on the Moon. Yuzhnoye State Design Office joined the MVA as an institutional member almost immediately after its establishment.

To honor the memory of Alexander Viktorovych Degtyarev, Moon Village Association together with Yuzhnoye State Design Office created and implemented the Mentorship Program called "PromoMoon Initiative for Moon Village Generation in honor of Dr. Alexander Degtyarev", whose main goal is to build the capacity of new participants in the space market, such as initiative groups, enthusiasts, and startups. This event was announced during the 5th Global Moon Village Workshop & Symposium held on December 15, 2021.

The Mentorship Program offers competition winners free, voluntary online B2B mentorship sessions in a Q&A format. Experts from MVA and Yuzhnoye Design Office – with extensive practical experience in the development, testing, manufacturing, designer's support, commissioning and operation of various space systems available on the global market – provide independent feedback on submitted technologies.

The Mentorship Program focuses on new lunar technologies, including infrastructure, methods of cargo delivery to the lunar surface; mobility solutions for lunar rovers; energy generation, construction and manufacture on the Moon.

The PromoMoon Initiative is back for its fourth year. Participants from 16 countries across five continents – Australia, Asia, Africa, Europe, and North America – submitted 19 innovative projects.

Presentation of main project groups

1. Residential module projects

Most projects are devoted to the creation of the lunar base infrastructure and technologies for extracting useful resources on the Moon. The project by James R. Wertz from the United States, a leading expert on space mission cost reduction, proposed to create a commercial lunar village *Selena*, which demonstrates the advantages of developing Earth's satellite for humanity. The Moon has a practically unlimited amount of aluminum, silicates, water and oxygen (in bound form), necessary for human life and interplanetary flights. There is sufficient Helium-3, which is an environmentally friendly fuel for thermonuclear fusion.

Moon exploration opens up enormous potential for scientific research and the use of the Moon for marketing and joint branding throughout America, Europe, Asia and Africa. There are countless ways to make billions of dollars – from energy, mining, marketing, tourism, and solar system exploration to religious and civic ceremonies, art, sports, dance, and entertainment. James R. Wertz's ideas are certainly ahead of their time, but they inspire young romantics to explore the Moon and create *Selena*.

Any lunar settlement requires, first and foremost, residential modules. The Oxygen Space startup from Italy (iSaisei Corporation Srl) offers modules that include an inflatable chamber and a combination of several layers of high-strength materials such as Kevlar and Vectran to protect against micrometeoroids, solar flares, radiation, and extreme temperatures. Modularity allows for structure expansion and meets the needs of a changing mission. The modules feature advanced life support systems and transformable interiors. An inner PVC or polyurethane membrane will integrate furniture, lighting, and sensors (Fig. 1). The Oxygen AI system will manage the environment inside the habitat.

Fig. 1. Oxygen Space module. Image Credit: iSaisei Corporation [1]

According to the authors, the lightweight and compact Oxygen Space modules will significantly reduce the launch cost and will make lunar missions more accessible.

Another design of standardized residential modules, assembled from rigid shells and inflatable components and allowing for the creation of different building designs – the "*Moon Arc/M.S.C.A.P.E (Modular Space Construction for Advanced Planetary Conditions)*" project (Fig. 2, 3) – was developed by a team of students from Arizona State University (United States).

Fig. 2. Moon Arc module. Image Credit: Arizona State University [2]

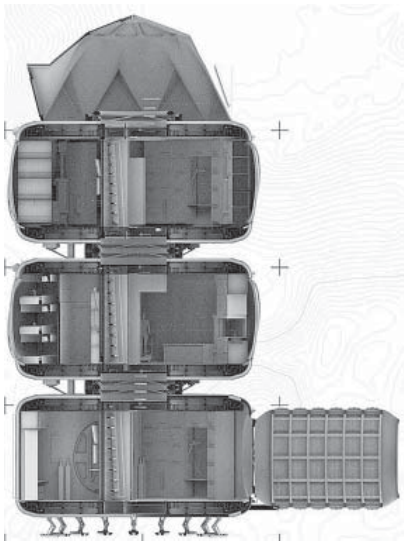

Fig. 3. Moon Arc module design. Image Credit: Arizona State University [2]

Providing rapid deployment with an integrated life support system and primary protection, the project will allow the module to be immediately populated after landing, reducing mission preparation time and increasing its efficiency, compared to 3D-printed modules or inflatable structures covered with regolith. The innovative system for protecting the modules from radiation and micrometeorite is based on sensors and air cushion technology.

The modules are deployed in two stages and expand at the expense of local resources, such as regolith and biomaterials, e. g., mycelium, which reduces dependence on terrestrial supplies and contributes to the creation of an autonomous lunar economy.

The main idea of the "Lunar Metropolis: 3D-Printed Modular Habitat" by the Canadian "Matrix GEMINI" startup is modular construction using pre-printed 3D panels, eliminating the need for bulky on-site 3D printers. Modular panels will be assembled autonomously into structures for various purposes and will be covered with layers of 3D-printed regolith solution to protect against meteorites, temperature fluctuations and radiation (Fig. 4).

Advantages of the proposed solution:

• Structures can be transformed as mission requirements change.

• Damaged panels can be replaced individually, avoiding reconstruction of entire sections.

• Versatility: the same modular system can be used to build residential modules, storage facilities, operational centers and scientific research stations with minimal modifications.

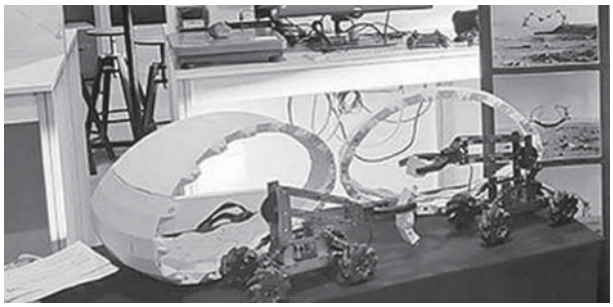

Fig. 4. A modular panel structural model and collector rovers. Image Credit: Matrix GEMINI [3]

In the "*Virtual life support system (VLSS)*" project, its author Javier Maldonado Romo from Mexico proposes to create a reliable and innovative virtual life support system. The VLSS will be based on modular habitats

created and maintained by autonomous microrobots. Artificial intelligence (AI) systems will continuously monitor environmental parameters such as air quality, temperature and humidity, and adjust them in real time. AI will enable predictive maintenance by identifying potential equipment issues before failures occur.

This innovative model leverages digital technologies to establish the VLSS, incorporating in-situ resource utilization, renewable energy systems, closed-loop recycling, modular architecture, and automated processes – all while prioritizing crew welfare. Such a comprehensive framework aligns perfectly with humanity's long-term vision for sustainable extraterrestrial habitation.

Using virtual reality tools, the author created a virtual model that takes into account various parameters and allows for the system evaluation.

The "*Pine Flex Lunar Biome*" project by Egyptian participant Samer El Sayary draws direct inspiration from nature's genius. By merging biomimetic principles from Earth's natural systems (specifically pine cone adaptation mechanisms) with the structural reliability of the Relau triangle to create an environment, the design achieves a dual breakthrough: uniform stress distribution at 50 kPa internal pressure while offering versatile assembly options in radial, linear, or clustered configurations (Fig. 5).

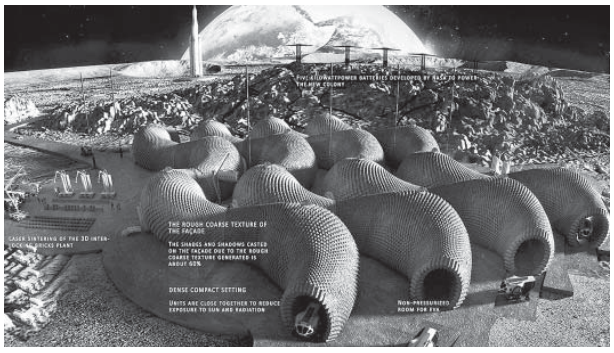

Fig. 5. PINE FLEX modular habitat. Image Credit: Samer El Sayary [4]

The outer habitat shell consists of regolith bricks arranged in overlapping diamond-shaped scales, providing radiation protection (effective mass 5–7 g/cm²) and thermoregulation. The scales are able to open, letting in heat during the lunar day, and close at night. A mesh of shape memory alloy (nitinol) embedded in the structure contracts during lunar nights, compressing the regolith scales into a dense radiation barrier, and generates power via piezoelectric nanowires during thermal cycling (10–12 W/m²).

The inner walls are lined with a fungal network (genetically modified Aspergillus nidulans), providing radiation protection by producing melanin, converting CO_2 to O_2, and filling microcracks in the structure through microbial biomineralization.

In the project "*BioShield-X: Biomimicry-Inspired Lunar Radiation Shielding for Sustainable Astronaut Protection*" – the participant from India, Krishna Bulchandani, also proposes a lightweight building material based on melanin-containing fungi that actively absorb radiation, and can be grown in situ using lunar regolith. The biomaterial can repair damaged protection layers.

Self-growing radiation protection can be used for residential modules, rovers, and astronaut spacesuits. Fungal colonies can expand in a controlled manner over time, increasing the level of protection and reducing costs.

The Mexican team from *Tecnológico de Monterrey* presents an innovative lunar construction solution with their "*PotatoCrete*" material. This bio-composite utilizes potato starch as a natural binding agent for lunar regolith, offering several advantages over conventional methods: exceptional adhesive/cohesive properties, significantly reduced energy requirements compared to high-temperature sintering, and minimal water dependency. With strength comparable to lightweight concrete, *PotatoCrete* demonstrates how terrestrial biology could sustainably enable extraterrestrial construction.

Research by young scientists demonstrates the potential of using potato waste in construction materials. While this technology is currently most practical for Earth-based applications (where potato consumption is high), it may become relevant for lunar use in the future, despite potatoes not being a priority crop for space agriculture.

2. Lunar power supply projects

The lunar solar power station with microwave power transmission from a satellite is developed by Lunar Energizers, a Jordanian team. The power supply infrastructure for long-term lunar exploration combines regenerative

fuel cells (RFCS), space-based solar power (SBSP), wireless energy transfer, and provides a continuous power supply with minimal Earth dependence (Fig. 6). Satellites with multilayer solar cells are placed in lunar orbit. The collected energy is converted into microwave rays and transmitted to the antennas installed on the lunar surface, which capture the microwaves and convert them into electrical power. For continuous power supply, the SBSP system is supplemented with RFCS for energy storage. During the lunar day, solar energy is used to electrolyze water, generating hydrogen and oxygen for fuel cells that produce electricity at night.

Fig. 6. Lunar solar power station. Image Credit: Lunar Energizers [5]

The regolith-based thermoelectric generator, developed under the *Lunar Regolith-Based Thermal Energy Storage for Moon Village Generation* project by an international team of young specialists, harnesses the Seebeck effect to directly convert thermal energy into usable electrical power. The operation relies on the generation of electromotive force when a temperature difference exists between the junctions of a thermoelectric pair. The thermal 'wadi' serves as the heat source, while a cold source will be positioned in the permanently shadowed region to maximize the temperature differential.

However, the thermal conductivity of regolith in a vacuum is very low, which does not allow sunlight to heat its layer and makes the idea of using thermoEMF ineffective. The project proposes special technologies for processing regolith, such as compaction, microwave sintering, controlled melting and enrichment with metals, which can significantly reduce the thermal resistance of the contact and increase the thermal conductivity, which will allow the creation of thermal 'wadis' from the resulting material.

Deploying a distributed network of thermal 'wadis' across the lunar surface would provide efficient in-situ energy generation and reduce dependence on materials shipped from Earth.

3. Mineral extraction projects

The *Tochtli* system is developed by Torres Orbital Mining (TOM) team from the United States, a space technology startup focused on sustainable mining and delivery of raw materials from orbital bodies. It is a compact and autonomous regolith excavation and processing system for efficiently sorting lunar soil particles to extract oxygen and other materials required for construction (Fig. 7).

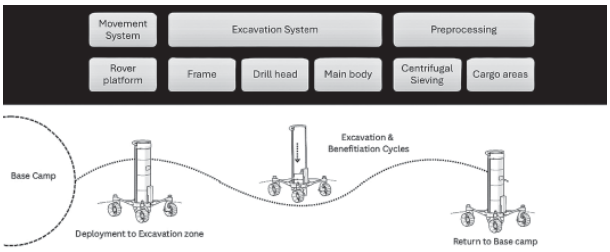

Fig. 7. Tochtli system. Image Credit: Torres Orbital Mining [6]

By reducing the volume of material moved and focusing on precise local processing, the *Tochtli* system minimizes environmental impact and optimizes resource use, ensuring that every operation contributes to long-term sustainability goals.

RegONE system for regolith extraction and transport was designed by a team of students from *MoonAixperts e.V.* in Germany. *RegONE* is vibration-based, modular and has no moving parts. The deployment of *RegONE* between mining sites and processing facilities allows for more efficient and sustainable use of local resources.

RegONE reduces surface contact through vibratory motion, which minimizes wear. The lack of rotating components minimizes

failure risk from dust contamination, while low vibration amplitude enables quasi-static impulse transmission. *RegONE* consists of several modules that can be configured to operate in different landscapes (Fig. 8).

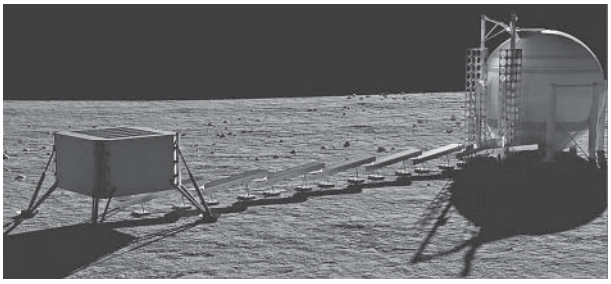

Fig. 8. *RegONE* – A Modular Regolith Transportation System for Lunar Surface Operations [7]

Regolith extraction and transportation enable the primary objective of lunar exploration: oxygen extraction from local resources. The only available method of extracting oxygen and metals from regolith that does not require the delivery of consumables from Earth is direct molten regolith electrolysis. The molten regolith electrolysis process requires operation at 1,600 °C, presenting a key challenge in selecting anode materials capable of withstanding highly reactive oxygen environments. Currently, platinum and iridium alloys are the most commonly used anode materials for this application, but they have an insufficient service life and are very expensive.

In their project "*Anodes for the molten regolith electrolysis*", Ukrainian scientists proposed a solution to this problem. They developed conductive, oxidation-resistant ultra-high-temperature ceramics (UHTC) based on zirconium boride with $MoSi_2$ additives [8, 9]. The application of metal or carbon anodes with protective ZrB_2-$MoSi_2$ ultra-high-temperature ceramic (UHTC) coatings presents an attractive solution. The scientific team developed a method and equipment for vacuum ion-plasma spraying of ZrB_2-$MoSi_2$ UHTC coatings [10].

4. Local agroforestry project

In the *Bringing Life to Moon* project, the *Sand to Green* team, with participants from France and Morocco, has developed a lunar agroforestry and resource optimization system. The proposed system includes:

• A lunar greenhouse and hydroponic farming to grow sustainable and fast-growing crops, as well as microalgae for food, oxygen, and water purification.

• Regolith to soil transformation (ISRU) through biochar-enriched and microbial ecosystems.

• Water harvesting and recycling: adapting desalination technology to extract, purify, and recycle water from lunar glaciers and astronaut waste.

• AI monitoring and resource optimization.

• Integrating the carbon and oxygen cycles: using photosynthetic plants and algae to convert CO_2 into oxygen while simultaneously producing biomass for food and enriching the soil.

By integrating agroforestry techniques with *in situ* resource processing and utilization, we can establish a highly reliable closed-loop system that significantly reduces Earth dependence.

5. Launch complex projects

The *Polytechnique Montreal/Astrolith Lab* team from Canada developed a launch pad, using parametric modeling combined with robotic autonomous construction (RAC) with the utilization of local resources.

The *Canada Lunar Base Launch Pad* (CLBLP) is capable of changing the shape, size and composition of the infrastructure autonomously, making it a truly scalable and reusable system for long-term lunar missions. The CLBLP's swarm of specialized robots performs tasks such as terrain mapping, excavation, 3D printing, sintering and structural compaction. This enables autonomous infrastructure development, without human intervention. The CLBLP is built entirely from lunar regolith, eliminating the need to transport materials from Earth.

In addition, the modular mosaic technology implemented by the CLBLP allows for autonomous repair or reconfiguration of damaged sections, significantly increasing the launch pad service life and reliability.

Lunar landing missions face challenges such as communication delays, low gravity, lack of atmosphere, and lunar dust with its abrasive and adhesive properties. The failures of recent missions highlight the need for an innovative approach to lunar landings. A team of students

from the University of Nairobi, Kenya, has developed the *Lunar Landing Interface* (LLI), which is expected to revolutionize the process. The novelty of the LLI lies in its compact origami-inspired design. On the lunar surface, the LLI unfolds into a robust, modular platform that can be deployed in various locations, increasing the mission flexibility and reliability. In addition, the LLI improves landing accuracy by using an advanced guidance system and ground computers that significantly exceed the capabilities of the lander's onboard computers. The LLI protects the landing area from dust using an active electrode-based capture system. The electrodes create a uniform electrostatic field that removes dust particles from the critical landing zone. The lunar dust captured by the electrodes is used to produce materials required.

Lunar regolith contamination poses a major challenge for sustained human exploration. The lunar dust clings stubbornly to spacesuits, astronaut boots, and equipment, while its abrasive properties accelerate mechanical wear and present serious health hazards to astronauts.

The *Lunar Electrostatic Dust Removal Station* (LEDRS) proposed by Jeremy Kruckel from Australia in his project meets this challenge. The LEDRS does not require consumables and removes dust using electrostatic attraction, vibration, and magnets. The retained regolith can be used for ISRU needs.

The LEDRS consists of an electrostatic mat, a hand-held electrostatic brush, and a built-in dust storage container. Astronauts stand on the mat to clean their boots, and the brush is used on their spacesuits, gloves, or small items that require dust removal. Using negatively charged surfaces, electrostatic fields attract dust from fabrics and equipment surfaces. Built-in magnets inside the mat capture particles with high iron content, reducing the overall electrostatic charge by removing a significant portion of the metal dust. Piezoelectric vibration actuators gently shake boots and other surfaces, dislodging even the most stubborn dust. Power consumption is about 16 Watts.

The second project submitted by the same author for the competition is aimed at developing a *Lunar Rescue Sled* (LRS). Made of lightweight carbon fiber and titanium, the LRS system weighs only 14 kg and does not require a power source. It features PTFE-coated cylindrical guides that provide low drag on regolith with minimal submersion (~2.5 mm at 350 kg), and a platform with a lever to position injured astronauts at a safe 45-degree angle during transport. Built-in lighting and emergency beacons improve visibility, and a paddle braking system ensures controlled descent on slopes. With no assembly required and a deployment time of less than two minutes, the LRS addresses a critical need for astronaut safety.

The need to leverage the vast amount of data from human lunar exploration has now become a necessity. Lunar missions operate in isolation, with limited information sharing between international and commercial partners. This fragmentation leads to inefficiencies, duplication of effort, and reduced interoperability between missions. To solve this problem, Hassan Abouseada from Egypt proposed creating the *Lunar Integrated Data Repository* (LIDR), centralized, open-access cloud platform for storing, sharing, and analyzing lunar mission data.

Conclusions

Translating novel concepts into functional systems under space conditions – marked by vacuum, microgravity, and cryogenic temperatures – demands interdisciplinary collaboration. These extreme environments alter fundamental physical processes, necessitating global cooperation between emerging researchers and seasoned experts in lunar development. This paradigm was championed by Dr. Alexander Viktorovich Degtyarev, whose vision inspired the partnership between Yuzhnoye State Design Office and the Moon Village Association. The *PromoMoon Initiative for Moon Village Generation in honor of Dr. Alexander Degtyarev* now embodies this ethos, advancing his mission through its Mentorship Program.

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